**Annex II**

**Strategic approach for Horizon 2020 - a contribution from foresight**

This paper draws on evidence derived from foresight activities, and serves as a background document for the reflections and discussions in the Horizon 2020 Advisory Groups towards providing advice to the Commission services on potential priorities for the work programme 2016-2017.

A key contribution to this paper has been a review of foresight literature carried out under the auspices of EFFLA (The European Forum for Forward Looking Activities), a workshop with 28 experts in different domains of Horizon 2020, and reflections of EFFLA and Commission colleagues.

*Horizon 2020 and the need for growth, jobs and addressing societal challenges in Europe*

Horizon 2020 was launched in the middle of difficult conditions in Europe, with the economy suffering from the after-effects of the financial crisis of 2008, and with populist politics becoming a rising force in Europe, fuelled by the social consequences of the economic crisis.

Focussing on excellence, industrial leadership and societal challenges, Horizon 2020 has been a key response for Europe. It has been one of the Union's main policy instruments towards the path to growth according to the vision of the Europe 2020 strategy: a smarter, more inclusive and more sustainable growth.

The recent Innovation Union Competitiveness Report (2013) highlighted some important baselines, of the competitive potential of the European economy. The knowledge intensity of Europe's trade-balance has been improving since the crisis, in contrast with that of the US and Japan who have been our traditional competitors in those markets (Figure 1 below, source: Innovation Union Competitiveness Report 2013). While Europe's competitive advantages against the US and Japan in knowledge-based industries are improving, new entrants, such as India, South Korea, and in particular China are capturing large parts of world markets in knowledge-intensive segments (see Figure 2 below, source: Innovation Union Competitiveness Report 2013).

Figure 1

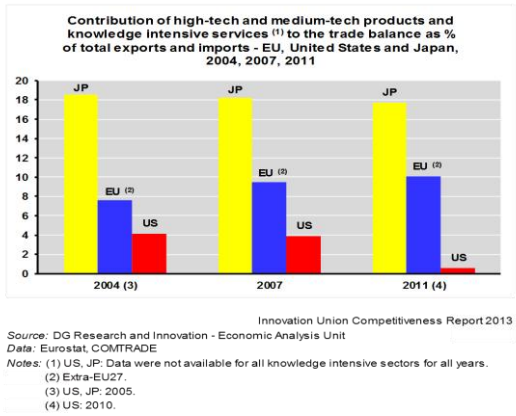
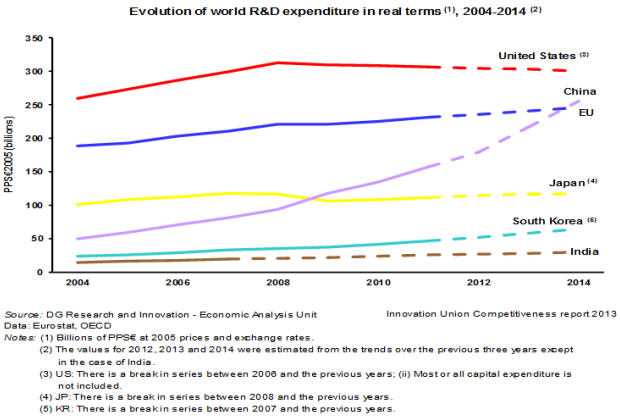



Figure 2




This transition in the competitive position of Europe is taking place in the context of the social and economic effects of the crisis. Unemployment in a number of European countries is higher than unemployment in large parts of the developing world (See Figure 3 below, source Innovation Union Competitiveness Report 2013). The slowly falling inequality between the rich and the poor countries of the planet is accompanied by an increasing inequality between people within countries, and this includes Europe (See figure 4 below)

Figure 3

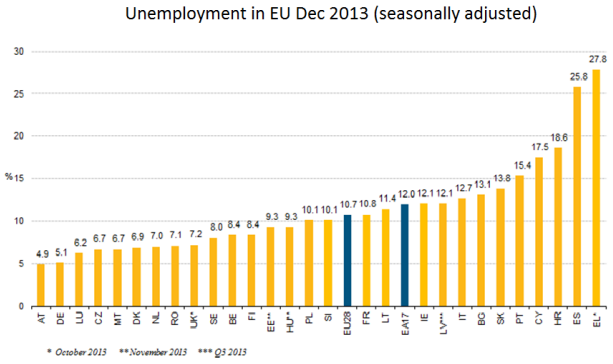
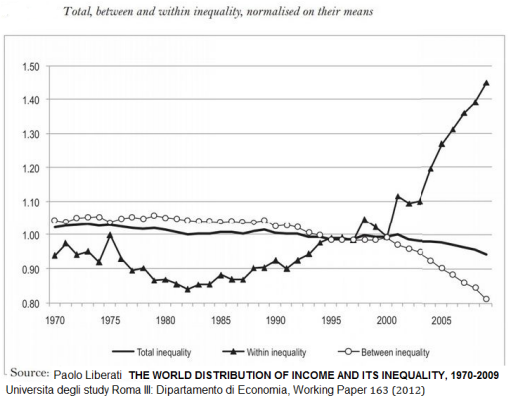



Figure 4




In this context, the success of Horizon 2020 is critical for competitiveness, growth and jobs and for leading the European economy out of its current crisis. However, success for Horizon 2020 is a moving target. Horizon 2020 has to nourish Europe's talent in scientific excellence and to channel resources and creativity to innovation, industrial leadership and societal challenges, in a rapidly changing environment in Europe and the world.

The rapidly changing environment requires Europe to run fast just to keep-up with the pace, taking stock of past experience and capitalizing on its strengths. It is therefore important that Horizon 2020 keeps the vision on the long term and address the big issues for the future, sustainability, prosperity, inclusiveness (including intergenerational dimensions) in a globalizing world that brings the peoples of Europe closer together.

*Structure of the paper*

The paper is structured as follows:

Section 2 provides a short overview of recent foresight evidence on global change and distils drivers of change that are relevant to Horizon 2020. Their disruptive potential is also discussed.

Section 3 draws strategic considerations that result from a first juxtaposition of the drivers of future change and the themes of Horizon 2020.

A final section lists ideas for possible foci and orientations for the implementation of Horizon 2020 in the period 2016-2017.

## 2. Drivers of change

The world is experiencing change at an unprecedented speed and intensity, and the EU is not immune to those. It is a major actor in the world scene and thus a major contributor to world trends, but is also impacted by those trends. The environment in which the priorities of the EU 2020 strategy are pursued is changing and this has important implications for Horizon 2020 and the areas where it should pursue its impacts on Europe's economic prosperity and competitiveness and on the ability of Europe to respond effectively to societal challenges.

The recent Communication of the Commission "Taking stock of the Europe 2020 strategy for smart, sustainable and inclusive growth" (COM(2014)130) identified 4 areas of key long term trends, which have been highlighted by the economic crisis and are likely to be affecting growth in the years to come:

- Societal change in European society adapting to domestic and global forces through new forms of urban and rural lifestyles, new consumption and mobility patterns, new and more diverse family settings, the growing presence of technology in daily lives etc. The Communication identifies demographic ageing, migration and rising inequality in Europe as key concerns for Europe 2020.
- Globalisation and trade, which involves not only trade in goods but also services (a potential growth area for Europe, as well as opportunities and challenges for joining global value chains and delivering products, services and technologies that no individual country would be able to produce on its own.
- Productivity developments which can come through use of information and communication technologies (ICT) but also through calibrated and sequenced reforms in the product, services and labour markets that match the needs of the economy, and through enhancing the quality of human capital, the performance of research, education and training systems and their capacity to foster innovation.
- Pressure on resources and environmental concerns resulting from the unsustainable use of the planet for fossil fuels, material extraction, waste etc. Sources of minerals, metals and

energy, as well as stocks of fish, timber, water, fertile soils, clean air, biomass and biodiversity are under pressure, as is the stability of the climate system.

These key drivers of growth for Europe figure amongst important concerns of foresight. They figure, for example, amongst the themes addressed by the European Strategy and Policy Analysis System (ESPAS)[1], which brings together the European Commission, the European Parliament, the Council of Ministers of the EU and the European External Action Service, in a comprehensive effort to anticipate and track future global change in three domains: the economy, social change and international governance and power.

The recent Report on Global Europe 2050[2] developed three contrasting views of the contexts of the different EU policies, along the axes of different levels of European integration: (1) 'A standstill in European Integration'; (2) 'EU under threat'; (3) 'An EU Renaissance'. The vision of a united Europe in a globalizing world and the benefits that the union will bring to the peoples of Europe in this context are the key message of that report, and this vision resonates with all European endeavours including Horizon 2020.

However, today more than any other period, it is extremely difficult to meaningfully cluster possible futures in a small number of scenarios. A recent experiment, a participatory foresight platform launched by the Commission called "The Futurium"[3], features more than 100 scenarios ("futures"), which have been co-created by thousands of people and are rated for desirability and likelihood, addressing top-line H2020 challenges such as the future of jobs and welfare, the prospect of a super-centenarian society, an emerging trans-humanistic society, new economic models, and new dimensions of media and learning.

The Assessment of Global Megatrends of the European Environment Agency[4] proposes important drivers of global change, tracing in some detail different types of megatrends:

- social megatrends (population trends, urbanization, disease burden and risk);
- technological megatrends (accelerating change),
- economic megatrends (economic growth, multipolar economic system, competition for resources);
- environmental megatrends (decreasing stock of natural resources, increasingly severe consequences of climate change, increasing environmental pollution load)
- political megatrends (increasing fragmentation and convergence of environmental regulation and governance).

[1] ESPAS is coordinated by BEPA (The Bureau of European Policy Advisers) attached to the President of the Commission.

[2] See http://ec.europa.eu/research/social-sciences/pdf/global-europe-2050-summary-report_en.pdf

[3] http://ec.europa.eu/digital-agenda/futurium

[4] EEA (2010) The European environment – state and outlook 2010: an assessment of global megatrends

Overall, an extended review of the global foresight evidence from the European policy perspective of Horizon 2020[5] places population changes, globalization, the environment, ICT, and new technologies at the centre, but includes also as drivers scarcity of resources and energy, health, personal aspirations and empowerment, changing creativity and innovation, education, space exploration, and urbanization. In addition it identified important factors that are understood be fundamental for the future as possible "game-changers" but are not as clear in their direction as the drivers: trust, values and beliefs, conflict and security, instability in the global economy, technological surprise, and rampant vulnerability.

These factors were discussed with different experts as to their relevance for Horizon 2020 in a workshop[6], and on the basis of the discussion the following strategic factors were identified:

- Population changes
- Globalisation and fragmentation
- ICT: the big disturbances are yet to come
- Transversality in new technologies and individual empowerment
- High expectations from new technologies
- Vulnerabilities are testing our resilience
- Environmental degradation, food security, scarcities of natural resources and bioeconomy potentials
- Constraints on materials and energy and the search for new opportunity spaces

They are developed below.

## 3. Strategic factors for Horizon 2020

### *3.1. Population changes:*

Population changes form the most powerful driver of global change for Horizon 2020.

As global population rises and people live longer, there are pressures on the environment and available resources, posing potentially serious challenges to food security as climate change and depletion of natural resources combine with loss of land to urbanization and environmental degradation.

Europe's population is not forecasted to increase drastically in the years to come, depending on migration policies, but it is expected to age drastically, with effects on labour markets and social

[5] DG RTD Internal paper (2013) Insights from the Futures: Contribution from EFFLA selected forward studies to the strategic planning process for Horizon 2020, EC Memo; V. Rousselet (2014) Using foresight to support the next strategic programming period of Horizon 2020 (2016-2018). Report to the European Commission

[6] See V. Rousselet (ibid).

security systems but also on market demand and politics. The median age in Europe has increased from 35.7 years old in 1992 to 41.5 in 2012 and could reach 52.3 by 2050. The population aged 65 plus is expected to double in the EU from 1990 to 2050. However, demographic ageing is likely to diffuse gradually to more youthful parts of the world as living and educational standards rise for populations around the globe.

All these factors translate into needs for innovation in society (including lifestyle, behaviour and consumption patterns), in technology and in the use of resources (e.g. *to alleviate environmental pressures, to sustain active ageing populations etc.*), but also lead to pressures for populations to move, driven for example by poverty, exclusion and loss of livelihood.

Migration is a key aspect of population changes, and it generates frictions and societal changes, which often fuel populist political movements. Migration generates needs for innovations to support the governance of the process (*control systems and technologies, and integration systems and technologies, including for example education* etc.). Migration can also be a means to alleviate pressures on the social security systems of countries with rapidly ageing populations that face workforce shortages.

Workforce shortages can also be alleviated by means of advanced automation. Advanced automation can deliver improvements in care and contribute to the general adaptation of technologies and infrastructures to supporting people who live longer, including performance enhancing technologies and treatments that use advanced ICT and materials technologies. However, at least in the short to medium term, advanced automation is likely to increase unemployment and inequality.

In Europe, with its ageing population, facing even population reduction in some countries in the near future, unemployment and inequality are rising. Economic dependency – the ratio between the number of people not in employment and those who are – is expected to rise from 1.32 in 2010 to 1.47 in 2030, with old age dependency creating unprecedented challenges for the social adequacy and financial sustainability of welfare systems. As poverty rises, the health of populations is deteriorating and the ability of disease control systems to function effectively is also challenged, raising the spectre of new epidemics. The objective to deliver a 2 year extension in healthy life-expectancy by 2020 may be challenged by this context.

### *3.2. Globalisation and fragmentation*

The EU is the world's largest exporter and biggest trader in goods. It is also the world's largest trader in services where it still has a strong potential to grow. It is estimated that in the next 10-15 years, 90% of the world's growth will come from outside the EU, so the EU has every interest in making sure that its companies remain very competitive and are able to access new markets and benefit from these sources of growth.

Globalisation is not just about facilitating trade and exchanges. It is about joining global value chains and delivering products, services and technologies that no individual country would be able to produce on its own. It is also about creating the conditions for a balanced partnership and development across countries, starting with Europe's neighbourhood.

Globalization is a process of international integration that involves economic exchanges (and in this way migration is part of the phenomenon), but also the evolving multilevel and multinational governance structures, from the EU and the United Nations to multi-national corporations and multinational civic actors e.g. Greenpeace, and the global interconnections and communications infrastructure that is the internet, with its profound implications for the economy but also for society and culture.

Ideally globalization is about people sharing the planet in freedom of movement and exchange, and provides opportunities for new markets, wealth creation and individual fulfilment. At the same time it may engender loss of diversity, autonomy and sovereignty across communities.

At the current state of affairs, globalization is less about a global free market of homogenized consumers and more about a space of large corporations and alliances. Globalization underscores the importance of two of the "lessons" of the recent European Innovation Union Competitiveness Report[7]: Innovation strategies need to emphasize comprehensive solutions that integrate manufacturing and services; and building alliances and networks is paramount as innovation is highly international.

However, as the international financial system integrates, new local currencies emerge. As supra-national federalism advances, existing federal states face disintegration tendencies. In some ways global integration strengthens local phenomena, and previously integrated spaces fragment. In a global market for agricultural products, food sovereignty becomes an issue. As cash crops and plant-reproductive material concentrate, the biodiversity and resilience of ecosystems rise in importance.

The global internet provides for the formation of on-line cultures that transcend physical spaces, and therefore facilitates the disintegration of local cultures, as people can choose to be integrated in totally different cultural spaces on-line. Online lifestyles have given rise to new cultures of sharing and new forms of exchange including exchanges such as e-bay and means such as bit coins.

Market formation and innovation in the context of fragmenting communities and cultures is an unpredictable and potentially important phenomenon, as it may give rise to "leapfrogging" and radically different uses of technology. An example is the use of satellite communications and mobile devices in Africa. It takes a lot of creativity and intelligence to innovate for newly emerging economies in the context of globalisation, but this segment will be a major source of growth in the future.

### *3.3. ICT: the big disturbances are yet to come*

Modern electronic communications and online services, including e-government, are important economic sectors in their own right but they are also crucial levers of growth and productivity for the economy as a whole. Lower investment in and use of ICT in Europe, accounts for a large part of the labour productivity gap between the EU and the US. EU investment in state-of-the-art

[7] See http://ec.europa.eu/research/innovation-union/pdf/competitiveness_report_2013.pdf

communications infrastructure is also lagging behind that of its main competitors, especially as regards mobile infrastructure. The average mobile data speed in the EU is half of that of the US,17 and Europe has only 6% of the world's 4G mobile subscriptions. In South Korea, 58% of households are connected by fibre to the home, but only 5% in Europe. 54% of European households have access to next generation networks, able to deliver 30 Mbps. In the new, data-based economy, European companies are almost absent from the value chain.

Our society, our lives and our economies are being transformed as precision agriculture increases productivity and environmental efficiency, robots continue to revolutionise industry but also mining and aquacultures, and advanced automation finds its way into services.

ICT is not only an indispensable part of our economy but an integral part of the fabric of our society, driving processes of integration (from simple organizational functions e.g. outsourcing to the global financial system) whilst at the same time raising fundamental ethical issues (e.g. property rights, privacy, ownership, community, participation etc.). Unresolved ethical issues may engender disintegration and fragmentation processes. For example, privacy and free speech debates bring about the threat of internet segmentation.

Yet, there is a sense that we are only scratching the surface and the big changes are yet to come. This sense is enhanced when looking into the future contained in “the Futurium”. There are two overlapping processes of integration driven by ICT that pose different sets of issues, challenges, threats and opportunities. The first is the integration of individual people and things in patterns of behaviour which transcend the boundaries of “organizations” as we know them in their legal and physical existence, as can be illustrated by the current on-line social networks. For some, this is only the beginning.

Looking into the Futurium, the vision illustrated by the movie "The Matrix" is no longer fully fictional. The internet will soon connect bits and atoms at the speed of light. Its algorithms will orchestrate zillions of smart objects, which will share zettabytes of data every day, thus bridging the physical and virtual worlds instantaneously. Prediction and decision will be easier and faster than ever, based on scientific evidence and people’s aspirations. The integration of individual people and things will evolve. People and objects will have a complete and accurate digital image in the virtual space incorporating all the senses and functions, while at the same-time it will be infinitely malleable, storable, copy-able etc. as digital objects are. The “matrix” as a social space would have massive implications for society in the physical world, for example, as digital communities form and may compete with, or reinforce, community relations based on physical social contact.

A key aspect of these implications has to do with the second process of integration which is between the virtual and the physical world. Interactions between the physical and the virtual world will be facilitated massively by advances in materials and biological sciences and the penetration of 3D printers in society. Human bodies may benefit from artificial parts. New materials may allow the production of soft robots with organic tissues. Artificial and human intelligence may combine and reinforce each-other with totally unpredictable results.

Kurzweil[8] argues that the rate of technological progress will grow exponentially. In a few decades, we could be able to enhance our cognitive and physical capabilities with bio-technological add-ons. Robots and cyborgs will perform complex tasks and could take over all routine jobs, from agriculture to construction, from office to industrial automation. The possibilities to apply pre-birth prevention and regenerate and repair organs as needed would enable us to live longer and healthier. We will be able to learn, work and play "from the cradle to the grave".

While these are seen as possible long term scenarios, they have massive disruptive potential, and some aspects of them are already visible. First, there is the dislocation of the person from their physical and social surroundings that was discussed above in the context of globalization and fragmentation. Second, there are the various technological augmentations of the human body not necessarily confined to medical purposes but possibly extended to applications in leisure and sport, from prostheses to wearable systems like the Google Glass. Third, there is the transformation in knowledge creation and creativity that results from the increasing automation of research and innovation. This automation increases massively the productivity of research (at least in terms of data production), changes the balance between labour and capital in the production of knowledge (on the one hand making science more dependent on infrastructures but on the other enabling individuals to generate much more knowledge with much less work than before), and there changes the thresholds of acceptable contributions to knowledge (on the one hand leading to the emergence of citizens-science and fully autonomous machine-creativity, on the other hand underpinning changes to education and scientific institutions). The development of sensors, for example, is already revolutionizing observation based sciences like biology and meteorology.

### *3.4. Transversality in new technologies and individual empowerment*

Transversality refers to integration processes that cross important boundaries and limitations. It can be seen as a specific form of integration of processes of production and use of services, through new infrastructures (and new ways of using old infrastructures) and new interfaces that allow better and more individualized services. Infrastructures become reconfigured some of them acquiring new uses and services while others become obsolete and redundant. The same happens to durable goods as means of supplying services. Intelligent interfaces allow new, better and more personalized services to be delivered through user empowerment. Supply-chains get redesigned and existing exchange patters become disrupted.

A huge disruption in manufacturing supply chains is expected to come from the diffusion of 3D printers, irrespective of whether they are able to print food or organs. In the longer-run the convergence between nanotechnology, biology, neuroscience, and ICT can take transversality different levels through for example, intelligent self-organizing artefacts combining biological and synthetic elements.

It is important here to address the issue of unpredictability in the use of technologies. This unpredictability is related to the innate creativity of human beings in their dealing with different

[8] Ray Kurzweil, The Singularity is Near, Penguin Group, 2005

contexts, combined with the complexity of technologies, tools and systems. The drive of individuals for empowerment has been a key driver of technological change. User-empowerment through intelligent interfaces has been a notoriously difficult problem, which the IT industry seems to be gradually overcoming through successive generations of networked configurable durable devices. Lessons from this experience can help thinking about transversality in relation to other technologies and sectors, especially for those where there is heavy infrastructure investment.

For example, the nexus of Energy, Transport and the Environment is a domain of very heavy infrastructural investment that can be potentially used in transversal ways or become obsolete because of transversality. For example, in transport, the use of public infrastructures, i.e. public transport and collective car ownership schemes, is gaining in popularity, enabled in its organization by the ICT infrastructure, and incentivised by regulatory frameworks and urban environments that penalize the ownership of cars. Another example of disruption is investments in solar energy parks, which can be undermined by new photo-sensitive materials that do not require parks to be efficient. Similarly it can be argued that fuel-cells can empower individuals to produce their own energy, with vast implications for the current energy infrastructure, and with great benefit to the environment. Bringing transversality into strategy is a potentially very important element. Characteristically China, in its roadmap for science and technology 2050 prioritizes research into photosynthesis, with the aim to increase the efficiency of light utilization in crops, biofuels and solar bio-cells.

Transversality requires skills and competencies that bridge many different areas and sectors, and provides the basis for "sweeping innovation", i.e. the rapid deployment of new and complete technological ideas across a wide range of markets around the world, capturing very quickly important parts of the added value generated by the innovations. Sweeping innovation is an important means of drawing benefits from globalization and the associated fragmentation phenomena.

### *3.5. High expectations from new technologies*

As technological change, the accumulation of knowledge and the rate of innovation are accelerating, society develops increasing expectations from technological change. The rate of change challenges regulatory structures, while at the same time innovations are assumed and discounted and their social implications become the subjects of important controversies. Europe has been the locus of political debates underpinned by scientific controversies related to the performance and risks from different innovations. Massive increases in the efficiency and effectiveness of regulatory science facilitated by the changes in knowledge production brought by ICT, may improve the application of the precautionary principle by our regulatory structures.

Overall the high expectations have two sets of implications for Horizon 2020. The first has to do with trust in science and technology, in particular with trust in the ability of our systems to regulate-out negative technological surprises. This is not only linked to regulatory science in a narrow sense, but more broadly to our ability to secure compliance with political requirements for scientific and technological performance (including for example the prevention of the development of new weapons). The second set of implications has to do with the pursuit of lines of technology

development that have already been assumed. This is especially important in areas of high infrastructural investment (such as energy and transport). Whilst it is important for society to deliver the performance improvements that have been assumed and road-mapped, it is also important to provide some space for radical positive technological breakthroughs that may come from completely different sectors and lines of research.

### *3.6. Vulnerabilities are testing our resilience*

Over the last 20 years a great deal of effort has gone to support alternative consumption patterns and lifestyles, and to develop technologies that would permit sustaining livelihoods and quality of life while restricting the amount of CO2 emitted in the atmosphere that would in turn prevent dangerous destructive climate change. Understanding and measuring climate change and extreme natural phenomena through real time data gathering and global networks of in-situ and space-based sensors together with new ways of organizing citizens' actions have made important contributions to our preparedness and resilience.

Yet strings of extreme natural phenomena, including weather related but not only, are developing into major catastrophes, destroying lives, infrastructures, human livelihoods and economic systems, and resulting in population changes, giving rise among other things to new health challenges. In this context there may be a case for revisiting the balance between climate-change mitigation and adaptation strategies in the context of Horizon 2020, and for strengthening the resilience of systems and infrastructures worldwide, including the resilience of cities, energy and transport infrastructures, and food-production systems.

Here it must be mentioned that resilience is important not only in view of natural phenomena but also in view of increasing security risks due, for example, to conflicts and associated humanitarian catastrophes, to extreme social and cultural phenomena e.g. terrorism, the increasing destructive potential of technologies, and the increasing interdependence of our ever more integrated world.

With the integrity of the planet under threat, change and demand management become important issues in their own right, and there is urgency to promote systems for public, economic and social transformation and the related technology needs (e.g. for systems of monitoring compliance, and systems supporting the diffusion of cultural norms).

### *3.7. Environmental degradation, food security, scarcities of natural resources and bioeconomy potentials*

Demand for food, feed and fibre may increase by 70% by 2050, yet 60% of the world's major ecosystems that help produce these resources have already been degraded or are used unsustainably. Water quality and air pollution levels are still problematic in many parts of Europe.

Environmental degradation is the reduction of the capacity of the environment to meet social, economic and ecological objectives. It involves the destruction of natural habitats and the depletion of natural resources. Environmental change and degradation are both natural and man-made. Man-made degradation often comes through intensive use of resources and waste production.

Unsustainable land use is consuming fertile soils, while soil degradation continues, and the use of green infrastructure remains suboptimal. Similarly, the unsustainable use of seas threatens the fragile balance of marine ecosystems and affects related economic activities such as fishing and tourism. Ocean acidification resulted into pH reduction approximately 100 times faster than over the previous 55 million years, making the seas 26% more acidic and dangerous for many species.

Our economic system still encourages the inefficient use of resources by pricing some below true costs. Promoting a more efficient use of resources makes a lot of business sense and should help improve competitiveness and profitability. It can also boost employment and economic growth: during the crisis, action to improve energy efficiency in the residential sector has proved particularly helpful in boosting local demand for local jobs and in producing financial savings over time. Horizon 2020 could support the development of circular economy models and experimentation, to foster the sustainable use of renewable biological resources, to reduce primary demand for materials and to reduce waste, thanks to recycling and reuse, in the spirit of "doing-more-with-less", aiming to decouple prosperity and growth from the use of resources.

Environmental degradation has strong effects on health and on the availability of resources, especially on land, water and biodiversity and biological resources, thereby threatening the resilience of eco-systems and ultimately the capacity to ensure supply of food and other vital services. Thus environmental concerns, be they with conservation or with improvement, are inherently cross-cutting for the challenges addressed by Horizon 2020, especially in relation to health (where the objectives can be placed at risk because of developments in the environment) but also in energy, food security, and transport where goals have a strong component of avoiding environmental degradation. Environmental degradation is closely linked to the precautionary principle. The precautionary principle has important implications for safety research, as it places the burden of proof on the non-harmfulness of interventions on health and the environment.

Environmental change should urgently reverse trends from degradation towards healthy and productive resources and ecosystems services. Positive environmental change helping to move forward towards a low-carbon economy could be articulated in the junction of the environment, agriculture, forestry, health and the bioeconomy, ensuring the provision of public and private goods including food and sufficient sustainable biomass, building on the potential of resource-efficient industries, bio-based products and bio-energy for green and sustainable blue -growth.

### *3.8. Constraints on materials and energy and the search for new opportunity spaces*

During the twentieth century, the world increased its fossil fuel use by a factor of 12, whilst extracting 34 times more material resources. Today in the EU, each person consumes 15 tons of

materials annually while generating 5 tons of waste. Businesses are facing rising costs for essential raw materials, energy and minerals, and the absence of security of supply and price volatility has a damaging effect on the economy.

Constraints on materials and energy result in bottlenecks and scarcities (absolute and relative), which make them geo-strategic, as they can be used, for example, to promote or disrupt political pursuits. Scarcities can result from overconsumption and thus relate to lifestyles, business models, consumption patterns, management of resources and the use of technologies. Scarcities may also result from inefficient supply or use technologies. Energy efficient technologies, for example, counteract scarcities in energy sources as they reduce demand. Constraints in the supply of energy may be the consequence of a lack of sources (e.g. in the availability of mineral fossil fuel or sustainable biomass), or due to the total cost of conversion – including resources and environmental costs (e.g. nuclear, photosynthesis, wind, wave and tidal, etc.). Those constraints spur research towards technologies that minimize the use of expensive and rare elements, be they energy (e.g. energy efficiency), critical materials or environment (in terms of costs of dealing with difficult waste-streams). They also spur research towards finding alternatives (energy sources, ways of sustainably using more abundant or renewable materials etc.). Finally, they also spur research towards new potential sources of supply, such as space and the oceans.

**4. Implications for possible orientations towards the next work programme**

Foresight evidence provides a number of pointers towards possible directions for the second work programme:

- Population and environmental developments in Europe and the world generate new risks for health and health policy objectives, and may challenge the preparedness of disease prevention and response systems. Agendas linking social and environmental determinants of health with the requirements of health systems for effective responses may be usefully explored in this context.

- It is important to address and to encourage new effective patterns of behaviour, be it in innovation (e.g. sweeping innovation), life-style (e.g. healthy and sustainable life-styles), governance (e.g. cyclical economy) and in many other aspects of life. Behavioural change is a challenge that has important social, personal, scientific and technological underpinnings.

- Research agendas in societal challenges require solid long-term road-maps in order to ensure real impact on the challenges themselves. The need is stronger in areas of high infrastructural investments and long-planning horizons. As success in addressing challenges can benefit greatly from unexpected technological breakthroughs, it is important to leave room for disruptive research and to establish the conditions for transversal application of new knowledge and innovative practice across societal challenges.

- The ability of Europe to harness the radical disruptions, that may originate in the combination of ICT and key enabling technologies and in the opening up of radically new opportunity domains such as Space and the Oceans, and to establish leadership positions in

global markets and strengthen its ability to address effectively societal challenges, will be directly related to its investment in technological knowledge, skills and competencies combined with appropriate social, organizational and regulatory frameworks.

- Transversality can be actively promoted, for example by focusing on abundant resources and by seeking alternatives to processes blocked by scarcities. For example, scarcities in scientific personnel can be overcome through automation of knowledge production and citizen-science. Abundant research will further accelerate innovation, although the rate of change will depend on the ability of actors to turn research into innovation. For Europe this has been a challenge that needs to be addressed through empowering individuals and enterprises and harnessing this power into a force for innovation.

- Transversality can also be nurtured, by developing research and innovation foci that bridge different challenges of Horizon 2020. Images of "positive environmental change", bridging visions of health, environment and the bioeconomy, can form a basis for such a focus. Another such focus may be the strategic for Europe nexus of food security, water and energy, which combines ideals of self-sufficiency with global commercial and environmental concerns and strategies.

- Accelerating change is a major challenge for regulation and for embedding technological change appropriately in its societal context. Engagement of citizens with Horizon 2020, is critical both in societal challenges and in emerging industrial technologies, upstream e.g. in the process of building roadmaps and downstream, e.g. in breakthrough research that will bring the benefits of technology and innovation to the market in a societally acceptable form.