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Foresight

Strategic Foresight:

Towards the 3rd Strategic Programme of Horizon 2020

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Towards the 3rd Strategic Programme of Horizon 2020

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FOREWORD

Horizon 2020 is the biggest EU Research and Innovation (R&I) programme ever with nearly €80 billion of funding available for seven years (2014-2020) in addition to the private R&I investment that this funding mobilises. It promises more breakthroughs, discoveries and world-firsts based on taking great ideas from the lab to the market.

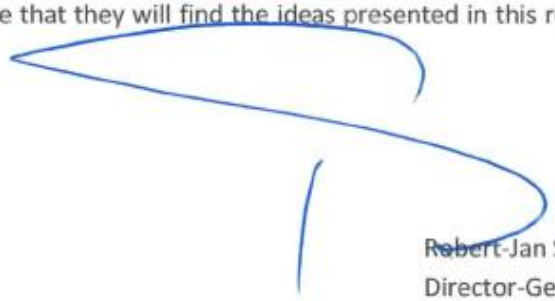
Horizon 2020 is a key instrument for driving economic growth and creating jobs. It aims to ensure that Europe produces world-class science, strengthens its industrial leadership and addresses societal challenges by making it easier for the public and private sectors to work together in delivering innovation. Horizon 2020 is, therefore, an investment in our future.

An important feature of Horizon 2020 is that its implementation is based on a strategic approach involving advice, evidence and foresight. Strategic programming cycles define broad lines of implementation for periods that go beyond the annual work programmes, providing focus areas with significant levels of resources. Strategic programming aims at maximizing the impact of EU funding by integrating different thematic domains and ensuring that the programme responds to new developments and emerging concerns.

Every strategic programming cycle involves a reflection phase and a consultation phase. Foresight is a key part of the reflection phase, where the aim is to open the agenda widely and to imagine the future, often in radically different ways, and then to reflect on the implications for programming. I believe that this reflection exercise raises awareness of different possibilities, and breathes creative spirit into the subsequent preparation of the strategic programme.

This report reflects, in a structured way, the views from a broad range of experts on the trends impacting the programming. I welcome this thought-provoking and creative input into the 3rd Strategic Programming period of Horizon 2020, covering the years 2018-2020.

As an even broader spectrum of stakeholders prepares to share their views on the priorities for the final period of Horizon 2020, I hope that they will find the ideas presented in this report stimulating and useful.



Robert-Jan Smits
Director-General
DG RTD

EXECUTIVE SUMMARY

The aim of this study was to support the implementation of Horizon 2020, and in particular the preparation of its third strategic programme, which covers the period 2018-2020, with foresight. The study reviewed existing foresight evidence and used it to develop a perspective of future change relevant to Horizon 2020. It involved three one-day workshops : one focusing on key relevant drivers of change; one developing future (2030) scenarios relevant for Horizon 2020, and one that explored the implications of potentially important emerging issues and disruptions for Horizon 2020. The following issues were highlighted:

Hyper-connectivity and Big Data driving accelerated change and innovation
There is a rapidly emerging nexus of opportunities and issues in the domain of Information and Communications Technology (ICT), with inter-connections to many other areas (e.g. food; healthcare; skills; cities; governance; energy and transport). Key drivers of change include cheap parallel computation, availability of data on the Internet and deep learning algorithms. Whether 'digital citizens' will be empowered or constrained by the systems they use, and who owns or controls their data, are key institutional questions that have profound implications for the research and innovation agenda.

Falling cost of energy: a potential game changer
Solar and wind energy are becoming competitive with fossil fuels, even though current prices for the latter are low. A drastic reduction in the price and environmental costs of energy will activate a myriad of improvements which seemed out-of-reach, like water production from the seas on a large scale. Fossil fuels may well become cheaper, as demand falls in developed countries, and as new sources emerge – for example shale oil and gas. A tipping point is approaching where powerful battery technology could precipitate rapid diffusion of renewable energy technologies. In both energy and transport, smart cities will involve cleaner and more sustainable services.

Migration and changing demographics: important changes for innovation in Europe
Waves of migrants and refugees will bring predominantly young people eager to work. This can compensate the current trends towards demographic ageing in Europe. To make positive use of the increasing diversity of European populations in order to benefit from advancing globalisation is a challenge for Europe, requiring new technologies and social innovation for education and health care, as well as governance, and social learning and integration.

Health as a major driver: key aspirations shaping attitudes to research and innovation
Demographic trends (ageing, migration), climate change and natural disasters, anti-microbial resistance, higher expectations for health in a context of increasing health costs per se will put high pressure on health systems. Through diffusion of data and hyper connectivity, the resulting citizen empowerment will radically change the nature of demand for healthcare. At the more radical edge, there is the prospect of "augmented" humans. Challenges to be met relate to health inequalities, ethics, risks and liabilities.

Facing climate change, oceans and space as pacifying/unifying projects
The climate, the oceans and the space are global commons which can give rise to pacifying / unifying projects for humanity as a whole. The prospect of resilient Big Data and hyper-connectivity depends on satellite infrastructures. Satellites also help better agriculture and land use, closer monitoring of climate and other environmental issues, including oceanology. Marine ecosystems offer huge opportunities but international cooperation is fundamental so that threats like ocean warming and increasing acidity do not result typically in the collapse of the ocean food chains. The enormous implications of rising sea levels, diminishing ice cover also require research on mitigation and adaptation strategies taking advantage of Big Data collection and sense-making capacity. At the more radical edge, space may become an alternative source of energy, and an important environment for health research. Space exploration in particular has the potential to become a unifying mega project.

Primary sector innovation: strategic and key for sustainability and well-being

The primary sectors and their rural-urban landscapes, city-scapes and ecological assets are the physical basis for Europe's future. Being at the beginning and end of industrial supply chains they are massively affected by changes in global markets. The 'primary' theme provides a counterpart to the 'metropolitan / services' centred view of Europe's future. 'Smart-countryside' can offer an alternative perspective to the organization of primary sectors across Europe, making them more sustainable and resilient.

Biotechnology as the next wave of disrupting technologies

The acceleration of biotechnology innovation will lengthen human lifespan and improve health, in particular through prevention via genetic testing and treatments. Biotechnology (and preference for certain patterns of diets) will affect industrial processes, biofuels, agriculture and animal breeding, and transform the food chain, waste treatment and environmental remediation. Abounding with radical opportunities, biotechnology is very likely to form the new wave of disruptive technologies.

A state of instability as the new norm in global society

Economic and political instability combine with an accumulation of problems related to climate change, desertification, and severe perturbations of the water/energy/food nexus to produce rising migration and social unrest, potentially including in the EU. As the link between climate change and conflicts will compound this systemic instability, the preparedness of society to face crisis has to be increased, and technologies and institutions have to strengthen resilience, which becomes a prominent concern. Organising principles that improve resilience include subsidiarity, decentralisation and ecosystem design. These apply both to institutions and to systems of institutions. Coping with diversity (of funding, of opinions, of cultures) will be a challenge.

Beyond strategic programming for H2020

There are four important structural and policy conditions that need to be fulfilled in order for Europe to benefit from the strategic choices of Horizon 2020:

- There is a need for a strong European science, technology and innovation system, in a society that is fully engaged with science, technology and innovation.
- There must be a strong economic base in Europe that can capture benefits from the capacity to address global problems.
- There must be congruence between the different policies involved - e.g. between research in transport, energy, environment, health etc. – but also with the key economic policies of the European Union in trade, competition, common market and monetary policy.
- Research will also contribute to building capacity for collective international decision-making, on a global scale, on fundamental issues for the future of mankind.

1. BACKGROUND

The aim of this study was to support the implementation of Horizon 2020, and in particular the preparation of its third strategic programme, which covers the period 2018-2020, with foresight. According to the regulation of Horizon 2020:

> "Detailed priority setting during the implementation of Horizon 2020 will entail a strategic approach to programming of research, using modes of governance aligning closely with policy development yet cutting across the boundaries of traditional sectoral policies. This will be based on sound evidence, analysis and foresight …. (this) will allow effective coordination between all specific objectives of Horizon 2020 and will allow to address challenges which cut across them, such as sustainability, climate change, social sciences and humanities or marine sciences and technologies." (OJ L 347/974 20/12/2013)

This paragraph defines the objectives of the strategic programming process in Horizon 2020. In order to facilitate the use of foresight in this process, EFFLA[1] proposed a policy-cycle model involving phases of strategic intelligence, sense-making, priority setting and implementation.

In this model, forward-looking informal expert consultations bring together available strategic intelligence in a sense-making process that derives possible policy implications for the strategic priorities of Horizon 2020. These policy implications are used to inspire and start the process of formal consultations with stakeholders during the priority-setting phase.

It is important to note here that the aim is not to provide a comprehensive and coherent view of what the future holds. This is neither feasible, nor desirable, as there are different possible futures depending on policies and actions decided today. The aim is rather to stimulate a discussion about the future and the desirable potential impacts of the Third Strategic Programme of Horizon 2020, that are likely to arise in the period after 2020 and have their impacts unfold throughout the decades that follow. Following from the EFFLA model, this report aims at provoking and opening the agendas rather than concluding and closing them. It looks at major trends that are unfolding and which will shape our perceptions of what the future holds, at important uncertainties and potential major changes in such trends and at what such scenarios imply for the possible impacts of H2020 research and innovation. The report is structured as follows:

The second section outlines the key features of Horizon 2020 in relation to its objectives and its current political context, explaining how these we operationalized in the study. The third section provides a short review of drivers of future change found in the foresight literature and debated and discussed in a workshop with experts from recent foresight projects. The fourth section presents briefly the scenario work carried out in the study and explains how this was used to derive a set of key considerations for the third Strategic Programme of Horizon 2020 that are exposed in the fifth section. Finally, the fifth section concludes with cross-cutting considerations beyond the mere programming of Horizon 2020.

The resources, participants in the workshops and the reports of the three individual workshops are annexed to this report.

[1] https://ec.europa.eu/research/innovation-union/pdf/expert-groups/effla-reports/effla_pb2_-_how_to_design_a_european_foresight_process.pdf

2. HORIZON 2020: THE CHALLENGE OF THE FUTURE

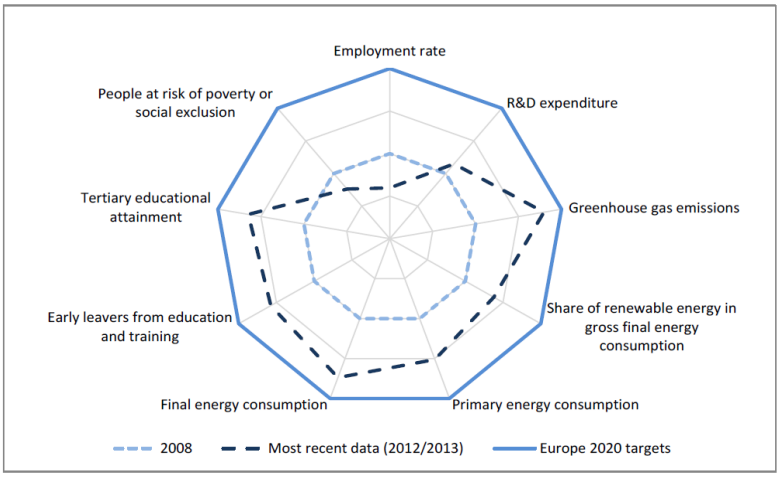
Horizon 2020 is the biggest EU Research and Innovation programme-ever, with €79 billion of funding available over seven years (2014 to 2020) – in addition to any investment that this money will attract. It promises more breakthroughs, discoveries and world-firsts, by taking great ideas from the research lab to the market. Horizon 2020 pushes the frontiers of knowledge, pursues industrial leadership for Europe and addresses key societal challenges of our time.

Shaping the context of these pursuits are megatrends, important directions of change which Europe can influence but cannot fully control or determine. Accelerating technological change is one of the megatrends of our times, identified in landmark foresight reports such as *Global Trends 2030* [2] from the European Strategy and Policy Analysis and *State of the Environment 2015*[3] from the European Environment Agency. However, this acceleration does not act in isolation. Other key defining features of our time are the overriding concerns with environmental, social and economic sustainability, in the context of climate change, demographic shifts and globalization[4].

Horizon 2020 pursues its objectives in the context of the Commission's priorities[5], especially the new Boost for Jobs, Growth and Investment, a Connected Digital Single Market, a Resilient Energy Union with a Forward-Looking Climate Change Policy and a Deeper and Fairer Internal Market with a Strengthened Industrial Base, but also a Deeper and Fairer Economic and Monetary Union, a Reasonable and Balanced Free Trade Agreement with the U.S, an Area of Justice and Fundamental Rights Based on Mutual Trust, a New Policy on Migration, (Europe as) a Stronger Global Actor and a Union of Democratic Change.

The importance of the objectives of Horizon 2020 is also underscored in the monitoring of the progress towards the goals of the Europe 2020 strategy, as can be shown in the figure below from a the recent Eurostat publication[6].

Europe 2020 headline indicators: target values and progress since 2008



Since 2008 substantial progress has been made both in the area of climate change and energy (through the reduction in greenhouse gas emissions and the increase in the use of renewable energy sources) and in the area of education (through the increase in the rate of tertiary educational attainment and the reduction in the number of early leavers from education and training).
Progress has been more limited for R&D expenditure, while the distance to the employment and poverty targets has increased.

From these different sources, three key perspectives emerge:

[2] http://europa.eu/espas/pdf/espas-report-2015.pdf
[3] http://www.eea.europa.eu/soer
[4] See SOER and ESPAS op. cit. Also Al Gore (2013) *The future: six drivers of global changes*, , published by Random House. Lecture available on https://www.youtube.com/watch?v=IQMcjNMgjBo
[5] COM (2015) 610 final *The Commission's work programme 2016: No time for business as usual*
[6] http://ec.europa.eu/eurostat/documents/2995521/6664132/1-02032015-CP-EN.pdf/e339ff6c-ee5c-4385-9cbc-bce32fbdb8d7

- The perspective of sustainability: Europe is making progress in energy and environment, and this progress involves an important opportunity to leverage climate and environment policy goals in economic contexts. At the same time it is not clear that meeting the EU goals would suffice to keep the world away from destructive climate change scenarios.
- The perspective of social change and societal challenges, especially but not exclusively challenges of unemployment, poverty and social exclusion.
- Innovation and competitiveness and the need to push ahead more aggressively in the pursuit of strengthening investment in R&D and innovation.

These perspectives have been built into the design of this study from the outset. In particular the scope of Horizon 2020 has been looked at from the perspectives of innovation and competitiveness, sustainability, social change and societal challenges and radical opportunity spaces – the fourth perspective added to address the technological ambitions that require leaps in scientific and technological knowledge, and large amounts of very risky investment (e.g. space travel).

The four perspectives: *sustainability, social change and societal challenges, innovation and competitiveness, and radical opportunity spaces* are used in this report as headings for the listing of important concerns under each area.

3. DRIVERS OF FUTURE CHANGE: THE STARTING POINT

The study began by using the megatrends identified in the literature[7] and the four perspectives to Horizon 2020 to develop an understanding of drivers of future change relevant for Horizon 2020. A workshop was organized for this purpose that involved experts from relevant foresight projects[8]. They started their discussions from the 28 Global Shifts identified in *The World Economic Forum (WEF) Global Strategic Foresight Community Report (2015).* The workshop concluded with the following list of 12 drivers of change which are coherent with the literature on megatrends but added a range of concerns that relate to Horizon 2020:

1. Globalisation: Global Governance of commons and management of risk is essential – related to rising inequity, new economic or military powers, new technology particularly in the bio sphere, conflict, environmental problems, in space and the marine environment. The innovation system and corporations operate at a global scale. Complexity, knowledge and data will fuel the spread of new models of political organisation, representing a challenge to the mainstream. There is a changing awareness of global/local ecological assets and risks. There is a systemic trajectory towards a global level of dysfunction, with profoundly negative effects on sustainability.

2. Demographics: A growing and **ageing population** will fuel demand for health and social care, and will financially challenge existing social models of welfare and pensions. Happiness and well-being is a major driver for individuals, leading to migration, which is also fuelled by high birth rates in poor countries, by political instability and environmental challenges. Global population pressures (sheer numbers and lifestyles) will put a focus on ways of changing resource limits – through harvesting space or the marine environment, or by using bio processes to generate energy. The increasing role of women has many impacts e.g. on family size and new forms of economy and society, and is linked to education and urbanisation. Population growth and current models of economic growth are driving the world towards greater environmental dangers.

3. Environment and biosphere: The driver here is a systemic trajectory towards a global level of dysfunction, with profoundly negative effects on sustainability. The pressure of population growth (10-12 billion by the end of the next century) will challenge the ability to sustain the biosphere. Environmental resource systems also change so that energy, water, food, light manufacturing etc. may be distributed and self-organizing, thus changing the mental models and policy models to deal with them. Understanding individual aspirations is crucial for the issue of sustainable consumption, and for 'bending the trends' of environmental impact, in a context of population growth and economic development.

4. Migration: The potential changes in Europe resulting from migration from other parts of the world over the next 20 years are massive. Global/regional conflicts and high population growth outside Europe – South Asia, Africa, South America - will lead more people to migrate to the EU and

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[7] All sources used are listed in Annex of the first workshop (26 May 2015) report

[8] 100 Opportunities for Finland and the World: www.sovelto.fi/application/files/8514/2997/7223/100opportunities.pdf); D-CENT (http://dcentproject.eu); Eco-innovation (www.eco-innovation.eu); EERA, (www.eera-set.eu); ETTIS (http://ettis-project.eu/); FORESEER, (https://www.foreseer.group.cam.ac.uk/foreseer-tool); Foresight and optimisation in Horizon 2020 (http://www.rand.org/randeurope/research/projects/foresight-optimisation-horizon-2020.html); FRESHER (http://www.foresight-fresher.eu/en/ Home/ Home); FUTRE (www.futre.eu); Global Opportunity Report: (www.unglobalcompact.org/library/1171); MilLESECURE-2050 (www.milesecure2050.eu); PASHMINA, (www.pashmina-project.eu); RECREATE (www.recreate-net.eu); RETHINK (www.rethink-net.eu); SPREE (www.spreeproject.com); VECTORS (www.vector-project.com)

between (south-south) countries. Growing awareness of the world beyond people's own borders, more access to travel and the growth of trafficking as an economic activity, all increase the risk of conflict and decrease the ability of international agencies to cope with problems. Migrants will seek to move to cities, the ethnic and social mix of which will change substantially.

5. Urbanisation: Cities will become larger and more politically important, for example with more Mayors and more delegated responsibility. Their ability to function will be crucially dependent on technology. Sustaining larger cities will require environmental innovations and technological progress (smart cities). The ethnic mix of cities will become more diverse as a result of migration. There is a risk of rising inequity within cities which could fuel unrest. The 'melting pot' of innovation and co-evolution in economic development, focused on digital, creative, professional, consumer services, often leads to a localised 'creative quarter' in cities, with critical mass of start-ups, freelancers, crowd-sourcing, network type firms and consortiums, and integrated supply-demand chains etc. In coming decades the majority of the economy could be in service/dematerialized cultural-creative type industries, and in distributed co-production with applications to sustainable systems of recycling, eco-efficiency and new patterns of sustainable consumption.

6. Climate change: The World faces a series of potential "tipping points" in climate change that could accelerate destructive impacts. Climate change is a threat multiplier: it exacerbates poverty and water scarcity; it compounds food and nutrition insecurity. Ecological resources are still largely monetised without externalities and extracted without proper acknowledgement of social and environmental costs. Key to addressing this is the ability of researchers to recognise the value of divergent/contrary views in scientific advice to policy. Enabling technologies including geo-engineering could be used to influence climate, but there would be a need for surveillance to support governance of such potentially high impact means of action.

7. Inequality: While global inequality between countries is decreasing, within the countries of the developed world inequality is increasing, as governments find it increasingly difficult to levy taxes from mobile wealthy individuals and corporations, and precarious employment is spreading. The challenge to the sustainability of existing social models may fuel challenges to the existing order with climate change being a threat multiplier, as it will exacerbate insecurity.

8. Limits to resources and energy: High population growth outside Europe – Asia, Africa, South America – will intensify competition for resources, and may spark greater migration, and innovation through harvesting space or the marine environment, or by using bio processes to generate energy. New technologies could change the limits and boundaries of production and consumption: nano, bio, material science etc. Bio processes could change the affordability of desalination. A number of new technologies – solar power, new techniques for managing gas – could revolutionise energy security and prices in Europe. Sustainability limits would need to be re-thought. There are new scientific frontiers in understanding complex inter-connected systems, with global / local thresholds or boundaries, together with the material cycles of carbon, nitrogen, phosphorus and other elements. Advances in agricultural science, precision agriculture, aquaculture and innovations in food could revolutionise the capability to provide food.

9. Digital revolution: Technological advances will change the way people live, work, conduct daily transactions, and travel. There will be opportunities for better and more efficient services, for greater empowerment of individuals. Threats to patterns of employment, and a greater security risk of major cyber-crime or cyber-terrorism, are destabilising. The system of digital surveillance is seen as a contributor to this, in that global digital corporations work closely with governments towards universal monitoring and potentially negation of liberty or privacy. Our dependence on ICT systems combined with our desire for privacy (hence encryption) leaves us open to cyber warfare and terrorism. People and objects increasingly have a complete, accurate digital image in virtual space, which will be more and more integrated functionally into the physical space. The interpenetration between the virtual and the physical world will be facilitated massively by advances in materials and biological sciences and the diffusion of 3D and 4D printers. As those gain in sophistication, human bodies may benefit from artificial parts. New materials may allow the production of soft robots with organic tissues.

10. Biotechnology and medical breakthroughs: There is an increasing understanding that the biosphere needs governance. What are the biological commons? What can be owned? As biology becomes DIY and the bio-economy becomes automated, the question of a post-work bio-economy e.g. oriented towards happiness, becomes important. Big Data and bio-informatics are crucial to the next generation of medical breakthroughs based on the genome and personalised medicine. Advances in medical treatment such as synthetic biology, regenerative and tissue engineering, prosthetic implants and human enhancements, combined with rising expectations, will increase the cost of health care. The role of the wealthy in leading the demand for bio enhancements and treatments will increase.

11. Jobs and skills, artificial intelligence: Technological advances will change the way people live, work, conduct daily transactions, and travel. A change in commuting – for example, send a hologram to work. A question for the post-work society – who will work and why? There will be opportunities for better and more efficient services, for greater empowerment of individuals, but also threats to patterns of employment, and a greater security risk of major cyber-crime or cyber-terrorism. Niches will flourish, e.g. creative jobs, eco-jobs, crafts etc. However volatility in job markets is expected to spread, and skills shortages may become significant. In terms of competencies needed, one could think of bio-designers – skilled bio-engineers will need to understand risk and ethical issues. Citizen science will need to be focused and managed to avoid bio-hazards from new stains of organism that "escape".

12. Individual aspiration and empowerment: Education, science and technology are empowering people, and new cognitive frameworks are emerging. The drive for happiness and well-being could fuel migration and become central in a post-work society. Private investors increasingly lead advances in space, marine and bio-environments. The changing role of women is one of the most significant forces for social change: they play a pivotal role in agriculture, food security, income generation and management of natural resources. There is rethinking on the meaning of happiness / well-being / prosperity / liveability / quality of life. New business models will emerge as changing aspirations are reflected in new value chains.

4. BUILDING AND USING FUTURE SCENARIOS

The drivers of change were used to develop '2030 scenarios' in the second workshop (26 June 2015). In each of the four perspectives expects were asked to define the key factors that would have the most impact and that are characterized by the highest levels of uncertainty. Those factors were defined at a lower level of analysis than the drivers of change, and there was considerable commonality in the way they were approached in the different perspectives. In this workshop a total of 15 scenarios were developed using as reference the following pairs of factors:

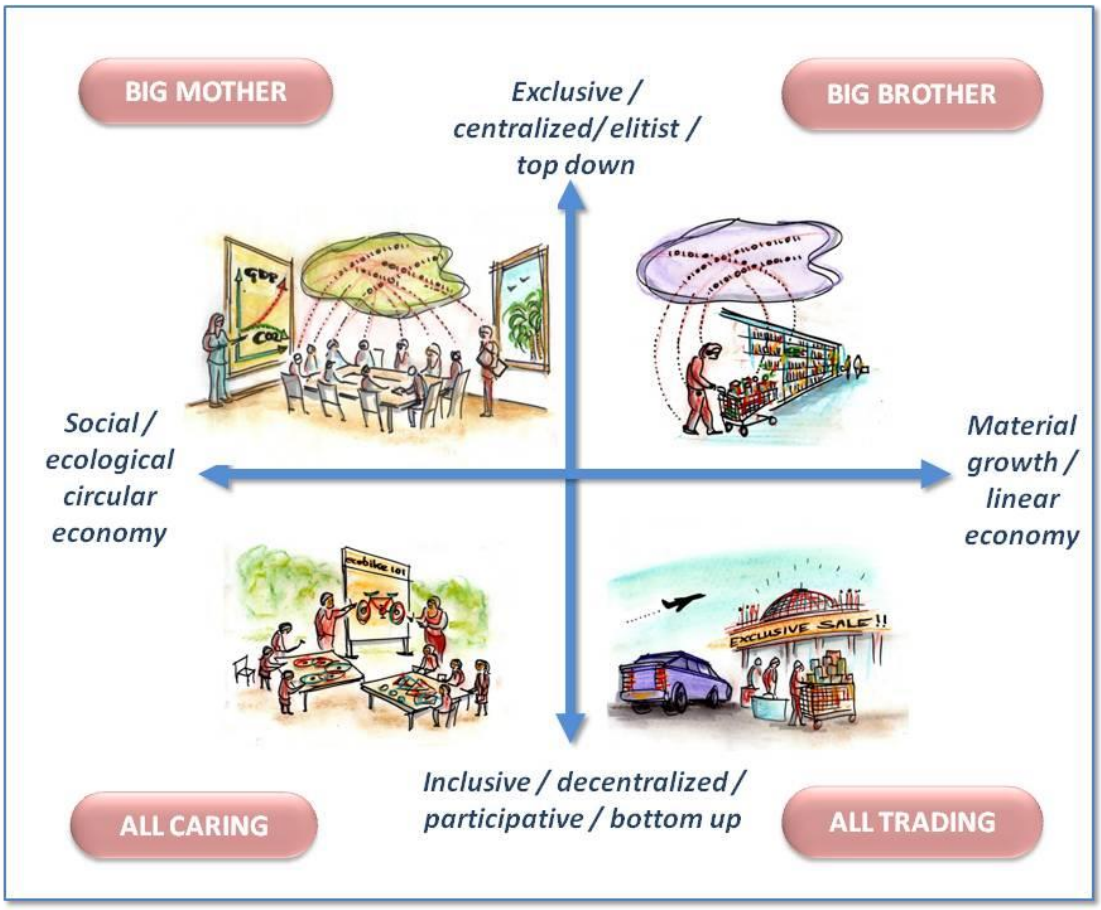
- Perspective: Innovation and competitiveness[9]
    - Driver a: Energy (abundant and environmentally benign vs expensive and polluting)
    - Driver b: Values (economic values vs new sources of value)
- Perspective: Sustainability
    - Driver a: Economic growth model (linear material vs circular ecological)
    - Driver b: Governance cultures: elitist/exclusive vs participative/inclusive

- Perspective: Social change and societal challenges:
    - Driver a: Data ownership
    - Driver b: Values (consumerist/materialistic vs non-materialistic)

- Perspective: Radical opportunity spaces
    - Driver a: Global governance (effective global governance vs fragmented world)
    - Driver b: Individual attitudes (engaged vs opting-out)

For the third workshop (26 September 2015), considering the commonalities between the different perspectives, the 15 scenarios were clustered into a set of four 2030 scenarios, exploring primarily the contradiction between materialistic and ecological "values" and between "centralised" and "decentralised" governance cultures. The naming of this "superset" of scenarios as ***Big Brother, All Trading, All Caring*** *and* ***Big Mother*** was adopted as symbolic of the main difference between the four scenarios.

[9] The scenario of expensive energy and economic values was not developed as it was thought to be too similar with current state of affairs.



Other key drivers raising important uncertainties, such as migration, economic and social inequality, and the possible abundance of cheap energy without environmental side-effects, were discussed within each scenario.

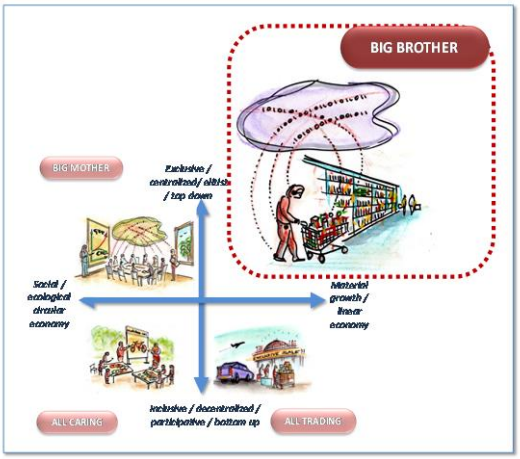
It must be noted here that the scenarios are not visions to be pursued and that there is no positive or negative scenario. Rather they are mental tests for the impacts of the different drivers identified in the first workshop. By stressing potential differences from the current state of affairs, the scenarios highlight desired and undesired future directions that could shape perceptions of potential impacts of Horizon 2020 either as objectives to be attained or as elements to steer away from.

In each scenario, the experts who took part in the third workshop were asked to consider what the key differences between the four scenarios and the current state of affairs are, and what are the challenges and opportunities that these differences highlight for Europe. In the light of those challenges and opportunities, appropriate potential impacts for Horizon 2020 were sought. These form the core of the implications for Horizon 2020 highlighted in this report.

Neither the 15 scenarios nor the superset have been extended to quantitative models: only qualitative images were used to frame the discussion.

5. THE SCENARIOS

5.1. Big Brother



Headline

- **I am a weapon of massive consumption**[10]

Key characteristics

- Materialistic and consumerist: a linear economy driven by growth.
- Governments and corporations own personal data, and encourage citizens to participate.

Key differences between Big Brother scenario for 2030 and the world in 2015

This scenario sees fierce competition for global resources, which may drive depletion and accelerate environmental catastrophes. Hyper-connected businesses grow very fast to join a global elite[11] of massive Schumpeterian[12] quasi-monopolies that will replace "national champions" in the world scene. One consequence is more polarisation of society. Some people are hyper-connected and others excluded, exploited and resentful. This is world of rising inequality.

All countries would need vibrant SME eco-systems to drive innovation and growth – or would risk sliding towards the periphery of the global economy. There would be more fluid labour markets, more self-employment and more varied careers.

The rise of global Big Data is contingent upon effective security. This is a world in which security and migration are managed top-down and effectively. However, global Big Data is also a potential threat to national governance and national identity, and raises issues of global democracy and governance.

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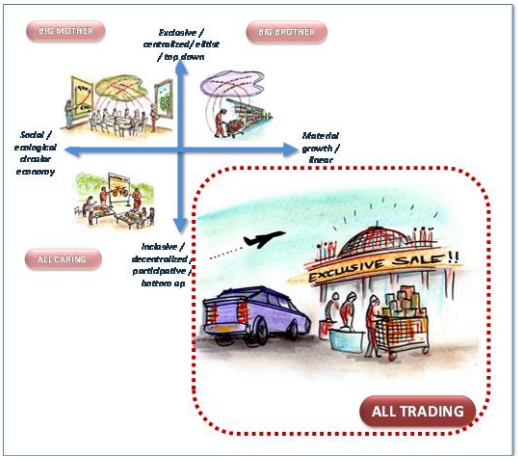
[10] From lyrics in the song: "THE FEAR" by Lily Allen

[11] In political and sociological theory, an elite is a small group of people who control a disproportionate amount of wealth or political power. This has been extended from its original usage to describe US Society to a global interpretation

[12] J. A. Schumpeter (1942) Capitalism, Socialism and Democracy. New York: Harper & Row

The applications and effect of technological potential game changers such as the Internet of Things are relatively predictable, while others such as 3D printing are less so. And the development of smart cites could lead to de-personalisation, or could enhance identity and personalised production.

5.2. All Trading



Headline

Tell us what you personally want – unless you are poor

Key characteristics

- Materialistic and consumerist: a linear economy driven by growth.
- Decentralised. People are able to take control and ownership of their own lives.

Key differences between All Trading scenario for 2030 and the world in 2015

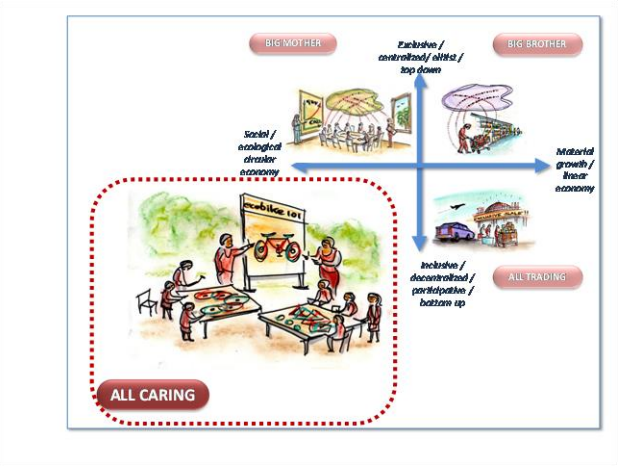
This scenario is underpinned by an assumption that the world will be largely connected – with the Internet of Things taken for granted and network connectivity used for trading of goods and services. Personal control of data and the ubiquity of trading could lead to a society in which anything could be traded – vital organs, visas and even children. The scenario implies little diversity of culture and loss of heritage. It does not provide a framework for social welfare, and this could be a society of extreme exclusion, where the have-nots - those not "data-savvy" - have no way of improving their condition.

The decentralisation implied by this scenario could create resilience against shocks far beyond that of centrally managed systems. Migration would become simply a natural process of adaptation and adjustment to changes through trade. As more services become traded, organisations, governments and companies would be increasingly replaced by contracts.

Governance of this scenario is a challenge: how are taxes collected? How to apply the precautionary principle? How to settle disputes? How to avoid phenomena like the tragedy of the commons[13]? This society cannot deal with public goods - except where participation can be traded. In enabling pricing of participation, the Internet of Things creates the potential for new industries.

[13] G Hardin (1968) "The tragedy of commons", Science 162, 3 December, 1243-1248

5.3. All Caring

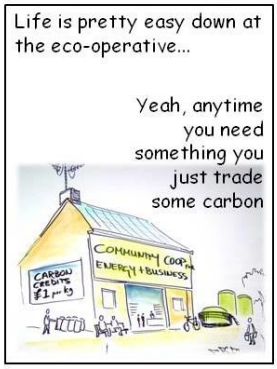


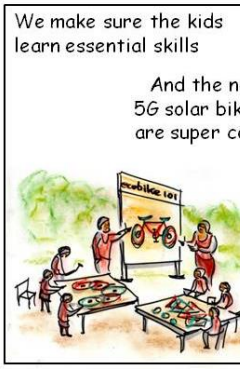
Headline

From shopping to re-shopping

Key characteristics

- People have become less materialistic, more driven by quality of life and the pursuit of happiness.
- Decentralised. People are able to take control and ownership of their own lives.





Key differences between All Caring scenario for 2030 and the world in 2015

This scenario paints a picture of a world in which people have become less materialistic in their pursuit of happiness and quality of life. Like ***All Trading***, it is a decentralised scenario in which people are able to take control and ownership of their own lives.

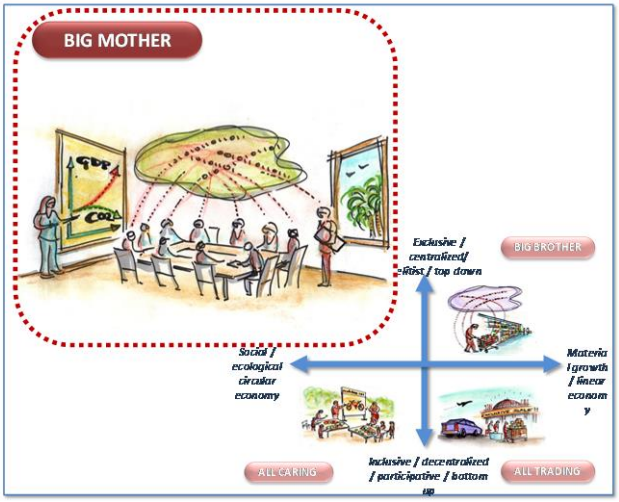
In measuring their well-being, people see the environment as more important than goods. Resource scarcities have been avoided by decreased consumption. Information Technology (IT) is used for participative governance, and there is more global government and more local government, with less national government. Public services are provided by a patchwork of local areas.

Many aspects of life and work are decentralised – healthcare, learning, social contact. This leads to extensive migration both within and into the EU to "chase the best deal", as it is accepted that people have the right to try to achieve what they want from life. People have multiple careers and portfolios of jobs – working in a corporate or government "office" is a rarity.

Major efforts to provide basic needs globally are partially successful, but there are still many migrants entering the EU. Cultural differences between immigrants and EU citizens lead to local concentrations of migrants in many cities.

A key challenge in this scenario is economic dynamism and entrepreneurship, to ensure that people can, as a whole, achieve what they want from life.

5.4. Big Mother

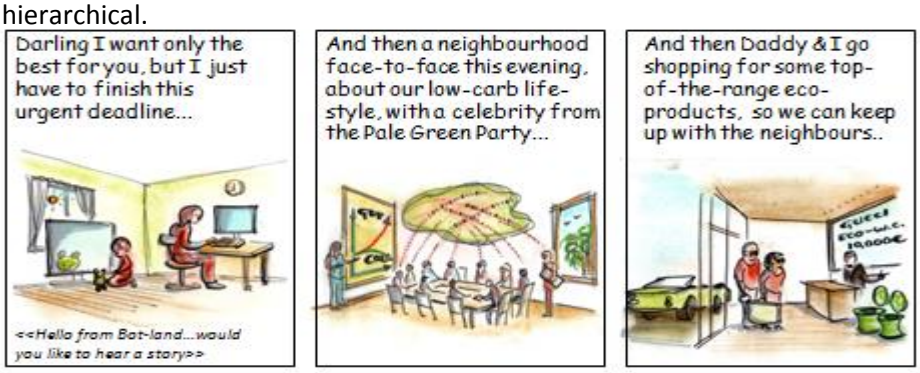


Headline

- **The affluent go eco-shopping**

Key characteristics

- People have become less materialistic, but more competitive.
- Governments and corporations control most personal data, and encourage citizens to participate in a social order which is elitist and hierarchical.



Key differences between Big Mother scenario for 2030 and the world in 2015

This 'Big Mother' is basically an information cloud, owned mainly by government bodies and NGOs, which organises most economic and social activity. The purpose of this system appears to be, to shift and "nudge" society towards greater community collaboration and non-materialistic and ecological values. However this comes with a hidden twist: the ideal of the collaborative community is seen by many as a cover for new forms of elitism and social hierarchy. State of the art eco-cars and eco-products are seen as a fashion accessory and a status symbol.

Some large enterprises also seek to bypass their non-materialistic public relations discourse to find new ways of promoting consumption – particularly global corporations based outside Europe, where materialistic values continue to predominate.

Also, many individuals find this 'Big Mother' world stifling and conformist, where stressed-out over-achievers are rewarded: these dissenters seek personal fulfilment and a more individualistic direction. Behind the community ethos publicly observed, there is hostility to inward migration and resistance to urbanisation.

Overall this is a scenario with an apparently unique agenda and direction of travel, but containing many tensions and contradictions - political, economic and ecological.

6. THE IMPLICATIONS FOR HORIZON 2020 3RD STRATEGIC PROGRAMME

Building resilience and avoiding environmental disasters, improving health and quality of life for everybody, accelerating innovation, building entrepreneurship and benefiting from new possible markets, are key directions that the scenarios point towards. For Horizon 2020 there are three types of implications:

- There are significant drivers and potential disrupters with important implications for the thematic orientations and potential impacts of Horizon 2020 actions.
- The drivers and disrupters affect the whole policy environment in which Horizon 2020 operates: Often the implications are for other policies, outside research and innovation, which are necessary for the societal objectives to be attained; and without which Horizon 2020 will not be able to achieve its desired impacts.
- There are significant implications for the conduct and organisation of the overall research and innovation effort, not only in terms of efficiency (e.g. open science, open innovation) but also in terms of societal engagement and ensuring a healthy and productive research and innovation ecosystem in Europe.

Resulting from the analysis of the megatrends, combined with other foresight sources[14], and the discussions in the three workshops, the following emerging issues and disruptions were highlighted as having potentially important implications for the third Strategic Programme of Horizon 2020:

- Hyper-connectivity and Big Data driving accelerated change and innovation
- Falling cost of energy as a huge economic and environmental game changer
- Migration and changing demographics: important changes for innovation in Europe
- Health as a major driver: a key concern in citizens' aspirations and a shaper of attitudes to research and innovation
- Facing climate change, oceans and space as pacifying/unifying projects important for humanity as a whole
- Primary sector innovation: strategic and key for sustainability and well-being
- Biotechnology as the next wave of disrupting technologies
- A state of instability as the new norm in global society

The rest of this section elaborates on each of these areas, starting with their general importance, the key drivers affecting them, the way they were treated in the four scenarios, and some illustrative ideas about their implications for Horizon 2020 listed under the headings of innovation and competitiveness, sustainability, social change and societal challenges, and radical opportunity spaces.

[14] All sources used are listed in Annex of the first workshop (26 May 2015) report

6.1. Hyper connectivity and Big Data driving accelerated change and innovation

There is a rapidly emerging nexus of opportunities and issues in the ICT domain, with inter-connections to many other topical areas (e.g. food, healthcare, skills, cities, governance, energy and transport).

Hyper connectivity, the Internet of Things and Cognitive Computing will transform our lives at a scale and a speed we hardly imagine today. Combined with Data Driven Innovation, hyper-connectivity will result in huge benefits, for example in health and in production methods allowing environmental gains etc.

The growing use of data will accentuate many of today's pressing questions e.g. on privacy and security, the impact of technology on jobs etc. Automated decision making and data-driven innovation (DDI) will have major impacts.

Advanced AI, autonomous systems and robotics could replace much of the employment of a wide range of workers. Professional practice in areas such as law, accountancy, medicine, research, banking etc. is likely to be massively affected over the next decade, while the use of robots in hazardous environments and warfare is already well advanced.

Key Drivers of change

Experts estimate that the Internet of Things will consist of almost 50 billion objects by 2020[15]. Originally designed for RFID[16] devices, it is expected to find early major uses in environmental monitoring and supply chain logistics. As it becomes pervasive, hyper connectivity is expected to be a "right" of all Europe's citizens by 2030.

Cognitive computing research has accelerated in the past few years. This has been driven by three inter-related developments in ICT:

Cheap parallel computation: Networks of massively parallel processors (derived from graphics processing units), able to process many tasks at the same time;

Availability of data on the internet: The best example is probably the Google Knowledge Vault. This collects data from many sources and merges information from across the web, to generate a single database of facts about the world and the people in it. The latest version collects data (1.6bn "facts" so far) automatically, rather than relying on human input;

Deep learning algorithms: Algorithms that enable computers to automatically identify and extract high-level features of unstructured data.

Cognitive computing and artificial intelligence (AI), automation and robotics, Big Data and data mining, are key drivers of change.

Better prediction and modeling via algorithms is likely to provide huge opportunities. Expert systems are becoming increasingly available as web-based services for a wide variety of applications.

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[15] http://www.iotsworldcongress.com/documents/4643185/0/IoT_IBSG_0411FINAL+Cisco.pdf
[16] Radio Frequency IDentification

The Internet of Things will raise issues of data storage and access, and citizen access to analytics will be a developing area of business opportunity.

Cyber-crime and cyber-warfare are likely to become more pervasive. Key areas for innovation are likely to be smart infrastructure, and building resilience. Big Data will require interchange between systems, greater bandwidth and new standards for interchange of data – referred to as infrastructure platforms.

Hyper-connectivity and Data in the four scenarios

Hyper-connectivity was central in all scenarios while data and their governance were at the heart of the contradictions explored by the scenarios.

Big Brother describes a society and economy in which governments and corporations (rather than individuals) own personal data. The rise of global Big Data is a potential threat to governance and national identity, and raises issues as to the nature of individual identity and self-determination, democracy and governance.

All Trading describes a decentralised society and economy, based on individuals control over their personal data. This could lead to a society where much more is traded than it is currently the case, in which trust in information, data-quality and data-security are key challenges.

All Caring was also about a decentralised society and economy in which individuals own their personal data. In ***All Caring***, personal data and privacy were built into all systems from the start, establishing a frame for trust in information, data quality and data security. Institutional arrangements suffice to control cyber-crime.

Big Mother describes a society and economy in which government, civil society and corporations (rather than individuals) own personal data and govern for the systemic "common good". 'Big Mother' is basically an information cloud, owned mainly by government bodies and NGOs, which organises most economic and social activity. The purpose of this system is to shift and "nudge" society towards greater community collaboration and non-materialistic and ecological values. The systemic definition of the common good combined with centralised control of data makes this scenario one in which democratic accountability can easily give way to new forms of elitism.

The scenarios differ in their answers to the questions as to whether 'digital citizens' will be empowered or constrained by the systems they use, and who will own or control their data. These are key institutional questions that have profound implications for the research and innovation agenda.

Implications for H2020

Innovation and competitiveness

Almost by definition, hyper-connectivity and developments in Big Data and data innovation will feed the rapidly emerging nexus of innovation opportunities and issues in the ICT domain, with inter-connections to many other areas. Big Data needs will drive hyper-connectivity by requiring interchange between systems, greater bandwidth and new standards for interchange of data – the infrastructure platforms.

Sustainability

The use of data plays a fundamental role in defining sustainability transitions and managing them. Sustainability is one of the first areas of application of big data. By allowing for example, tracking of waste, Big Data is helping to meet the planet's growing demand for energy and food as the world population reaches near nine billion and climate change will be major disruptions in food production patterns. Another powerful use of Big Data is its ability to help assess environmental risks, both in real time and in the future. Breakthroughs in sense-making of Big Data are expected to visibly contribute to resolving environmental issues. Hyper-connectivity in 'smart cities' and 'smart-countryside' will enable sustainability to be managed and monitored.

Social change and societal challenges

Widespread use of big datasets will drive innovation across many areas (such as food, healthcare, skills, cities, governance, energy and transport). Expert systems will complement and increasingly supplement professional practice. For example, in healthcare, expert systems will not only drive biotechnology-based innovations, but will also change many aspects of the doctor-patient interface and will mine big datasets for new insights in medical science. In transport, expert systems will combine with automation (autonomous vehicles continuously communicating with other vehicles and the infrastructure) and big-data techniques, to optimise not only traffic flows but also the design of transport systems, and infrastructure investment and management.

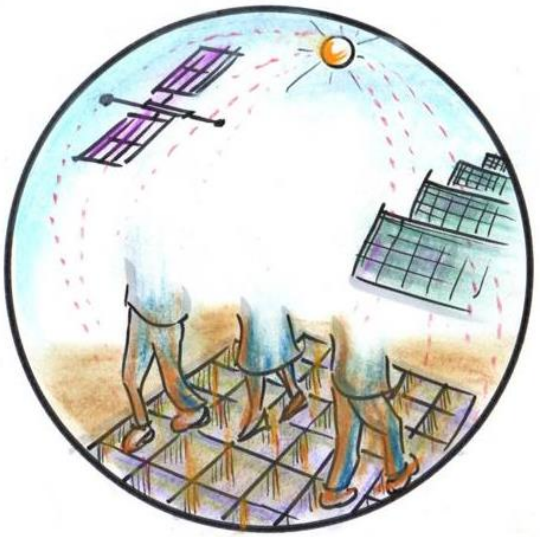
The impact of developments in computer science on society will be profound. Employment in many professional services will be impacted through cognitive computing and autonomous systems which could replace many e human tasks till considered today as expert task. Cyber-crime and cyber-warfare may become important menaces for society.

Radical opportunity spaces

The infrastructure needs of ICT deployment drive space activities which provide resilience of terrestrial communication systems, and also observation data for terrestrial environments and activities.

6.2. Falling cost of energy as a huge economic and environmental game changer

Solar and wind energy are becoming competitive with fossil fuels, even though current prices for the latter are low. A drastic reduction in energy prices and environmental costs will activate a myriad of improvements which seemed out-of-reach, like separation and recycling of all raw materials, conquering deserts through cooling, cheaper and safer transport of people and goods, creation of materials, water production from the seas on a vast scale, etc.



Energy and transport are inextricably linked – transport is one of the major uses of energy and shares with it the requirement for a reliable and robust infrastructure. Attempts to change patterns of energy use therefore rely heavily on attempts to transform the means of transport and patterns of use of transportation.

In both energy and transport, Europe, and the rest of the world, is rapidly approaching radical change. Opportunities lie with combining cleaner energy, better conservation, offsets of carbon emitting energy, better storage of renewable energy, and smarter generation and distribution.

The technologies required are already available but not yet being widely implemented. Critical to making the decisive changes will be the development of infrastructures to support the implementation of technical innovations in energy generation, storage and supply, and in the management of transport systems.

Key Drivers of Change

In the field of energy there is likely to be a significant shift towards renewable energy – but the pace and extent of change will depend on the ability to achieve reliable and secure supplies of energy. Particular importance in this lies with energy storage. There is a sense that with improvements and diffusion of powerful battery technology we may be approaching a tipping point that will precipitate rapid diffusion of renewable energy technologies.

Fossil fuels may well become cheaper, as demand falls in developed countries, and as new sources emerge – for example shale oil and gas. A falling price may have a distorting effect on the economic case for renewable energy. But the environmental case will continue to be very strong, and there will be a drive to develop carbon capture and storage, and other “cleaner” ways of using fossil fuels.

In transport, the move towards automatic vehicles, non-carbon fuels and materials, and smarter logistics will all lead to major changes in the transport infrastructure. Demand for goods and mobility will continue, so innovation will focus to a great extent on ways of meeting demand, whilst ensuring cleaner and more efficient systems.

In both energy and transport, smart cities will seek to develop cleaner, more sustainable services provision, and there is likely to be a move to more efficient energy trading as batteries decrease the reliance of individuals on the grid, and enable individual energy provision. Advances in battery technology are at the heart of the perception that a new era of abundant and cheap energy is in sight.

Energy in the scenarios

In ***Big Brother***, growth is central to the viability of the scenario. Demand for energy will rise, as will the demand for mobility – both for individuals and goods. Growth in renewable energy, flexibility of supply and better infrastructure management will therefore be critical. Critical areas for development will include infrastructures for the generation and storage of energy, and carbon capture and storage. There will be a move to radically different vehicles and more rational systems for the movement of goods, through the development of the physical internet[17] to underpin the latter.

In ***All Trading***, the development of decentralised energy markets can be envisaged, as can greater use of ICT to control and regulate the supply of energy and management of transport and logistics. Energy could become cleaner, with less use of fossil fuels as renewable technologies diffuse and batteries enable individuals to enter the market.

In ***All Caring***, there is again a move to more efficient energy, based on greater use of renewable energy, and safer, cleaner transport. Under this scenario, demand for energy might reduce, as part of a move towards greater self-sufficiency and local production of food and other goods.

In ***Big Mother***, effective local collection, generation and distribution of energy was envisaged, and a more collective management of usage – for example community heating. Again there is emphasis on the development of storage technology for renewable energy and automatic, cheap transport. Transitions may be slowed down by a combination of strong incumbent interests and centralised management of information.

Implications for Horizon 2020

Innovation and competitiveness

Innovation is needed that helps use fossil fuels more sparingly and to offset their effects through for example carbon capture and storage. Energy management and energy efficiency is pushed by ICT advances but is curtailed by the abundance of renewable energy. Battery technology innovation is a key component to the transition to a state of abundant renewable energy, which is likely to fuel innovation in all other areas.

Sustainability

Renewable energy is an important component of the efforts to mitigate climate change. Abundant renewable energy may push innovation in new areas, such as waste management and recycling, and de-pollution of the environment. In addition, the decentralisation of energy production and supply – through technology and infrastructure to allow a significant move to renewable energy – will enable better (and more secure) generation, more local self-sufficiency and more resilient energy systems for all.

In addition to bio-energy supplies, bio-technology opens the prospect for more energy efficient industrial processes. For example, many industrial processes are energy intensive, often requiring high temperatures. Bio-technological processes using enzymes typically work at low temperatures, and could achieve the same results as chemical processes using less energy.

[17]The Physical Internet is defined as an open global logistics system founded on physical, digital and operational interconnectivity.

Social change and societal challenges

Energy and transport considerations drive urbanisation processes. While off-the-grid living becomes possible through renewable energy[18], urbanisation trends are likely to be supported by innovations in transport and in the provision of environmental services. Alongside the development of cleaner vehicles, there will need to be the development of a transport infrastructure to support these vehicles and more generally to support innovation in the management and integration of both private and public transport and the movement of goods.

Radical opportunity spaces

While energy production and storage technology is very actively developed and highly dependent on infrastructures, existing technologies leave a lot of room for improvements, and radically new technologies may emerge. Two spaces of radical opportunity search are nuclear fusion, and harvesting energy from space.

[18] The US Department of Energy estimates between 1M and 4 M US households could be powered by rooftop solar energy by 2020 - http://www.theplaidzebra.com/tesla-motors-homemade-battery-will-let-independently-power-house/

6.3. Migration and changing demographics: important changes for innovation in Europe

As well as migration due to climate change, while major crises prevail in unstable zones, waves of migrants and refugees will bring predominantly young people, talented and eager to work, to Europe. This can compensate the current trends towards demographic ageing in Europe.

At the same time the ethnic demographic make-up of our societies will become more fluid, with all the challenges and opportunities that this would bring. It will be a challenge for Europe to make positive use of the increasing diversity in order to benefit from advancing globalisation.

Europe has always been influenced by waves of migration, and the European Union was built on guarantees of the free movement of persons, goods, services and capital within the Union and strictly prohibits any discrimination on grounds of nationality. Yet, the Union is challenged as citizens react against increased migration, which is fuelled not only by labour mobility but also by waves of refuges from political crises and natural and humanitarian catastrophes.

The widespread use of ICT in Africa which massively facilitates information diffusion, combined with demographic developments, make it plausible that by 2030 Europe will be home to large numbers of migrants from Africa. This will have implications for health and education systems, but also for the broader societal normative frameworks and social integration mechanisms.

Key drivers of change

The key drivers of migration are:

Globalisation, including the vastly increased availability of information; the increasing facility to travel; and the general decline in the power of nation states over corporate and individual actors, which results from the globalised freedom to move goods, money and individuals;

A state of protracted political and economic instability in many parts of the world, where states fail and wars, environmental and humanitarian catastrophes form people's everyday reality. Furthermore climate change is already pushing people to migrate just as lack of water availability and other issues resulting from environmental deterioration (e.g. soil erosion);

Migration in itself was identified early in the study as a key driver of change. Of particular concern is the challenge that large population movements represent for local social, economic and political systems – for Europe it refers mostly to the arrival of people from outside the EU.

Migration in the scenarios

All the scenarios describe how significant immigration into Europe is tackled: in each of the scenarios the way in which migration is seen, and migrants/refugees are regarded, is different.

In ***Big Brother*** legal migrants are welcomed by the authorities, as extra consumers, workers and taxpayers. Such migration is favoured by corporations – but not necessarily by EU citizens – as it brings into the economy highly motivated people of working age. Technological innovations to control movement of people, to recognise and deal with problems quickly, and to support adaptation and integration of newcomers in local social contexts, all form parts of this scenario.

In ***All Trading,*** migrants will be willing to trade off the escape from conditions at home against exploitative and poorly-paid work in Europe. But there will be greater resentment and possible social conflict with poorer and middle class EU citizens, who see migrants from Africa and the Middle East as a threat to their own work and earnings. As governments weaken, migration forms a domain of competition between nations, and some EU governments openly trade visas.

In ***All Caring***, migrants continue to see Europe as a safe haven. The ways in which they are received, and helped to integrate into their new homes and jobs are devolved under this system, and so attitudes vary in different parts of Europe. Places that already have large and settled immigrant communities tend to attract the most migrants, and are better at integrating them. There, technology first developed for "millennials"[19] will be extended to include language translation and online services for migrant families and singleton workers. However in this scenario any smart city system needs to take into account the ability of people to opt-out. Cultural differences and resource distribution issues form the challenge of migration to the limits of the ***All Caring*** scenario.

In ***Big Mother***, the conformist view of society makes migration more problematic, as there is suspicion of people whose values and belief systems do not coincide with those of the mainstream of society. This fuels tensions and mutual suspicion. Ghettos in the cities become the norm, regarded as no go areas. Migrants with low educational attainment create replicas of the societies they have left behind. Migrants with good education and qualifications adopt “European” names and behaviours. In this context brain implants could provide a way for people to rapidly improve their job prospects.

Implications for Horizon 2020

Innovation and competitiveness

Migration is likely to increase diversity and creativity and to speed up the pace of introduction of innovations. Increased diversity in demand will contribute to this. New forms of health and educational innovations (and skills enhancements) are likely to take shape. The challenge will be to channel the creativity of the melting-pot cities of Europe towards socially beneficial business rather than socially destructive crime.

Sustainability

Migration will alleviate environmental pressures in other parts of the planet but will become a bigger challenge in Europe, as incoming populations need to be included in environmental impact calculations and in sustainable local societal practices. What this means is that Europe’s drive for technical and social solutions to sustainability problems needs strengthening further on both fronts. Migration can provide an opportunity to shape the cultures of people far away, towards more sustainable environmental practices, as the bonds between expatriate communities and those left behind are important avenues for developing economic, business and cultural links.

Social change and societal challenges

Migration to the cities from rural areas, and immigration from outside Europe, will change the nature of cities. The health, education and social needs profile of immigrant populations will bring new challenges and opportunities for innovation, in cities and countries, in diagnostics as well as in interventions. There is likely to be a need for a great deal of social learning and for exchange of information and practice on policies: what works and what does not, how to reduce social conflict and develop new models of participatory governance in cities.

[19] Generations born after the year 2000.

Radical opportunity spaces

While acute problems often give rise to radical ideas – e.g. wearable or implantable translators come to some people's minds - overall, migration is a challenge that requires an overarching and systemic response. An umbrella initiative to make migration positive for Europe would include actions under a number of Horizon 2020 objectives, with ICT and social sciences as key enablers.

6.4. Health as a major driver: a key concern in citizens aspirations and a shaper of attitudes to Research and Innovation

Demographic trends (ageing, migration), climate change and natural disasters, anti-microbial resistance, higher expectations for health in a context of increasing health costs per se, will all put high pressure on health systems. Through diffusion of data and hyper connectivity, the resulting citizen empowerment will radically change the nature of demand for healthcare.

With progress in medical science, biotechnology, pharmacology and in the understanding of the determinants of health, opportunities exist to revolutionise health care – prevention, diagnosis and treatment - and individuals and populations are becoming more demanding of science and of the economy and policy.

As people become increasingly informed globally, health inequalities may become a key driver of political developments and population movements.

New developments in preventive medicine will include the use of technology to allow more intensive and personal health screening via smartphones, wearables and implants, and the use of genetic treatments. There will be earlier and faster diagnosis and predictive diagnosis, based on the use of genetics. There will be more personalised and effective treatments, based on biotech and genetech, and potentially also human enhancement and organ replacement rather than transplant. Advances in treatments will often require linked developments in the biotech, genetech and IT sectors. All this will be in a context in which healthy environments and lifestyles will be demanded by informed individuals and the actions of policy-makers and corporations will be judged on the basis of their effects on peoples' health (and not only on their wallet).

These developments will have three potential effects:

- They will in themselves represent a potentially valuable source of economic activity and innovation, as relatively new technologies and areas of innovation begin to mature. Europe will have the opportunity to become a leading player, but will face fierce competition from the USA and Asia.
- The developments will drive up demand for (and the cost of) improved health services and health outcomes. Personalised medicine may, at least initially, be confined to those individuals who can afford it; but the pressure to make it more generally available will grow very fast.
- The new developments – in particular the use of technology to closely monitor people's health, and personalised medicine – will change the relationship between clinicians and patients. Medicine will more and more be something that is done by and with the patients, not to them.

Key Drivers of Change

Health is an area in which developments are pushed by progress in science, technology and innovation in an increasingly wide range of fields and disciplines.

Developments in ICT, such as wearables, implants and Big Data, along with biomedicine and genetech offer the prospect of personalised medicine, in which there is faster prevention and diagnosis, leading to better outcomes and potentially earlier – therefore cheaper – and more effective interventions.

Data availability and Big Data analytics are driving the understanding of the influence of genetic and environmental factors and their combinations, raising individual aspirations and demands for healthy longevity.

In addition, this more personalised approach opens up the prospect of what was termed "democracy of health", where health care is something that people do to themselves in consultation with professionals, rather than something that is "done to them". At the more radical edge, there is the prospect of "augmented" humans.

The technologies to make this happen are in the pipeline; but there are challenges to be met. Some are related to health inequalities which are likely to become increasingly controversial. Some are associated with regulation of health risks and liabilities and in a broader sense with the close-knit link between health and ethics. This is why health was a key concern in the four scenarios.

Health in the scenarios

In ***Big Brother***, there is a significant risk that health inequalities will widen, as a result of immigration, the wider economic impact and the environmental issues raised by the scenario. Improved health status will be achievable through commercial opportunities benefitting the incumbents which in turn will increase health inequalities and will drive innovation towards the needs of the rich. It will be a challenge to make the benefits widely available, and to have a regulatory system that brings them rapidly and safely on-stream.

In ***All Trading***, there is likelihood that personal data related to health will be traded. This could push the greatest benefit – e.g. better and earlier prevention – to the wealthiest in society thus widening health inequalities. However, the trading of information may also provide opportunities for rapid health improvements – including mental health – both by technological and other forms of innovation e.g. through the use of the natural environment to increase mental wellbeing.

In ***All Caring***, the emphasis is on social interventions including effective (and cost-effective) new technologies, better health monitoring, better quality of life, and healthier diets. This scenario would place emphasis on prevention rather than cure. In this scenario, trust, public education, and data security are key, as is regulation to bring innovations forward rapidly and safely. Personalised medicine will be pushed by diagnostics, but the development of interventions will be driven by considerations of societal cost-effectiveness.

In ***Big Mother***, the pursuit of health is an important objective. ***Big Mother*** raises the possibility of a "democracy of health", with lower costs, and opportunities for new cures and more active ageing – feeding into a "One Health" principle, a holistic approach to human, animal and environmental health. However, the political nature of such a "One Health" principle raised the risk of important inequalities in the distribution of health benefits.

Implications for Horizon 2020

Innovation and competitiveness

The level of expectations of citizens is such that the innovation pipeline in pharmaceuticals and in other relevant industries – e.g. diagnostics, functional foods, healthy materials, needs to be accelerated. Testing methods and tools as well as the resilience of regulatory systems are critical in achieving this.

Sustainability

Sustainability is similar to the concept of "One Health" – a sustainable environment is a healthy environment, one which preserves the health of current and future generations. Whilst the importance of the effect of the environment of health is understood, it remains a scarcely exploited opportunity for environmental research and innovation practice.

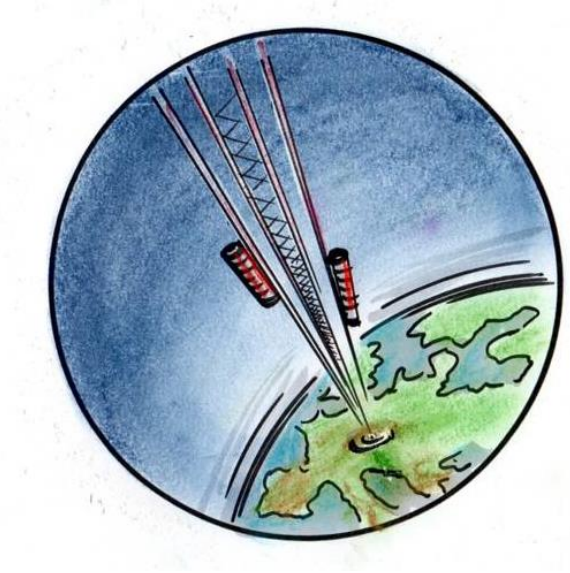
Social change and societal challenges

There is a perceived trade-off between the cost of new medical technologies, including biomedicine and personalised treatments, and the potential savings from better health management, prevention, and earlier diagnosis and treatment. The four scenarios have shown that the form of this trade-off is shaped by the social model in which it is perceived – that defines the importance of enhancements and the importance of tolerable inequalities. A key part of this social model is how data are handled. Making medical data available to research is seen as a key exploitation of the potential of Big Data. In addition, following the success of the human genome project, "open science" wants to build on rapid communication of findings to support management and prevention, as well as (personalised) diagnosis and treatment.

Radical opportunity spaces

Human enhancement and robotic (assisted) care are two radical opportunity spaces that are driven by health considerations. Advances in biotech and genetech are beginning to open up the prospect of significant extension of healthy human lifespans.

6.5. Facing climate change, oceans and space as pacifying/unifying projects



The climate, the oceans and space are global commons which can give rise to pacifying / unifying projects for humanity as a whole.

Many of the 17 Sustainable Development Goals [20]require global governance related to the environment, resource use and climate change. The IPPC[21], a global scientific effort to help global governance, illustrates how research on climate change can help decisions dealing with global commons and can inspire other areas such oceans and space.

Space exploration could constitute in itself a 'great challenge for humankind' for which nations could collaborate. The delivery of benefits from Big Data and hyper-connectivity depends partly on satellite infrastructure. Satellites help agriculture and land use, closer monitoring of climate and other environmental issues, including oceanology. The offshore economy can bring new opportunities for health, energy and food security. At the more radical edge, space may become an alternative source of materials, energy, and an important environment for health research.

There are important institutional issues to be resolved (in space or deep oceans: who owns what?), with safety and impact on health being a central issue. There is already a considerable body of legal commitments as regards oceans and space, which form a basis for existing commercial uses. At the same time new nations are entering the space domain with ambitions and investment. However space is not only a domain of competition. In international space missions, involving myriad technologies, many countries find incentives to participate. A superior sense of 'mission' is a catalyst for peaceful cooperation.

Key Drivers of Change

Environmental sustainability and resource concerns are driving the perceptions of climate, oceans and space as "commons".

An increasing involvement of private actors characterizes all three domains. The governance of space science and technology has been shifting from an exclusive state affair (for military and other earth observation needs and telecommunications) to a business model where states, private companies and billionaires interplay. Different aspects of ocean science and technology bring together important state and private concerns, of which, climate services are seen as an emerging business sector with high potential.

The increasing demand from users creates a need to “manage” space and the oceans better – cleaning up and depollution efforts, including the removal of old and broken satellites and keeping paths as clear as possible of old debris.

[20] www.un.org/**sustainabledevelopment/sustainable-development-goals**

[21]Integrated pollution prevention and control directive, http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:l28045

The drive to explore unexplored places, in space as well as in the ocean, will continue to be strong. People will continue to explore the potential for wider exploration, including the potential for "mining" of other bodies in space.

Climate, Oceans and Space in the scenarios

All the scenarios saw a key role for space as a resource to assist developments in key areas such as ICT and Big Data, agriculture and environmental management.

In ***Big Brother,*** the risk of destructive climate change is the highest, and so is the pressure to develop radical solutions to the problems caused by the growth of the material economy. Space and the oceans are explored and exploited by small and large companies and by governments. New financial instruments are needed to assist this involvement, as cleaning and maintaining the environment is a major challenge. The observation powers of government and corporations were a defining part of the ***Big Brother*** scenario.

In ***All Trading,*** the global commons form areas of huge potential problems. Trading of satellite data for example has the potential to improve efficiency in farming and climate management, and wider monitoring of land use, but the issue of who owns the observation and how it is traded is an important barrier. Trading carbon emissions would be an important step forward that could then be expanded to trading ocean pollution, and even to licenses for space exploration.

In ***All Caring,*** climate, space and the oceans form part of the common inheritance. Their value is high and their conservation is paramount. Climate services, ocean and space research can provide sources of important spin-offs, and information that could help improve services, for example by providing important experimental environments for health science and health data. However, the environmental and economic cost of experiments would be relatively high and thus ***All Caring*** is not a scenario favouring radical research and innovation.

In ***Big Mother,*** the importance of overall regulation of climate, space and the oceans and the key role for the EU as the "owner" of data was a defining element of the scenario. Research and innovation could support radical visions of environmental sustainability goals such as closed-loop living and harvesting solar energy from space.

Implications for Horizon 2020

Innovation and competitiveness

Because of the cost of deploying technology in space and the drive for reliability, space technology defines the most stringent performance standards. Space programmes represent a fruitful environment for small and large engineering companies, with spin-offs in virtually all sectors, including health.

Innovation is likely to be increasingly shaped by the needs for mitigation and adaptation to climate change, as climate models provide estimations on the likely future environmental conditions.

The global commons will be perceived differently by the Internet generation coming of age, compared to baby boomers raised in less environment-conscious world. Demand for products which are both 'smart and green' from cradle to grave will increase.

Sustainability

New environmental services including ocean and space information could become a significant market. Dramatic climatic or geological events will accentuate the sense of urgency for more monitoring services and research.

Geo-engineering is highly controversial as its interventions are often seen as irreversible. Space technology could enable incremental and reversible geo-engineering interventions.

Research and technology on closed living systems associated with the needs of long-term space travel may provide new sustainability orientated insights including in health, energy, food and social needs. For example, 3D un-printing to re-use material might become particularly important in space colonization research.

Social change and societal challenges

Environmental catastrophes such as sea-level rise, desertification, or extreme weather, will changes peoples' perceptions, and industry and government priorities, shifting investment to mega-projects in off-shore platforms, coastal protection, relocation of coastal cities.

Research on multi-purpose marine or space platforms will need to address energy generation, bio culture, etc. and may give rise to mega-infrastructure projects.

Should it become likely that the target of a two degree temperature increase to limit climate change effects will be completely overtaken by reality, the social push for research in climate change, oceans and space will be pivotal, increasing the demand for economic evaluation of environmental impacts (policies, investment and actions) of such mega-projects.

Be it for the oceans (which are finite and polluted) or for space (which is quite infinite but already with potentially harmful junk), governance is needed to deal with the problem of commons.

Radical opportunity spaces

Outer space is an unexplored boundary, a radical opportunity space. Having tamed inner space for our telecommunications and hyper-connectivity needs is a first step. A great deal of initiative goes into developing reusable means of space transport and in exploring old ideas such as the space elevator[22] and the harvesting of solar and wind energy from above the atmosphere. These projects face important technical barriers, overcoming which will propel our technology to much higher levels of performance.

[22] First proposed by Konstantin Tsiolkovsky in 1895, and recently revamped .
http://www.telegraph.co.uk/news/science/science-news/11805987/Inflatable-space-elevator-invented-by-scientists.html

6.6. Primary sector innovation: strategic and key for sustainability and well-being

The primary sectors and their rural-urban landscapes, city-scapes and ecological assets are the physical basis for Europe's future.

This is about not only food and farming, but also fisheries, forestry, minerals and aggregates, waste management and the whole physical circular economy.

Each of these sectors has a physical land-use component, in landscapes and ecosystems of all types. And each of these is under growing pressure from demographic change, economic restructuring, technological innovation and in particular from climate change, with new opportunities emerging for mitigation and adaptation.

This 'primary' theme provides a counterpart to the 'metropolitan / services' centred view of Europe's future. There are new kinds of settlement-landscape patterns emerging in extended peri-urban areas, and also in the greening of the cities and the urbanization of the countryside.

Key drivers of change

The key drivers of primary sector innovation are related to demographic and economic development combined with resource scarcities.

The primary sectors are at the beginning and end of industrial supply chains, and are directly affected by changes in global markets, technologies, logistics and governance. Some are of strategic importance for national governments, but they all are crucial to the rural-based economies, communities and landscapes which depend on them.

Urbanization processes and the rapid growth of peri-urban settlements are often destructive for the countryside. Many rural locations are in rapid change, for example with the positive effect of broadband services; or negatively, the effects of depopulation, ageing and desertification. Many previously rural-based primary activities are transferred to urban or peri-urban locations: for instance, urban food, energy, water and other ecosystems reflect a new agenda for the greening of cities.

How the primary sector is perceived in the scenarios

In ***Big Brother***, primary activity is seen through the lens of an innovative and materialistic, digital economic world. Rural landscapes and ecosystems would be privatised, and the supply chains of food or forestry would be industrialised and centralised. In response to climate change impacts, geo-engineering and land engineering could emerge with newly profitable business models.

In ***All Trading,*** there is a more fluid and decentralised economy, where primary sectors might see new enterprises springing up, e.g. with a 'wood renaissance', small portable water treatment plants, or in new products made of waste streams in a self-organising circular economy. New local industries emerge, based on Europe's assets, whether heritage, cultural or natural.

In ***All Caring,*** the possibility of a localised primary sector in synergy with a return to localised communities and economies, goes hand in hand with ecosystem management perspectives. For example, a 'wood renaissance' would include carbon sink capacity building, and the health aspects of the circular economy will be safeguarded.

In ***Big Mother***, a circular economy primary sector could be elitist and hierarchical, with urban-rural land use and ecosystems management. The urbanisation tendencies and the environmental

regulation aspects of the ***Big Mother*** scenario are close to the current situation in Europe's countryside. Smart country-side, a concept analogous to Smart Cities, will be enabled by the Internet of Things spreading into farming and environmental management. Connected sensors will be used monitor all aspects of the environment, and AI techniques like cognitive computing will be needed to interpret the big datasets that result. Precision and autonomous farming techniques will grow and increasing use will be made of satellite-based monitoring and management.

Implications for Horizon 2020

Innovation and competitiveness

Most primary sectors are mature markets with low profit margins. A great deal of innovation in the primary sector comes directly from engineering and is driven by the efficiency concerns of large business. The challenge is to support a vibrant environment of innovative small businesses taking advantage of streams of innovations coming from biotechnology, materials science and ICT and from their combinations, an example is in water treatment.

Sustainability

The primary sectors are core for sustainability concerns. They have important direct effects on the environment, and they are directly responsible for the use (and misuse) of natural resources - they are important users of energy and they generate major parts of CO2 emissions. The primary sectors are at the forefront of the development of circular economy models and they are the targets of a great deal of technological innovation associated with the pursuit of sustainability.

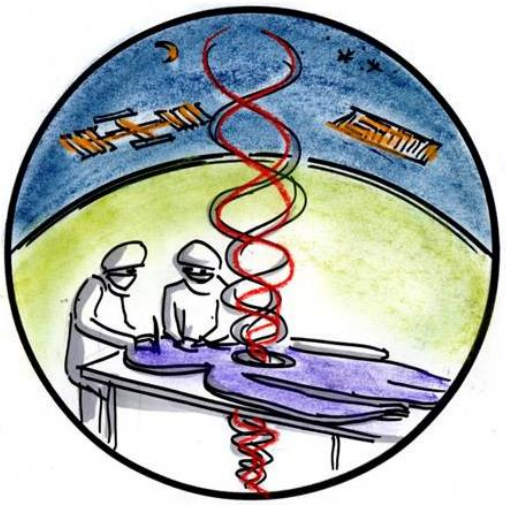
Social change and societal challenges

The important aspect of a forward looking agenda for the primary sectors is not only about technology breakthroughs, but also about development of new societal models for science, policy, enterprise and development. These could involve transformations of the rural landscapes (e.g. "smart countryside" models), but also the increasing transfer of primary sectors to cities and peri-urban areas (e.g. urban and sub-urban farming models) bringing new kinds of health risks and benefits to the city.

Radical opportunity spaces

Establishing security of supply of food and materials is driving geo-engineering pursuits as much as, or more than, climate change. Large irrigation and mining works and large land reclamation and environmental remediation projects may provide radical opportunity spaces for European businesses who could find their skills needed in a much more urbanised world of 8.5 bn people.

6.7. Biotechnology as the next wave of disrupting technologies



The acceleration of Biotechnology, driven by developments such as gene editing, will be transformative.

Biotech will lengthen human lifespan and improve health, through genetic testing and treatments. It will affect industrial processes, biofuels, agriculture and animal breeding, and transform the food chain.

It will affect Europe through European practice as well as through its adoption in other parts of the world.

Gene editing of bacteria, yeasts, animals and plants allows individual genes to be disabled or modified, and permits the rapid transfer of specific genes within species and between species.

Techniques such as CRISPR–Cas9[23] have dramatically accelerated the pace of change in biotechnology. Developments that previously would have taken decades can now be achieved within years or sometimes even months.

Key drivers of change

Genetic engineering can be used to modify or introduce new metabolic processes into bacteria, yeasts and higher organisms. Depending on the changes made, these could be to produce pharmaceuticals or other useful chemicals; to develop new food varieties; or to create biological sensors to detect and measure a wide range of conditions, with environmental or medical applications.

ICT is another key driver of biotechnology. Genome mapping has advanced rapidly and will continue to advance driven by advances in ICT. Big Data techniques and the increasing availability of genetic information accelerate biotechnological advances.

Demand for healthcare. A key driver for the advance of biotechnology is the demand for health related products and services, be they diagnostics or treatments. The prospect of "miracle cures", as well as earlier diagnosis and prevention of ill-health is likely to accelerate demand. DNA mapping and genetic treatments are changing how we think about healthcare. For example, the genetic modification of a child's immune system this year has enabled her to recover from previously untreatable leukaemia.

Food security. . Increasing farm yields has been one of the first drivers of biotechnology. Nowadays, a main claim to justify the need for biotechnology advances is the current and projected scarcity of food resources[24].

Public attitudes. The food scarcity argument has been embroiled in political positions about GMO's[25] in agriculture and food, and the conservation of genetic strains, that, if anything, has delayed rather that accelerated technological change.

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[23] A technique allowing precise and predictable changes to be made to the genome of virtually any organism

[24] However, it must also be noted that one-third of food produced for human consumption is lost or wasted globally, http://www.fao.org/fileadmin/user_upload/suistainability/pdf/Global_Food_Losses_and_Food_Waste.pdf

[25] Genetically Modified Organisms

Biotechnology in the scenarios

In ***Big Brother,*** ICT and data propel the development and deployment of biotechnology to underpin a new wave of innovations. Health technology and the nature of bio-regulation are driven both by demand for better health, but also by the need for strong economic growth. Extravagant products such as 3D printed meat are launched for as a long as there is a market for them.

In ***All Trading,*** information is valued and is used to promote personalised knowledge, understanding and technology – be it for precision plant breeding and agriculture, or for personalized medicine.

In ***All Caring,*** there is a need to reconcile local food with healthy and affordable diets, and with radically reducing food waste. In this environment biotechnology serves existing practices in health care and agriculture, rather than bringing in revolutionary changes – the pursuit of which could be judged as unethical or irresponsible.

In ***Big Mother,*** biotechnology serves environmental goals but is guided by policy. Here we could see projects aiming at radical new food ingredients (proteins etc.), taxation of unhealthy food, and new models for agri-food systems (including urban food systems with minimised transport needs).

Implications for Horizon 2020

Innovation and competitiveness

Biotechnology will revolutionise nearly all aspects of healthcare, with the prospect of personalised medicine; pharmaceutical productions; treatments for cancers; and curing of genetic diseases, to name a few. GMO's will be increasingly used to produce pharmaceuticals and other therapeutic bio-chemicals.

Biotechnology will be used to produce any number of bio-sensors for diagnostic, preventative and curative use in medicine or applications like food testing.

In global agriculture, gene editing will be used to speed up the introduction of new varieties of animal feed, crops and of livestock, with desirable traits such as increased yields or disease resistance. (One possible example is the development of allergy-free peanuts.)

Ultimately, entirely new genes will be introduced into animal feeds, food crops and livestock to change the nature of the food derived from them (such as fish oils from plants).

Sustainability

Many industrial processes are energy intensive, often requiring high temperatures and pressures to promote chemical reactions with. Bio-technology offers the prospect of introducing biological pathways fir industrial process using enzymes which typically work at low temperatures, and thus use a lot less energy to achieve the same results as traditional high-temperature catalysts. Biotechnology can be used to promote other sustainability traits in a range of production processes.

Synthetic biology can give rise to new bio-sensors to allow cheap and widespread monitoring of environmental conditions, especially of pollutant levels.

Social change and societal challenges

The prospect of new cures and longer, healthier lives will fuel public demand for change in the medical and healthcare sectors, and bio-technology seems unlikely to become an issue with bio-sensors and industrial enzymes in enclosed systems

However, in the food sector and sometimes with biofuel, the spread of biotechnology is facing important social resistance in Europe and elsewhere on ethical (religious) as well as on health and environmental risk grounds.

Although ethical and regulatory barriers may affect the spread of biotechnology, it is important to realise that technologies cannot be de-invented – even if for ethical reasons their deployment may be seriously curtailed by some fears– and that Europe cannot be an island immune to genetic influences from other parts of the globe. For example, more than 80% of the total soybean meal use - one of the biggest ingredients in the EU livestock and poultry feed - by EU member states is estimated to be GM. and this issue may be repeated across all food categories.

Radical opportunity spaces

Biotechnology abounds with radical opportunities. It is a transformative technology on a par with the advent of steam power in the eighteenth century, and the development of electronics in the 1920's. Gene editing is a specific advance that is accelerating the rate of change in biotechnology, akin to the invention of the separate steam condenser by James Watt in 1775, and the invention of the transistor by Bell Labs in 1947. And like these technologies at the time, it is difficult to predict the nature of the changes that they will ultimately deliver.

In medicine, enhancement of human cells offers the prospect of delaying the ageing process, and the onset of the frailties of old age. In addition, mammals, such as pigs, could be bred to provoke a reduced immunological response from human immune systems, offering the prospect of safe xeno-transplants with unlimited donors.

In food, entirely new genes could be introduced into animal feeds, crops and livestock to change the nature of the food derived from them. Such foods could be healthier or more nutritious, or have a smaller ecological footprint than traditional agriculture. For example, bio-technology and other food sciences could be used to replace animal protein with proteins derived from plants, but with the same meaty and creamy tastes and with less harmful fats, or even to produce laboratory-grown meat without involving animals in the process at all.

In energy, possible applications include bio-engineering of bacterial, algal or plant cells to photosynthesise in useful ways, e.g. with the prospect of direct production of hydrogen from sunlight.

6.8. A state of instability as the new norm in global society

Economic and political instability combine with an accumulation of problems related to climate change, desertification, and severe perturbations of the water/energy/food nexus to produce rising migration and social unrest, potentially including in the EU. As the link between climate change and conflicts will compound this systemic instability, the preparedness of society to face crisis has to be increased, and technologies and institutions have to strengthen resilience, which becomes a prominent concern.

Organising principles that improve resilience include subsidiarity, decentralisation and ecosystem design. These apply both to institutions and to systems of institutions. Coping with diversity (of funding, of opinions, of cultures) will be a challenge.

As half the world will be vulnerable (in particular due to failing states, climate change, desertification, severe perturbations of the Water/Energy/Food nexus), migration and social unrest will increase in the short term, potentially including in the EU.

Key Drivers of change

A classic list of potential disruptors includes:

- The risk of escalation of current conflicts in North Africa and the Middle East, which could easily "spill over" into Europe, e.g. through disruptions caused by waves of migration.
- Another financial crash with global impacts as in 2008.
- Ecological or environmental catastrophe either from natural disasters, nuclear plant malfunction etc. or global changes like climate change or soil erosion.
- Pandemic from new strains of virus.
- Melt-down of infrastructure and society from terrorism – cyber or physical.

However, structural factors may cause disruption and affect the capacity of the EU to deal with disruptions. For example, factors such as the fragmentation of the EU social model, combined with the effect of AI and robotics on jobs, could cause societal disruption on a major scale.

Instability in the scenarios

Big Brother depends on a global governance system that has enough regulation so that governments and corporations can own and use personal data without outcry from the citizens. This in turn requires effective security against the growing threat of data theft and cyber warfare/terrorism. It is also a scenario in which the scramble for resources is most likely to provoke environmental catastrophe and/or wars. It is also the scenario least able to manage instability due to the centralised organisation and the homogeneous culture.

All Trading is dependent on effective global governance to ensure that individuals can own and manage their personal data, and use it to opt in or out of society. The courts uphold and defend individuals' rights in this regard. The richest belong to an international elite, and are largely able to operate beyond national or local governance. A high level of consumerism is paralleled by the growth

in inequality in this model, which will be reflected in politics, with greater polarity between the point of view of the rich (and those who aspire to be rich, or depend on them) and the poor. This is potentially a very unstable world, and though decentralised, and able to cope with local disruptions, it is not likely to have enough capacity to be resilient to global shocks.

All Caring envisages greater local autonomy, and greater participation in politics at the most local levels. There is an issue about what should be devolved, and what needs to be done at regional, national or supra-national level, but the underlying assumption is that local is best, and this in turn means that there is a greater sense that politicians are accountable for what they do. Opponents see this as a world that lacks dynamism and restricts opportunities. But other localities may provide more opportunity and attract new citizens. While this is therefore a scenario of an assemblage of diverse communities, it does not have effective mechanisms for global governance, and is likely to fragment when faced with disruptions***.***

Big Mother has a centralised top-down structure focused on the aspiration of the 'circular economy', which in practice takes an unexpected turn towards the elite: celebrities and bankers now lead the way in the low-carbon transition. The result is management of resources or ecosystems which tend to widen the gaps in an elitist and unequal society, increasing instability and not necessarily guaranteeing resilience.

Implications for Horizon 2020

Innovation and competitiveness

The overall topic that emerges is the need for the design of systems able to be resilient against instability, from a range of sources including terrorism.

Sustainability

Securing food and water supply chains against environmental catastrophes, be it due to sudden events or resulting from long-term degradations, will lessen instability. Disaster preparedness in the environmental field will be a key component of societal resilience and cohesion.

Social change and societal challenges

Essential hyper-connectivity should be resilient to system breakages. Infrastructures need to withstand challenges from shocks including cyber-crime and warfare, and should ensure appropriate levels of data privacy and security. Smart Cities and Smart Countryside approaches need to promote resilient design principles, including energy supply based on local as well as "grid" sources, and resilient transport infrastructures and services. Resilient health care systems should address the effect of instability, especially on vulnerable groups and how to ensure their continued access to health care is maintained.

Radical opportunity spaces

Space systems are built and tested for resilience and important lessons for terrestrial systems can be derived from there.

7. BEYOND STRATEGIC PROGRAMMING FOR H2020

Strategic programming in Horizon 2020 is about choosing the most impactful / highest promise areas to invest in research and innovation in order to strengthen the benefit of the programme to Europe's economy and society.

This study illustrates the global nature of many future challenges and opportunities, and the multiple possibilities for responses. For example, future local community responses may compete with those of global corporations. How is Europe's benefit from the strategic choices of Horizon 2020 to be ensured?

There are three important structural and policy conditions that need to be fulfilled:

- There is a need for a strong European science, technology and innovation system, in a society that is fully engaged with science, technology and innovation.
- There is a need for a strong economic base in Europe to capture benefit from its capacity to address global problems. Here we do not refer only to manufacturers but also to designers, experts and managers of service firms that deliver solutions.
- There must be congruence between the different policies involved. Horizon 2020 must address problems and provide solutions that need favourable framework conditions for innovation. This congruence is not needed only between the thematic policy areas directly concerned – e.g. environment, climate, transport, energy, health etc. – but also in relation to the key economic policies of the Union in trade, competition, common market and monetary policy.

With those conditions satisfied, the EU can pursue agreements and science diplomacy and seek international agreements to face the challenges that humankind faces. The EU has the potential to become a leader in shaping global frameworks for global solutions to global problems and a promoter of unifying and pacifying mega projects for the benefit of humankind. In this context, Europe being "Open to the World" would be an important step towards making the world a more open and fair space.

Open science projects, like the human genome project, can spearhead global science diplomacy. Open science projects are based on strong conditions for privacy and intellectual property[26]. Such projects can galvanise research communities and facilitate trusted exchange of early findings and data, speeding up discoveries and innovation.

Open science, however, cannot be only for specific communities of scientists. Openness needs to permeate scientific institutions, which need to be part of societal deliberation, in order to engender the engaged public that Europe needs. As change accelerates and instability becomes the new norm, public engagement with science becomes key for Europe, while science in itself becomes more concentrated.

This public engagement, in particular involving citizens and users in the development and acceptance of biotech solutions. is all the more necessary in a time of disruptive innovations. Biotechnology for example, raises major questions on the ethics of trans-humanism, gene editing or synthetic biology. Social network technologies can create a surveillance society, and advanced robotics threatens mass

[26] A moratorium on publishing has been a key element of success in the human genome project.

unemployment. There are few 'objective' answers to the questions posed by these developments. So the research and innovation community will need to include extended processes of peer-review, civic debate and public participation, taking evidence from multiple viewpoints and critical perspectives. Such deliberation should then inform not only 'closed door' funding agencies, but new institutions for open governance based on democratic principles.

In fact, a strong science, technology and innovation base depends increasingly on large scale concentrations of capacity in diverse fields, around large facilities and important research equipment, involving the public and private sectors and building on rapid exchange and cross-fertilisation of ideas. While the Knowledge and Innovation Communities of the European Institute for Innovation and Technology (EIT) are dispersed, there is a need for concentration and collocation of labs to build on large scale interactions between research, industry and higher education. Such spaces may become engines of open-innovation that will propel Europe forward in the 21st century. These are beyond the remit of the 3rd Strategic Programme of Horizon 2020, but are vital for Europe.

Appendices

Appendix 1 Report of the first workshop (26 May 2015): important trends and game changers

Appendix 2: Report of the second workshop (26 June 2015): selection of relevant drivers and details on the fours scenarios

Appendix 3: Report of the third workshop (22 September 2015): how Horizon 2020 can maximise benefits and minimise risks in the four scenarios

Appendix 4: List of participants to the three workshops and foresight sources

KI-02-15-938-EN-N

The aim of this report is to support the **preparation of the third strategic programme of Horizon 2020** (2018-2020).

The report highlights the following potentially important considerations: **Hyper-connectivity and Big Data** driving accelerated change and innovation; **Falling cost of energy** as potential game changer; **Migration and changing demographics** as important for innovation in Europe; **Health as a major driver for aspirations**, shaping attitudes to Research and Innovation; **Climate change, oceans and space** as projects important for humanity as a whole; **Primary sector innovation** as a strategic concern, key for sustainability and well-being; **Biotechnology** as the next wave of disrupting technologies**; Instability, as a new norm in global society.**

In addition, the report emphasizes the importance of public engagement, a strong export-oriented economic base; congruence between the different policies involved and the contribution of research to building capacity for collective international decision-making on a global scale.

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