European Commission

Preparing the Commission for future opportunities

Foresight network fiches 2030

Working document

Vision

The future belongs to the ones that can handle complexity and engage with uncertainty. Anticipating the technology convergence revolution and the societal expectations within a political vision is the key.

A political vision is a must, not for a technology -pushed but for a technology-enabled society.

If political guidance brings 'the what and the why', science and technology can bring 'the how'

Preface

At a time when the new European Commission announced that it will concentrate on bold initiatives, it is important to recall that any policy decision has complex ra-mifications. Indeed, an increasing number of decisions affect several policy portfolios, and they need to take into account an increasing number of parameters, like geo-politics, economics, finance, security, health, environment, climate change, sociology, urbanisation, ageing society, and integrate fundamental European social values such gender equality and ethics. In addition, the technological breakthroughs are accelerating as never before in history and social innovation (e.g. social media) augments the speed of information gathering and dissemination.

Because societies become ever more complex, collaborative long-term anticipation must replace the "silo" thinking habits and the short-termism that has characterised many aspects of policy-making in Europe.

Foreseeing is not sufficient anymore because it is only a tactical extrapolation of current trends; it is the future of the past. Foresighting however is strategic because it is based on more disruptive views; it is about the future of the future.

But foresight needs also to become more integrated and collaborative, using coproduction of knowledge by means of "concurrent design" approaches. These will foster anticipatory and more consistent policies and thus lead to more visionary governance.

'The rougher the seas the more connected watch-towers are needed'.

Europe invented the modern World despite a resource poor continent because we used the most precious resource we have: our brains. Europe's real strength lies in its diversity that is a powerful driver of innovation. Where different minds meet, there is inspiration. This is why the network of foresight experts has such a great potential. It is an excellent way to obtain a comprehensive analysis that integrates the various scientific, technological, but also social aspects. This is encompassed in the concept of at is Responsible Research and Innovation.

'We cannot predict the future,
but we have the opportunity to invent it,
based on sound science and technology foresight'.

Preamble

The Chief Scientific Adviser (CSA) and the Director General of the Bureau of European Policy Advisers (BEPA) initiated a network of foresight experts within the Commission services end 2013. The network was registered by the Secretariat General on 3.12.2013 with the following mandate:

> *"This internal Commission network aims at improving the coherence of existing and future foresight activities by strengthening complementarities and synergies and help setting priorities. It will nurture the work of the Science and Technology Advisory Council - through identification and analysis of relevant subjects -, and provide future reflection topics for European Group on Ethics for science and new technologies. This network will also support, where appropriate, the European Strategy and Policy Analysis System foresight exercise, provide a valuable input in different areas of interest to all DGs, and improve, by doing so, the policy planning process of the different services of the Commission."*

The project, led by Didier Schmitt (CSA/BEPA), comprised 21 DGs (AGRI, BEPA, CLIMA, CNECT, DEVCO, EAC, ECHO, EMPL, ENER, ENTR, ENV, HOME, JRC, JUST, MARE, MARKT, MOVE, REGIO, RTD, SANCO, TRADE); in total over 230 staff participated in the various activities. The list of the experts is provided in Annex.

President Barroso gave a video address at the inaugural meeting on 17 February 2014.

The experts developed the foresight Fiches and were also involved in:

- The definition of the questionnaire of the Special Eurobarometer on foresight *"Public Perceptions of Science, Research and Innovation"* in the next 15 years
- Six workshops *'2030' Science, Engineering, Technology & Innovation*:

  What's in it for Society?
  How will we access and use resources in 2030?
  What and how will we produce and consume in 2030?
  Where will we live in 2030?
  How will we interact in 2030 How healthy will we be in 2030?
  How will we participate in society in 2030?

We would like to thank all actors who have made this initiative possible, and especially all network members for the time dedicated to this voluntary *ad hoc* activity, and to Carmen Tresguerres for her editorial support.

The analyses in this report do not necessarily reflect the views of the European Commission.

Table of content

4. Environment and energy

5. Society and wellbeing

6. Physical science and manufacturing/ enabling technologies

7. Aeronautics and space applications

Conclusion

Annex 1. List of contributors

Chapter 1.
Digital enabling technologies

Introduction

Digital technologies are on the move. They are not anymore just trendy technologies available for information and communications, but they are dramatically changing the very criteria for market access for almost all kinds of products, services, and ideas. They are often combined in a system of system, like into a Smartphone and next, Google Glass.

Digital technologies are enabling a new era everywhere in the globalised economy and not just in the most advanced economies. The mass of data storage and handling is exponential and needs new security paradigms.

A third industrial revolution and social mutation is underway.

Cloud computing

Cloud computing is a major technology leap that can give to public organisations, companies and SMEs virtually unlimited access to computing power without substantial capital investments in local IT infrastructure or advanced in-house ICT skills. Cloud computing can bring substantial advantages in particular as regards productivity growth as well as bring the tools needed for the digital revolution.

Key figure or a highlight: cloud is estimated to add around €940bn to the EU GDP by 2020 creation of 400.000 new SMEs.

Keywords: Cloud computing, IaaS, PaaS, productivity growth.

Current status

Cloud computing is a major technology leap that can disrupt existing industries and *status quo*. For the first time, companies can have virtually unlimited access to computing power without substantial investment or advanced in-house IT skills. This opens up enormous possibilities in terms of innovation and business creation, but most importantly, brings down cost and barriers to entry, as the user does not need to cover upfront capital expenditures, but instead pays for actual usage. This translates into high elasticity of services that scale quickly and at low marginal cost to peaks and troughs in demand. Cloud is already transforming the way organisations are doing business, and the pace of this transformation is expected to accelerate in the future.

Future trends (~2030)

On the science

In the future, we can expect highly efficient, low-power processors crunching many workloads in the cloud, contained in highly automated datacentres and supporting massively federated, scalable software architecture. Rapid increase in processing power and economies of scale will make ICT services delivered through cloud even cheaper, while technologies currently limited to supercomputing will make it into the mainstream.

On the applications

It can be expected that software will be more and more delivered through the cloud – as a service – and will become detached from hardware (being hardware agnostic). With the growth in the size and complexity of individual applications, the developers will place an emphasis on modular software — i.e. large applications with components that can be modified without shutting down the program.

Moreover, the completion of the digital single market in 2015, notably with the data protection reform, aims at boosting trust of European individuals and businesses in cloud computing and big data technologies. More transparency is needed in the cloud market to ensure that European individuals and businesses can safely use cloud products.

Expected overall impact in/for Europe

The impact of cloud on the society actually depends on the imagination of the users. What cloud does is simply to enable people doing what they want to do, without the need of big capital. While cloud almost eliminates the needs of financial capital, it requires the trust of individuals in the proposed application. It is the responsibility of the Commission to provide for a framework that guarantees trust.

Some of the benefits are: (i) closing the digital divide gap – it enables organisations and private users to obtain ICT services (from storage to more advanced IaaS services) for a fraction of what it would cost to build a data centre; (ii) benefits for education: new generation of teaching tools delivered though the cloud enable anyone with a broadband connection to learn wherever they are; (iii) science: in sectors facing a steep rise in demand for computing power, such as the scientific sector, cloud may be the only way to respond to a substantial increase in demand for computing power; moreover, it allows for new forms of collaboration – crowdsourcing; (iv) crowdsourcing: cloud solutions enable new form of collaboration for people who share a common objective; getting people working on the same idea from around the world gets easy, cost and environment friendly.

Regarding the economic impact, cloud computing is expected to contribute up to €250 billion to the EU GDP in 2020 – that could reach a total cumulative gain of €940 billion for the period 2015-2020, as well as lead to creation of around 400,000 new SMEs over a period of 5 years and permanently shifting the structure of the economy. Moreover, through the cost reductions and lowering barriers to entry, cloud has a potential to drive productivity growth and competitiveness across in the private sector.

Synergies and conflicts with other fields

Cloud computing can strengthen Europe's efforts in combating climate change and help to reduce the environmental footprint of ICT and impact of the increase of data flow over the internet. This is mainly due to pooling of cloud data centre infrastructures – thus reducing over-allocation of infrastructure, sharing application instances between multiple organisations, as well as improving data centre efficiency. It is estimated that cloud can reduce Green House Gases (GHG) emissions by up to 90%.

Emerging policy issues

Cloud computing offers both security benefits and security risks. Amongst others, cloud computing offers benefits to network and information security as the larger scale of computing resources allows for a better protection, including filtering and patch management. Security risks associated with cloud computing in particular result from the loss of governance over one's own computing resources, which might create several security issues related to the confidentiality, integrity and availability of information. Data protection aspects of the cloud computing services are often related to the lack of transparency, trust and confidence to the cloud customers that the personal data is processed with an appropriate level of data protection. More, many times Cloud computing also involves cross-border transfers of personal data that might results in uncertainty regarding the storage of data and the jurisdiction issues. The PRISM revelations have shown that data stored in the cloud may be very vulnerable to access by foreign authorities, possibly in breach of EU laws and EU fundamental rights and value. Also, the cloud transforms the business models of cloud providers, which may take increased responsibility vis-à-vis the personal data. As regards the storage of the data, the ambiguity of some legal provisions create uncertainty towards new technologies, which often leads to negative decisions in order to avoid legal repercussions. Legal fragmentation may hinder the free flow of data both within and outside the EU, where adequate data protection safeguards might be difficult to enforce. As part of a proper risk-management approach, the risks of using cloud computing services should be assessed and compared with other possible solutions such as conventional onpremises solutions and if possible be mitigated. Under the European Cloud Computing Strategy the European Union Network and Information Security Agency (ENISA) has published and is fine-tuning a validated list of existing cloud relevant security certification schemes, which can be used by cloud users to assess to what extent a cloud services meets their security needs.

Also, the industry of providing cloud services requires enormous investments and builds on economies of scale; some cloud computing infrastructures are bigger and more costly than nuclear power plants. Especially as regards raw storage and computing services, the cloud develops like a utility, raising question on whether a regulatory framework similar to the one used to regulate utilities would be required. At least, contractual terms offered by cloud providers must be non-discriminatory, safe and allow for fair access and pricing to all EU individuals and companies.

Contributors

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High performance computing

Solving complex problems– societal, scientific, industrial- needs trillions of calculations which cannot be done without High Performance Computing (HPC). Some of the examples are: integrated policy assessment, understanding and solving a wide range of problems in life sciences and health, materials research, fusion energy, aircraft fuel efficiency, reduction of aircraft noise, weight reduction of cars, safer transportation, climate and weather prediction, earth observation etc. HPC is of paramount importance for European competitiveness, and nearly every industrial sector depends on supercomputing to be competitive.

"*Europe needs to smart-compute in order to smart-compete*".

Keywords: High Performance Computing, HPC, supercomputing, HPC for health, HPC for climate modelling, HPC for societal challenges, HPC for science.

Current status

High Performance Computing (HPC) is a crucial asset for the competitiveness of Europe and for solving complex scientific, industrial and societal challenge problems. Other world nations (USA, China, India) have declared HPC an area of strategic priority and massively increased their efforts in this area, whereas Europe spends substantially less than other regions on HPC acquisitions and has lost high-end computing capacity in the last years; moreover, no single Member State has the resources to develop the next HPC computing generation (exascale computing).

Critical mass of investment remains a challenge, in part due to fragmentation across EU countries. Many existing High Performance Computing (HPC) applications are not optimised for big machines and for new requirements. There is insufficient European-level pooling and sharing of resources and overall scarcity of HPC resources. Many SMEs and public sector stakeholders are not aware of possibilities offered by computing infrastructures and skill shortages of HPC are serious concerns for research and businesses.

Most of the industrial companies that employ HPC consider it indispensable for their competitiveness. Also HPC plays a key role in research and development in a wide spectrum of areas such as health, sustainable energy, transport, materials, complex climate and weather modelling and prediction.

The Commission adopted its HPC Strategy on 15 February 2012 in the Communication "High Performance Computing (HPC): Europe's place in a global race". Following this communication, the Commission has launched a Public Private Partnership (PPP) for HPC in December 2013 which will bring together the users and technology providers for developing the next generation of HPC technologies, systems and applications, with an EC funding of EUR 700 million. The PPP will work closely with PRACE[1] the world class provider of pan-european HPC infrastructures. These are significant steps towards implementing the HPC strategy.

[1] www.prace-ri.eu

Future trends (~2030)

In science, engineering, technology

Modern scientific discovery requires very high computing power and capability to deal with huge volumes of data and complex algorithms and models. HPC processers will become massively parallel for increased performance, while energy consumption will continue to be an issue. Significant increase of co-design of software and hardware with close involvement of users is also envisaged.

For innovation/applications perspectives:

Industries and SMEs are increasingly relying on the power of super computers to find innovative solutions, reduce cost and decrease time to market for products and services. The power of supercomputers will contribute to find innovative solutions, reduce cost, increase quality and decrease time to market for the cars and planes of the future, and up to next generation medication. HPC underpins also the future of science, be it for understanding the functioning of the human brain, to foresee and monitor environmental risks or to elaborate more accurate climate change models. Finally, HPC is becoming an essential tool for many sectors that discover its added value such as insurance, construction etc. Some examples are:

* reducing the time to market for planes by several years using computer modelling for aerodynamics (reducing the need for mock-ups and large scale wind tunnel tests) and simulating advanced structures and materials' behaviour or even virtual production-line validation.
* the automotive industry is able to reduce the number of car accident fatalities by using computer simulation of crash-tests and simulating the technical alternatives for improving safety as well as designing better engines by using virtual test benches.

Futuristic high potential high risk research

Disruptive technologies are expected to emerge to meet the challenges of the next generation supercomputing and its architecture. Linear progression of HPC development is not sufficient to achieve exascale computing and to reduce the high cost of energy for supercomputing.

In 2030 we may have mobile access to the HPC capabilities in the hands of each interested citizen supported by high performance intelligence algorithms and a large portion of autonomous decision making processes. This will accelerate and disrupt the process of scientific discovery, accelerate engineering (co-design, more customized solutions), allows to investigate (and model) highly complex problems /challenges in different fields including societal ones.

Expected overall impact in/for Europe

Society

Better decisions by the policy makers based on fast and accurate analysis (eg; policies for transport planning or ageing population), improved prediction of weather and climate modelling, better monitoring of the state of the environment, increased integration of renewable sources into energy supply, smart grids, modelling for safer cars, improved prediction of earth quakes, better understanding of environmental and health impact of pollutants and better understanding of diseases aetiology. The latter should also lead to better care solutions (pharmaceutical and non-pharmaceutical approaches). In the future HPC could help in the prevention, diagnosis or treatment of diseases such as neurodegenerative diseases (e.g. Alzheimer's disease), infectious diseases, cancer or cardiovascular disease.

The economy
A well-developed leadership strategy for HPC can substantially contribute to economic growth and potentially add 2-3% to GDP in EU by 2020. The Public Private Partnership launched by the Commission is a major step towards contributing to this. 7% growth is predicted over the next five years for HPC.[2] It can also make EU an attractive focus for scientific and engineering research and reverse the 'brain-drain'. EU researchers can become the most productive and innovative in the world.

Governance and policy issues
Investment in exascale computing, policies on sharing of supercomputing resources across EU for research and innovation, skill development and training for potential end users, including SMEs and professionals from interested sectors, support for SMEs for the use of HPC, pre-commercial public procurement and continued support for public private partnership.

Safety and security
Improved prediction of potential disasters (including flooding, storms, and earth quakes) and epidemics.

Synergies and conflicts with other fields

HPC is a cross-sectorial activity which is an excellent example of the unique ability the Commission has to pull together different sectors and players for the benefit of European competitiveness, scientific excellence and addressing societal challenges. HPC is of interest to various DGs (CONNECT, RTD, MOVE, ENER, ENTR, SANCO, CLIMA, ENV, MARKT, DIGIT, JRC). Some of the application sectors with strong HPC needs/use are: integrated policy assessment, car industry; aeronautics; health; pharma; life sciences; space and space-based services; materials research; particle physics; fusion physics; smart grids; climate and weather predictions; defence and security.

HPC is also a key technology that can contribute to the initiatives such as the Human Brain Project (HBP) Flagship initiative or the public private partnership Innovative Medicines Initiative 2 (IMI2).

Processing and analysing large volumes of data in scientific, industrial, and societal challenge applications significantly depend on availability of HPC infrastructures and training of end users. Complementarities with cloud technologies and 'big data' should also be explored. However, careful attention should be given to ensure that Data Protection and privacy rules are strictly followed, which are of particular concerns when dealing with medical and personal data.

HPC technologies can have 'trickle down' effects that can benefit future consumer products, and also impact upon other embedded systems and 'Internet of Things' (IoT).

Emerging policy issues

a. HPC could be a significant technology in developing complex simulation and projection of the socio-environmental-economic situation of the EU, including integrated policy evaluation and impact assessment in the context of smart regulation.

b. Member States have different approaches depending on their national competences and interests, but they all agree that HPC is a strategic topic for competitiveness. More coordination is needed between Member States and with the Commission on HPC, either in some sort of a flagship or joint undertaking. Despite some valuable initiatives, European HPC is still fragmented in terms of funding and critical mass applications.

[2] IDC HPC Market and Technology Update, December 2013

c. The competitiveness of nearly every key sector depends on supercomputing and probably even more so in the decade to come. HPC is therefore a topical strategic sector for the European industry (big potential for SMEs) and research sector.

d. A European scale initiative is necessary to put us back on track, and even lead. Europe has both the technological know-how and market size to play in first league at all levels: generating and handling big data, developing HPC technologies from chip to integrating supercomputers, and getting down to industrial applications. Europeans are good at cooperation and federating common objectives. HPC could be such a federating objective in an 'HPC Alliance', but this will require that the entire HPC ecosystem is addressed and that all Member States find their interest: be it for HPC use by industry - especially SMEs - and by science; for HPC industrial supply with next generation computing technologies; for excellence in HPC applications; for achieving a level-playing field for EU companies.

e. Pre-commercial procurement is much underutilised in Europe and should be promoted. In HPC it has been used extensively for many years in the US. Joint pre-commercial procurement also has a key role to play in Europe to drive the development of HPC supply by demand by a better understanding of the current and future market.

f. Public Procurement of Innovative (PPI) solutions co-fund action as referred in H2020[3] can enable groups of procurers to share the risks of acting as early adopters of innovative solutions, whilst opening market opportunities for industry. PPI is a powerful instrument to support the European HPC strategy, supporting the deployment in Europe of the most advanced HPC solutions.

g. Centres of Excellence should be established for the application of HPC, focussing on scientific, industrial or societal challenge applications.

h. Creating new skills is an urgent need for HPC, in order to develop software, tools and algorithms to meet existing and future needs of science and industry. In addition there is a need for HPC experts to work closely with SMEs to train and help them understand and capitalise on its significant potential.

i. HPC also fits well with policy initiatives on:

- EU smart growth and international competitiveness
- Combining forces with national, and even regional, initiatives such as smart specialisation strategies[4]
- The flagships: Innovation Union; the Digital Agenda for Europe; "An agenda for new skills and jobs".
- *'A New Start for Europe: My Agenda for Jobs, Growth, Fairness and Democratic Change'* [5]

j. HPC will be a pillar for any smart society and it needs a specific initiative to put Europe back into the race: a *'European Smart Supercomputing Initiative'*

[3] http://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/annexes/h2020-wp1415-annex-ga_en.pdf

[4] http://s3platform.jrc.ec.europa.eu/s3pguide

[5] http://ec.europa.eu/about/juncker-commission/docs/pg_en.pdf

High-level generic references

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Text and data mining (data analysis)

ICT technologies are getting better at processing large volumes of unstructured or non-uniform data and text. New techniques, learned on data sets in life sciences and drug discovery, are being applied in particular in social sciences, humanities, security, business, marketing and legal areas. Text and data mining (TDM) refers to the different tools, techniques and technologies for the automated processing of the large volumes of information available in order to obtain new knowledge and insights and discover patterns and trends. While its importance is growing with the increasing large amounts of data stored in corporate data warehouses and databases, realising the full economic and societal potential afforded by this vast sea of information will require new technologies, processes and business models.

According to the McKinsey Global Institute's (MGI) 'Big Data' report, the generation of information and data has become a 'torrent', pouring into all sectors of the global economy and is predicted to increase at a rate of 40% annually. Exploitation of this vast data and information resource can generate significant economic benefits, says the report, including enhancements in productivity and competitiveness, as well as generating additional value for consumers.

Keywords: TDM, text and data mining, big data, analytics, trends.

Current status

Text and data mining involves various tools, techniques and technologies for the automated processing of large volumes of texts and data that is often unstructured or not uniformly structured. Mining is undertaken for purposes such as the identification and selection of relevant information, retrieval, extraction, interpretation, analysis, etc. of such information, and the identification of relationships within/between/across documents and datasets. This allows data miners and analysts to obtain new knowledge and insights and discover patterns and trends.

Text and data mining is a common tool in particular in social sciences, humanities, social media, security, business and marketing and even the legal field. Its importance has been growing with the increasing large amounts of data stored in corporate data warehouses and databases. Moreover, nowadays different Internet companies try to extract structured information and derive trends from the Web by using data mining techniques. Text and data mining techniques are used as well as on a daily basis not only by researchers but also in business, in particular in the fields of pharmaceuticals, chemistry, abstracting and indexing services, libraries, suppliers of mining tools and services, publishers, large supermarket chains, retail industry, advertising companies, etc. The unprecedented data deluge we are already facing today is drawing notable discussions and developments in the aforementioned fields on Big Data and Big Data analytics (data mining, integration and analysis).

Future trends (~2030)

On the science

By 2030, the technological developments underpinning text and data mining would have advanced enormously due to the explosion of vast amounts of new and heterogeneous digital data between now and then, arising from initiatives such as free and open data access policies, continued expansion of social media, real

-time sensory data feeds as the Internet of things' evolve (HYPERLINK to Fiche on Internet of things) as well as a result of new infra-structures and social platforms that allow domain experts and citizens to produce large volumes of data everywhere and anywhere (HYPERLINK to Fiches on Biometrics, Advanced cloud infrastructures and services, Cloud Computing, Future [smart] cities, Social Technologies).

The International Data Corporation forecasts that by 2020 new and heterogeneous digital data shall be generated at a yearly rate of 35 Zettabytes and that unstructured data shall account for 90% of all such massive amounts of new and heterogeneous data in years to come. These prospects are stirring much debate today on what advances and new developments do we need for data storage, processing management, maintenance, analysis and visualisation technologies.

On the applications

With the corresponding exploitation of the vast data and information resource available, there is the potential for generating significant economic benefits, including enhancements in productivity and competitiveness, and products and services more tailored to consumers' needs.

Expected overall impact in/for Europe

The steadily growing number of journals and scholarly articles published will mean text and data mining becomes indispensable to save reading time, information handling time and costs, as well as to facilitate new discoveries. The impact of not having TDM technologies and not having invested in appropriate skills sets will be an inability to keep abreast of state of the art and to draw links between different fields. The economic potential may be illustrated by the investment that technology giants such as IBM and Microsoft are making in developing data analytics technologies.

Realising the full economic and societal potential afforded by this vast sea of information and data will require text and data analytical capability, access to the information and data sources, and the development of technologies and computerised analytical processes. This could lead to the emergence of new business models that may transform the technology/internet business space – similar to the recent transformation brought about by 3G mobile technologies.

In addition, the availability of such large amounts of new and heterogeneous data will have a considerable impact on processes and workflows of organisations, the public sector and industries, which will have to support an increasing shift toward data driven decision–making, and will necessitate the development of new skills by a specialised workforce. In the US, consultancy companies are already predicting a shortage of data scientists in the next 5 years to deal with the challenges and opportunities of Big Data, underlining the pressing need to invest in the education and training of the future generation of data scientists as well as in research in data science. Handling the future challenges will require integrated skills sets that span mathematics, machine learning, artificial intelligence, statistics, databases and optimisation underpinned by a an ability to engineer effective solutions.

Synergies and conflicts with other fields

The technology/internet business space could be transformed by the new business models that emerge with the development of the technologies and computerised analytical processes necessary for accessing and analysing the information and data available.

The potential for societal benefits are significant, for example with regards to finding drug treatments. Environmental benefits have still to be investigated further. On the other hand, data mining has the potential to provide faster access to information, which may decrease the time during which the electronic devices are used, an thus in turn save energy.

Emerging policy issues

In order for the benefits that could be derived from these relatively new tools, techniques and technologies to be fully developed, the legal uncertainties across different fields of law (data protection, fundamental rights, contract law, copyright and database rights, technical standards, etc.) will need to be addressed.

The necessary development of new skills in mathematics, machine learning, artificial intelligence, statistics, databases and optimisation by a specialised workforce will require investment in the education and training of the future generation of data scientists as well as in research in data science.

High-level generic references

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Advanced autonomous system

Advanced autonomous systems are on the rise: Algorithmic trading with no human in the loop already accounts for around 50% of all stock-market trading, and some parts of the car manufacturing process have automation levels of above 90%. These systems will gain more capabilities in the future enabling their widespread use in many market domains. While these systems make a strong contribution to productivity and can perform jobs which are dull, dirty and dangerous for humans, there is a danger of them eliminating a large number of jobs in a relatively short time frame. In addition, they pose a challenge for established legal concepts such as liability.

Almost 50% of all jobs could be automated in the next 20 years.

Keywords: Autonomy, automation, unemployment, liability.

Current status

Automation and autonomous technology is advancing rapidly:

* During an average commercial flight, a human typically controls the plane for only three minutes while it is flown automatically the rest of the time.[6]
* Some parts of the car manufacturing process have automation levels of above 90% such as stamping or welding.
* Algorithmic trading with no human in the loop accounts already for around 50% of all trading on European and US stock exchanges.[7]

This development raises obvious question of liability: What happens if such autonomous systems cause an accident or damage? In 2010, for example, the so-called Flash Crash[8] was the result of a large number of trading algorithms interacting with each other and reinforcing selling orders. Within minutes, the Dow Jones Index had dropped by about 1000 points (the equivalent of $1 trillion), the biggest one-day point decline ever recorded. It regained all its losses within another couple of minutes, but serious questions were asked, and the Securities and Exchange Commission opened an investigation.

On a more positive note, many of these systems make a strong contribution to productivity. Without advanced automation, the European car industry would not be able to compete with non-European competitors with much lower wages. In manufacturing, automated systems are normally also much more precise and deliver a higher quality – and these systems can provide the same high quality and precision every time they perform the action. Moreover, these systems perform jobs which are dirty, dull and dangerous for humans. Think of inspecting windmills or patrolling border areas with unmanned aerial vehicles.

[6] http://www.theatlantic.com/magazine/archive/2013/11/the-great-forgetting/309516/
[7] https://en.wikipedia.org/wiki/Algorithmic_trading
[8] http://en.wikipedia.org/wiki/2010_Flash_Crash

Future trends (~2030)

Nowadays, automated systems are largely used in very constrained environments. For example, many manufacturing processes in car manufacturing are already highly automatized, but they often take place in cages where the system is not interrupted by humans.

Currently, the challenge is to move these systems out of their cage and equip them with greater flexibility and autonomy. Key technological ingredients to reach this goal are enhanced learning abilities, and improved action and motion planning including navigation.

Another important goal is to make these systems intrinsically safe to enable human workers to cooperate with them in close proximity. Equally important is the development of a more intuitive human-computer interaction so that also non-expert workers can program them.

The challenges outside of manufacturing are even greater, given that the environment is often much less constrained. Technologically, similar topics have to be tackled such as learning and human-computer interaction.

In addition, specific application domains require the solution of equally specific research problems. For autonomous aerial vehicles, for example, it is important to have robust and reliable data and communication links, to sense and avoid other aircraft and to be able to remotely sense the weather.

At the same time, a lot of progress has been achieved outside manufacturing as well. For example, several car manufacturers are already testing autonomous vehicles on streets, and an impressive array of advanced driver assistance systems is available; unmanned though often still remotely-piloted aerial vehicles roam our skies; software algorithms are at work in domains ranging from healthcare to banking to journalism.

In sum, we will see a move from automated (where everything is pre-programmed) to autonomous (where the system can react dynamically to events) systems in the coming decades. With the systems becoming more intelligent and more autonomous, they will also be used in more complex environments and will thus conquer new application domains.

Initially, automated systems were confined to the manufacturing industry, in particular car manufacturing. In 2030, it is very likely that autonomous systems will be ubiquitous in all manufacturing sectors. In addition, autonomous systems will be used in many other domains outside manufacturing, e.g. logistics and mobility, and possibly also in our private homes.

Expected overall impact in/for Europe

While autonomous systems will have an impact on many areas of life and even politics, the biggest impact is expected to be on the economy and more specifically on the labour market.

With respect to labour markets, one recent study concluded that advanced autonomous systems could replace 47% of all jobs in the US within the next two decades[9]. While the labour market structure in Europe is somewhat different from the US, a similar picture is likely to emerge in Europe.

Of course, new jobs will appear as well along the autonomous systems value chain, e.g. designers and developers of these systems, and it is not clear at all at this stage whether the overall impact on the la-

[9] "The future of Employment: How susceptible are jobs to computerisation?", Oxford Martin School, September 2013 (http://www.oxfordmartin.ox.ac.uk/downloads/academic/The_Future_of_Employment.pdf).

bour market will be positive or negative. Some studies hint at negative effects, but there are also studies which argue convincingly for positive employment effects.[10]

Not only will the labour market be affected, but there is tentative evidence that a greater reliance on technology in general may also contribute to rising income inequality[11]. This seems particularly true for capital-intensive autonomous systems which very often directly replace a human worker.

Looking at it more positively, McKinsey came to the conclusion[12] that the automation of knowledge work, autonomous vehicles and advanced robotics could lead to a total annual economic impact between $7.1 trillion to $13.1 trillion in 2025. Much of this impact - $600 billion to $2 trillion – could come from improving the lives of the more than 50 million amputees by equipping them with intelligent and advanced prostheses.

Numbers aside, autonomous systems will surely have positive effects on society. They will help to cushion the blow of demographic change by providing systems which will support workers on the shop floor to perform their functions in a healthier and more sustainable fashion. Advanced autonomous systems will help the elderly to maintain an independent live style – and if they are in care, these systems will relieve and support care workers. In agriculture, advanced autonomous systems will enable a dramatic reduction of the use of pesticides, some say in the order of 90%, by only applying them when it is really necessary.

Synergies and conflicts with other fields

Many domains will be affected by autonomous technologies. Manufacturing is the first domain to be truly affected, but mobility and logistics is not far behind. Almost all car manufacturers develop autonomous cars and trucks, for example, and it is only a question of time until they will be rolled out and see a widespread adoption. In the long-term, many more domains will undergo a similar transition.

Emerging policy issues

With respect to governance and policy issues, truly autonomous systems challenge our notion of liability. While liability currently very clearly rests with the user and/or the producer of a system, this distinction will be blurred with autonomous system which can take decisions that neither the producer nor the owner/user could have possibly foreseen. The question is how liability will be attributed in these instances.

Furthermore, if autonomous systems really do have a strongly negative impact on income equality and employment, this might call into question our current social and economic models, and new governance and taxation models might need to be developed taking into account the growing role of capital. More realistically, however, many new jobs will develop over time, and the relevant question in the medium-term will be how to train and prepare people for these new jobs.

As a side issue, autonomous military technology might lead to a transformation in defence and security policy making conflicts more likely since it reduces the political costs to enter into a conflict (something military leaders in the US and Israel quite openly acknowledge and cite as the reason for investment into this technology). No soldier is in danger of being killed any longer with autonomous systems doing the job. First signs of this are the ongoing "drone wars" in Pakistan and Yemen.

[10] For example: "Automation, labor productivity and employment – a cross country comparison", Copenhagen Business School, April 2013 (http://www.aim-projekt.dk/files/robot-employment.pdf).

[11] "Rising Income Inequality: Technology, or Trade and Financial Globalization?", IMF Working Paper, July 2008 (http://www.imf.org/external/pubs/ft/wp/2008/wp08185.pdf).

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Models and data in the decision making

Keywords: Models, data, decision making.

Current status

Evidence-based policies is an often used term but apart from a general notion of impact assessment there is little 'evidence' that evidence-based decisions in society have become standard practice. It is not even clear whether evidence-based decisions are feasible or even desirable in all cases. Analysis and research is needed across behavioural science, political sciences and technology. We do have increased simulation capacities (link to HPC, simulation), increased access to data (link to 'Big Data') pertinent for decisions of importance to society and we have new tools to engage citizens more in both the use and the collecting of data (link to citizen science). There is an increase of cross-sector impact of decisions due to the various webs that society has spun not the least due to the increased use of IT. This puts decisions in large systemic contexts that are often hard to grasp and where system analysis based on models&data, in particular systemic risk analysis would be of great help. System science and modelling allow such system analysis and are already used in various parts of decisions making (e.g. in re-insurance industry).

It is worthwhile reflecting further on the use and limits of models, data and system analysis in a policy context as well as in broader societal contexts. This will result in new uses of models&data, new tools for bringing models&data into the societal processes, and new forms of citizen engagement. This has been in part taken up by the CONNECT initiative on global systems science.

Future trends (~2030)

We will have ever more accurate description and models of many technical and natural phenomena; we might even have better models of human activity (behavioural models and data). We will have an ever increasing range of data on all aspects of policy and societal decisions. Citizens will be ever more involved in decisions processes in society, redefining the role of experts and even policy makers. We need to analyse opportunities and pitfalls from these developments in time. The ultimate use of models will most likely be as tools for orientation rather than as tools for prediction.

Expected overall impact in/for Europe

In various policy areas models and data will play an increasing role; brief impact analysis in three policy areas: In economics, models are widely used but these models do not take fully into account the human (behavioural) aspects underpinning economic decisions (rational agent paradigm). Likewise the systemic dimension of economic decisions (as exemplified by the 2008 crisis) is underexplored. Network effects are an important aspect of dynamics in an economy and need to be better addressed. A dedicated effort in economic modelling could have important impact on the way we as a society can handle better crisis. A concrete example is use of network analysis by DG MARKT in their shadow banking regulation. Similar network effects can be seen in policy areas like energy or food chain.

Urbanism is a growing area of policy (due to urbanisation). Here understanding networks of influence and network of diverse actors in a urban society is crucial. New techniques to understand social, economic, environmental dynamics in an urban context are being developed and put to use in urban planning (e.g. increasing urban resilience through risk informed urban planning). Citizen engagement is an important factor both contributing data and enhancing engagement of citizens in urban issues.

Finally, in evaluating food chain network effects, citizen-gathered data on efficiency of e.g. crop use, cascading effects within the food chain and side effects (biofuels influence crop availability for food use) are now currently analysed. Talks with FAO have highlighted such interactions and the use of methods grounded in data/models and citizen observatories.

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Cyber-security

Shopping, media, and publishing, but also democratic processes such as elections, are moving online. This can only work with a high level of trust. Furthermore, the same holds for many future sectorial infrastructures, processes, and resources, like sewage systems or smart buildings, that will be adaptive, distributed, collaborative, and efficiently controlled. They will depend on ICT and cloud infrastructure and services that must be reliable, predictable and always available, ensuring confidentiality and protection of privacy and being capable to react to cyber threats in real time.

In this context, higher user awareness and control stemming from a trustworthy and competitive European digital single market, which is based on harmonised legislation, including the personal data protection reform and common security rules, will usher in a larger demand for ICT ecosystems that reflect common European ethics and social values when it comes to security, privacy and data protection. In addition, formal channels of cooperation (i.e. agreements) with third countries will ensure that the fundamental rights of EU individuals are protected, even when digital technologies operated from abroad are used to deliver goods and services to them.

According to a September 2013 report by the European Parliament, the direct costs to all enterprises (except micro-enterprises) of security incidents with malicious motivation (excluding accidents and failures) is at least €935m. Including hardware and software failure, this rises to a staggering €4.15bn in a single year. According to the impact assessment in preparation of the data protection reform, the cost of legal fragmentation in the field of data protection is 2.3 billion Euros per year. According to an Internet industry source, by the end of 2013 61% of measured Internet activity was generated by robots, where presumably 70% of robot activity were linked to credit card and home banking personal data fraud attempts, the remaining 30% being a diverse lot of less malicious activities, albeit with a growing share of automated hitting of commercial ads to generate fake statistics about website hits.

Key words: Cyber-security, privacy, data protection, trust, security, industrial control systems (ICS), supervisory control and data acquisition (SCADA), surveillance, fundamental rights, digital life, cyberspace, critical infrastructures, ICT, global risks, cyber attacks, cybercrime, cyber threats, digital single market.

Current status

Information and communication technology (ICT) systems use data in order to implement a function. Ensuring the security of such systems requires a guarantee of confidentiality, availability, and integrity of both data and functionality. The Cybersecurity Strategy of the European Union offers the following definition: *Cybersecurity commonly refers to the safeguards and actions that can be used to protect the cyber* *domain, both in the civilian and military fields, from those threats that are associated with or that may harm its interdependent networks and information infrastructure. Cybersecurity strives to preserve the availability and integrity of the networks and infrastructure and the confidentiality of the information contained therein.*

Innovative ICT has a tremendous potential in every aspect of our lives and there are no signs that the pace of innovation is slowing down. However, many of the novel ICT interfere with fundamental rights. In particular, the fundamental right to personal data protection is often at stake, as most software technologies process personal data in a more and more automated way, from social networks and web browsing history to body scanners and video surveillance cameras that embed face recognition. The internet of things is now the internet of things and of personal data.

Given the exponential rate of technological change in the area of ICT, it is all but impossible to develop external security solutions for functionalities that have not yet been imagined or created. This is one of the reasons behind the current thrust in the development of software that is 'secure by design' and that include privacy and data protection both 'by design' and 'by default'.

Increased instances of cybercrime, including traditional forms of crime committed online (e.g. fraud or forgery) as well as crimes against the cyber infrastructure (e.g. attacks against information systems, denial of service and hacking) are undermining consumer confidence in the digital environment on a global scale. Furthermore, there are technical similarities between common cybercrime related attacks and US and other government-sponsored attacks on ICT systems security. The insufficient framing of these government activities and their impact on the fundamental rights of EU individuals erode trust in the global online world and in governments' digital engagement.

Concerns are growing that it may be impossible to maintain an acceptable balance between the power of a pervasive digital realm, including but not constrained to the Internet, and the rights and freedoms of people as individuals, citizens and communities. In short, trust in the global Internet is vanishing, and it is not anymore unthinkable that in developed countries individuals will have to accept a fragmentation of the Internet, at least for some services. In that context, there will be an increased role for the European digital single market.

Future trends (~2030)

Shopping, media, and publishing, but also democratic processes such as elections, are moving online. This can only work with a high level of trust. Furthermore, the same holds for many, if not all, future sectorial infrastructures, processes, and resources, like sewage systems or smart buildings, that will be adaptive, distributed, collaborative, and efficiently controlled. They will depend on ICT and cloud infrastructure and services that must be reliable, predictable and always available, ensuring confidentiality and protection of privacy and being capable to react to cyber threats in real time. In this context, higher user awareness and control stemming from ICT-enabled increased transparency and harmonised practices will usher in a larger demand for ICT ecosystems that reflect common European ethics and social values when it comes to security, privacy and data protection, making the case for a trustworthy and competitive digital single market.

On the other hand, some governments and companies have difficulties to set their limits and to limit the interference with fundamental rights of their data collection practices. As a result these actors foster the weakening of the very ICT systems they need their citizens to trust in order for the economy to prosper. Organizations and governments that listen to citizen and user outcry, and address the issue on the basis of democratically agreed proportionate and transparent rules, may be able to counter the expansion of the practice of unaccountable and systemic surveillance, before it becomes an unstoppable arms race. In addition, serious (organised) cybercrime is steeply on the rise.

The variables described above point to the development of two extreme, opposite scenarios, as follows. In one scenario, a persistent surveillance society will govern all aspects of life and culture, driven by human beings who misuse technologies to support fear-based command and control structures. In the other scenario, an individuals-empowered society will implement systems-wide changes in governance that place the emphasis of trust and fundamental rights back on accountable human beings, instead of on the technologies themselves.

Cybersecurity “guru” Bruce Schneier wrote that the security gap is a sort of a gap between the good guys and the bad guys, and it’s caused by the delay in restoring the balance after technology imbalances things. And this gap is greater when there’s more technology and greater in times of rapid technological change like ours.

Expected overall impact in/for Europe

The overall impact of wrongly addressing cybersecurity as discussed above will be enormous on all aspects of our societies, from the individual wellbeing to the economy and governance, since trust is central to all human relations, even more so in those intermediated by ICT. It will lead to the failure of the digital single market as the gold standard for a modern and trustworthy digital environment.

Synergies and conflicts with other fields

Digital infrastructures and digital intermediation underpin most of current European systems and daily transactions. As a consequence, trust and security in the digital world underpin many other fields that are seemingly unrelated at a first glance, from industrial control systems through transportation to health and finance.

According to the World Economic Forum’s Global Risks 2014 report, cybersecurity – or rather the lack of it, leading to a so-called Digital Disintegration – is prominent among the many conceivable ways in which possible interconnections and interdependencies between global risks could play out systemically over the 10-year horizon.

It should be noted that too much cybersecurity may stifle innovation in many areas, while too little cybersecurity may give raise to risks that are too big to bear. On the other hand, innovation will thrive in a more stable and secure Internet, as more services can be made available online. As written above, wise compromises must be designed.

Emerging policy issues

It is likely that the future will unfold as a mix of the scenarios above, in which trade-offs between trust and privacy, on one hand, and cybersecurity and cyber-surveillance, on the other hand will be necessary.

For cyber security strategies to be sound and effective, they need to be based on the respect of fundamental rights as enshrined in the Charter of Fundamental Rights of the European Union. Any information sharing for the purposes of cyber security, when personal data is at stake, should be compliant with EU data protection law and take full account of the individuals' rights in this field. Security and data protection must go hand in hand since they are two sides of the same coin.

To address the lack of trust in the global market and the global Internet, as well as the fragmentation in the Member States, the digital single market should build in the coming year on the foundations of harmonised legislation, including the reformed rules on personal data protection as well as common security rules, as proposed in the Network and Information Security (NIS) Directive. These initiatives should be complemented by ad-hoc sectorial initiatives for the digital sector, including better and EU harmonised data protection and security standards, codes of conducts and certifications, so as to restore trust in the digital single market and to ensure that citizens can recognize products and services that meet the gold standard of the future digital single market.

Research programmes under the Horizon 2020 and beyond should foster the development of products and services that meet the gold standard of the digital single market, in terms of security and data protection, thus ensuring the fundamental freedoms of individuals and an effective fight against cybercrime.

At a European level, stronger cooperation between Member States is truly needed, and there are many other players that must be in the picture. Europe must set the example and the direction to follow (as in a lighthouse). It must also recognise that only a broad engagement, from a fundamental rights perspective, can restore trust in the digital life, ensuring both economic development and citizen protection.

High-level generic references

Cybersecurity Strategy of the European Union: An Open, Safe and Secure Cyberspace - JOIN(2013) 1 final - 7/2/2013: http://ec.europa.eu/information_society/newsroom/cf/dae/document.cfm?doc_id=1667

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According to a study 82% of the German do not trust the internet anymore: http://www.heise.de/newsticker/meldung/NSA-Skandal-Internetznutzer-halten-ihre-Daten-zunehmend-fuer-unsicher-2216709.html?wt_mc=rss.ho.beitrag.atom.

When procuring secure services on the Internet for US federal agencies, the US FedRamp programs already prohibits that those secure services would be accessible from outside the United States. This is also common practice in many emerging countries.

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EU wide Internet of things initiative

The next Commission should envisage a European initiative to unleash the potential of the Internet of Things (IoT). IoT is a key enabler 1) for the European industry to rejuvenate, expand further and take a leadership position in an increasingly global and digital economy, and 2) for European society to meet its societal and sustainability objectives. EU Member States have so far failed to live up to the challenge and bring a common vision in the digital single market, with the risk that Europe will miss the IoT bandwagon just like it missed the smart phone revolution.

Such initiative on IoT must target the deployment and adoption of IoT-powered new solutions in the areas of smart houses, cities, transport, energy, agriculture. It would offer targeted actions like 1) developing EU standards and technology: providing seamless and generic connectivity and open platforms delivering high level of security and data protection and involving all service providers and end-users, 2) funding large-scale pilots to test business models, boost deployment and achieve wide acceptance, and 3) supporting European-wide adoption of IoT, through research and innovation support in identified sectors and targeted policy actions.

The number of IoT connections within the EU is estimated to increase from approximately 1.8 million in 2013 to almost 6 billion in 2020. IoT revenues (including the value of system shipments, devices, IoT technologies and correlated IT services) should increase from more than €307 billion in 2013 to more than €1,180 billion in 2020. IoT is expected to impact all economic sectors, with faster take-up in manufacturing and consumer packaged goods. The digital market being the most competitive market for IoT products and services, it should be equipped with appropriate open and high level standards applicable EU wide and with appropriate soft and hard law initiatives ensuring a high level of trust in IoT devices and seamless access to the public and private sector.

Keywords: Internet of things, Web of things, Smart Cities, Hyper-connected Society, Machine to Machine Communication, Internet of everything, Cyber-physical objects, 5G, Future Internet.

Current status

The Internet of Things is an essential element of the hyper-connected society vision, where the Internet of Things, cloud computing and Big Data will endow every human being and every object with immense additional abilities to observe, learn, decide, act and communicate, and where objects, from the macro right down to the nanoscale dimension, will become smarter, cognitive, communicating and 'thinking'.

Significant business decisions have been taken by major ICT players like Google, Apple and Cisco to position themselves in the IoT landscape. Telecom operators consider that Machine-to-Machine (M2M) and the Internet of Things are becoming a core business focus, reporting significant growth in the number of connected objects in their networks. Manufacturers of devices, such as wearable devices offering full mobility, anticipate a totally new business segment and a wider adoption of the IoT.

The EU started to invest in IoT Research and Innovation in 2007, notably in the areas of embedded systems and cyber-physical systems, network technologies, semantic inter-operability, operating platforms and security, and generic enablers. A series of components are now available, which could usefully be exploited and enhanced by the market. These results are now feeding into innovation to lead significant future developments in the context of smart cities, smart homes, smart infrastructures, smart industry – smart everything.

Future trends (~2030)

On the science

Self-configuring and adaptive networks will provide generic and seamless connectivity everywhere and all-time. Objects like home appliances, glasses, autonomous vehicles but also industrial assets and objects previously considered as unrelated to communications, will be networked with intelligent communication modules. Thanks to the breakthrough in semantic interoperability, information and knowledge can be processed and understood across vertical application silos. Smart objects, cognitive and with a capability of learning will be our daily companions and act to a large part autonomously. Beyond keyboard, mouse and touchscreen we will communicate in much more sophisticated ways with the artefacts surrounding us.

On the applications

At the current phase of the IoT, most applications are independent and deployed for specific users, e.g. wearable fitness trackers or devices that 'know' how we really feel. With the development and maturity of distributed intelligent information processing technologies, IoT systems will make intelligent sensing, actuating and learning widely available through information sharing, collaboration and intelligent use of large sets of data. Areas like Smart Cities, Smart Water, and Catastrophe management, Smart Manufacturing and Creative Industries among many others will largely benefit from a variety of connected services and objects. We are going to see more technology that's woven into the fabric of the planet, such as intelligent lighting systems or microcontrollers in parking spaces. A hyper-connected society with super-intelligent machines embedded in a super-intelligent environment will support future human, societal and environmental progress.

Expected overall impact in/for Europe

A European-wide IoT initiative will be essential for broadening the economic impact of the information revolution. Our ambition is that European companies capture a sizable part of the IoT supply market, that EU society and EU businesses have access to the most advanced IoT technologies, and that citizens enjoy better, more efficient public services and a sustainable future.

The IoT economic potential can be seen from three angles, a) the business opportunities for providers of IoT solutions (components, systems, smart devices, services), b) the economic gains of industry/business sectors by exploiting the potential of IoT, and c) the efficiency gains of public services (better quality/lower cost services) in healthcare, transport, education, energy and water provision, environmental protection, and city planning.

Synergies and conflicts with other fields

From a strategic perspective it is important to focus on the future and not on legacy networks, to provide guidelines for smart cities and grids, to encourage public sector take-up, and to address the lack of harmonisation across 28 EU member states. Business and market issues concern the creation of the right space for SMEs to flourish, to focus on software and hardware, data analytics, and the availability of IoT platforms. Technology issues circle around the integration of various approaches like IoT, cloud technologies, 5G, semi-autonomous devices; need for reference architectures, interoperability, computing, algorithms and standards. From a societal perspective a recurring issue is the development of a trusted cost efficient and accepted IoT in Europe.

Emerging policy issues

Data protection and security is a critical area for IoT where a number of research and societal challenges must be solved towards a trusted and reliable IoT and for putting the relevant safeguards for its applications in place (e.g. liability, quality assurance).

The evolution of the IoT towards increasingly invisible and ubiquitous objects being reusable for new purposes, more complex, learning and unpredictable systems, more captured, recorded and stored behavioural data, and 'augmented' human performance, is likely to generate unprecedented ethical challenges. It is important to anticipate possible interference of IoT technologies with fundamental rights.

The availability of (very) high-speed broadband Internet and access to digital service infrastructures as the building blocks of a modern Single Market – enabling IoT, cloud, and big data applications to exploit their full potential – must be assured to all.

Furthermore, the availability of a skilled workforce will become a crucial factor for developing solutions and process all information towards a knowledge industry. Policy and governance must provide the appropriate incentives for public sector organisations and civil servant cultures to evolve and adopt new business models.

As the IoT will contribute to the democratisation of innovation in design and manufacturing and to direct policy involvement of the citizens, open access for everybody both as users and service providers needs to be ensured.

The IoT will also contribute to establishing a super intelligent environment where smart machines and citizens can work alongside each other; therefore, the consideration of digital social innovation and artistic practices for a more human development of future societies is crucial.

High-level generic references

The Commission adopted a communication on the IoT in June 2009 (http://eur-lex.europa.eu/legal-content/EN/ALL/;ELX_SESSIONID=wP4YTzZTq7bTpLHSQRGCn7YQQm6VnCKGqnT2nxpJwRz1WzLnpByG!-1409359622?uri=CELEX:52009DC0278). An expert group addressed the main challenges between September 2010 and November 2012 (http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32010D0811(02))

A series of reports have been adopted that predict high benefits from IoT (ex: Cisco valuing Internet of Everything at $14 trillion from 2013 to 2022; http://www.cisco.com/web/about/ac79/docs/innov/IoE_Economy.pdf; Deloitte announcing new eco-systems http://www.deloitte.com/assets/Dcom-UnitedStates/Local%20Assets/Documents/TMT_us_tmt/us_tmt_IoTEcosystem_062014.pdf).

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Brain inspired technologies

Understanding the human brain is one of the greatest challenges facing 21st century science. Advances in this understanding can help us gain profound insights into what makes us human, develop new treatments for brain disease and build revolutionary new computing and robotic technologies. Modern ICT has now brought these goals within sight.

260 million European citizens are likely to develop a form of brain disease during their lives; the cost of treating brain disorders in Europe mounts to 800 billion Euro per year.

Keywords: Brain, brain complexity, brain simulation, brain disease, healthcare, brain and robotics, neuroscience.

(Possible links to other fiches: Omics; Synthetic biology; Advanced autonomous systems; big data; High-performance computing; Personal assistants, Personalised medicine).

Current status

The human brain is a complex organ with ~100 billion neurons dynamically interconnected by ~150 trillion links; even though it has been the subject of scientific and technical interest for centuries, its biology, the cause of diseases, and cognitive processes are far from being understood.

One obstacle to understanding the human brain is the fragmentation of brain research and the quantity of data it produces. An urgent need is thus a concerted international effort that uses emerging ICT technologies to integrate this data into manageable pictures of the brain as a single multi-level system. Today, the convergence between biology knowledge and ICT capabilities is matured enough to turn the goal of understanding the human brain into a reality.

It is this realisation that motivates the Human Brain Project (HBP), an EU Flagship initiative, to propose a new "ICT-accelerated" vision for brain research and its applications. HBP aims to combine existing knowledge and data about the human brain and build a first sufficiently comprehensive computer model of the brain. Such a model should help researchers understand how the human brain works and the diseases affecting it. By doing so, HBP may bring many advances in neuroscience, new treatments for brain disease, and also future brain-inspired neuromorphic computing and robotics technologies.

Understanding the human brain is a global challenge and there are many other major brain initiatives developing in the world, in particular in the USA, Canada, Japan, China and Australia. Scientific exchanges are already occurring amongst these and the first steps towards programme-level collaboration are being discussed.

Future trends (~2030)

In science, engineering, technology

Availability of integrated, accurate models across brain scales (from genes to cognitive functions) will boost neuroscience progress: understanding and simulating the origins of brain functioning and diseases; understanding neuro-biological and cognitive processes.

Brain models, for both male and female human beings, will allow also for novel, low-power neuromorphic multi-processor systems and brain-inspired robotics; new more powerful super-computers; advanced machine learning and decision-making theory and systems.

For innovation/applications perspectives

Availability of biological signatures of brain diseases and related brain data networks for medical applications, and of brain simulation infrastructures will permit a) designing and testing with computers new personalised interventions to prevent, diagnose and treat brain diseases and b) to aid human-computer interaction and develop tools that could improve our performance in some high level cognitive tasks (e.g. learning).

Availability of neuromorphic chips will open new possibilities for information processing (e.g. for resilient and autonomous robotics control) and as co-processors for cognitive / decision-making assistance.

Expected overall impact in/for Europe

Society

Dealing more effectively with brain diseases like memory disorders, dementia and Alzheimer for the benefit of patients, families and carers; more efficient, adaptable, intelligent and ubiquitous aids – gadgets – that can learn, make autonomous decisions and interact with humans (e.g. personalised for patients/older persons, who cannot be autonomous, helping them in their home) will transform our daily lives.

New insights will help to make learning and teaching more effective and will help to fight addictions and to understand and cure psychological problems.

The economy

Reducing the cost of brain disorders (estimated in the EU at 800 billion Euro a year)[13]; developing new brain medical practices and medicines, boosting pharmaceutical industry.

Creating new industries around neuro-inspired chips, computers, and robots, and software industries commercialising robust, adaptable, flexible and semi-autonomous decision-making systems.

Governance and policy issues

Brain-inspired automatic decision support systems will aid human decision-making.

Integration and sharing of data will be facilitated with open data platforms, models, data (and meta-data) standards, data privacy and security measures.

Ethics will safeguard the new types of interventions (e.g. healthcare or cognitive enhancements).

Autonomous systems will aid and eventually substitute human intervention wherever desirable.

Safety and security

Assisted or automatic detection of events or risks.

Synergies and conflicts with other fields

Brain understanding and simulation or replication is directly linked to brain research, which has received

[13] The economic costs of brain disorders in Europe. Olesen J1, Gustavsson A, Svensson M, Wittchen HU, Jönsson B; CDBE2010 study group; European Brain Council, European Journal of Neurology 2012, 19: 155–162.

considerable funding at EU level over the past years. Between 2007 and 2012 the FP7 supported projects from basic research to clinical applications for a global budget of EUR 2 billion, along 4 mains axes: (i) to better understand how the brain works and identify diagnostic and treatment targets for the benefit of public health, (ii) to streamline the drug development process and support EU industry competitiveness, through the Innovative Medicines Initiative (IMI) from which brain research has directly benefited, (iii) to develop modeling and predictive neurosciences, with the major contribution of the Human Brain Project, (iv) to better address brain diseases through European and global cooperation, including support to the Joint Programming Initiative on Neurodegenerative Diseases with a focus on Alzheimer's disease (JPND).

Dealing with the whole brain, modelling the interactions between all scales and levels, from genetic to cognitive, requires establishing synergies not only between the above mentioned initiatives and projects but also with other research areas dealing with: dynamic and complex systems theory, chaos theory, high performance computing and robotics. Dealing with the corresponding amount of biological data and also with the quantity of knowledge will also share approaches with work on big data.

Potential conflicts may arise due to ethical concerns, for example consent and privacy regarding personal medical data, or the responsible use of cognitive-enhancement devices. Brain research may also give rise to many other potential controversial issues such as, for example, public concerns about modelling the human brain in a machine, building conscious robots or controlling the mind.

Emerging policy issues

There are a number of policy areas where brain-related science will call for special and quick action: open data platforms, data and meta-data standards and data privacy and security rules.

The scale and nature of such challenges as understanding the human brain and developing the brain-inspired technologies of the future require an integrated and synergetic research approach between the EU and the Member States.

There is a need to create for wide coalitions between brain researchers, medical professionals, psychologists, educators, pharmaceutical, computing and robotics industry to bring science and knowledge into new and improved products, medicines, treatments, forms of processors and computers, and robots, taking into account possible gender differences and ethics requisites.

Clearly explain the impacts of publicly funded brain research to the European citizens and engage the organised civil society and the public at large through appropriate campaigns.

The scale of the challenge requires international cooperation, starting with those countries having similar initiatives: the USA, Canada, Japan, Australia or China.

High-level generic references

HBP project website
HBP - Digital Agenda for Europe

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Big data

Key words: Big data, decision making, information process.

Current status

'Big Data' loosely describes a set of technologies that deal with very large volumes of fast changing information, usually from a variety of disparate sources with substantial economic, scientific or public value. Currently data value chains are emerging across almost all sectors of the economy and society, as information technologies increasingly accompany most aspects of our life and society in general.

Future trends (~2030)

By 2030 most human activity and many natural phenomena will generate detailed real-time data redefining the basis of many scientific models and engineering. Humans as well as the environment will be an integral part of the global information processing network; not only do we consume the services but we are in fact computing and 'sensing' ourselves. In parallel, knowledge extraction through automated text and data mining, including from scholarly sources, will create a radically new knowledge base. Taken together, these trends will be transformative in science, engineering and technology.

Innovation and applications will probably be largely designed around this data, leading in particular to the personalisation of products, but also of approaches to healthcare, education, environment and other fields. The "Internet of things" of smart connected objects will enhance this trend by generating dramatically more contextual data.

Non-customised products will be less competitive in many areas of the economy, and those organisations with more data than others may have extreme competitive advantages over those that don't.

In domains such as health care, the integration of personal genomes and real time monitoring data can help identify high risk patients and lead to preventive strategies and more effective and safer treatments. Sharing of medical data at the initiative of the individual is rapidly increasing, opening new avenues for knowledge generation but also posing a risk of misuse of data against the interest of the individual.

Expected overall impact in/for Europe

The societal transformations will be in the context of the increasingly strong interweaving between the digital and natural self: the hyper-connected human in a hyper-connected environment. Increasingly powerful inference technologies can, in several circumstances, match or surpass cognitive abilities of humans. The concomitant mutual shaping of technology and society can lead to a variety of scenarios, not all desirable. Critical accompaniment of this transformation through a public dialogue is essential.

Currently, Big Data technology and services are expected to grow worldwide to USD 16.9 billion in 2015 at a compound annual growth rate of 40%. At the same time, markets and trade will be increasingly driven by Big Data related technologies.

Some fundamental governance issues will continue to be challenged in the long run, e.g. notions of data ownership, informed consent, anonymity, cross-border application of rules, as well as notions of access, ethics, surveillance and effective transparency. As one important and illustrative example of such a governance challenge, big data related technologies will present significant new challenges in law enforcement: big data related technologies will offer possibilities for increased cybercrime, but at the same time come with greater opportunities for fighting criminal behaviour.

Technologies around Big Data are already being used for environmental monitoring (through sensors) and climate change (through modelling). It is not so much that Big Data will have a large impact on the environment and climate (besides through increasing energy demands), but it will help society better sense, model and adapt to environmental and climate change challenges. One particular example is monitoring of the marine environment where real-time data from robotic underwater, surface and airborne sensors can provide information relevant to environmental indicators, as well as facilitate the sustainable exploitation of the marine environment.

In a similar vein, estimates of risks and hazard underlying safety and security policies will be routinely based on big data technologies, but allowing ICT based modelling of systemic and non-systemic risks.

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Chapter 2.
Health and biotech

Introduction

Science and technological progress has contributed vastly to the increase of our life expectancy. There was Pasteur and the antibiotics, now the progress in cancer and gene therapy and soon organ replacements using stem cells.

The combination of ICT and the Omics (e.g. genomics) will open up even more possibilities, like personalised medicine, not just for treatment but also probabilistic prevention as a function of environmental parameters. But health is not only a matter of technology but also life style and personal responsibility.

The line between healthcare and human augmentation is fading...

Personalised medicine

Personalised medicine refers to a medical model using personal health data and molecular profiling to tailor the right therapeutic strategy for the right person at the right time, and/or to determine his or her predisposition to disease and/or to deliver timely and targeted prevention.

Personalised medicine has the potential to offer safer and better treatments and diets, earlier diagnostics and prevention. No longer based on averages or statistics, but on what you need, when you need it, while taking into account your specific genome, biochemistry, environment and behaviour. Citizens will actively manage their health through sensoring devices, mobile apps etc. which can eventually lead to advanced tools such as personal medical avatar.

Keywords: Personalised medicine, medical Avatar, Digital Patient Record, Electronic Patient Record.

Current status

Personalised medicine can help deliver better, safer and more sustainable health and care for European citizens and societies and drive research and innovation. It promises to deliver the right treatment or prevention strategy for a specific person, either male or female, at the right time, capitalising on advances in health research and IT. Personalised medicine can improve people's quality of life and reorient healthcare systems away from costly ''one-size-fits-all'' approaches.

In many countries digitisation of basic health care data registration is already taking place, e.g. with Electronic Patient Records, e-Prescription and Patient Files. Also new streams of health data are generated via various telemonitoring technologies. These data are important building blocks for a new approach to health care research and delivery, tailored to the needs of specific patients – for prevention, prediction and treatment.

Based on data on patients provided by carers, medical professionals and sensors, the first generation of 'digital patient profiles' is being developed, enabling better, safer and cheaper integrated care, treatment and diets.

Specific challenges in this early stage of development include standardisation and harmonisation of big data-efforts, education and communication, improved translation of new knowledge into medical applications, and an efficient use of best practices,. There is also a need for proof-of-concept examples demonstrating the value of this new approach.

Future trends (~2030)

On the science

As costs for sequencing a human genome decline rapidly, new avenues are opened up for personalised medicine, revolutionising medicines development and the treatment of cancer, and degenerative and cardiovascular diseases.

Parts of the clinical trial trajectory for new treatments and medications can be moved to the digital domain, thus making it faster and shorter.

Potential treatments and medicine protocols for a person can be tested on a medical 'avatar' (a sophisticated 'big data'-based model of the individual), to optimise effectiveness and minimise conflicts of medication.

On the applications

Treatments and prescriptions will no longer be based on 'average' people, but medicine and care will be tailored to an individual or a group of patients with a specific genome and biochemistry taking into account possible sex and gender differences.

Pre-treatment 'virtual' testing of medication can speed up clinical trials for new medication or avoid conflicting medication for particular patients.

Personalised medicine has the potential to respond to, amongst others, the increasing burden of chronic disease and the complexity of co-morbidities, thus contributing to the sustainability of health and care systems.

People will be enabled to manage their health with highly customized lifestyle plans – diet exercise, and relaxation – as well as manage acute health problems with precision.

Roles of GPs, medical specialists and other professionals will change radically. Part of health research will be data-driven and risk-assessment will be done by non-medical specialists, who will have to make high-impact choices.

Primary care providers may have to build new service lines around prevention and wellness in order to replace revenues lost from traditional medical procedures. Physicians will also require a solid background in genomics and proteomics to make the best use of new data...

Expected overall impact in/for Europe

Personalised medicine will contribute to a higher quality of life and more health life years for the already ageing population in Europe.

The potential to offer new treatment opportunities for the benefit of patients, including better targeted treatment, avoiding medical errors and reducing adverse reactions to medicines (increased efficacy and safety of medicines).

Reductions in healthcare expenditure of interventions by avoiding inappropriate treatments.

People are empowered to manage their health pro-actively (lifestyle choices, preventative medication and diets).

Synergies and conflicts with other fields

Big data - cloud computing; cryonics/life extension; epigenomics and personalised nutrition; human enhancement; human-computer interaction; novel pharmaceuticals; *omics, dna-fingerprinting and personal genomes.

Emerging policy issues

Data protection and privacy

How to manage the integrity, trustworthiness, confidentiality and quality of personalized health data 'in the cloud' and how to deal with (new) information monopolies regarding (personalised) health data?.

Training
Improving the education and training of healthcare professionals on data management, statistics and bio-informatics will be needed.

Business models
Who owns the data: the individual (trust) or the authority (protected data-monopoly)?

Discrimination
Genetic testing can induce discrimination, e.g. from insurer or employer.

Investment
Underinvestment in Personalised Medicine developments may occur as preventive or predictive products and services (yielding efficiencies and ' avoided costs') generate less income for industry than (new) conventional medicine.

Insurance –reimbursement
Current insurance models are based on large, predictable populations, but shift towards small populations (or even unique persons) which are far less predictable and attractive for industry. There is uncertainty if eventual higher costs of personalised medicine will be outweighed by higher effectiveness of treatments and the reduction of inappropriate treatments. New actuarial assumptions are needed and possibly a shift towards 'pay for performance' (health gained or preserved) from the current 'pay for treatment provided'.

Allocating risks and liabilities
The roles of GPs, medical specialists and other professionals will change and part of health research will be data-driven: risk-assessment, done by non-medical specialists who will have to make high-impact choices.

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Regenerative medicine and tissue engineering

Regenerative medicine has developed from new scientific discoveries, notably in the stem cell field. It offers hope for life-threatening or untreatable diseases, such as Parkinson's or Huntington's disease, and provides new approaches to treat diseases with serious societal impact, such as diabetes, and for the ageing population.

Unknowns about the underlying science, clinical application and possibly unsound treatments demand regulation to protect patients, but regulation must be adapted to scientific progress and should be proportionate.

Regenerative medicine treatments are innovative and complex from clinical and business perspectives and require substantial investment; at present large pharmaceutical companies are not heavily involved and most development is done by SMEs, academia and medical charities.

Over 200 clinical trials conducted in EU on these new therapies.

Keywords: Stem cells, biomedicine, personalised medicine, patents, ageing.

Current status

Regenerative medicine is a new approach to treatment based on replacing damaged or diseased tissue or on stimulating the body's own regenerative capacity. It has developed as a result of new scientific discoveries, notably in the stem cell field. There is also new evidence that sex differences are essential for the understanding of basic stem-cell biology, diseases associated with stem cells, and regenerative medicine.

Regenerative medicine, particularly cell-based treatments, offers hope for life-threatening disease and other unmet medical needs such as cancer or neurodegenerative disorders, and for conditions related to the ageing population. Regenerative medicine products for skin repair and damage to cartilage are already on the market but for more ambitious targets, such as neurodegenerative or heart disease, safe and efficacious products and their corresponding business models are still in development. Regenerative medicine can be a complex approach to treating patients, requiring integration of different disciplines, such as cell production technology, immunology, biomaterials and surgery, and re- quires its own personnel and infrastructure.

In order to ensure patient safety when using the new products, the EU pioneered, in 2007, regulation subjecting these products, identified as Advanced Therapy Medicinal Products (“ATMPs”), to the strict authorisation process that applies to medicines. While only four such medicinal products have been authorised for marketing in the EU so far, there is a rich pipeline of potential products to come.

The development of ATMPs is confronted with a number of difficulties. Firstly, the development of ATMPs is more complex than the development of other medicines due to factors such as the variability of the source materials, the lack of adequate animal models, or the impossibility to conduct randomized controlled clinical trials in cases where the administration of the product requires surgery (i.e. the majority of tissue engineering products). Autologous products present additional challenges as the starting material is different for each patient and, in some cases, the last part of the manufacturing process may need to be conducted at the hospital immediately before administration to the patient.

Additionally, most of the ATMP developers (typically SMEs or university hospitals) have only limited financial and human resources and, furthermore, they lack experience in dealing with the complex regulatory framework that governs medicinal products.

Future trends (~2030)

This is a fast-moving field that is hard to predict, particularly in terms of scientific advance. For example, the discovery of induced pluripotent stem cells which led to the 2012 Nobel Prize was quite unexpected.

At present, large pharmaceutical companies are not significantly associated with ATMP development. To some extent the new products represent a challenge to their traditional business. What is clear is that although an increasing number of regenerative medicines are entering clinical trial phase, their development is more complex and intensive of time and resources than initially envisaged and continuity of support is needed for the new therapies to emerge.

Expected overall impact in/for Europe

New medicines could bring significant benefits for patients and society at large as it could significantly alleviate some of the disease burdens linked to ageing population.

Europe is strong on the basic science underlying regenerative medicine and in biotechnology; significant research in the field is carried out in the EU. From an economic standpoint, it is important to maintain and develop the competitiveness of the sector. At present academic groups and SMEs are the main players. Big industry is waiting on the side-lines for successful therapies to emerge and for business models and regulatory pathways to be developed.

Synergies and conflicts with other fields

Developments in genetic engineering techniques and biology as well as the development of new biomaterials will support new developments in the field of regenerative medicine.

This field is very closely related to medical devices, cosmetics, and transplant of tissues/cells of human origin. It is important to ensure compatibility between these legislative frameworks and to avoid loopholes that could be exploited by unscrupulous traders.

Finally, it needs to be acknowledged that the sector would not kick off if there are no appropriate instruments that ensure a reasonable return for investment. The application of the patent protection system and data exclusivity schemes in this field should be clarified. Where appropriate, new instruments should be developed.

Emerging policy issues

In order to unlock the full potential of this new field of biomedicine, it is important to create conditions that facilitate the appearance of new medicinal products. However, it is also key to maintain strict controls on the quality, efficacy and safety of these treatments so as to avoid safety incidents that cast doubts on this technology or even generate opposition from EU citizens. Medical tourism to destinations with freer regulations is already a reality, as is the existence of for-profit clinics offering unproven treatments and preying on vulnerable patients.

Certain developments in the regenerative medicine field raise sensitive ethical questions, such as the patentability of products that essentially consist of human materials, the use of embryonic stem cells (even though the majority of research is currently conducted with non-embryonic stem cells), or the use of cloning techniques, that require careful handling if the field is to fulfil its promise.

Regenerative therapies represent a new class of treatment and introduction of appropriate reimbursement regimes for them will be essential for their promise to be fulfilled.

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Prosthetics and body implants

Pushed by ever more knowledge on tissues, bio-compatibility of materials, biological processes and IT, prosthetic implants are about to be developed for ever more human body parts. Europeans will continue to embrace this development. Double-digit growth rates can be expected. There will also be policy and regulatory challenges. The question of affordability and a possible social divide may arise.

It can be expected that by 2030 more than half of the body can be replaced

Keywords: Prosthetic implants, artificial organs, medical devices, risks, high growth rate, affordability.

Current status

A wide range of prosthetic implants is either already available or under development. Some types of prosthetic implants, like dental implants, breast implants or pace-makers, exist already for decades. In recent years, the number of types of prosthetic implants has exploded, namely with regard to bone, vessel and inner tissue implants. Furthermore, there are more and more reports about prototypes of organ replacement implants. This goes from artificial skin, over artificial eyes, ears, kidneys even to hearts. By the end of 2013, the first patient received, in France, a completely artificial heart. Though he died early 2014, efforts will continue. Even extremely complex organs, like the liver, are now targeted by research. This trend is backed by the exploding knowledge about (human, animal and artificial) tissues, bio-compatibility of materials, biological processes and IT.

Future trends (~2030)

On the science

The borderline between device and tissue engineering will be further blurred.

On the applications

It can be expected that by 2030 more than half of the body can be replaced.

Expected overall impact in/for Europe

Society

Except from religious groups opposing mankind to intervene in God's creature, society will, generally speaking, embrace the trend. Men and women are willing to spend for prosthetic implants, be they life-prolonging or not.

Economy

The current double-digit growth rates will continue. The exploding medical opportunities will burden health insurances and foster inequality.

Synergies and conflicts with other fields

There are synergies with many fields of mechanics, IT and bio-technology, but in particular with the field of tissue engineering and human enhancement. Some applications will first be developed for non-medical purposes and then re-used for medical purposes.

Emerging policy issues

Governance and policy issues

Equal financing of what is medically possible will be the main topic. Secondary effects of longevity will come next.

Environment and climate

The respective industry requires a medium amount of natural resources and produces a medium amount of waste.

Safety and security

As to safety, there is the classic dilemma of medical device legislation: the higher the requirements for safety, the more medically beneficial progress is slowed down. Those prosthetic implants having an IT component will raise the classic IT security and compatibility issues (hacking, unwished interactions with other IT etc.).

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Human enhancement

Pushed by military and medical research, human enhancement might change the day-to-day life experience of many Europeans in a few years from now-on, e.g. by creating an "augmented reality" and receiving information from IT via nerves-IT-interfaces. The big potential in terms of economic growth will be accompanied by policy and regulatory challenges and maybe even a societal divide. Any regulatory response must build on international cooperation to be efficient.

For certain professions, e.g. in the military, human enhancement may become a prerequisite by 2030.

Keywords: Human enhancement, prosthetic implants, augmented reality, human identity, societal divide, risks, economic potential, international cooperation.

Current status

This sheet builds on the sheet for prosthetic implants. Some of the prosthetic implants currently tested are already more performing than the natural organs and thus pave the way to human enhancement (HE). E.g. artificial eyes can see infrared light and artificial muscles can be stronger than natural ones. Some medical devices which are not prosthetic implants can also be used for HE, e.g. electric brain stimulation devices. A big potential for HE is opened by nerves-IT-interfaces which pave the way for an "augmented reality". Ministries in charge of research, the military and the IT industry are investing in HE.

Future trends (~2030)

On the science

Today's focus on mechanical and senses/electrical interfaces will be complemented by technologies dealing with emotions (already today some emotions can be "read" by analysing brain activity patterns).

On the applications

HE will become common practice. For certain professions, e.g. in the military, HE may become a prerequisite.

Expected overall impact in/for Europe

Society

HE will to some extent split the society between those who want HE and can afford it, those who would like to use it but cannot afford it and those who reject it for reasons of personal conviction. HE will raise questions of human identity (as for transplanted organs), legal questions (e.g. responsibility under civil and penal law in case of failure), and questions of ethic benchmarking (can HE be requested from those steering certain vehicles?).

Economy
The economic potential is huge as life experience can be upgraded.

Synergies and conflicts with other fields

There are synergies with many fields of IT and bio-technology, but in particular with the field of prosthetic implants.

Emerging policy issues

Policy issues
Governments will have to protect both the right to use and the right not to use HE. They will have to settle the legal and ethical questions listed under 3.a. and data protection issues.

Environment and climate
See the sheet for prosthetic implants.

Safety and security
Moreover, identity modifying effects and the risk of addiction or of other psychological disturbances must be closely followed. Once there are nerves-IT-interfaces, there is a risk of possibly harmful distance steering by service providers outside the enforcement reach of individual regulators / jurisdictions. International regulatory cooperation seems paramount.

High-level generic references

http://ec.europa.eu/digital-agenda/futurium/en/content/evolving-human-enhancement.

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Synthetic biology

Scientific advances in synthetic biology are expected to provide the foundations for realising the full innovation potential of biotechnology in contained-use applications, mainly in health and industrial biotechnology applications. It will provide innovative solutions for the conversion of our current unsustainable fossil-based industries into sustainable and competitive bio-based industries for bioproducts (e.g. chemicals, polymers) and bioenergy, for new antibiotics and vaccines, and new diagnostics and treatments for cancer and rare diseases. At the same time, one has to take note of the ongoing debate regarding the scientific and legal definition of what synthetic biology comprises and of the discussions concerning potential risks and benefits of synthetic biology in terms of the environment, consumer health and biological diversity.

The market for synthetic biology products and applications is expected to grow to $ 10.8 billion in 2016 and at least $ 100 billion by 2025.

Keywords: Synthetic Biology, Biotechnology, Bioinformatics, Key Enabling Technologies[1], Industrial Biotechnology, white/red/grey/green Biotechnology.

Current status

Origin of the field of synthetic biology

The term *synthetic biology* dates back to the beginning of the 20th century, when in 1912 Stéphane Leduc published a book entitled *'La biologie synthéthique'*. He was a biologist, who tried to explain biological processes of development and growth on the basis of physical and chemical models. Eventually, his view did not find much support with other scientists.

With the advances of molecular biology, genetics and others since the early 1970's, the meaning of the term *synthetic biology* has evolved into describing the use of engineering principles in biology; to deliberately design and construct novel biological parts, devices and systems to perform new functions, e.g. new microorganisms to produce antimicrobials and other pharmaceuticals or fine chemicals. Synthetic biology mainly aims to engineer biological systems in a (fast) modular, reliable and predictable way as opposed to the (slow) evolutionary principles of live on earth.

It is important to note that the word *synthetic* in today's context should refer to *'placed together'* or *'constructed',* e.g. when microorganisms were genetically engineered to produce specific biocatalysts they were not able to be generated previously. This could benefit the engagement of scientists in communicating with the general public on this subject, as in many cases the general public rather considers synthetic biology in the meaning of being *'artificial',* thus not natural and therefore potentially hazardous.

[1] In 2009, the EC identified nanotechnology, micro-nanoelectronics, advanced materials, photonics, industrial biotechnology and advanced manufacturing systems as the EU's six key enabling technologies KETs are defined as knowledge and capital-intensive technologies associated with high research and development (R&D) intensity, rapid and integrated innovation cycles, high capital expenditure and highly-skilled employment. They enable process, goods and service innovation throughout the economy and are of systemic relevance. (COM(2009)512).

The current and future valorisation of scientific advances in this field will need to be closely accompanied by appropriate research efforts about the potential risks and benefits on a case-by-case basis and considerations of the appropriateness of the applicable EU regulatory framework, consistent with the precautionary principle.

Current status on Synthetic Biology

According to the strategic vision for European synthetic biology, published by the FP7 project ERASynBio in 2014, the following 6 current scientific areas are the main users of synthetic biology approaches:

* Metabolic engineering;
* Minimal genome design;
* Regulatory biochemical circuits;
* Design of orthogonal biosystems;
* Development of protocells (chassis or host cells);
* Bionanoscience;

The ERASynBio project

This project comprises 16 European research funding organisations from 14 countries and observers from Europe and the United States of America. The central idea of ERASynBio is to promote the robust development of Synthetic Biology by structuring and coordinating national efforts and investments. The project received a start-up funding from the seventh EU Framework Programme for Research in 2012, and has since launched 2 calls for proposals with a total requested research budget of around € 30 million, entirely provided by the national funding organisations.

Scientific advances in synthetic biology are expected to provide the foundations for realising the full innovation potential of biotechnology in industrial applications, in particular in the areas of red (health applications) and white (e.g. applications in the chemical industry) biotechnology. Applications of synthetic biology in these areas are almost exclusively based on so-called contained-use applications, i.e. production environments, which are hermetically separated from the surroundings. The very good safety record of contained-use applications is based on 3 main components, namely the applicable EU legal framework, the mandatory national approval procedures and the Good Manufacturing Practice Guidelines established by industries and the related Standard Operating Procedures.

The following table presents the main societal challenges for which the further development of synthetic biology may provide viable solutions in the short, medium and long-term. The table also includes activities managed by the Key Enabling Technology Biotechnology area under the Leadership in Enabling and Industrial Technologies area of Horizon 2020.

Challenge	Expected impact
Health and wellbeing	Synthetic biology enables the rational design of new antibiotics and the development of novel solutions, such as engineered bacteriophages (viruses infecting potentially harmful bacteria).
Resource efficiency, climate change and energy	Europe is currently world leader in terms of employing industrial biotechnology for the production of bioproducts, including enzymes and bioenergy from renewable resources. Contributions from synthetic biology are expected to increase product yields, recovery and quality, discover new metabolic pathways and generate new production microorganisms (hosts) for industrial applications. These activities will enhance EU industrial competitiveness by lowering the use of fossil resources and reducing greenhouse gas emissions, while creating growths and jobs.
Sustainable agriculture and forestry, and food security	Competition between food and industrial uses of agricultural and forestry resources will be avoided by valorising the non-edible residues from these areas for industrial uses on the basis of establishing advanced biorefineries in the EU. The research and innovation actions funded by the Key Enabling Technology Biotechnology part of Horizon 2020 related to synthetic biology and the Joint Technology Initiative on Bio-Based Industries will speed-up the development and deployment of the necessary technology base.
Environmental sustainability	In line with the development of synthetic biology under the Key Enabling Technology part of Horizon 2020 for the deployment of advanced biorefineries in the EU, bioremediation of polluted industrial sites in the EU and worldwide remains in the focus. In particular, the development of bio-detectors for sensing the presence of micro- pollutants, such as endocrine disruptors, and pesticides and herbicides in drinking water presents a significant challenge. This could at the same time be tackled by developing e.g. membrane-bound biocatalysts in water treatment applications, which would reduce or eliminate such pollutants.

The ERASynBio project conducted a mapping exercise in 2012, gathering detailed information on relevant funding organisations, national and transnational funding programmes, funded synthetic biology projects and others. It emerged from this exercise that since 2004 EU Member States and non-Member States spent around € 450 million for synthetic biology research. Leading countries are the UK, Denmark, and Switzerland, followed by Germany, Austria, Spain, Slovenia and France.

Almost 1/3 of this funding was dedicated to metabolic engineering projects, reflecting the European leadership in this area, followed by research into regulatory circuits and bionanoscience. In terms of primary area of R&D interests of European companies engaged in synthetic biology research, 58% of these companies are working in the area of health, medical, and diagnostics markets, 45% in industrial and bioenergy applications and 24% in waste processing and bioremediation.

It is also worth noting that the above research activities are accompanied by transnational European synthetic biology reports of more strategic nature, e.g. authored by the European Academies Science Advisory Council and the European Group on Ethics in Science and New Technologies.

It should be noted however that there is currently no agreed definition at EU and international levels of what is synthetic biology.

The global context

Synthetic biology approaches were first adopted by US scientists, institutions and companies, supported by proactive prioritisation and investments by national funding organisations and industry. Therefore, the US is currently the leading world region in this regard. The EU is trailing closely behind in terms of scientific publications, but in comparison the research area remains rather fragmented, marked by volatile funding opportunities and limited financial support from private investors. Also China has identified synthetic biology as a key priority area.

According to reports authored by BCC and McKinsey, the market for synthetic biology products and applications will grow to $ 10.8 billion in 2016 and at least $ 100 billion by 2025 respectively. The first products on the market include pharmaceuticals such as artemisinin, an anti-malaria drug and a range of antimicrobial drugs. BCC also reports that there are currently 20 additional drugs under development, which will be derived from synthetic biology. Similar developments are expected in the areas of biofuels (e.g. by TMO Renewables, a UK-based company) and biomaterials (e.g. DSM, a Dutch-based chemicals company).

In the international context, the UN Convention on Biological Diversity (CBD), and its Protocols is of particular importance: the Cartagena Protocol on Biosafety, and the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization. The COP11 (Conference of the Parties) decided to urge Parties to take a precautionary approach, when addressing threats of significant reduction or loss of biological diversity posed by organisms, components and products resulting from synthetic biology.

It was also decided to continue gathering information on positive and negative impacts of synthetic biology and gaps and overlaps with international agreements and legislation and views from Parties and stakeholders, and the issue together with the need for a definition will be on the agenda of CBD COP12 in October 2014. There will furthermore be a need for a dedicated discussion on the relationship between the Convention and its Protocols when considering synthetic biology.

Future trends (~2030)

On the science

By 2030 a range of host/chassis cells should have been developed. Together with the development of a wide range of metabolic/biochemical modules this should serve to create sustainable processes and products in a wide range of industries and applications. Development and standardisation of biological modules (biochemical circuits) will be on top of the research agenda.

Further development of minimal genomes and full exploitation of the principle of orthogonality, meaning designing biochemical circuits in living cells that do not interfere with the normal metabolism of this particular type of cell. This will tremendously increase predictability of the resulting organism and increase its efficiency of producing the target molecule.

Increased knowledge of metabolic engineering and much improved tools and instruments for designing genetically engineered organisms. This includes genomics and know-how of regulation of gene expression in living organisms as much as proteomics and metabolomics.

Significant investments in bioinformatics will have to happen between now and 2030. Already today, the wealth of (bio-) information available exceeds the human resources needed to make use of it. Therefore, the design of electronic libraries and BioCad tools (Computer-assisted design of biomolecules) will be crucial in the future.

On the applications

Focal application areas for synthetic biology are in the fields of industrial biotechnology and biorefineries (bioproducts, like chemicals and polymers, and bioenergy) in contained-use environments, waste processing and water treatment; health and pharmaceutical applications for the production of new vaccines, antimicrobial drugs, treatment of rare diseases and others.

Expected overall impact in/for Europe

Due to the cross-cutting nature of synthetic biology, it is difficult to assess its specific expected impact for Europe. In any case, one should take stock of current developments in this scientific field and relate it to EU policies on resource efficiency, climate change, re-industrialisation and others.

For instance, it is expected that by 2030 the EU chemical industry will have a 30% share of its product portfolio being produced by either using renewable resources or biotechnological processes or both. This means that of the current annual sales of around € 500 billion, € 150 billion will be generated by using biotechnology approaches in general or synthetic biology in particular. In addition, it is estimated that by 2030 globally around 50% of all pharmaceuticals will be produced on the basis of biotechnology/synthetic biology approaches, which represents a global market value of more than € 500 billion. In both areas, EU industries are currently leading the global competition already at a very high level. In order to maintain or even improve the industrial leadership positions, the potential of EU industries for competitiveness gains from advances in applied biotechnologies are of strategic importance.

As regards the international obligations of the EU in terms of climate change, it is estimated that the contributions of biotechnology to reduce industrial CO_2 emissions account annually for around 33 million tons. Given that the market penetration of biotechnology in the various industries is expected to be at least three times higher in 2030 than it is today, biotechnology could easily reduce CO_2 emissions in the EU by another 100 million tons by 2030. In the light of the current discussions on the Renewable Energy Directive in the EU and the potential need to reduce industrial CO_2 emissions in the EU by 300 million tons by 2030, biotechnology alone could contribute 33% of the required reductions.

More generally, societal and political issues are likely to have a significant influence on the future market potential of synthetic biology in Europe. Robust societal embedding of synthetic biology, via responsible governance and engagement, is therefore highly important. For that reason, the EC also funds activities that promote responsible research and innovation in synthetic biology.

Synergies and conflicts with other fields

Synergies

Possible synergies with health biotechnology approaches could be better valorised by facilitating links between the various research groups.

Synergies with the societal challenges 'Health, Energy and Agriculture, Food and Bioeconomy' will be valorised to the extent possible, e.g. the Key Enabling Technology Biotechnology part will focus on technology development, including synthetic biology, whereas the Societal challenges Energy and Agriculture, Food and Bioeconomy should focus on technology deployment throughout the EU Member States.

Complementarities and synergies with the Horizon 2020 area of 'Science in Society', focusing on engagement with societies, on ethics and responsible innovation.

The related field of systems biology is expected to contribute necessary know-how, in particular in terms of understanding the functioning of biological systems, to the further development of synthetic biology.

Challenges

The need for legal certainty as regards the applicability of the existing EU legislation (e.g. on biosafety of GMOs, and contained-use *vs* deliberate release applications).

Emerging policy issues

The two sets of questions will be addressed in three Opinions: The first opinion on Definition was adopted by the Scientific Committees in September 2014. This Opinion is the first of a set of three Opinions addressing a mandate on Synthetic Biology (SynBio) from DG SANCO, DG RTD, DG Enterprise and DG Environment requested to the three Scientific Committees (SCs). This first Opinion concentrates on the elements of an operational definition for SynBio. The two Opinions that follow focus on the methodology to determine what, if any, risks SynBio may potentially pose to public health and what type of further research in this field is required.

Current definitions of SynBio generally emphasise modularisation and engineering concepts as the main drivers for faster and easier GMO design, manufacture and exploitation. However, the operational definition offered in this Opinion is sufficiently broad to include new developments in the field and is derived from a working understanding of SynBio as a collection of conceptual and technological advances: SynBio is the application of science, technology and engineering to facilitate and accelerate the design, manufacture and/or modification of genetic materials in living organisms.

But beyond providing that definition, this first Opinion also provides an overview of the main scientific developments, concepts, tools and research areas in SynBio and a summary of relevant regulatory aspects in the European Union (EU), in other countries such as the USA, Canada, South America, China, and at the United Nations. The two additional Opinions on SynBio to follow will focus on risk assessment methodology, safety aspects and research priorities, respectively.

The second opinion, on Methodological and safety aspects and the third one, on Research priorities will be adopted during 2015 (first and second term).

Potential for international cooperation, in particular with the US and China.

Evaluation of the legal status of synthetic biology within the current framework of the EU legislation on Genetically Modified Organisms.

Under the responsibility of DG SANCO, the Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR) is requested to answer the following questions through a joint opinion in association with Scientific Committee on Health and Environmental Risks (SCHER) and Scientific Committee on Consumer Safety (SCCS) and if relevant other European Community bodies e.g. European Environmental Agency (EEA) and European Food Safety Agency (EFSA):

What is Synthetic Biology and what is its relationship to the genetic modification of organisms?

* Based on current knowledge about scientific, technical, and commercial developments, what are the essential requirements of a science-based, operational definition of “Synthetic Biology”? These requirements should comprise specific inclusion and exclusion criteria, with special attention given to quantifiable and currently measurable ones.

* Based on a survey of existing definitions, to which extent would the definitions available meet the requirements identified by the Committee as fundamental and operational?.

These questions are part of a set of 11 questions from the European Commission on synthetic biology. Apart from the above questions on the scope and definition, there are five questions on risk assessment methodology and safety aspects and a further 3 questions on research priorities. The two sets of questions will be addressed in future Opinions.

Potential impacts on the environment, the conservation and sustainable use of biological diversity and human health must be fully assessed on a case-by-case basis and in order to avoid potential negative impacts.

The relation to biodiversity-related international instruments needs to be clarified: UN Convention on Biological Diversity (CBD) and its Protocols: the Cartagena Protocol on Biosafety, and the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization and their implementation.

High-level generic references

European Academics Science Advisory Council - Realising European potential in synthetic biology: scientific opportunities and good governance.

European Group on Ethics in Science and new Technologies – Ethics of synthetic biology.

FP7 projects ERASynBio - Next steps for European synthetic biology: a strategic vision from ERASynBio; and SYNENERGENE - Synthetic biology – Engaging with New and Emerging Science and Technology in Responsible Governance of the Science and Society Relations.

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DNA fingerprint and personal genomes

Personal genomes will replace more traditional forms of identification. Newborns will be screened for possible genetic diseases and the genome data will be added to the healthcare record as a reference diagnostic point. Genetic information will be available if necessary for specific purposes. While individuals will own and actively manage their genetic and health data, safeguards will make sure that fundamental rights, including human dignity will be preserved in the EU.

Keywords: DNA fingerprinting, DNA barcoding, DNA sequencing, genetic discrimination, consumer genomics, personalised medicine, fundamental rights, human dignity, data privacy, data protection, private and family life, integrity of the person.

Current status

DNA fingerprinting (DNA typing, DNA profiling, genetic fingerprinting) is a DNA analysis used to identify an individual. The technique was developed in 1984 by the British geneticist Alec Jeffreys, Each organism has a unique pattern of DNA sequences (minisatellites), the only exception being multiple individuals from a single zygote (e.g. identical twins).

DNA fingerprinting is an important method of genetic analysis in medicine (screening for genetic diseases, prenatal diagnostics, paternity determination and forensic medicine), molecular archaeology (evolution of human populations), veterinary medicine (parentage testing and individual and sex identification), plant breeding and seed industry (identification of cultivars to protect the rights of breeders), wildlife conservation (tracking the migration habits of animals or even identifying whole new species of animals) and other disciplines.

In 2003, a new identification system, DNA barcoding, was developed. Just as the unique pattern of bars in a universal product code (UPC) identifies each consumer product, a "DNA barcode" is a unique pattern of DNA sequence that identifies each living thing. It has the advantage of combining identification with standardisation of the procedure and computerisation. DNA barcoding is a useful tool for identification of (new) species (iBOL, http://ibol.org), for detection of food fraud (food traceability) and for assessing freshwater marine water quality and its impact on marine life etc.

DNA sequencing is increasingly used either in combination with, or as a replacement for non-sequencing techniques like traditional DNA fingerprinting techniques.

DNA sequencing may be used to determine the sequence of individual genes, larger genetic regions or entire genomes. DNA sequencing is indispensable in molecular biology, evolutionary biology, metagenomics and personalised medicine.

DNA screening technologies are becoming affordable and available to everyone through commercial web-

*Refer to Annex for a comprehensive list of current activities sites. The era of consumer genomics is here. Citizens want to and need to actively manage their personal data, genetic data, health and wellbeing data. There could be little, if anything, more private to the individual than the knowledge of his genetic make-up. These technologies can potentially lead to processing of DNA data for unlawful purposes and genetic discrimination. Consequently, there is a concern that governments or private companies (e.g. insurance companies or prospective employers) will have unnecessary access to such genetic data, or to medical predisposition information on individuals to the individual's detriment, or may make the human body and its parts as such a simple source of financial gain.

The main challenges are therefore preserving in particular the fundamental rights of individuals to human dignity, integrity of the person, private life and personal data protection. Genetic information not only affects the individual whose DNA has been analysed, but to everyone who shares that person's blood line.

Future trends (~2030)

On science

Personal genomes will replace more traditional forms of identification. Newborns will be screened for possible genetic diseases and the genome data will be added to the healthcare record as a reference diagnostic point. All genetic information will be available at any time to citizens. Citizens will own and actively manage their genetic and health data. Social networks will be a driver for health change in the future.

Europe needs harmonised genetic information privacy laws that permit justified forms of genetic databases, or of genetic testing, or processing of genetic data only for clearly defined purposes with appropriate safeguards given the unique and sensitive character of DNA data, and forbid those that are judged to or risk to result in violations of fundamental rights laid down in the EU Charter, such as human dignity, unlawful processing of personal data or resulting in genetic discrimination. Individuals all over the EU should always be able to complain to the appropriate authorities and courts and tribunals, if they believe their genetic data have been processed unlawfully or they have been discriminated against because of their genotype.

On the applications

With the advances in sequencing technologies in the last decade, the price for whole genome sequences has dropped significantly, and a further price decrease is expected in the coming years. Therefore, the use of genomic technologies in medicine and other fields is likely to grow. Next generation sequencing (NGS) is now entering the clinical phase of its adoption cycle.

Expected overall impact in/for Europe

DNA technologies have revolutionised the 20st century and mark continual rise today. Rapid advances in next generation sequencing (NGS) technology are driving down the cost of sequencing and bringing large -scale sequencing projects into the reach of individual investigators and consumer genomics to citizens. DNA is becoming another metric of quick identification. DNA technologies help to reconstruct evolutionary history and answer questions concerning human origins, migration, and the effects of adaptation to different environments, as well as susceptibility and resistance to disease.

It seems inevitable that millions of individuals will undergo genome sequencing. The future of sequencing lies in enhancing the clinical utility of genome, whole genome screening for prevention and prediction (newborn screening in specific cases) and treatment, where this is necessary. This will be challenged by large data repositories, data standardisation, data ontologies and integration of data, sharing of data and data security.

Industry especially molecular diagnostic companies are driving the change nevertheless leadership in regulatory arena is super important.

It will be essential to have clear, detailed and EU-harmonised rules governing the scope and application of measures, as well as appropriate safeguards concerning, inter alia, duration, storage, usage, access of third parties, procedures for preserving the integrity and confidentiality of data and procedures for its destruction, thus providing sufficient guarantees against the risk of abuse and arbitrariness.

Synergies and conflicts with other fields

PERSONALISED MEDICINE, BIG DATA – CLOUD COMPUTING, GENETIC ENGINEERING/GENOMICS; *OMICS

Emerging policy issues

Moving research into practice: Clinical utility of personal genomes: prevention and early diagnosis.

Empowered citizen (patient): Citizens will own and actively manage their genetic and health data.

Data and information management: (Reimbursement: One has to calculate the cost of genome through lifetime - then it is not so expensive – it is sufficient to sequence the genome once in a lifetime. and add the data to the healthcare record as a reference diagnostic point.

Ethical, legal and social issues arising: The European Commission's proposals for new data protection legislation include express references to the necessary protection of genetic data, being unique personal data, and requiring specific protection and safeguards on a high level, as evidenced in judgments by the European Court of Human Rights.

New business models for diagnostic and pharmaceutical industry.

High-level generic references

Use of '-omics' technologies in the development of personalised medicine:
http://ec.europa.eu/health/files/latest_news/2013-10_personalised_medicine_en.pdf.

European Best Practice Guidelines for QA, Provision and Use of Genome-based Information and Technologies: http://www.phgen.eu/typo3/index.php.

EU Charter of Fundamental Rights

New EU Data protection proposals: http://ec.europa.eu/justice/newsroom/data-protection/news/120125_en.htm.

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*See Annex

Annex

Directorate General for Health and Consumers and Directorate General for Research and Innovation have jointly prepared a staff working document on the **"Use of '-omics' technologies in the development of personalised medicine",** a renewed vision for the pharmaceutical sector http://ec.europa.eu/health/files/latest_news/2013-10_personalised_medicine_en.pdf.

European Commission, through FP6 and FP7, invested more than 2bn EUR in genomic and post-genomic research and its application for health and biotechnology. European Commission is actively involved in international consortia in large-scale -omics data (the International Knock Out Mouse Consortium www.knockoutmouse.org , the International Human Microbiome Consortium www.human-microbiome.org, the International Cancer Genome Consortium www.icgc.org, the International Human Epigenome Consortium www.ihec-epigenomes.org and the International Rare Diseases Research Consortium www.irdirc.org. European Commission has observer status in the recently launched Genomic Medicine Alliance http://www.genomicmedicinealliance.org coordinated by NIH.

European Alliance for Personalised Medicine (EAPM) http://euapm.eu/who-we-are/ brings together Europe's leading healthcare experts, healthcare organisations and institutions, and patient advocates to improve patient care by accelerating the development, delivery and uptake of personalised healthcare including personalised medicine and diagnostics.

Genomic data privacy triggered the creation of Global Alliance to Enable Responsible Sharing of Genomic and Clinical Data last June at Broad Institute MIT with 90 different organisations from academia to healthcare signing the white paper: https://www.broadinstitute.org/files/news/pdfs/GAWhitePaperJune3.pdf.

In parallel, ''Cornerstones for an ethically and legally informed practice of whole genome sequencing: Code of Conduct and Patient Consent models'' were published by EURAT project from Heidelberg University http://www.uni-heidelberg.de/md/totalsequenzierung/informationen/mk_eurat_position_paper.pdf.

PGP- Personal Genomes Project http://www.personalgenomes.org/ (Harvard Medical School) uses a cohort of fully-consenting individuals with extensive genomic data and then invites a network of researchers to recruit from this cohort for additional phenotyping and molecular profiling, under the condition that they return computable datasets to the research participants. These participants, in turn, may donate their data to the public domain for others to use, thereby reinforcing the virtual circle of sharing. They may also withdraw at any time. The term open consent was introduced. Participants are informed explicitly about the benefits and risks of participating; they accept the risk and upload their data online.

Genomics England http://www.genomicsengland.co.uk/

The U.K. plans to sequence 100,000 National Health Service patients by 2017—in a bold push to be a genomic medicine leader. But the U.K. project stands out for the large number of genomes planned and the integration of the data into a national health-care system that serves more than 60 million people. The initial programme will focus on rare inherited diseases, cancer, and infectious pathogens.

Estonian Genome Chip: every adult inhabitant of Estonia should have a gene chip containing the 700,000 most common markers, which would be used for evaluating disease risk.

Chapter 3.
Food and nutrition

Introduction

Progress in the **agri-food sector** has significantly improved human prosperity, and productivity gains have reduced the burden on our wallets in the last century. Despite that the pendulum tends to swing back from an **agro-industry** to a more 'green' agricultural production, science and technology should not be neglected. **Technological innovation** is still an asset for more, better and safer food.

Food is also a fundamental aspect of **health and personalised diets** may well be a **prevention** means for many chronic conditions and non-communicable diseases. But food is also about improving, with simple measures, access to quality and to quantity of food in developing countries.

Food and nutrition is beyond just science and technology...

Agriculture sciences

Agricultural sciences reflect the diversity of production systems and conditions and build upon a multi-and interdisciplinary curriculum encompassing disciplines from within natural, political and environmental sciences, engineering, socio-economy and humanities. Research has helped to establish a highly productive but also resource intensive sector. In the wake of emerging resource scarcity and effects of climatic variation attention is shifting from mere productivity considerations towards increasing resilience of agriculture vis-a-vis more variable climate and decoupling production increases from resource and energy use. Solutions to these challenges are likely to come from a better understanding of complex agro-ecosystems and the integration of ecological principles into traditional agricultural disciplines. Research into knowledge and innovation systems is seen as crucial to support translation of the proposed solutions into practice.

Yields of major food crops for example have doubled in the last 50 years but the amount of external nitrogen used in the same period increased by seven times and that of phosphorus tripled. Since the green revolution, energy inputs in agriculture increased by 50 times.

Keywords: Multidisciplinary research, ecological principles, systems thinking, knowledge and innovation systems, food security, resilience.

Current status

Agricultural activities are based on the use of natural resources and management of land under a wide range of conditions to produce food and non-food products. In doing so, they shape landscapes, impact on ecological services, deliver public goods and drive development and communities in rural areas. Agricultural sciences reflect this diversity building upon a multi-and interdisciplinary curriculum and encompassing disciplines from within natural, political and environmental sciences, engineering, socio-economy and humanities. Advances in chemistry (e.g. fertilisers, pesticides, herbicides) and engineering (e.g. mechanisation, irrigation) have led in the past to major productivity gains in agriculture and together with significant breeding progress have been at the centre of the so-called "green revolution". However, remarkable yield increases have largely come at the cost of high resource use - and often depletion. Yields of major food crops for example have doubled in the last 50 years but the amount of external nitrogen used in the same period increased by seven times and that of phosphorus tripled. Since the green revolution, energy inputs in agriculture increased by 50 times.

Efforts in agricultural research are increasingly addressing the trade-offs between productivity and the stewardship of resources and seek to enhance the efficiency and precision of agricultural activities. In doing so, they capitalise on new types of collaborations and build on further advances in biology (incl. genomics and other –omics disciplines), computing/ information technologies and – more recently - the emerging discipline of agroecology. The integration of ecological principles into traditional agricultural disciplines is extending our knowledge into the functioning of agro-ecosystems and is seen as crucial to move beyond "incremental" innovations.

Future trends (~2030)

On the science

A number of foresights point at the significant challenges faced by agriculture arising in particular from global demographic, economic and environmental trends. It is argued that the pre-dominant model of small (family) farms in Europe is under particular pressure and research is considered essential for pioneering novel ways of land management in support of adaptation, diversification and overall resilience of the sector. Continued scientific advances in molecular biology, ICT along with a revival of "traditional" disciplines such as physiology and soil sciences are expected to bring about the requested biological, technological and organisational solutions. Contrary to previous innovations focusing on broad applications, future innovations are supposed to be "smart", i.e. capitalising on the specificities of local conditions thus provide tailor-made solutions, potentially helping the farming sector to diversify and fully exploit local competitive advantages. A deeper understanding of agro-ecological principles is altering our views into the functioning of agricultural systems and allowing us to exploit the interplay between organisms and their biotic and abiotic environment to benefit sustainable ways of production.

On the applications

In combination with increasing modelling capacities these insights will help to better monitor and guide the effects of agricultural practices at various scales (e.g. from the field to farm and landscape levels) and also lay the ground for developing resource-efficient agricultural systems closing loops from nutrient and energy flows within and outside farms. Increasing connections between the farming and other economic sectors (such as food and biobased industries) are further strengthening interdisciplinary research in the agricultural domain with input from other sciences. The management of by-products from agriculture and their up-cycling for energy and industrial applications is a good example for this new type of scientific collaborations: While initially driven by developments in second generation technologies, research is increasingly looking at this process from various perspectives taking into account on-farm processes and their effects on soil, climate and other environmental parameters, the needs for plant breeding arising from new demands for plant (by)-products as well as logistics, market development and trade.

Biocontrol, bio-fertilisers or pollination focused crop management are examples for alternatives to chemical inputs giving rise to new products and services often championed by innovative, small businesses. In combination with increasing modelling capacities these insights will help to better monitor and guide the effects of agricultural practices at various scales (e.g. from the field to farm and landscape levels). Increasing connections between the farming and other economic sectors (such as food and biobased industries) are further strengthening interdisciplinary research in the agricultural domain with input from other sciences. The management of by-products from agriculture and their up-cycling for energy and industrial applications is a good example for this new type of scientific collaborations: While initially driven by developments in second generation technologies, research is increasingly looking at this process from various perspectives taking into account on-farm processes and their effects on soil, climate and other environmental parameters, the needs for plant breeding arising from new demands for plant (by)-products as well as logistics, market development and trade.

A major bottleneck for innovation as raised in a Horizon2020 stakeholder consultations is the perceived "distance" between research and practice and /or the difficulties in applying complex research outputs. Accordingly, the management of knowledge exchange between agricultural sciences and the user communities (farmers, breeders, advisory services) is gaining in importance and developing into a dynamic discipline on its own.

Expected overall impact in/for Europe

Agricultural sciences, their outputs and applications are serving basic societal needs and will continue supporting a diverse, complex and knowledge intensive sector.

They will generate knowledge and ready-to-test solutions to benefit production systems which turn the sustainable use and management of natural resources into competitive advantages. Ecological, organisational, social and technological options will help to move towards lower resource use and depletion and will thereby have an immediate impact on:

* food security and food safety;
* the delivery of public goods including contributing to CHG mitigation and carbon sequestration;
* fostering businesses in jobs in the farming sector, the whole food chain, bio-based industries;
* contributing to rural development and a "rural renaissance";

Synergies and conflicts with other fields

Major synergies exist with biological sciences in particular –omics technologies – but also with precision technologies and mechanisation.

Emerging policy issues

Food Security, Climate Protection, Resource Efficiency, Biodiversity, Development and Trade.

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Precision agriculture

Precision Agriculture (PA) is a farming management concept. It aims to optimise returns on inputs, including machinery, labour, chemicals, water and energy, whilst potentially reducing environmental impacts and enhancing food safety. The concept is based upon observing, measuring and responding to inter and intra-field variability in crops, or to aspects of animal husbandry. The technology offers opportunity to stimulate co-innovation, strengthen competitiveness and to contribute to a more climate and eco-smart farming. PA is seen as an important route to 'sustainable intensification'.

Adoption of PA has become possible due to the development of Global Navigation Satellite Systems (GNSS) based applications as a major enabler of precise guidance and mapping. In addition, new *in situ* and remote sensors methodologies assess the spatial variability of farm parameters related to practises such as tillage, seeding, weeding, fertilization, herbicide & pesticide application and harvesting, or are used to optimise the growing of individual animals. The same techniques, technologies, and management strategies used in PA can be applied to create documentation about cultivation practices for proving compliance to environmental and sustainability legislations, climate goals, animal welfare regulations as well as improving food safety by ensuring its seamless incorporation into traceability from farm to fork.

Number of policy incentives and regulations can encourage the uptake of PA in Europe and maximise the sustainability effect that can be achieved with it.

Precision agriculture is a key technology and management concept to achieve sustainable intensification.

Keywords: **Precision agriculture, satellite positioning (GNSS), remote sensing, information technology, farm management, sustainable agriculture, food safety, food traceability.**

Current status

Precision Agriculture (PA) is a farming management practice that measures and responds to inter and intra-field variability in crops or to aspects of livestock husbandry. The main enabler of PA is Global Navigation Satellite Systems (GNSS). GNSS means systems like GPS, Galileo, Glonass in combination with an augmentation system, i.e. a means to increase the accuracy of the positioning.

The latter is achieved by Real Time Kinematics (RTK) for centimetre accuracy and DGPS for sub-meter accuracy. Space Based Augmentation Systems (SBAS) such as EGNOS for Europe is typically offering sub-meter precision without the need of subscription fees or investment in ground infrastructure. Literally all newly sold receivers in Europe are EGNOS enabled. This helps also smaller farms to reap the benefits of PA.

With the advent of Galileo farmers will be able to even better profit from GNSS starting at Early Services expected for early 2015.

The goal is to optimise returns on inputs, including machinery, labour, chemicals, water and energy, whilst reducing environmental impacts and enhancing food safety. Adoption of PA has become possible due to the widespread availability of machine guidance systems with GNSS. Furthermore the development of new *in situ* and remote sensors and methodologies assess the spatial variability of farm parameters related to practices such as tillage, seeding, weeding, fertilization, herbicide & pesticide application and harvesting, or are used to optimise the growth of individual animals. Significant progress has been made with the miniaturization and development of cost-effective accurate GNSS, proximal sensors on board machinery, and new remote sensing approaches based on high-resolution satellites with higher revisit time and low cost unmanned systems (UAVs, RPAS). Controlled Traffic Farming (CTF) and auto-guidance systems are the most successful applications currently used. Variable Rate Application (VRA) methods profitability depends on factors such as crop type, nutrient and water limitations, and upon the size of the farm. Precision livestock farming enables improvements to managing animal growth and health, and within meat, egg and milk production.

The same techniques, technologies, and management strategies used in PA can be applied to improving food safety by ensuring its seamless incorporation into traceability from farm to fork. Since a fundamental principle of PA is the attachment of traceable geographic coordinates to all activities associated with food production, it is a matter of associating those records with any product entering the food chain and the production of biofuels and biomass energy. Signal authentication and reliability that GNSS systems provide can play an important role hereby. Driven by globalisation, food production and distribution systems are becoming more interdependent, integrated and complex. At the same time, escalating and heavily publicized outbreaks of foodborne diseases have raised awareness of the need to ensure food quality and safety, which drives much of the technological innovation to trace food consistently and efficiently from the point of origin to final consumption.

An important growth area of PA is the development of biological and electronic sensors with the ability to detect minute amounts of organic and inorganic compounds emitted in the atmosphere. This mix of compounds is as unique as the human fingerprint. Under conventional agricultural applications, these sensors detect the presence of plant disease or pests. In food safety applications, the sensors can be used to detect naturally occurring toxins commonly known as mycotoxins in grains, fruits, vegetables, and dangerous pathogens that threaten our food supply. More importantly, these sensors can be used to detect the presence of pathogens or other dangerous agents in foods in less disruptive, more efficient and less costly ways than current sampling methods. Adoption rates are variable across the globe with the highest in the United States and the European Union. The Corn Belt is the most intensive user of PA technology in the US with usage in California and the southeast rapidly expanding and driving the development of technology and service start-ups. In the EU, the largest users of PA are the United Kingdom, Denmark, Sweden, and Germany while the Mediterranean MS are lagging in the adoption of PA. Central European countries are currently catching up quickly. The standard market failures due to environmental and resource use externalities render profitability the main driver for PA adoption underscoring the need for appropriate policy responses for incentive development.

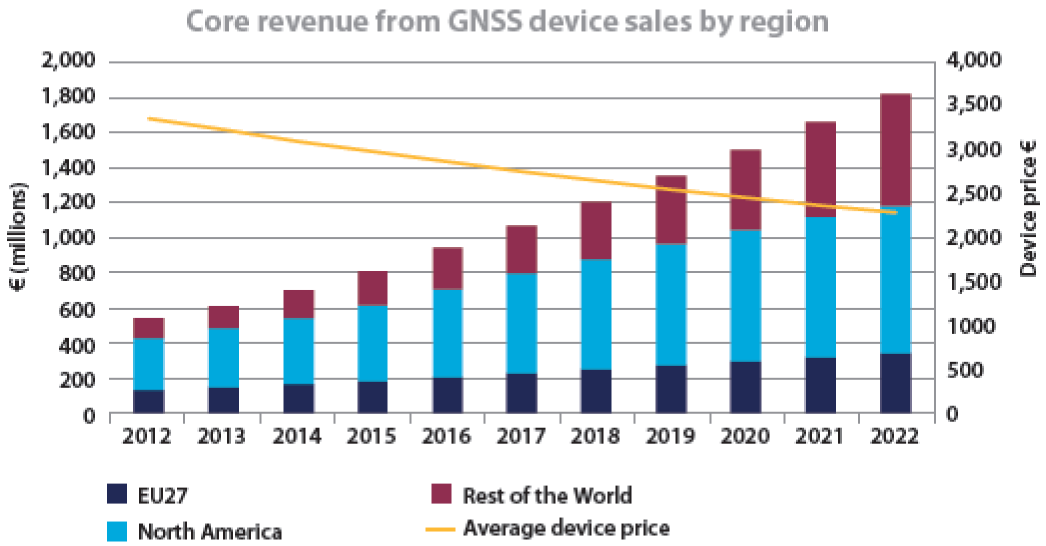
PA's benefits on food safety include:

* Improved hazard identification and risk management;
* Enhancement of supply management and improvement of product quality;
* Improved reliability of product authenticity and customer/consumer information;

Future trends (~2030)

On the science

The GSA Market Report 2013 (http://www.gsa.europa.eu/market/market-report) depicts a consistent growth of Precision agriculture aver all regions of the world:



The report emphasizes for example that:

In Europe, future growth is expected to be increasingly driven by uptake of GNSS technologies in Central and Eastern Europe, currently representing lower GNSS penetration.

Falling prices will be an important driver for the uptake of precision agriculture over the next decade.

New tailor made systems for small-scale farms are needed. Knowledge of the environmental benefits going hand in hand with the economic benefits of PA requires first dissemination of research conducted and second further research where required. Promoting PA benefits to advisory services provided at the Member State level, or linking to possible CAP funding sources needs appropriate implementation assistance.

On the applications

From the technical point of view, progress in miniaturization and development of cost-effective technology will continue, and an innovating industry for machinery and services is already in-place. GNSS and remote sensing data sources will improve through upgrade of EU infrastructures (i.e. Galileo and Copernicus) and resulting services and applications, aligned to continued progress in proximal sensing methods and more powerful (but simpler to use) IT installations. However, the expansion of PA from the early-adopters (large farms, high investment) has obstacles including cultural perception, lack of local technical expertise, (IT)-infrastructure and institutional constraints, knowledge and technical gaps and high start-up costs with a risk of insufficient return on the investment.

Expected overall impact in/for Europe

PA is seen as the important route to 'sustainable intensification'. Indeed, expanding the use of PA technologies to a wider group of regions and typology of farms in Europe may in some areas produce both significant productivity increases and significant reductions to environmental impact and food safety risks due to increased precision of operations and reduction in inputs including pesticides. In addition to its direct benefits for food safety the enhanced traceability and disease and pest detection capabilities will positively impact global market access. Precision livestock farming lead to increased food safety and better animal welfare.

The impact is therefore extended from 'increased profitability' to improved environmental stewardship and food safety, which can potentially feed-back into profitability. The potential value should also consider the wider environmental footprint and food quality improvements beyond the farm, and the calculation of these benefits, including the potential to improve adherence to environmental directives and food safety standards is identified as an important incentive to meeting sustainability goals. Nevertheless, the prevailing market failures due to environmental and resource use externalities would necessitate an appropriate policy response for incentive development.

Synergies and conflicts with other fields

* Synergies with other fields related to PA and the sensors and technologies used in precision agriculture, such as "Space based services / Space technologies, Advanced autonomous systems (autonomous aerial / terrestrial systems);
* Possible synergies with Big Data / Cloud Computing, Collaborative systems, Models and Data in decision-making, and Photonics and light technologies;
* Synergies with sustainable agriculture, food security, food safety;
* Relation to climate change resilience;

Emerging policy issues

Number of future EU policy options and incentive development schemes should be considered to encourage the uptake of PA in Europe and maximize the sustainability benefits that can be achieved with it. PA can help to address the food security objective.

As recommended in the recent JRC report (reference 1) the roles of the Farm Advisory Services (FAS), and the European Innovation Partnership (EIP) on Agricultural Production and Sustainability, already established within the CAP implementation, could be fostered. These instruments allow Member States to share knowledge and expertise and then draw conclusions concerning advice and research needs for wider use within Europe. Several of Pillar II measures are available for MS to support PA development through their Rural Development programmes (e.g. investments in physical assets, cooperation measures).

Data produced in precision agriculture should support the IACS (Integrated Administration and Control System) procedures.

High-level generic references

Joint Research Centre (JRC) of the European Commission; Monitoring Agriculture ResourceS (MARS) Unit H04; Pablo J. Zarco-Tejada, Neil Hubbard and Philippe Loudjani: Precision agriculture: an opportunity for EU farmers – potential support with the CAP 2014-2020.

http://www.europarl.europa.eu/thinktank/en/documents.html?word=&documentType=STUDIES&id=&body=AGRI&dateStart=&dateEnd=&action=submit

The GSA Market Report 2013. http://www.gsa.europa.eu/market/market-report

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Fisheries and aquaculture

Fisheries and aquaculture are a vital source of nutritious food, economic opportunities and jobs. Large volumes of fish are traded in international markets and the European Union is by far the world's biggest importer. Overfishing continues to be a problem worldwide, though in the EU the proportion of fish stocks advised as overfished has fallen from 94% in 2005 to 39% in 2013. In 2013, the EU adopted the objective of the maximum sustainable yield for the management of its fisheries.

Global aquaculture has grown at an impressive rate over the past decades and could provide two-thirds of world fish production by 2030. An increase in world human population from 7 billion towards 9 billion by 2050, and the emergence of a middle class will significantly increase demand for fish. Given the limited potential for further growth in world capture fisheries production, future demand will mainly rely on a substantial increase in aquaculture production.

Keywords: Fisheries, aquaculture.

Current status

Fish already represents 16.6% of all animal protein consumed globally and 6.5% of all protein for human consumption[1]. Large volumes of fish are traded in international markets, as 38% of all fish produced in the world is exported. The EU imports 60% of its aquatic products. The European Union is by far the world's biggest importer of fish, seafood and aquaculture products. More than 80,000 people are already directly employed in European aquaculture. Through its recently reformed fisheries policy, the EU will support the sector's growth, create more job opportunities, and make sure that all farmed fish produced in Europe continues to be high quality, healthy, and sustainable seafood.

Like all human activities, fisheries and aquaculture have to be managed sustainably. Overfishing continues to be critical worldwide. The EU has adopted the objective of maximum sustainable yield for the management of its fisheries. The number of stocks overfished in the EU has fallen from 94% in 2005 to 39% in 2013. However, in the Mediterranean and Black seas only few stocks are assessed and 88% of these were overfished in 2013. European aquaculture is subject to strict environmental and animal health rules and follows very high standards of safety and sustainability.

Future trends (~2030)

On the science

The theory of managing capture fisheries according to maximum sustainable yield is well developed and has been successfully implemented in many single-species fisheries. However, management taking account of fishery interactions (the way different fishing gears catch different mixtures of fish at certain place and times) and ecological interactions (the way different fish stocks predate on each other or compete for food) is still just beginning. To solve these problems a substantial increase in data collection intensity will be needed, and it is not clear how far such expenses can be met worldwide, although the EU is committed to these tasks.

[1]See Fish to 2030. Prospects for Fisheries and Aquaculture by the World Bank in collaboration with FAO, IFPRI, and AES, 2014.

Fish production may well change due to global climate change, with different amounts of different species being produced. Warming oceans may result in distributional changes, with fish moving polewards or into deeper waters to stay in their preferred temperature zones. Substantial changes in the dominant species are possible in the world's most productive marine ecosystems. In addition, ocean acidification is likely to change the composition of the plankton, with effects on the fish populations that cannot yet be predicted.

Overall, there are efficiency gains and production gains to be expected from improved fisheries management and by redressing the overfishing of the recent past. Better handling practices can also mean that improved financial and consumer benefits can be achieved. However, the current scientific consensus is that global fish production is somewhere near its peak and that increases in production due to better management will be moderate and progressive rather than game-changing.

Inland freshwater fisheries production is around 32 million tonnes and is especially important in the great tropical river systems (e.g. Mekong, Amazon, Congo) and African lakes. This production is important for local food security but probably has little scope for expansion as the productivity of these areas is close to fully exploited.

In aquaculture, the main challenges are space, feed, and the development of breeding technology. More space for marine aquaculture is being freed up by the development of extensive, offshore production systems that can use remote and exposed locations. Progress in feed technology will mean that marine fish could be produced more efficiently and with a higher proportion of feed of plant origin than at present. Improvement of breeding technology (the production of young fish from captive broodstock) will make new species available for sustainable aquaculture that is not dependent on wild-caught young individuals. Using these developments, there is a much greater scope for expansion in aquaculture than in capture fisheries.

Recent technical developments of large-scale fish farms show that widespread automation and control techniques can be used to increase production with low manpower inputs. Such technology is not yet widespread.

On the applications

The world contribution of fish to food is also likely to increase with the growing world population from 7 billion towards 9 billion by 2050 and especially with the rapid growth of middle class consumers in China which is projected to account for 38% of global consumption of food fish by 2030. Aquaculture could provide two-thirds of world fish production by 2030. Further substantial expansion of this production is possible, and even essential if world supplies of fish products are to keep pace with human population growth. China and other countries are increasing their investments in aquaculture to help meet this growing demand.

Global production of fish from marine capture fisheries should level out around current levels of 85 million tonnes and would contribute substantially to food security. However, if international governance systems fail, there is a high risk that stocks will be depleted and production will fall. This would seriously threaten the world's food security.

In the European Union, the new fisheries management framework should redress the overfishing that led to many stocks being depleted up to 2000, so that yields increase and stabilise, and costs and environmental impacts fall. The contribution of fish to food is likely to increase as consumers become more conscious about the nutritional value of seafood and as aquaculture provides more high-quality, sustainable seafood. Increased production and stronger economic performance of the sector will also have an important impact in terms of jobs and growth, in particular in coastal and rural areas.

Global freshwater aquaculture production is currently around 37 million tonnes annually and is growing at a rate of around 7% per year. Marine aquaculture production is around 18 million tonnes, of which around 14 million tonnes shellfish and 4 million tonnes finfish. Marine finfish farming has a high potential for expansion. Increased efficiency in feed conversion – e.g. through better husbandry practices, selective breeding, etc. – and substitution of fish-based feed with products from land-based agriculture will also help deliver growth in this sector.

Marine shellfish farming, which in the EU represents half of total aquaculture production in volume, requires limited inputs and provides important environmental services by removing nutrients from the water. This type of farming is particularly sensitive to water quality and coming research is expected to focus on selective breeding of the most resistant shellfish families.

Expected overall impact in/for Europe

As there is only limited potential for further growth in world capture fisheries production, yet there will be a substantial increase both in the number of consumers and their desire to eat fish world food security will largely have to rely on a substantial increase in aquaculture production. The EU's high dependency on imports to meet its fish needs could be a risk factor if global supply does not keep up with demand.

The new EU Common Fisheries Policy recognises that the impact of fishing on the fragile marine environment is not fully understood and adopts a cautious approach which takes into account the impact of human activity on all components of the ecosystem. Together with policy initiatives, such as the Blue Growth, is expected to help improve the EU's food security and bring much-needed jobs to coastal and rural areas, while safeguarding the integrity of ecosystems.

Sustained production from international capture fisheries relies on the cooperation of neighbouring countries to fish sustainably. If food security becomes problematic, there could be a risk of states placing short-term food security before long-term sustainability, with very poor long-term outcomes.

The EU's dependence on imported fish (as for many other foodstuffs) makes it particularly reliant on the persistence of unrestricted, globalised international trade in food.

Inter-relations with other fields

Expected synergies

The development of offshore wind farms and/or tidal energy harvesting systems could create areas suitable for siting aquaculture installations, so allowing increase productivity.

Integrated multi-trophic aquaculture, e.g. the integrated farming of algae or shellfish and finfish could be further developed to ensure the optimal use of available space.

Biofuels from cultivated algae could be developed in integrated multi-trophic aquaculture.

The integration of activities such as angling and tourism in extensive aquaculture ponds could add environmental and landscape management services.

Possible conflicting aspects

Both finfish and shellfish farming need appropriate sites and can be in competition for space with other coastal economic activities. Shipping, tourism and recreational activities are often seen as antagonistic to aquaculture, while some farming practices are also detrimental.

Marine finfish in aquaculture presently need substantial marine protein inputs as part of their diet. Until this issue can be overcome, the eventual extent of possible growth of this sector may be limited and the use of marine protein either for direct consumption, or for indirect consumption either in situ or in aquaculture will need to be considered.

Possible adverse environment impacts of aquaculture include localised eutrophication events, changes in benthic communities, contamination from antibiotics and introduction of non-indigenous species.

Emerging policy issues

Increasing need for food security of the EU and the growing world population.

The development of genetically-modified marine organisms tailored for high aquaculture productivity may offer benefits but also faces large challenges for marine environmental protection and for consumer acceptance.

Food safety in relation to the quality standards of aquaculture products imported into the EU on a level-playing field with locally-produced aquatic products.

Generating and capturing synergies between aquaculture and the off-shore industry while addressing environmental concerns.

Biofuel-oriented aquaculture.

Maritime spatial planning is expected to help reducing such competition and promote synergies among activities.

The development of equipment that is more resistant to waves, currents and other environmental factors could allow moving further offshore.

High-level generic references

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Innovative food

Innovative smart food products and processes will be developed that will better respond to consumer preferences, health issues and environmental concerns. Policy bodies, industry and the public should be prepared to foster this transition that will open new job opportunities and bring benefit to society.

Innovative food products are already on the market and more will come. Is the regulation ready to face this challenge?

Keywords: Innovative food, alternative food sources, safety, regulation, new processes.

Current status

Innovative foods and ingredients can boost innovation in the Food Industry by (a) generating new molecular structures, (b) resulting from non-traditional processing technologies, (c) introducing food from plants/animals using traditional practices but without a history of safe food use (e.g. baobab), (d) utilizing novel sources, and (e) being the result of modern biotechnology.

Over recent decades, much research on innovative food production strategies (farm to fork approach), food products and processing has been carried out with a view to increase food safety, increasing shelf-life, reducing waste, finding new nutrient sources, optimising process efficiency, improving the functionality and convenience of use of foods, and improving the nutritional and sensorial properties of food responding to the demands of different consumer niches and markets, also in terms of affordability.

Future trends (~2030)

On the science

Innovative foods often required new processing and formulation technologies (non-thermal sterilization, encapsulation, green extraction and processing). New products and processes will be developed and put in the market, such as 3-D printing, digitalisation in food science (not only for traceability but also for consumer-oriented tools such as scanning devices that could identify calories, ingredients and allergens in seconds), alternative nutrient sources, urban farming, innovative food processing, packaging and storing techniques, nano-technology in food, packaging and sensors, development of new and improved packaging materials on the basis of renewable resources, reuse of food waste.

On the applications

There are several products in the pipeline some of them really innovative that could have beneficial impact on consumers particularly for healthy aging, weight management, food for special medical purposes. The outcome of ongoing research can be applied in novel or optimized food products and processes (sustainable food production, street food, personalised diets, functional foods, convenience foods, food design) and innovative marketing models and supply chains (short, local, regional, personalised).

Expected overall impact in/for Europe

Society

Food science addresses societal challenges such as how to provide safe food to consumers that is corresponding to the changes in life-style and changes in society such as demographic changes, (urbanisation, ageing population, household size…). Food innovation may impact public health. The actual impact will be subject to the level to which innovations address societal needs, the way they are communicated to the public and consumer acceptance. A significant potential is expected for the whole food sector in the aging society. The challenge is consumers' awareness of real food qualities in a very diversified market. If the anticipated potential benefits can penetrate society at large or will be limited to a restricted population will depend on accessibility, acceptance and perceived/real added value of the proposed solutions.

The economy

Design of innovative foods is a main innovation driver in EU food industry which is by far the world leader and the second EU industry by turn over. The market potential of innovative foods, mostly to complement rather than to replace existing food, is largely linked to the purchasing power (the growing global middle class may be balanced out by increasing inequalities within countries) and perceived added value by potential customers. In addition, this sector may improve competitiveness as well as opportunities for growth, diversification and job creation for the EU food sector in general and SMEs in particular. Innovations may contribute to improved health having additional benefits at the macro level (i.e. improved productivity, reduced costs on healthcare, etc.).

Environment and climate

Innovative foods often originate from transition country. Issues of fair trade and local sustainability should be considered. Innovative foods may reduce pressures on the environment and on land use (food, feed, biomass nexus), e.g. novel sources of protein replacing traditional animal sources.

Safety and security

In the search of alternative sources of food (e.g. protein), safety aspects will of course play a major role in food science. Food science contributes to increased food safety and quality, to improved traceability and to reducing fraud. Development of new products, technologies and processes could contribute to ensure food security.

Synergies and conflicts with other fields

'Sustainable Consumption and Production'; agricultural science; fisheries/aquaculture; genetic engineering/genomics; behavioural science; 3-D printing.

Emerging policy issues

Is the EC innovative food regulation too conservative and does it hamper innovation in the food industry?

Communication to the public about novel techniques and processes must improve with regard to consumer acceptance.

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Chapter 4
Environment and energy

Introduction

Climate change has revealed that our economies and life styles have stretched the limits of nature to a tipping point. The bulk part of our energy come still from **fossil fuels** but new technologies, like **artificial photosynthesis**, can reduce our **carbon emissions**. Despite that air and water quality or biodiversity can be degraded or improved due to technology, science and technological progress is also part of the solution. Like for health issues, **waste management** is also a matter of individual behaviour. A greener and even a more **circular economy** are on the verge of changing significantly our quality of life.

Energy and environment are sectors that have been opposed but need **reconciliation**.

Recycling

In a context of increasing global awareness over the adverse environmental effects of improper handling of waste, European waste management is becoming increasingly complex due to growing waste generation and number of waste streams needing tailored management routes. It is thus challenging to improve the efficiency of the use of natural resources (e.g. "turn waste into resources" in a circular economy approach) and, ultimately, improve the environmental sustainability of current waste management strategies. Science-based evidence is nonetheless available showing that, from a life cycle perspective, significant environmental benefits can be achieved through higher rates of reuse, recycling and energy recovery. This is reflected also in several EC Directives. However, to identify cost-efficient and environmentally sound recycling options and set up waste-type specific targets for optimal recycling rates, adapting life-cycle based methodologies and applying them in a consistent way across high priority waste stream is required. Equally, it will be required to take into account also the social and economic aspects of waste management in a systematic manner.

Keywords: Waste management, recycling, reuse, recovery, resources, environmental sustainability, life cycle assessment.

Current status

Several pieces of European legislation exist, which are relevant in this context, e.g.: Waste Framework Directive (2008/98/EC), Packaging and Packaging waste directive (94/62/EC), Thematic Strategy on the prevention and recycling of waste (COM(2005)666), Roadmap to a resource efficient Europe (COM(2011)571), Communication on future steps in biowaste management (COM(2010)235) or Directive 2012/19/EU on waste electrical and electronic equipment.

In particular, the Waste Framework Directive (2008/98/EC) in article 4(1) establishes the waste hierarchy, i.e. the legally binding order for European waste management, which prioritises prevention, reuse and recycling of waste, while landfilling is regarded as the least desirable options. Article 4(2) opens to deviations from the waste hierarchy if it can be shown by LCT that these deviations lead to a lower overall environmental impact of waste management.

Several targets for recycling of e.g. construction and demolition (C&D) waste, packaging waste, etc. are defined by current EU legislations; however, these are sometimes ambiguous or not coherently defined.

Lack of high-quality life cycle data and of robust sets of quantitative life cycle indicators, makes it difficult to define coherent / science-based targets for prevention and recycling of waste.

Future trends (~2030)

On the science

Development of a widely recognised life cycle based methodology to evaluate the environmental and social performance of waste management systems and strategies, and in particular able to identify and assess options for prevention and recycling of waste, taking into account economic aspects. This methodology should be applicable to any waste type (as well as to e.g. the overall municipal solid waste), and should be flexible in term of its technological, geographical and temporal representativeness.

Development of comprehensive and quality assured life cycle database including resource and energy consumption as well as emissions into air, water and soil for different waste management options (both at EU level and Member States level) to be used to conduct systematic sustainability assessments of waste management and recycling options, covering all three sustainability pillars.

Development of robust sets of quantitative life cycle indicators which can be used to define sound targets for prevention and recycling of waste, towards an increased sustainability of European waste management and, in particular, increased resource efficiency.

Development of a method and underlying data to gain better understanding of the environmental, social and economic impacts of waste exports outside the EU, especially into non-OECD countries.

Closer cooperation between research community and industry to minimise losses of valuable resources in different pre-processing and recovery steps.

Improved and economically viable technologies for separation and re-use of complex hybrid waste streams, for secondary mining of land-based or marine litter, for re-use of agricultural, animal and human-based wastes in agriculture, energy production or bio-industries.

On the applications

Prioritisation of waste streams based on the assessment of the potential environmental and social impacts arising from their management, in order to identify opportunities for improvements of their performance in different waste management scenarios/contexts taking into account economic aspects such as job creation potential.

Definition of coherent, LCT-based targets for prevention, reuse and recycling of waste, especially with respect to food waste, C&D waste, mining waste, e-waste, and all separately collected waste streams (paper, plastic, glass, metals, etc.), especially if relevant from a "scarcity" perspective, if containing critical raw materials and/or if embedding hazardous/toxic components.

Complete ban of landfilling of biodegradable waste fractions and recycling of these fractions into highly efficient plants for biological treatment (e.g. composting and anaerobic digestion) or energy recovery, so that biomass and/or the embodied energy are fed back to the supply chain.

Minimisation of landfilling of all recyclable fractions, especially those with scarce materials embedded (e.g. some metals).

Definition of waste streams that require specific attention when foreseen to be exported outside of the EU, especially into non-OECD countries, due to their environmental, social and economic impacts. Definition of waste streams that should be restricted (e.g. setting minimum criteria for environmental, social and economic conditions of reuse or recycling) or banned from exports into certain countries or regions.

Substantial reduction of food waste both through technological advances and social innovation, which will also contribute to food security and reduce conflict on land use for food, feed, fibre and eco-system services.

Expected overall impact in/for Europe

Society

Reduced exposure to pollutants and hazardous substances arising from waste management; more simple / intuitive and efficient waste separation and collection at households; reduced occupation of land from waste management activities/plants (e.g. waste incinerators, landfills). Higher acceptance for waste management facilities on local level due to serious and trustworthy efforts to not waste the resources of future generations.

The economy

Biomasses, critical raw materials, and other valuable resources are fed-back to the economy leading to increased resource productivity and cost savings possibly enhancing the competitiveness of European industries; new business and employment opportunities in the recycling / waste management sector. Increased resource productivity.

Environment and climate

Reduced emissions of greenhouse gases and other harmful emissions to the atmosphere from waste management activities; reduced emissions to surface water and groundwater arising from waste management activities (e.g. leaching of contaminated leachate from landfills).

Safety and security

Reduced hazard/nuisance to citizens arising from sub-optimal waste management; improved safety conditions for workers within the waste management sector; increased recycling will decrease Europe's dependence on imported raw materials.

Synergies and conflict with other fields

A main synergy is that with the fiche on "Sustainable Consumption and Production", in that an efficient recycling of waste has the potential for feeding back to the society/economy valuable resources such as biomasses, metals, plastics, and a wide range of critical/scarce raw material, thus minimising the need to extract/exploit virgin resources and/or reducing import dependency from third countries.

Emerging policy issues

A main potential policy issue is that conflicting/inconsistent target for recycling of waste streams are defined in different pieces of legislation. An additional risk is that of defining unclear/confusing target, e.g. due to an inconsistent definition of the boundary of the waste system considered, and/or imprecise/overlapping definition of certain waste streams (e.g. biowaste, biodegradable waste, organic waste, food waste). These potential issues can be avoided by clear definition of the different waste types, different management/treatment options, as well as by developing a widely recognised quantitative methodology for the definition of sound targets for waste recycling.

High-level generic references

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Postcarbon society

To prevent the most severe impacts of climate change, the international community has agreed that global warming should be kept below 2ºC compared to the temperature in pre-industrial times. This means a profound change for the world economy, biodiversity and oceans. EU leaders have committed to transforming Europe into a highly energy-efficient, low carbon economy and society.

Key figure or a highlight: To lead the world to the post-carbon era, the EU has committed to cutting its emissions to 20% below 1990 levels by 2020 in view of reaching 80-95% emissions reductions in 2050. The European Commission proposes a mid-term target of 40% emissions reductions by 2030.

Keywords: Post-carbon society, low-carbon economy, low-carbon energy, carbon sinks.

Current status

The EU is well on track to meet the 2020 targets for greenhouse gas emissions reduction and renewable energy and significant improvements have been made in the intensity of energy use. Since 2009, the EU managed to decouple growth from energy consumption. These achievements are all the more significant given that the European economy has grown by around 45% in real terms since 1990 sustaining the employment of more than 4.2 million people in various eco-industries.

Over the last decade, renewable energy technologies have matured and costs have fallen substantially. Offshore renewable energy technologies are taking off and advanced biofuels and bio-based products from sustainably sourced biomass[1] are showing good progress. Many energy using products are now more efficient and consumers and industry are starting to benefit from real energy and financial savings. There has been further development of novel technologies and systems which still need to be proven on commercial scale.

Recently, the Commission has proposed to set a greenhouse gas emission reduction target for domestic EU emissions of 40% in 2030 relative to emissions in 1990. The 2030 framework for climate and energy recognises new technological opportunities that will deliver economic and environmental benefits and will trigger innovation on a global scale. All policy actions ensure that the EU is on the cost-effective track, set out in the Commission's Low Carbon Roadmap, towards meeting the 2050 objective of an 80-95% emissions cut across sectors, with sectors such as power sector, industry, the built environment to provide the strongest contribution to decarbonisation.

Beyond energy the post-carbon society also relies on the “greening” of industrial production from fossil-based towards biological resources within the bio economy.

But new technologies alone are not sufficient. The preservation of terrestrial and marine biodiversity is key for healthy carbon sinks. Healthy oceans are of ultimate importance for climate regulation.

[1] Agricultural co-products, forest residues, waste streams, algae, etc.

A lot more is necessary if we are to have answers to the issues of security of energy supply, availability of natural resources and the environment. Political initiatives, economic incentives and social behaviour should make a difference. Worldwide agreements to reduce greenhouse gas emissions, market mechanisms to push for the implementation of clean technologies and local action to change the way of producing and consuming are needed. Ocean acidification, another a major effect of the increased CO_2 levels also needs to be urgently addressed.

Future trends (~2030)

The International Energy Agency informs that the safety threshold of +2° will be overpassed by 2030 in some world regions if no decisive action is taken. Ocean acidification could reach unacceptable for marine ecosystems and habitats levels.

The European Union, the world forerunner in green energy and environmental protection, is in a process of profound energy transformation: the growing share of renewable and decentralised generation, the progressive increase in energy efficiency along the whole energy value chain, the emergence of the consumer as an active player in the energy system and the appearance of new network users are the main changes affecting the way in which energy producers, operators, regulators and consumers interact in an increasingly complex market. The EU also has a great potential in offshore energy in particular offshore wind, tidal and wind energy. The European Bioeconomy strategy is catalysing the move towards a post-carbon economy through the replacement of fossil-based energy and industrial products and has the potential to transform and green large industrial sectors, such as chemistry, while at the same time contributing to a more circular economy.

Innovation is needed to make this transformation possible: to further reduce primary energy demand, diversify and consolidate sustainable supply options (both external and indigenous) compatible with Member States energy mix choices and divergent needs for biomass, and to develop flexible and integrated energy network infrastructures. Technological progress should be accompanied by innovative business models and schemes that guarantee a fair reward of the services ensuring the adequate functioning of the system.

Future smart cities could lead by example in developing and implementing transformation strategies towards a sustainable development including social, economic and ecologic dimension with ambitious greenhouse gas emission reductions of up to 80%. They integrate all infrastructures – buildings, energy and transport networks, green infrastructures, and through spatial and energy planning and management can ensure precious synergies. They embrace active participation of various stakeholders and citizens and search new ways of governance as a prerequisite for these fundamental changes.

Expected overall impact in/for Europe

Science, technology and innovation play a central role in providing solutions and turning the risks of climate change and natural disasters into opportunities for business and the citizens. Reducing costs, enhancing efficiency and searching better ways to solve problems can be attractive to businesses, the public sector and individual citizens, leading to new investment patterns and diverse ownership structures.

Large investments across sectors will be needed to realise the transition towards the post-carbon society in Europe. It will be necessary to encourage consumers to take up innovative products and services and to consider appropriate financial instruments to ensure that all energy consumers benefit from the resulting changes.

Technological innovation for the post-carbon society can stimulate a gradual structural change in the economy. In terms of employment, the post-carbon society will create opportunities in fields of basic engineering, basic manufacturing, bio-based industries, transport equipment, construction and business services. New network industries can emerge in view of the increased importance of ICT in the energy sector. At global level, increased importance of technology transfer due to global climate action can contribute to the realisation of new international markets for low carbon technologies and systems and climate-resilient solutions.

The post carbon society is expected to be more ageing, urban and near-city-dwelling. Living conditions may be impacted by advancing climate change and the increasing risk of natural disasters, depending also on adaptation and risk prevention policies and scarcity of resources. The education-level required to be competitive will increase and diversify as regions begin to specialise in active, cultural, or health and green leisure. There will be significantly more jobs in new and innovative technologies such as renewable energy and in the bioeconomy.

Synergies and conflicts with other fields

The realisation of a post-carbon society is expected to lead also to additional environmental benefits such as decreased air and water pollution. The market uptake of climate friendly technologies will contribute to shape a new pattern of urbanisation and land use, with significant impact on energy and transport provisions, both at local and regional level.

The post-carbon society would benefit from increasing energy independence, economic profits and environmental well-being. Reaching the 2030 proposed targets is estimated to decrease energy import volumes by at least 10% compared to 2010 level. This leads to increased energy security and stability.

Emerging policy issues

There is a need to address risks, acceptability, governance and consequences associated with innovative technologies and infrastructures to be deployed in post-carbon societies at European as well as at global scale. For instance, the issue of trust in data protection could have a major impact in the realisation of the post-carbon society.

Increasingly decentralised energy production processes will necessitate multi-level coordination and management of systems, from individual installations through local community/neighbourhood and up to the regional, country and EU-level.

More in general, there will also need to increase systemic governance of technology innovation, combining technologies in a systemic approach to exploit opportunities across sectors.

High-level generic references

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Science for energy transition

Keywords: Science, energy, transition.

Current status

The EU is defining a new set of energy policies that will shape the evolution of energy systems and markets towards 2030 and 2050, potentially transforming society in many ways. The 2030 Framework for Climate and Energy policies foresees a new European Governance Framework for integrating the plans, interests and concerns of all public and private actors. This will require the assessment and reconciliation of economic, financial, social, political/geopolitical, environmental/climate and technical/technological factors, not the least for managing a portfolio of investments that is expected to exceed 1T Euro. The science for supporting that Governance Framework and the Energy Transition in general is multi- and inter-disciplinary by nature, and the conjunction of disciplines required is still in its infancy. This has been discussed for instance in the book Infranomics[2].

Future trends (~2030)

In science, engineering, technology

Smart grids/smart cities, internet-of-things with smart houses, electric vehicles, integration of low-carbon technologies and distributed generation (including DC, storage, etc), energy efficiency as service, systems-of-systems and global systems sciences, multi-disciplinary integration of economics, social/political sciences with natural and engineering disciplines.

For innovation/applications aspects (and possible fading out of other areas)

New energy retail/wholesale markets, new services and social process (eg integration of energy, social networks and markets), emergence of new social roles (Prosumer), new financial products related to energy investment (from micro to macro level), new governance processes for energy/environmental decisions (micro to macro)

Expected overall impact on

Society

Energy as central societal topic in a democratic society, issues of adoption/adaptation by citizens, dealing with concerns with excluded/vulnerable social segments, basic energy rights.

[2] Infranomics. Sustainability, Engineering Design and Governance. Gheorghe, Adrian V., Masera, Marcelo, Katina, P.F. (Eds.). Springer (2014). http://www.springer.com/engineering/civil+engineering/book/978-3-319-02492-9

The economy

Full development of the internal energy market, integration of ETS/carbon costs/externalities, need for new financial processes and mechanisms, development of extensive opportunities for innovation in technologies and processes.

Governance and policy issues

Emergence of the low carbon society with new role for citizens in the decision making process, integration of geopolitics within and extra-EU, impact on global positioning of EU.

Environment and climate

All-inclusive consideration of the impact of energy.

Safety and security

Integration of risk and resilience in relation to social and environmental issues and the management of critical infrastructure.

Reuse of CO_2

Keywords: CO2 storage, circular economy.

Current status

For ages, CO2 has never been considered an issue worth dedicating significant scientific attention to. This has changed with the growing certainty about man-made climate change and the role of CO_2 as a greenhouse gas: CO2 emissions need to be avoided or CO_2 needs to be stored 'eternally' (Carbon Capture and Storage – CCS, see separate fiche).

However, CO2 can also be used as a raw material in industrial processes, notably by using the carbon component (C) through chemical or biological reactions. Research and first pilot installations have started on a number of different technology paths (polymerisation, mineralisation, bio-engineering, etc.)

Future trends (~2030)

In science, engineering, technology

Variety of technologies and applications at different stages of maturity; cost reduction largely depends on new catalysts, bio-agents, etc. to reduce energy use; important field for bio-tech.

For innovation/applications aspects (and possible fading out of other areas)

Establishment of new branch of circular economy (comparable to water and waste); widespread capturing of CO_2 at small, medium and large-scale installations; replacement of hydrocarbons for some basic commodities.

Expected overall impact in/for Europe

Society

Boost for 'circular economy' habits; increased acceptance of CCS (as necessary intermediate step).

The economy

New innovative industry; EU global frontrunner because of economic incentive through carbon price; reduced import dependence on hydrocarbons; large parts of bio-economy to integrate CO2 re-use.

Governance and policy issues

Need to enlarge climate policy toolkit (today either CO2 not emitted or 'eternally' stored) to cover carbon cycles – implications for emissions trading, taxes, etc.; labelling based of life cycle assessment.

Environment and climate
Potentially important contribution to reach climate target of max. +2°C (in particular if solutions can be implemented globally).

Safety and security
Increased energy and raw materials security, standard safety requirements for industrial installations apply.

Carbon dioxide capture and storage technologies

Keywords: Science, engineering, technology and innovation trends.

Current status

Carbon capture and geological storage (CCS) is a technique for trapping carbon dioxide as it is emitted from large point sources, compressing it, and transporting it to a suitable storage site where it is injected into the ground. The technology of CCS has significant potential as a mitigation technique for climate change, both within Europe and internationally, particularly in those countries with large reserves of fossil fuels and a fast-increasing energy demand. Given the dominant role that fossil fuels continue to play in primary energy consumption, there is an urgent need to deployment CCS in Europe and beyond.

The individual component technologies required for capture, transport and storage are generally well-understood and, in some cases, technologically mature. However, the largest challenge in terms of engineering and technology for CCS deployment is the integration of the individual component technologies into large-scale demonstration projects of the full CCS chain.

Despite considerable efforts to take the lead on CCS developments in Europe, of the 12 CCS large-scale demonstration projects currently operating in the world[3], none of them are situated in Europe and even the most promising EU demonstration projects are stopped or are facing delays. Bringing costs down and securing a business case in Europe remains still a challenge. As recalled by the Commission in the Communication on the 2030 policy framework on climate and energy, increased R&D efforts and commercial demonstration of CCS at European level are essential over the next decade so that CCS in Europe can be deployed by 2030.

Future trends (~2030)

Efforts to reduce costs and improve technology over the long term are a priority; R&D efforts across CCS chain, in particular for capture technologies, higher efficiency power generation cycles and industrial processes are important to accelerate the long term deployment of CCS technologies. In power generation, for example, the capture element accounts for more than 90% of the cost of the entire CCS chain. In the next 10 years, it would be particularly important to obtain improvements and cost reductions of capture technology, including novel approaches and techniques to alleviate the high energy penalty associated to CCS. Novel approaches and techniques in the use of solvents, membrane and sorbents must be further developed to improve the efficiency of CO2 capture and reduce costs.

As additional future trends, it must be highlighted that CCS has a potential role to play when applied in conjunction with the production of transport fuels, particularly for the production of alternative fuels like hydrogen from fossil sources. CCS can also be used to capture biogenic carbon from the use of biomass

[3]GCCSI, The Global Status of CCS: 2013, Global Carbon Capture and Storage Institute
http://www.globalccsinstitute.com/publications/global-status-ccs-2013

(Bio-CCS). Bio-CCS application can range from capturing CO2 from biomass co-firing and biomass-fired power plants to biofuel production processes, giving raise to the so called "negative-emissions technologies". The technical feasibility of biomass-CCS value chain has still to be demonstrated on a large scale and as future trend it can be expected that this might well be developed and demonstrated in the run to 2030. Overall, synergies with technologies of CO2 reutilization (waste carbonation, algae, CO2 use in chemical processes, production of renewable fuels) will need to be considered as complementary means to CCS to reduce GHG emissions in the future.

Expected overall impact in/for Europe

Society

Issues of public perception and acceptance linked to CO2 storage and CCS must be addressed. Lack of understanding and acceptance of the technology by the public and some stakeholders also contribute to delays and difficulties in deployment.

The economy

Financial viability of CCS demonstration projects is an issue at EU level. CCS can offer opportunities to innovate fossil fuel based industries; furthermore, the deployment of CCS in industrial processes may also help to increase public understanding and acceptance of the technology given the very visible link between jobs in local communities and continued industrial production.

Governance and policy issues

Implications for Emissions Trading, CO2 taxes, "carbon leakage".

Environment and climate

The role of CCS in cost efficient climate mitigation has been confirmed by the Roadmap for moving to a low Carbon Economy by 2050, as well as the Energy Roadmap 2050. The Roadmap for moving to a low Carbon Economy by 2050 shows also that a delay in the deployment of CCS would result in a significant increase of the amount of investment needed to reach the required emission reductions, in line with the conclusion of similar assessments conducted at global level (e.g. IEA). According to the assessments of the two Roadmaps, CCS starts to contribute on a broader scale to reducing CO2 emissions from power generation and industrial processes in the EU after 2030.

Safety and security

Activities to accelerate confidence building on the permanent containment of CO2 and safety of the CO2 storage sites are needed.

Additional content for the Fiche will have to be added after the workshops.

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Hydrogen society

The Vision: a future in which millions of individual players can collect, produce and store locally generated renewable energy in homes, offices, factories, and vehicles, and share their power generation with each other across a Europe-wide intelligent hydrogen energy web.

Keywords: Hydrogen, fuel cells, low-carbon energy system, energy storage, energy security, renewables, Hydrogen-Energy-Web (HEW).

Current status

Enhanced EU energy security, mitigation of climate change, and globally affordable energy are facilitated by transitioning to an integrated, decentralised energy system that links multiple primary energy sources to serve multiple end-use applications in transport, industry, and commercial-residential sectors. This can only be achieved by a targeted combination of an increasing share of renewable energy sources in the generation mix, smarter grids, demand-side management and an increased role for energy storage and intermediate energy carriers.

Hydrogen and fuel cells definitely have a role to play in this as indicated in the 2003 Vision Report of the EU High Level Group on Hydrogen and Fuel Cell Technologies. Whereas a full-fledged Hydrogen Society is only expected on a time horizon beyond 2030, some elements already take shape now and will become increasingly evident in the years to come. Indeed, hydrogen production, storage, distribution and conversion technologies have now reached technology readiness levels that allow their deployment in a number of applications. For example renewables, hydrogen based storage and fuel cells are already used to provide power for remote, island and off-grid communities. In the transport sector, breaking the dependency on fossil fuels remains a critical issue not only for Europe, but for the whole globe, and major OEMs are currently starting worldwide commercialization of fuel cell vehicles. The current technology status of hydrogen and fuel cells is described in the Multi-Annual Work Plan of the recently approved second phase of the European Fuel Cells and Hydrogen Joint Undertaking (www.fch-ju.eu).

A Hydrogen Energy Web (HEW) as described in the above Summary card would definitely contribute to all elements included in the Conclusions of the March 2014 European Council on the 2030 Climate and Energy Package that envisages rendering Europe more sustainable, cleaner and more energy efficient(http://www.consilium.europa.eu/uedocs/cms_Data/docs/pressdata/en/ec/141749.pdf)

Future trends (~2030)

On the science

Research, development and demonstration is and will remain important to reduce costs and improve technology performance in terms of higher overall efficiency and reduced global, regional and local environmental impact of hydrogen and fuel cell technologies. Progress will have been made in hydrogen production from renewables, including from sunlight and from biomass, and in cost-effective integration of locally and centrally generated renewable hydrogen in smarter grids with storage at different locations in the overall energy chain. Durability requirements for fuel cells will have been met for stationary and transport applications. Holistic research to enable synergetic coupling between power, transport and heat grids, covering technology and social behavioural sciences, will be increasingly needed.

On the applications

Delivery of energy products will be replaced by delivery of energy services, breaking the current geographical and temporal links between power generation and consumption. Distributed electricity production will increase its share in the generation mix. Next to electricity, hydrogen will become a major energy carrier in an increasingly integrated power-transport-heat system, with dedicated large-scale infrastructures for the production, storage and distribution of renewable hydrogen for subsequent conversion in stationary and transport applications using highly-efficient, zero-emission fuel cells, or use as chemical feedstock. Closer linking of power and gas infrastructure, facilitated by the use of hydrogen as a storage medium, will increase resilience of the overall low-carbon energy system and reduce needs for capital-intensive power grid refurbishments. ICT will serve as enabler to increase and ensure efficiency and security of the overall energy system. It will also allow peer-to-peer energy buying and selling by new actors under new business and regulatory models for the distributed, yet synergistically integrated energy networks of the HEW. The resulting enhanced decarbonisation and electrification of society will lead to a concomitant confinement of fossil fuel use to niche applications.

Expected overall impact in/for Europe

General

Similar to the coincidence of coal and steam and industrial print (which triggered the industrial age) and that of centralized power generation and electric communication (2nd industrial revolution), the HEW facilitated by hydrogen technologies and internet (referred to as the 3rd industrial revolution) will have profound impact on economy, society and governance

The HEW facilitates increased penetration of renewables, higher energy security and reduction of pollutants. In addition to the impacts associated to these (e.g. improved health conditions, mitigation of climate change effects…), deployment of the HEW results in specific impacts listed below. Relevant affected policy areas are energy, transport, climate change, industrial policy, research and innovation, education, environment, trade.

Society

Citizens, communities, companies, governments increasingly become users of services rather than owners/consumers of goods and resources that are used for providing these services (e.g. mobility). This leads to an increased role, expectations and liability of providers of these services (impact on economy, social, governance).

Society will see a transition from an individual/company-centered to a member-of-a-community model, with shared caring responsibilities and systemic consciousness.

The multiplicity of actors involved in the HEW leads to more equitable wealth distribution, standard of living and social cohesion ("energy democracy")

Economy

A focused EU-level effort on low-carbon energy system solutions, including renewables and hydrogen technologies, supported by the second phase of FCH-JU, as well as targeted domestic investments in cutting-edge technologies and manufacturing will spur European ingenuity, accelerate breakthroughs, create jobs and increase EU competitiveness in the global low-carbon energy economy.

Coordination of efficient and cost-effective provision of energy services rather than self-standing production or transmission and distribution becomes the economic incentive.

New "shared" ownership and business models will emerge, based on novel financing means and instruments that value public goods and interests

At the global level, the HEW can allow developing countries to leap-frog to a more sustainable, secure and self-sufficient energy system by avoiding the disadvantages of and the costs for establishing a centralized energy infrastructure

Safety and security

Enhanced in-built resilience and lower dependence on imports of a distributed, yet integrated, energy system enabled by the HEW, reduce sensitivity to external disturbances compared to nowadays' centralized energy system, which leads to longer term economic and financial stability.

Enhanced share of renewables in the energy mix and distributed geographical coverage of energy producing/consuming communities alleviate energy import dependence and reduce the hegemony of few countries with fossil resources.

Increased interdependence of energy and informatics networks may cause system level vulnerability from external interferences as well as data protection issues.

Governance

Management of distributed energy networks to provide the needed energy services necessitates collaborative rather than hierarchical command and control.

The ability of individuals and communities to buy and sell energy ("prosumers", "distributed energy capitalism") reduces the role of centralized energy providers which gives rise to (i) new social patterns with associated new responsibilities and liabilities for actors; (ii) need for the adequate involvement of new and different from current actors/owners/beneficiaries in policy and in decision-making.

Synergies and conflicts with other fields

Synergies exist with the following fields identified in the set of "fiches":

Science fields	Application fields
Biofuels	Behavioural science
Carbon dioxide re-use	Future [smart] cities
Science for the energy transition	Future Mobility
	Post-carbon society
	Sustainable consumption and production

Emerging policy issues

A policy framework needs to be put in place that accounts for the higher-level policy goals of energy security, climate change and competitiveness, and that considers the geographical specificities in terms of energy resources and of needs for energy services of the EU Member States. Such a framework should target the following objectives:

* Increase awareness of the potential and of the advantages (from individual to society, from local to global) offered by the HEW.
* Lift barriers for tapping the potential of the HEW:
    * Prevent obstruction by vested interests:

- ⇒ Ensure a level playing field for all competing technologies by including societal costs in the life-cycle costs from exploration to final end use, correcting thereby the market failure.
- ⇒ Create access to novel financing means and instruments that value public goods and interests (energy security, sustainability, resource efficiency, health..).

♦ Support techno-innovation:

- ⇒ Continue support for technology improvement and cost reduction, in particular for large-scale H2 production from intermittent renewable sources, H2 storage, fuel cells.
- ⇒ Support peri-normative research to accumulate the science-base needed for establishing enabling performance-based harmonized standards and regulations (preferably global).

♦ Provide an enabling framework for deploying the necessary infrastructure (e.g. COM(2013)18: proposed directive on Alternative Fuels Infrastructure, decisive for increased uptake of fuel cell electric vehicles). In particular, ways to reward first movers on infrastructure and to coordinate progress across Europe need to be found.

* Establish appropriate educational and professional curricula (electrochemistry in particular).

* Support emergence of new business models enabling large-scale roll-out of fuel cell and hydrogen technologies within the overall power-transport-heat energy system.

* Agree internationally on the needs and drivers for, and on common support measures that contribute to the establishment of a global HEW.

High-level generic references

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Chapter 5
Society and wellbeing

Introduction

Future societal divide will be more than rich-poor; the **uneven access to the digital world** will widen the gap between those who have access to knowledge and those who don't.

Human-human interactions will remain important but are challenged by the increasing acceptability of **online interactions** as a substitute for **real-life interactions**. Citizens' perceptions of what 'community' means are about to be changed.

The **ageing population** (in Europe) will be a driver for new products and services, across various sectors such as healthcare and living environments. Urbanisation will increase citizens' desires for **healthy environments**.

Citizens should not be seen as part of the problem but as part of the **solution**...

Social sciences and humanities

Innovation in the service sector (75% of the EU economy) and social innovation are largely dependent from findings in Social Sciences and Humanities (SSH).

SSH also allow understanding the changing multicultural, multi-ethnic and multi-religious European societies faced by issues like inequalities, including gender inequalities, and ageing of population.

SSH as such and SSH integrated in interdisciplinary research (e.g. on health, climate change and food) play a key role in long-term EU growth and quality of life.

50% of tertiary graduate students in Europe are coming from social sciences and humanities.

Keywords: Social sciences, economics and business, law, humanities, psychology, scientific support to policies.

Current status

According to the OECD Frascati Manual, Social Sciences and Humanities (SSH) cover economics and business, educational sciences, psychology, sociology, law, political science, social and economic geography, media and communications, history and archaeology, languages and literature, philosophy, arts, ethics and religion.

At European-level, multi/pluri/inter/trans-disciplinary research is often promoted in order to tackle the various dimensions dealing with *knowing* (data, statistics, indicators), *explaining* (tools, definitions, methods), *understanding* (context, causes, mechanisms), *forward looking* (modelling, foresight, scenarios) and *recommending* (from knowledge to policy).

SSH is also often integrated (or "embedded") to other grand challenges like health, food, energy, transport, environment or security in order to provide evidences on the economic feasibility of emerging technologies, on social acceptability and behavioural aspects, on governance and institutional issues.

In the seventh European Framework Programme (FP7), SSH mostly covered research on economy, finance and growth, statistics and indicators, intangible assets, social cohesion and equality, social innovation, employment, ageing and migration, justice and human rights, foresight, socio-ecological transition, international dimension of EU research, citizenship, identity and cultural heritage. SSH research provided scientific support to policies and recommendations for the Europe 2020 strategy pursuing smart, sustainable and inclusive growth.

Future trends (~2030)

In science, engineering, technology

The Specific Programme of Horizon 2020 expects to fund Research and Innovation on:

* Mechanisms to promote smart, sustainable and inclusive growth;

* Building resilient, inclusive and creative societies taking into account migration, integration and demographic change;
* Europe's role as a global actor (cf. human rights and global justice; mutual influence between world regions);
* Promotion of sustainable and inclusive environments through innovative spatial urban planning and design
* Exploring new forms of innovation including social innovation and creativity;
* Promoting coherent and effective cooperation with third countries;
* Studying European heritage, memory, identity, integration and cultural interaction (cf. history, literature, art, philosophy and religions).

Looking at trends until 2030, with the blurring between industrial and services sectors, with the increasing individual empowerment associated to the development of social networks, the aspects related to personal and collective behaviour will probably get more and more importance.

Expected overall impact in/for Europe

Society

Building and supporting a more resilient, innovative and creative European society; EU demographic changes (enabling, educating and training the young generation and including the ageing population); EU social participations, inclusion and cohesion (equity in education through ICT tools; access for the disabled; etc.).

Economy

New solutions to lay the foundations for a sustainable job-rich recovery and transformation of the economy itself (overcoming the crisis). Increased impact on public sector innovation, social innovation and new business models creating opportunities for growth and creative industries. Providing new knowledge on business models innovation covering different areas of the economy (social entrepreneurship; donation-funded for-profit activities; new sharing models).

Governance and policy issues

The future of the EU and European integration, understanding the global trends affecting the EU's economy and governance (cf. migration, promotion of human rights, global responsibilities); research, education and public service financing and organisational models.

Environment and climate

New sustainable lifestyles for a more efficient use of natural resources; supporting the socio-ecological transition, the green economy and smart urban futures.

Safety and security

Provide knowledge and contribution for building a more inclusive, cohesive and therefore secure society.

Synergies and conflicts with other fields

Under Horizon 2020, Social Sciences and Humanities (SSH) are given an enhanced role as a cross-cutting issue. Horizon 2020 calls are aimed at solving complex societal problems and should therefore fund contributions from SSH disciplines that can tackle these problems. Contributions from SSH may appear alongside other disciplines.

Emerging policy issues

Although representing 50% of the tertiary education students and more than 30% of researchers, SSH research funds are at risk in several Member States.

The EU Horizon 2020 expects to integrate SSH in different parts (e.g. in Health, in Energy, in the European Research Council) but there is not anymore an SSH programme as such like in the previous Framework Programmes.

In these times where the human/technology interface becomes more and more important, a certain Renaissance spirit should ensure multi/pluri/inter/trans-disciplinarity.

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Social innovation

In addition to technological, product, process, organizational and marketing innovations, social innovation answers to pressing social demands that require the combination of actions coming from the market, the public sector and the civil society. Social innovation delivers results that are positive for economic and social cohesion (cf. new social problems, vulnerable groups, gender discriminations), create new social relationships and foster collaborative economy. Social innovation addresses societal and environmental challenges while improving collective well-being.

Social innovations are particularly relevant in times of crises and budgetary constraints.

Keywords: Non-technological innovation, inclusion, sustainability, collaborative economy, third sector.

Current status

Social innovation plays a crucial role in both in the European Union and at Member States level. It is also a central element of the Europe 2020 strategy and the Innovation Union Flagship, as well as in the context of the Social Investment Package and European Social, Structural and Investment Funds. The EU Research Framework Programmes are supporting R&I actions that are both innovative and socially relevant tackling innovation in the broadest sense and including services, social and public sector innovation. Across Europe the number of grassroots non-profit and social entrepreneurship organisations that undertake social innovation is increasing. Social innovation responds to the need of social cohesion and it involves private, public and third sector.

Future trends (~2030)

Research and Innovation in Horizon 2020 may:

- Address societal challenges and experiment alternative ways of scaling up social innovation;
- Develop the conceptual tools of social innovation research to overcome health inequalities and re-evaluate the social determinants of health;
- Explore the contribution of social innovation in urban and rural areas addressing the challenges of employment, intergenerational equity, economic development and sustainability;
- Explore the potential of the financial and banking sector for supporting and fostering social innovation and greater well-being;
- Develop research on the role of private companies, their responsibility towards the citizens and their contribution in social innovation (cf. Corporate Social Responsibility; Social Entrepreneurship);
- Promote the mindsets of openness and sharing that underlie most social innovation, e.g. through the promotion of collaborative creation models (cf. Open Source, Open Educational Resources, etc.);
- Address social innovation in relation to immigration and cultural diversity;

Expected overall impact in/for Europe

Society
Gradual take-up and implementation of social innovations in other geographic and thematic areas (e.g. via European social or structural funds, or via national or local funding); engagement and citizens participation and opening of new employment areas and opportunities.

The economy
Social innovation seeks a balanced combination of economic growth and social well-being, at both production and consumption-levels including new products and/or services. It can contribute to the expansion of social enterprises and to the definition of indicators beyond the traditional economic performance measurement. It can be the basis of sustainable growth and societal long-term investments (youth work, education, etc.); particularly through social entrepreneurship.

Governance and policy issues
Social Innovation requires a special policy attention to the third sector (NGOs, non-profit organisations, cooperatives and charities). It inspires institutional changes, changes in social policy and delivery of public and social services; policy frameworks (e.g. procurement rules) need to allow for social innovation possibilities.

Environment and climate
Social innovation contributes to sustainable development through the integration of social, economic and environmental progress. It can also enhance social resilience in the face of climate change and disaster risk.

Safety and security
Social innovation by nature tackles the issue of personal safety and addresses equity and ethics.

Synergies and conflicts with other fields

Social innovation complements and enlarges the product and process innovations, the marketing and organisational innovations. But social innovation specifically relates to the development of new forms of organisation and interactions to respond to social issues. It aims at addressing social demands that are traditionally not addressed by the market or existing institutions and are directed towards vulnerable groups in society. It deals with societal challenges in which the boundary between 'social' and 'economic' blurs, and which are directed towards society as a whole. Finally social innovation tackles the issues of empowerment and learning as sources and outcomes of well-being.

Emerging policy issues

The conditions under which social innovations flourish and lead to societal change are not yet fully understood.

Among future research fields that have to be addressed, one can mention social innovation to overcome the inequalities of health and re-pattern the social determinants of health; social innovation in rural areas and societies; social innovation in the financial sector and the private sector; and social innovation for managing diversity.

Social Innovation is a key part of the Horizon 2020, the European framework programme for R&I. It is at the cross-border of the Stability and Growth Pact, the Renewed Sustainable Development Strategy, the Renewed Social Agenda and the Digital Agenda.

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Behavioral sciences

People make mental shortcuts in order to make complex choices. These shortcuts help in many situations where fast reaction is needed. But when time is available to decide, a profounder thinking process is needed, which requires effort. The Human Behaviour can be studied and influenced. It is studied in Behavioural Science and it can be predicted in order to set conditions and choices so that desirable behaviour occurs; e.g. in relation to health, climate, energy and other policies. Behavioural Science is helping us to understand why and how we behave the way we do.

Organ Donation Behaviour: Depending on whether the choice is "opt-out" or "opt-in" the rate of organ donors can vary from 10% in one country to 90% in another country.

Keywords: Behavioural science, Nudging, Intuition, Behavioural Economics, Thinking Fast, Thinking Slow.

Current status

Behavioural science studies how people make choices in their day-to-day life. It relies on the insights and methods of behavioural economics, behavioural and social psychology and cognitive science.

It takes an empirical rather than deductive approach and relies on field experiments, simulations and even brain scans. These controlled experiments – similar to the Randomised Controlled Trials (RCTs) used in Biology or Medicine – can be easily replicated and can also be used in policymaking.

The subject received high popularity in 2002, when Daniel Kahneman – who in 2011 published his best-selling book "Thinking fast and slow" - received the Nobel Prize in Economic Sciences, for "having integrated insights from psychological research into economic science, especially concerning human judgment and decision-making under uncertainty". Another best-selling book, Nudge (Thaler and Sunstein, 2008) further increased the influence of this subject among policy circles. Sunstein went on to become the Chief Regulator under Obama, and Thaler helped set up the Behavioural Insights Team (BIT) at the UK Cabinet Office, where the latest projects are organ donation and charity giving.

The 'nudge' tool offers Governments new ideas on how they can steer people to do the right thing – to be healthy, to pay taxes on time and to save energy – without a heavy burden on the taxpayer.

The potential of Behavioural Science for governance and policy implementation has already been recognized in some EU countries. In 2010, the UK government created a dedicated unit (the afore-mentioned BIT) using behavioural science principles to improve policy implementation. Its success led to its privatization in February '14, was partly privatized with a mission to advice governments around the world. In 2013, the US Federal Government created its own behavioural insights team. The EC has been applying behavioural science into policymaking since 2008. It was firstly applied in Consumer and Competition policy. While DG SANCO and the JRC are leading, other DGs (MARKT, CNECT, COMP, JUST, ENER) launched behavioural studies since.

Future trends (~2030)

On the science

Some new avenues of research are enabled by technology, such as new forms of very large-scale double blind experiments on internet users. Eye-tracking methods and magnetic resonance imaging are already being used, and new tools may come forward. New interdisciplinary fields are developing – e.g., social neuroscience and neuroeconomics – and their findings may allow cross-fertilisation.

On a more aggregated level, insights from rigorous research in behavioural sciences might open the door to more sophisticated modelling of the complex dynamics of socio-economic systems, allowing for better forecast of impact of different policy options.

On the applications

In terms of the applicability of behavioural science, there is practically no limit. So long as a policy area has a 'behavioural element', meaning that human behaviour is relevant, insights from behavioural science will apply. A behavioural element might exist because the policy aims to change behaviour, or because the behavioural response to a policy will determine its very success. Concrete application examples are improvements in personal health-affecting behaviours, the design of motivating environments, tools and tasks for work and education or the design of buildings and public spaces with various intentions in mind, whether motivation to shop, easy escape or prevention of unwanted behaviour.

Expected overall impact in/for Europe

The application of behavioural insights to policy could become a very important innovation in the provision of public services in Europe, and the overall impact could be substantial. Businesses already use behavioural insights for marketing purposes, for analysing customer behaviour and increasing sales and company turnover. Its application in policy-making is relatively newer, and here is where the big opportunities lie. With clever thinking and minimal expenses, the effectiveness and efficiency of policies could be significantly improved.

The expected benefits to Europe are difficult to quantify – any attempt would be speculative at this point. However, the UK BIT did make some estimates from a trial they conducted on tax letters. In order to nudge people towards paying their taxes on time, they changed the wording on tax letters sent out to people. Instead of a menacing letter warning of the potential consequences of not paying on time (the traditional way), they sent a letter explaining that most people in Britain paid their taxes on time. This trial boosted repayment rates by up to 15% in the first 6 weeks. It was estimated that this would have advanced £160 million of tax debts in over the six-week period of the trial, generating £30 million of extra revenue annually by freeing up resources allocated to collecting debt and improving cash flow. The cost of the intervention was practically zero.

This is just one example of what the impact of a behavioural intervention in one policy area could be. But since behavioural science can be potentially applied to any given policy area, the aggregated impact would be larger. For example: Health is amongst the possible fields of application for behavioural science. Behavioural insights can influence health awareness and implementation of health policy, e.g. promotion of healthy food, prevention of tobacco use, reduction of obesity, etc.

In the field of energy, behavioural science could contribute to the understanding of how to make the shifts towards more sustainable energy and transport systems: a) at individual level, from energy as a good to energy as a service, b) at community and city level, towards an integrated sustainable planning of energy, buildings and transport systems and c) in energy markets, to equilibrate the demand/supply side.

In the field of environment protection and climate change, citizens can be nudged to act with an environmental and energy-related conscious behaviour.

In education, behavioural science could, among others, identify causes and suggest remedies for early school leaving, contribute to more effective pedagogies and teacher training and might aid policy attempts to motivate low-skilled and older citizens to take up learning offers.

With such a wide range of policy areas where it could be applied, and given the low cost of implementation of behaviourally-inspired interventions, behavioural sciences does seem to have the potential of offering great bang-for-the-buck as a complement, not a substitute, of existing policy initiatives.

Synergies and conflicts with other fields

Cultural differences in citizen behaviour – which behavioural insights can be generalized to other populations and which remain culture-specific? The EC's first 12 studies rarely found a country effect.

When can we rely on insights obtained through laboratory experiments to inform policy-making, and when do we need to complement these with field trials?

Can we run Randomized Controlled Trials in collaboration with EU Member States (emulating the approach of the UK Behavioural Insights Team)?

Where is the borderline between "nudging" and manipulation of citizens' behaviour?

Emerging policy issues

For Behavioural Science the "emerging policy issues", are different from other areas. In the case of behavioural science / studies / economics, we are talking about the application of greater insights about human behaviour on policy issues. All policy issues could potentially have a behavioural element to them. The question to ask is whether people's behaviour is in any way relevant to the success of a policy. If yes, then that policy issue can be said to have a behavioural element. Behavioural science can help shed light on that behaviour, and indeed some "nudging" might be called for. However, and as it is documented in the JRC report, just because nudging is a policy option does it mean that it is the right policy option. It is true that nudging can be a low cost option. In some cases it can lead to great success, and in others less so. The political truth is that it is often a preferred option because the alternative would be politically not acceptable. In any case, one needs to be critical about when it is OK to apply to behavioural insights, and when not. Or, as an article in a newspaper said: "sometimes we don't need a nudge, we need a shove".

Another "emerging policy issue" worth pointing out is the fact that so much of citizens' activity takes place on-line, including commercial transactions, dealing with government, etc. While there is clear-cut regulation, in Europe, about how off line commercial transactions take place (including regulation on labelling, advertising, etc.), this is less clear in the on-line world. So perhaps, since this is on the rise, there is a need for greater behavioural insights into on-line behaviour and how it should be regulated. Also, we need to keep in mind that there is no longer a clear boundary between on-line and off-line behaviour, as we are on-line all the time, even while driving our cars for example. So there is a ripe area for research there.

Another issue could be to counter the insight knowledge that was already exploited, e.g. privacy, in the case of Internet companies that slowly nudge consumers to reveal more information. It could become an important field for consumer protection. There is a potential for Behavioural Science to contribute to "marketing and advertisement" regulation and to "addiction" prevention.

Last, but not least, there are ethical issues regarding research, where Behavioural Science could contribute to political guidance.

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Media and Culture

Europe's vibrant cultural life, its rich and diverse heritage and its sustained capacity for creativity in a changing world are assets to be protected, nurtured and promoted. Culture and creativity are vital to the formation of values, identity and citizenship; they contribute to citizens' well-being, engagement and social inclusion, and they are important drivers of economic growth, jobs and external trade.

The digital shift is having a profound and sometimes disruptive effect on creative ecosystems. New types of intermediaries between creators and consumers have emerged in the value chain. Co-creation of knowledge and culture through online social networks is a "game-changing" social innovation that empowers citizens and has the potential to address societal challenges. Users become ever more expert in creating their own user-generated content, as new cohorts of young people become adept at shaping and exploiting cultural and creative content through social media. Social media is poised to become the biggest component of mainstream media, in many cases at the expense of editorial media. Consumers' appetite for new cultural formats and media – and their capacity to be active actors in this transformation - will depend on their ability to embrace the opportunities brought about by technology.

A key trend is that as of 2013, 100 hours of video content are uploaded to YouTube every minute, and more than 1 million creators from over 30 countries, globally, earn money from their YouTube videos. More than 4,000 "partners" use Content ID to monetise the use (and re-use) of their material on YouTube, including major US network broadcasters, film studios, and record labels.

Keywords: Culture, media, technology, creativity, societal challenges.

Current status

Creation

Thanks to media convergence, creation occurs increasingly on a cross-sectoral basis; for instance, visual arts are increasingly based on digital-only techniques; in contrast, the value of "live experiences" increases (concerts, museums, sports…). The rise of amateur creation resulting in "prosumer" status and user-generated content continues – in fact, "free" & paid stock footage and music sites are helping this phenomenon. The development of co-creation and user generated content (UGC) is a new trend that will develop further.

Production

Some industrial production costs are undoubtedly going down, and producers try to adapt to the new realities, but they are also likely to be caught between the artists trying to access audiences directly and powerful internet intermediaries. Projects are beginning to be driven by crowd-funding and by consumers. As concerns journalism, the rise of data journalism is accompanied by a decline in the number of professional journalists and newspapers.

Distribution

Digitalisation affects distribution on a large scale, but the actual extent varies depending on sectors and countries, levels of copyright protection and enforcement. The rise of internet intermediaries competing with traditional intermediaries is a huge factor; at the same time there are uncertain coexistence modalities between new and more traditional media, i.e. between terrestrial and online radio. In general, the most important trend is the rise of content consumption based on access rather than ownership.

Access

Thanks to broadband coverage, consumers expect to have ubiquitous access to all sort of content: cloud computing and streaming models provide full and all-time access to content, within the constraints of a still fragmented market. New phenomena are the rise of customer curation of content and the pervasiveness of personalized recommendations thanks to personal data processing – which rises privacy and security issues.

Future trends (~2030)

Creation

With falling software costs, amateur creation will reach near-professional levels; there will be widespread creation of cultural and artistic objects in the form of .obj files. There will be more cultural content available online, most of it available through free access. Use of crowd-funding will become more widespread.

In the audio-visual field there will a "competitive" coexistence between different technologies and modalities (3D vs UHDTV). All creative industries will be impacted: for instance, the fashion industry will be changed by the availability of cheap technological fabric.

The art scene may reach a new frontier with the advent of body art via bio-electronic implants. In addition to personalized suggestions of cultural content, artworks themselves are becoming personalized thanks to a wider range of data being collected, including emotional data such as current mood. Social media are having a long-term impact on the news chain production. However, much creation will be ephemeral as websites or their replacements will come and go – archives will have to make difficult curation and preservation choices as not all work can be kept.

Production

Due to falling production costs, the producers' job will become to pick up, among the constant flow of available amateur creation, those people who have the potential to become professional artists, to initiate -funding campaigns and to manage worldwide licensing agreements. It is also possible that the huge quantity of data from distribution –coupled with the increased capability to process it - will reduce the risks attached to audio-visual productions, while financing through advertising will become more precisely targeted. In the news business, the role of "citizen reporters" will grow, and they will be probably ranked according to their credibility and accuracy.

Distribution

There will be full media convergence, with TV channels turning into professionally-curated video websites and apps. Radio too will become more interactive, and movie theatres will change into attraction venues. Live shows are likely to include augmented reality, just like museums will offer the virtual "feel" of art works and will continue their transformation from "temples to the arts and sciences" into forums of social interaction and knowledge exchange. There will be a generalization of the phenomenon of consumption based on access rather than ownership; this will be accompanied by the shrinkage of traditional editorial media and their embedding in bigger social media streams, characterised by more UGC.

Access

3D printing will usher in a new stage of mass customization of products, and new display techniques will allow a near-ubiquitous streaming of visual artworks and certainly of advertising images. Personalization may also result in the use of content and advertising filters. In any case there will be a multiplication of wearable devices giving access to cultural content. All this underscores the importance of new forms of media literacy; at the same time, it might be expected that technology for helping people with disabilities will improve.

Expected overall impact in/ for Europe

Society

Overall, the impact on society will be broadly positive, with some caveats. Creativity will be more diffuse within society. Individuals will have more opportunities for personal development and there is a potential for improving social inclusion – but also for new forms of exclusion to take hold. Artists should in the main benefit from the changes and the possibilities of reaching potentially huge audiences, provided that new business models that ensure their remuneration can emerge.

The Economy

Europe should continue being the leader for the production of culture and creative content. The pre-condition is to promote innovation fostering entrepreneurship. The impact on consumers could be mixed: more choice, more access, more personalisation, and the possibility of driving production – but there are some risks highlighted in the next section.

Governance and policy issues

The risks concern above all data protection issues, due to the need for a new "arbitrage" between privacy and personalization. Powerful global digital intermediaries are already imposing cultural standards (see for example Apple, Facebook or Google censorship on European content) – which may result in the homogenisation of content or the relegation of quality content to specialised niches.

The increased role of amateur creation may co-exist uneasily with professional creation. The empowering of creativity across the population could come at the expenses of professional creation ecosystems.

There will certainly be remuneration issues, due to the dissolution of territorial markets, and the considerable amount of amateur creation that will be made available also through an extensive re-use of copyrighted work in UGC mash-ups – rising issues of copyright protection and enforcement.

The impact of social networks on media plurality is hard to gauge at this stage, but might be potentially disruptive. The impact on the functioning of democracy is also hard to assess: the result could be a further push towards "liquid democracy," where fissures in society and voter apathy co-exist uneasily with– or are mitigated by, in the optimistic scenario - "always-on" technologies".

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Future education and learning

Education bears ever-increasing importance as an enabler of economic, societal and political participation and is a core vehicle by which society's values are passed to the next generation. Yet education too has to adapt to a changing world – not just the knowledge and skills taught, but also materials, tools and pedagogies need to step into the digital era. Never before have the potentials for equity, access and quality of education been greater – and not since the 19th century has education gone through such a severe transformation.

In the 12 months to June 2014 the number of Massive Open Online Courses (MOOCs) increased by 327%. Of those the 2625 MOOCs 597 were European.[1]

Keywords: Education, personalisation, digital, non-formal, data, analytics, learning.

Current status

A large variety of processes will crucially impact or be impacted by education and learning (e.g. demographic change, globalisation) and should not be overlooked; however due to its scope this note will focus primarily on technological and scientific developments.

New pedagogies, technologies and insights have only slowly impacted education, although naturally in some countries and educational sectors more than in others. 19th and 20th century models of teaching and learning, in particular the frontal lecture, still dominate large parts of modern education systems, but societal life and skills needs, labour market demands and student expectations regarding content and pedagogies have changed drastically. The gap to 'real life' – the world outside formal education – is often too wide as large parts of education and learning still occur with suboptimal methods and with materials that are only of limited relevance to learners' lives. Most actors, in particular the educators on the ground, see a need for change and a multitude of initiatives attempts to close at least part of the 'reality gap'. In parallel an increasing shift from 'education' to 'learning' in informal or non-formal settings has become visible. This is reflected in the labour market – particularly in recruitment practices – but also in universities' foci and citizens' increasing awareness of learning needs.

While the 'reality gap' and the mental shift from 'education' to 'learning' have become apparent, knowledge, skills and values have become more important than ever before. Low-skilled jobs are diminishing and individuals increasingly require high-level and specialised qualifications and skills, including in particular digital competences. Such learning needs and interests drive the emergence of new forms of learning providers, the branching-out of current providers into new fields (e.g. provision of Massive Open Online Courses (MOOCs) by traditional universities) and nudge individuals to become self-guided learners that choose from a wealth of learning opportunities, but also face an overwhelming amount of choices.

[1] OpenEducationEuropa.eu MOOC Scoreboard

Future trends (~2030)

In the science/technologies

Progress in learning technologies, pedagogies and research on the neuroscience and the science of learning is rapid and wide-ranging. Among others we can expect learner-controlled and immersive learning environments (e.g. virtual reality [[LINK: Human/Computer Interaction]]), gamification (educational tools that use game elements to increase motivation and information retention) while personalised learning (learning analytics/metrics [[LINK: Big Data, Data Mining/Semantic Web]]) will collect and use data during students' learning process to dynamically assess progress and adjust material, difficulty, pace and means.

These developments will be particularly aided by the proliferation of free-to-use resources and tools, and the general appearance of more flexible, networked and learner-centric ICT-based education and learning tools and pedagogies [[LINK: Collaborative systems]]. Technology can thus enable dynamic, personalised and learner-driven learning paths, increased access for disadvantaged groups (those with disabilities, learning difficulties, etc.) as well as increased efficacy. These methods are increasingly prevalent both in- and outside of formal education and promise increased learner independence, engagement and motivation.

All these processes are augmented and sped up as educational policy shifts from a current focus of "time spent" (such as in higher education, where credits are given are mostly given according to estimated workload) to the actual assessment of learning outcomes (the acquired knowledge, understanding and skills).

On the applications

As digital technologies speed up societal and economic change processes, lifelong learning necessarily becomes a norm required of all individuals. The emphasis for policy makers and individuals shifts from "education" towards "learning"; non-formal and more or less informal learning gain in importance. Thus while individuals need more and better skills and competences – which ensures the continued importance of formal education – education systems and institutions need to adapt to a gradual loss of their monopoly on knowledge (re)production and provision. Furthermore, less formal learning opportunities (such as work-based and project-based learning) are encroaching on the provision of formal education and blur the separation between initial (formal) and continuous (non-formal/informal) education. A more continuous “blended” learning path might appear, with each individual combining formal and non-formal elements of learning throughout their lifetime. Simultaneously the physical location of learners and educators becomes less important, leading to more competition among education providers. Education systems and institutions will require higher flexibility and adaptability, so that innovations in pedagogies, tools and learning content can constantly be developed, tested and, if successful, find rapid large-scale uptake.

Learners in formal as well as non-formal learning increasingly have the opportunity to determine their own learning goals and means. For the foreseeable future teachers and face-to-face instruction will remain the most important element of formal education and learning, but the increased opportunities and choice will not just lead to better results, they also lead to more confusion and increased guidance needs. Thus while interactive and personalised learning tools ensure that learners require less direct interaction with teachers, teaching professionals will increasingly adopt the roles of guides that aid learners in choosing fitting learning goals and resources, deliver feedback, provide advice, support practical learning and intervene when difficulties arise; data-driven feedback will allow for earlier and more effective intervention and guidance.

On a broader scale, learners are becoming part of a globally connected learning system where the boundaries between educational sectors and roles (e.g. learner/teacher/resource producer) are blurred. Due to an increasing number and variety of learning opportunities and resources, existing systems for accreditation, validation and quality assurance will likely need to be adapted. New assessment tools and methods are being developed and explored (e.g. formative assessment) and could change the way in which we measure learning outcomes and educational attainment.

Expected overall impact in/for Europe

Education and learning are making leaps in efficacy, access and learner engagement potential. However, the precise impact of new education and learning pedagogies, tools and resources will depend on policy choices, also regarding oversight, funding and guidance mechanisms. Depending on the exact implementation and use cases, new ICT-based tools and models could either enable and encourage (social) responsibility, critical thinking and self-expression – or stifle it. Lifelong learning will be expected from all and while this might increase individual skills levels it might also cause an additional lifelong "up-skilling workload". Associated investment costs and the digital divide could cause a widening of educational and learning attainment levels between regions and social groups; within populations particularly older individuals or those with disabilities or otherwise disadvantages might not be able to keep up.

The increasing competition, across borders and with non-EU actors, will put pressure on educational institutions, particularly universities and vocational education and training organisations, which increasingly find their business models and market niches challenged. An unbundling of educational institutions, where activities such as assessment, guidance and teaching occur in different institutions, is likely. These processes might need guiding policy that prevents long-term harm to equality and quality in education. While assessment systems will likely stay state-governed, the flexibility of educational governance might need to be increased in other areas.

Regarding safety and security, the safe and effective use of ICT will need to be taught; privacy and security issues regarding teaching situations, student data and assessment veracity will increase; educational data, particularly if collected from early on in life, must be governed by specialised privacy legislation and ethical principles and it has to be ensured that educational data points, particularly those from early age, do not "determine" individuals' life paths or "lock" individuals in new low-achievement traps.

Overall, the transition from education to learning and the increased individual choice and flexibility can provide a level of freedom, satisfaction and engagement unknown to previous generations of learners.

Synergies and conflicts with other fields

Education is a fundamental issue that interrelates with a multitude of technological, scientific and social trends. For instance Social Innovation will generate new technologies and materials for use in education; in return an increased focus on teaching entrepreneurship will promote social innovation. Technological trends such as Big Data, Data Mining/Semantic Web, Cloud Computing, 3D Printing, Brain-inspired technologies, Collaborative Systems, Human/Computer Interaction and Virtual Reality and simulation technologies all will lead to improvements in educational tools, materials and pedagogies while education will need to enable current and future generations to acquire the skills and competences to use, understand, or advance these technologies. Behavioural Science, Knowledge Technologies and advances in Human Enhancement will impact the efficacy of pedagogies and educational materials or might change the nature of education and learning.

Emerging policy issues

Policy will need to determine how new forms of teaching, learning, assessment, guidance and skill and educational/learning attainment certification, validation and communication are enabled and governed. Quality (e.g. assessment veracity), access, equity and mobility are key issues. Some private-sector initiatives are developing (e.g. "Open Badges", peer-recommendation systems), but most of these issues will be addressed by regional or national government. Some EU action might be needed, particularly on validation, recognition and certification.

Important novel policy issues surrounding digital learning tools are privacy, data security and "determinism" – the risk that an individual's educational data might determine access to opportunities at a later point of their lives. Policy intervention might address the governing of learning data and its protection, exchange and use cases. As for other emerging privacy issues, the cross-border nature of the technology involved and increasing mobility among learners and workers suggest this might best be addressed at EU level.

Financing, quality control, equal access, social exclusion and the potential of skills gaps and low skills traps need to be addressed; here initiatives at national and EU level will likely be complementary. European education institutions need to define and develop their role in the global educational system – they will require funding, policy support and guidance.

High-level generic references

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Future Smart cities

In the cities of the future, ICT will play a key role in the challenge of ensuring the wellbeing of large numbers of inhabitants. And cities will become smart.

Smart cities will empower citizens by simplifying their daily life and providing them with more resources and opportunities, supporting new life styles, social inclusion and involvement in participatory governance.

Policies, however, shall not understate the additional pressure on strategic sectors as logistics and transport and new risks and threats related to the large deployment of ICT (cybersecurity, data protection and privacy).

70% of the world population in 2050 will live in a city.

Keywords: Sustainable cities, Social inclusion, Local governance, ICT, Citizen engagement, Urban planning, Urban communities, Energy and resources efficiency.

Current status

Humanity's entrance into the era of homo urbanus is irreversible. In 2007, 50% of the inhabitants of the planet were urban. Urban dwellers are expected to be 70% of the world population in 2050. Sixty five million people come to cities every year and 95% in the cities of the developing world, where 1 billion of world citizens live in slums.

Cities are the only places where people and resources congregate to optimise possible outcomes. Their ability to pool together so many diverse resources makes cities seedbeds of invention and laboratories of innovation. Furthermore, cities are influential centres of power and command and forceful enablers of value chains. They promote open democracies and citizenship and create patterns and models that are disseminated to the whole planet. In an uncertain interconnected world, dynamic interlinked local leadership initiated the era of "urban geopolitics". More and more foresight exercises[2] advocate for a future world in which coalitions with committed cities, businesses and countries initiate new global governance systems. Coastal cities at the crossroads of land, sea and human ecosystems face particular opportunities and threats.

In the EU urban areas are responsible for around 70% of the overall energy consumption. Cities are therefore major contributors to GHG emissions, but smart cities represent an opportunity for a more sustainable future.

All the many definitions of a smart city recognise the central role of Information and Communication Technologies (ICT) as an enabling instrument in many areas of application: environmental, economic, societal, governance, health. A smart city is "a city seeking to address public issues via ICT-based solutions on the basis of a multi-stakeholder, municipally based partnership", with an embedded idea of participatory governance.

[2] See "Now for the long term" by the Oxford Martin School, 2013; Mega, V. Quintessential cities, accountable to the future. Sustainability, innovation and citizenship (New York, Springer, 2013)

Current status

Humanity's entrance into the era of *homo urbanus* is irreversible. In 2007, 50% of the inhabitants of the planet were urban. Urban dwellers are expected to be 70% of the world population in 2050. Sixty five million people come to cities every year and 95% in the cities of the developing world, where 1 billion of world citizens live in slums.

Cities are the only places where people and resources congregate to optimise possible outcomes. Their ability to pool together so many diverse resources makes cities seedbeds of invention and laboratories of innovation. Furthermore, cities are influential centres of power and command and forceful enablers of value chains. They promote open democracies and citizenship and create patterns and models that are disseminated to the whole planet. In an uncertain interconnected world, dynamic interlinked local leadership initiated the era of "urban geopolitics". More and more foresight exercises[1] advocate for a future world in which coalitions with committed cities, businesses and countries initiate new global governance systems. Coastal cities at the crossroads of land, sea and human ecosystems face particular opportunities and threats.

In the EU urban areas are responsible for around 70% of the overall energy consumption. Cities are therefore major contributors to GHG emissions, but smart cities represent an opportunity for a more sustainable future.

All the many definitions of a smart city recognise the central role of Information and Communication Technologies (ICT) as an enabling instrument in many areas of application: environmental, economic, societal, governance, health. A smart city is "a city seeking to address public issues via ICT-based solutions on the basis of a multi-stakeholder, municipally based partnership", with an embedded idea of participatory governance.

Hence, smart cities are not about disruptive scientific or technological or engineering solutions but rather about the innovative and evolving integration of smart existing technologies and governance models.

In Europe, policy initiatives are currently supporting the diffusion of ICT as enabling tools for citizens (e.g. Digital Agenda for Europe), or for specific sectors such as energy, through the deployment of smart meters and grids. As a forerunning initiative fostering the sustainable planning of environmental measures at city level, the Covenant of Mayors is a successful example of the involvement of local and regional authorities, voluntarily committing to meet and exceed the European Union 20% CO2 reduction objective by 2020 through the implementation of Sustainable Energy Action Plans. The initiative counts more than 5000 signatories, and covers almost 200 million inhabitants, nearly one third of the EU population.

Another initiative, the European Innovation Partnership on Smart Sustainable Cities is gathering ICT and city stakeholders in all sectors to build up a roadmap that identifies priority challenges towards the creation of smart cities. An international initiative 'The making cities resilient campaign launched in 2010 addresses issues of local governance and urban risk to disasters and brings together more than 1800 cities world wide.

Outside Europe, the constant expansion of megacities will call for smarter and more sustainable solutions to ensure the supply of commodities, including the procurement of food, water, energy, resilience to disasters as well as health and security services.

Future trends (~2030)

On the science

European cities are not threatened by massive urbanisation despite the fact that 60% of the world population in 2030 will live in cities. They are expected however to lead the cities of the world towards higher quality of life. Through higher energy efficiency patterns, cities can lead towards the sustainability revolution. With the advent of more empowered citizens and the rise of a global conscience, cities become more eco-responsible and resource-conscious and try to reduce their ecological debts and footprints. Cities promise to address all interacting societal challenges concretely on the ground and offer efficiency gains towards a better life for all citizens, present and future, within the limits of the planet.

Within the context of the future Smart Cities and Communities, ICT remains the pivotal element. In order to closely follow and adapt to the needs of final users ICT becomes embedded into everyday life, including devices and systems. From households to organisations and industry, smart devices and smart appliances will be interconnected and will support the final user in a more sustainable use and management of resources, thus reducing costs and ensuring an optimal use of utilities, networks and services. In the energy sector, for example, new or diffused energy-related systems such as electric vehicles, storage devices or small scale renewable energy systems at household level will also need to dialogue, by means of smart meters, both with a central household system and with the distribution grid for a safe and sustainable balance of the systems.

Thus the full deployment of enabling ICT-based technologies (smart appliances, smart meters, and smart grids) will be the technical priority to 2030. This will necessarily be accompanied by standardization efforts for the full interoperability of all systems and the opening of competitive markets for the industry.

Based on the technological progress, innovative business models will be developed and new services, such as those proposed by Energy Service Companies in the energy sector, will be provided to end users to sustainably and efficiently improve their quality of life and work.

Monitoring and assessing the new technologies and services shall open new frontiers for geographical information tools and systems.

On the applications

Innovation is expected to focus on the integration of ICT enabling tools, increasing the need for technological standards and information exchange protocols. More and more networks (electricity, gas, heat, water, transport), and systems (buildings, e.g.) will become smarter, with increased deployment of sensors, converters and actuators, and progressively become integrated within a system and with other systems. Dematerialisation will continuously change entire sectors, such as the public administration, the healthcare and mobility.

Given the more active role of end users, governance models will necessarily need to adapt to embrace the wider participation of citizens. More platforms will be developed for the multilevel handling of governance challenges, following the example of the CoM, which fosters sustainable energy and climate policy at local level, providing the methodological and scientific framework for action and for the deployment of measures, contemporarily addressing the integrated governance challenges. In the horizon 2030, more cities or districts will evolve into living laboratories to demonstrate the potential of smart solutions and governance in the sustainable development of urban areas.

Expected overall impact in/for Europe

Future Smart Cities will bring the most evident benefits on the environmental and climate level, along with positive impact on the economy and society. However, innovative governance models and new policy measures will be needed to ensure the safe and smooth deployment and use of smart technologies.

Society

The societal changes driven by the deployment of ICT and digital technologies can promote the evolution of working patterns, different mobility schemes, the advent of more connected citizens brining increased inclusion, and more benefits on healthcare.

Empowered citizens and consumer preferences will be at the heart of human-centred cities. Their needs will trigger technological change and social innovation and digitally enabled citizens could become more engaged and participative, favouring the inclusion of all. New forms of poverty and exclusion in multi-ethnic cities will need local holistic approaches together with participatory models for urban renewal and sustainable regeneration, in a continuous evolution of communication habits, for new places and forms of social dialogue.

The economy

The technological deployment is expected to produce industrial growth, and job creation beginning from the ICT sector. Urban diversity of different generations and cultures, including immigrant ones will greatly affect the performance and attractiveness of EU cities.

With improved communication options and enabling tools, citizens are exposed to more personal and professional opportunities, including at local level.

New and local business models shall also contribute to develop more opportunities in cities: those efficiency gains shall convey economic savings that can be reinvested locally.

Governance and policy issues

Global alliances of cities, businesses and civil society, from both the developed and developing world could be decisive for knowledge sharing and technology transfer down to the local level.

As demonstrated with the Covenant of Mayors initiative, tackling sustainability issues calls for integrated local planning which is fundamental for the deployment of smart cities. Beside the engagement of the public authorities it is central that citizens are involved actively in governance schemes, and that participative decision-making processes are applied.

Novel business models and market opportunities will add new challenges to the regulatory authorities' tasks, to market operators and stakeholders: more than ever engaging in a constructive and transparent dialogue, alongside with policy-makers, will be vital.

Environment and climate

Mitigation of and adaptation to climate change as well as disaster resilience are essential for the future cities, especially for coastal cities that most attract citizens and investors and which present the highest risks for exposed populations and assets. Although European cities in general less vulnerable (only Dutch cities are in the top 20), European technologies can help world megacities.

Smart cities will have the primary scope of reducing their environmental impact and offering sustainable lifestyles. The building blocks of these changes will be the elements of a city where higher efficiency can be achieved, in particular through technological and ICT based improvements: in buildings, in transport systems, in local electricity and heat production including from renewable energy sources, for optimised networks and lifestyles and ultimately bringing lower CO_2 emissions per capita.

New generation of houses and urban infrastructures, lighter, more modular and efficient, are already appearing and promise to better shelter the urban dwellers of the future.

Coastal cities face particular risks with the exposition of population and economic assets to storm surge coastal flooding and sea-level rise. Land-use patterns, as well as transport and accessibility issues will be difficult to address; it is however expected that urban sprawl will be contained in the EU and this will serve as a model. As for energy consumption, it decreases significantly thanks also to tighter energy efficiency measures and is now decoupled from growth in the EU. Moreover, carbon-neutral eco-districts start offering an array of models.

The city dimension will become the reference for optimising the societal response to environment and climate change issues. Future smart cities will be able to anticipate and to adapt to the threats of climate change, thus becoming less vulnerable to natural to technological hazards and more resilient.

Safety and security

A smart city will also allow improving citizens' safety and security, at private and households level, as well as at city level, with the spread of smart devices for health care, of more mobile devices, remote sensing technologies and enhanced communication systems. This will bring along privacy issues and also concerns about privacy, big data, the handling of large amount of very different and eventually sensitive data, including personal files.

Hence, smart cities will need to address from the very beginning the need for procedures and standards protecting private life in a context where the increased application of telecommunication devices could overlook the balance between security and privacy.

Inter-relations with other fields

Expected synergies

By their nature of aggregating centres, Future Smart Cities relate to many other technologies and applications, particularly in the areas of resources (including energy, water, food), of tools and automation systems for the optimal use of resources and of citizens and societal challenges.

For the resources, in order to ensure that the needs of the future larger cities are sustainably met, more Sustainable Consumption and Production will be required. Agricultural and Food Sciences will be solicited to provide safe and sufficient food with the lowest foot-print, Innovative Foods could become necessary, as well as Precision farming for instance; renewable energy sources could become part of the urban and domestic landscape, including small scale Solar or Biofuel plants (and more) and altogether cities could be the seed of the Post-carbon society, or the test bed for a Hydrogen Society. Science for Energy transition could also provide insights into the energy transition of cities. Applications as Photonics and light technologies would consistently reduce the energy consumption of the lighting sector. Recycling will also have an increasingly important role in cities. Smart logistics and Mobility will play a strategic role.

Concerning tools and systems to better satisfy cities' and citizens' needs, ICTs will be leading the future: more Collaborative systems based on ICT will allow enhanced interactions between technologies and human beings; thus inevitably calling for new tools to handle more Complex systems and to deal with Complexity but also modelling and simulation. Data will become the resource of the future and ICT are expected to provide solutions such as Data mining to extract valuable information and knowledge from Big data and Cloud supported applications, backed by High-performance computing systems and advanced Knowledge technologies. Cyber-security will become more and more an embedded feature in ICT and its applications.

Citizens remain at the heart of the Future Smart Cities, on one hand dealing with more Automation, more Autonomous systems and robots. This will require a better understanding of Human/computer interaction and it will provide the citizens with better and more targeted services including health (Personal medicine) and education (Future education and learning. On the other hand, the social structure and dynamics will evolve and will require further investigation (Social innovation, Citizen Science).

Possible conflicting aspects

Balance will be the key for the harmonious development of Future Smart Cities.

However the increased concentration of resources, technologies and people might bring critical questions and potential conflicts.

Resources to satisfy the needs of a more concentrated population cannot be all produced locally, thus putting pressure on the logistics and the transport systems.

The large deployment of ICT will accentuate the issue of automation versus autonomy in citizens' daily decisions. Moreover, access to additional and more sophisticated tools for personal enhancement might cause the need to rethink the boarders between personal wellbeing and social welfare. New individual behaviours and societal development might call for new forms of governance.

Emerging policy issues

In future smart cities, the constant flow of resources (food, energy, water) and waste to and from future enlarged cities, combined with new lifestyles enabled by ICT (teleworking, online shopping) will change the requests put on strategic sectors such as logistics and transport.

The technological drive of ICT is also raising new policy issues that start now to be tackled but that will represent unavoidable themes in most of the future policy measures: cybersecurity, data protection and privacy are the other side of the coin when dealing with ICT.

In the future the augmented role of cities centralising resources and opportunities could lead to new geopolitical equilibria at local level. Combined with a more accessible participation of citizens' in the public life, this could trigger the need for multi-level and well-coordinated governance systems.

Generally, the policy making process shall ensure that the technology underpinning the development of Future Smart Cities remains a tool supporting their sustainable growth in all their aspects, including economics, ethics and the environment.

High-level generic references

The European Innovation Partnership on Smart Cities and Communities, http://ec.europa.eu/eip/smartcities/

The Green Digital Charter, http://www.greendigitalcharter.eu/

The Covenant of Mayors, http://www.covenantofmayors.eu

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Future mobility

Over the next decades, demand for mobility will further increase. Although in some geographical areas less transport is possible, in general people and goods will be moving more often, further and faster. Technologies servicing mobility needs are largely fossil fuel based and characterised by little inter-connectivity and inter-modality. The transport sector is currently characterised by a high degree of 'technology lock-in'; high investments in existing assets prevent the introduction of transformative solutions in the market.

Keywords: Decarbonised mobility, integrated transport system, smart mobility, autonomous transport solutions, alternative fuels, intelligent transport systems, connectivity.

Current status

A future based on non-fossil fuel based and well-integrated mobility is considered to be further out than 2030, but some ingredients are already coming together and will become increasingly evident in the years to come. Several socio-economic and technological trends, which include demographic and life-style changes, increasing urbanization, shifting balance of the global economy and exponential growth of connectivity between people and devices, will have a strong impact on how transport is designed, organised and used; its quality of delivery to the customer; and its efficiency. This will result in the emergence of new mobility and vehicle concepts and lead to new mobility patterns.

Future trends (~2030)

On the science

Research, development and demonstration activities will remain important to increase safety, energy efficiency and reduce the environmental impact of transport. ICT related research will continue to support the development of semi-autonomous and eventually fully autonomous transport solutions (incl. drones). Efforts geared towards enabling better integration and connectivity will have to be stepped up in order to ensure a truly efficient and 'smart' transport system.

On the applications

The transport system will be gradually decarbonised and fossil fuels, to some extent, will be replaced by renewable energy carriers but this process will be slow as the renewal of the fleet and creation of an alternative fuels infrastructure is a capital-intensive and gradual process. ICT will be leveraged as an enabler to increase the efficiency and integration of the transport system, and also the transition towards electro-mobility. These developments can support the emergence of seamless mobility, (semi-) autonomous driving, and customisation of transport equipment and services.

Expected overall impact in/for Europe

Society

The transition to a more sustainable, well-integrated transport system provides a big value creation potential. On the other hand this may create some data privacy issues and threats through misuse as well as systemic vulnerabilities. Social effects (e.g. both positive and negative impacts on socially weak groups) should be considered.

The economy

Future transport technologies and services offer a strong growth potential for Europe, which is world innovation leader in a number of sectors (engineering, manufacturing of transport equipment, services). But global competition is increasing.

Governance and policy issues

Experience shows that innovation in services and transport networks, in particular in relation to the role of ICT, has largely outpaced innovation in regulation and in organisational/institutional structures. Overcoming barriers to implementation of innovation requires strong political leadership, buy-in from transport service providers and significant investments – which will increasingly need to come from the private sector. Rules and structures must be flexible enough to evolve rapidly. Data privacy and issues related to liability must be solved.

Environment and climate

It is yet unclear if the decarbonisation can off-set the transport growth, hence, if the GHG emissions caused by transport will grow or reduce until 2030. Nevertheless it is important to increase transport efficiency and reduce its specific GHG emissions.

Safety and security

More 'intelligent' transport systems are a means to increase safety, but fault tolerance and vulnerability to attacks need to be addressed.

Synergies and conflicts with other fields

Synergies exist with the following science fields: Alternative fuels, Human/ computer interaction, Nanomaterials, Science for the energy transition, Space based services.

Synergies exist with the following application areas: Advanced autonomous systems, Behavioural science.

Cyber-security; Drones, Future [smart] cities, Hydrogen society, Personal assistants (virtual & robotic), Recycling, Sustainable consumption and production.

Emerging policy issues

Europe relies on efficient transport for the economy to stay competitive and for the internal market to function smoothly. Policies must guide the transition towards a sustainable, well-integrated transport system, while addressing privacy, safety, and security concerns as well as social and distributional aspects. Maintaining the leading role of Europe in transport innovation and warranting the related positive employment effects should be a priority for European policy makers. Ensuring flexible rules and structures in the transport system will be key to foster innovation and increase the leverage of ICT for smarter mobility solutions.

High-level generic references

WHITE PAPER Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system [COM/2011/144].

COMMUNICATION on Research and innovation for Europe's future mobility - Developing a European transport-technology strategy [COM/2012/501].

PACKAGE on Clean Power for Transport– Alternative fuels for sustainable mobility in Europe [COM/2013/17] & [COM/2013/18].

PACKAGE on Urban Mobility – Together towards competitive and resource-efficient urban mobility [COM/2013/913].

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Chapter 6
Physical sciences and enabling/ manufacturing technologies

Introduction

The current system of **goods and services** may well shift from predominantly business-to-consumer to consumer-to-consumer via a **consumer empowerment** and a switch from ownership to leasing/sharing. Democratisation of additive manufacturing opens up new avenues for distributed production and consumption. **Robotics and automation** could challenge employment and be disruptive to the current economic system if we are not becoming more creative at the same time.

A less egocentric and a more **'Legocentric'** society may emerge...

Graphene and related materials

Graphene is a form of carbon, in sheets one atom thick. The outstanding material properties of graphene give it the potential to replace or supplement many other materials, in a vast range of potential products and applications. It is the first of what will become a large family of new 2-D materials.

It is expected that graphene will be a "game-changer"; it will enable new or enhanced applications, processes and products in a wide range of industries and sectors of the economy. The long-term forecast worldwide potential market will be hundreds of billions of euros.

Keywords: Graphene, 2-D materials, basic materials, composite materials, nano-electronics, advanced materials, key enabling technologies[1].

Current status

Graphene is a form of carbon, in sheets one atom thick. It was first isolated, and its properties measured, in 2004. It has a two-dimensional layer structure in which each carbon atom is bonded (connected) to three other atoms in a planar honeycomb lattice, in a configuration that provides great mechanical strength and outstanding electrical, optical and thermal properties. The importance of this discovery and its potential impact were recognised by the award of the 2010 Nobel Prize in Physics, and Graphene is now the focus of intensive further research in Europe, including an EC FET Flagship project, and worldwide.

Future trends (~2030)

a. Further research is underway, to understand more deeply the (unique) physical properties of graphene and related 2-D materials and how these unique properties can be exploited in the future.

b. Intensive efforts will be devoted to study how graphene can be produced in high volume and at economic cost, as a prerequisite to use in future mass-market applications. Graphene can be used in several ways: as single sheets, as flakes a few layers thick, or in combination with a wide range of other materials.

c. Potential areas of application, include: high speed, transparent, flexible and printable consumer electronics (displays and chips); highly efficient energy storage solutions, such as lightweight batteries for electric cars; chemical /biological sensors, replacing scarce metals such as platinum as catalysts in chemical processes; ultra-strong coatings and lightweight composite materials for aircraft, satellites and vehicles.

d. In micro-electronics and ICT, the limits of silicon for electronic integrated circuits are getting closer. Graphene with its unique combination of outstanding nano-scale electronic and optical properties could offer an alternative for the next generation of faster and smaller electronics, displays and photovoltaic panels.

[1] In 2009, the EC identified nanotechnology, micro-nanoelectronics, advanced materials, photonics, industrial biotechnology and advanced manufacturing systems as the EU's six key enabling technologies KETs are defined as knowledge and capital-intensive technologies associated with high research and development (R&D) intensity, rapid and integrated innovation cycles, high capital expenditure and highly-skilled employment. They enable process, goods and service innovation throughout the economy and are of systemic relevance. (COM(2009)512).

Expected overall impact in/for Europe

Over the next 30-50 years, Graphene and related materials have the potential to become as widely used and as important to the European economy and industry as were iron and steel, 30-50 years ago.

For the economy, the forecast worldwide potential market for products based on Graphene and related materials will be worth hundreds of billions euros.

For society, the impacts of graphene and related materials (including environmental benefits from their applications) will-be wide-ranging; for example in healthcare applications (such as artificial retinas, new drug delivery and sensing and imaging devices) as well as in transport, energy production and storage.

Synergies with other fields

Expected synergies

It is expected that Graphene and related materials will enable "game-changing" new applications and products in a whole range of industries and sectors of the economy. The versatility of graphene as a basic material opens the possibility for new solutions to some of the fundamental societal challenges for Europe, in ICT, in (renewable) energy production, in air and land transport, in cities/buildings, and in healthcare applications, amongst others.

For example, in the energy sector, efficiency improvements and cost-savings for production are expected in wind-power and in photovoltaic cells, and for storage, in batteries and superconductors. In the transport sector, new graphene-based composite materials will reduce the weight and improve the fuel efficiency of road vehicles and aircraft.

Possible conflicting aspects

It is important to create the optimum balance between the fast introduction and economic take-up in Europe of new products and processes based on graphene, and the relevant safety and environmental assessment.

Emerging policy issues

It will be essential to ensure that the industrial development and economic exploitation of new graphene-based products is located in Europe. A key challenge will be to put in place efficient mechanisms to promote the take-up and exploitation of the results of European research programmes by European industry.

It is necessary in the European Single Market, to create the optimum balance between the exploitation of products and processes based on graphene and related materials, and the relevant safety and environmental assessment, following the precautionary principle.

In the context of the sustainability of the global supply chain for basic materials, the supply of high quality graphite is required for producing graphene.

High-level generic references

Graphene and related materials will contribute to the creation of jobs and economic growth in Europe, by enabling new or enhanced applications, processes and products in a wide range of industries and sectors of the economy.

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Nanoelectronics

Nanoelectronics is the advanced technology which exploits qualitatively new phenomena of electric circuits functionality emerging at nanoscales. Particularly promising are applications involving quantum nature of those systems such as quantum coherence and the intrinsic spin of an electron. Current research deals with new generation of quantum devices, which open up horizons for qualitatively new applications such as quantum computing/communication, quantum metrological standards, various logic devices.

These developments will provide systemic solutions addressing fundamental limitations of conventional ("More Moore"), and even less conventional CMOS technologies (‘*more than Moore’* or ‘Beyond CMOS’).

Exploiting a broad variety of materials, phenomena and integrating multiple functions in miniaturised smart systems is the next frontier in Nanoelectronics.

375 B€ production in Europe for electronics components and systems (Source Decision – see viewgraph)

Keywords: Nanoelectronics, nanoscales.

Current status

Over the last several decades the development of commercial microelectronics, based on c*omplementary metal–oxide–semiconductor* (*CMOS*) technology, followed the, so-called, Moore’s law: Number of elements per area on a chip doubles each 18 months[1]. At the moment the reproducible features in mass production (e. g. node region of a commercial processor) have reached 22 nm. At the same moment, modern nanofabrication (e.g. based on electron beam lithography) comes close to 10 nm scales. However, it has been already commonly anticipated that by 2015-2018 the increase of performance of conventional (CMOS) circuits by further miniaturization of critical elements will become impossible. The limitation has two fundamental origins: heat dissipation (surpassing in modern processors the impressive 100 W/cm^2), and various quantum phenomena emerging at these ultra-small scales. In parallel with CMOS technology, dominating so far the commercial sector of micro- and nanoelectronics, certain approaches, alternative to CMOS, have been demonstrated in academic research or/and small-scale production.

Future trends (~2030)

On the science

Though the stagnation of CMOS technology is already noticeable nowadays (much more slow introduction of new processors, compared to, let say, mid-90th), still there is a room for mass production to rely on ‘‘*more than Moore’* pathway. At least for couple of years, the well-developed CMOS technology will still dominate the commercial market. Given the fundamental limitations, one cannot expect breakthrough results in this direction. Hence, presumably, in the nearest future we will witness the ‘war of auxiliary’ between the main industrial players. The core features of electronic components (e.g. speed of processing and compactness) will not evolve noticeably. The introduction of new products will mainly

[2] Electronics, Volume 38, Number 8, April 19, 1965.

exploit the 'supplementary' characteristics: ergonomics, multifunctionality, lower energy consumption, etc. In the alternative domain for nanoelectronics -'*more than Moore'*, so far mainly developing by academic resear -chers, one can outline two main trends. First, explicit exploitation of qualitatively different, from conventional CMOS devices, quantum phenomena in 'conventional' (metal and semiconductor) nanoscale systems. Among the most fascinating phenomena, demonstrated a proof-of-principle alternative to classic logic devices, are: (macroscopic) quantum tunneling, various single electron effects, mesoscopic superconductivity. These systems have been widely studied during the last decades and can be reproducibly fabricated using rather conventional 'top-down' approaches such as: e-beam lithography and nanoimprinting. However, the mandatory requirement of observation of these quantum effects is refrigeration, which makes the approach not so that user-friendly so far. At the same moment, utilization of (mesoscopic) superconducting elements removes the heat dissipation issue, common for all nanoelectronic systems. Given the noticeable progress in development of various cooling techniques (particularly, 'dry' or solid state refrigeration requiring no cryogenic liquids) one may expect a very significant outburst of these quantum logic applications in the nearest future. Second, very trendy '*more than Moore'* approach deals with molecular (or even atom) size 'building blocks' such as carbon nanotubes, fullerenes, various organic molecules. Several fascinating results have been demonstrated by academic researchers, particularly claiming the possibility of 'bottom-up' self-assembly of these objects. However, so far neither the reproducibility of assembly, nor the performance reliability of those atomic/molecular scale nanoelectronic 'devices' can be considered satisfactory even for small scale production. In the foreseen future those ultra-small nanoelectonic elements will still remain the subject of academic research.

On the applications

Fabrication of such molecular-size systems requires tremendous efforts, sophisticated laboratory equipment and is extremely poorly reproducible. Hence, on the scale of the nearest decade, we should definitely support the corresponding basic research, not requiring the immediate industrial implementation of academic results.

Summarizing, presumably during the nearest several years we will observe: (1) the die-out of conventional "*more than Moore'* approach; (2) proliferation of the qualitatively new concepts, based on various quantum phenomena in nanoscale solid state systems; and (3) a lot of 'science fiction' speculations, which ignore the tremendous gap between the proof-of-principle demonstration of an effect in a unique (e.g. molecular-size) laboratory sample and the reproducibility of the result, mandatory for any durable application.

Expected overall impact in/for Europe

Without any exaggeration, among all nanotechnology-related applications, nanoelectronics have the highest potential to change the landscape of the modern technology-oriented society. New devices (e.g. quantum computers) may not immediately enter the homes of the customers. However, even utilization of the qualitatively new concepts in cost-no-object applications such as satellite or/and Earth based telecommunication systems will significantly increase the speed of information exchange, improve the reliability and confidentiality of communication, dramatically expand data storage capability. All these factors will inevitably strengthen the security and raise the quality of life of EU citizens

Synergies and conflicts with other fields

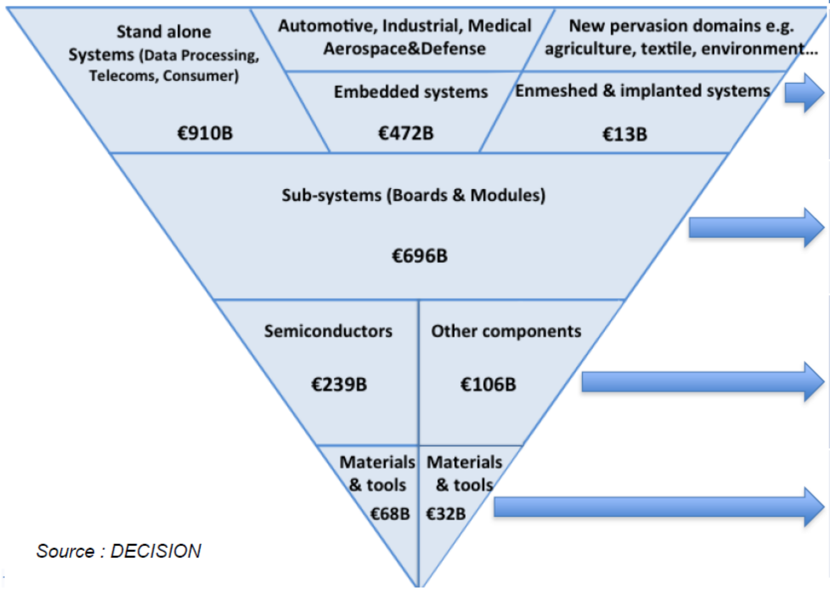
The progress in nanoelectronics is naturally related to developments of nanotechnology and material science. Reduction of costs and, hence, wider proliferation of currently rather expensive nanofabrication and analytical equipment might significantly boost the advances in nanoelectronics. The involvement of wider academic communities in nanoelectronics, as well as the growth of SMEs ready to implement the recent discoveries, should inevitably positively affect the field.

Among the major threats one can foresee the understandable reluctance from large industrial micro / nanoelectronic manufacturers to shift from the well-established CMOS technology to the new one, where the 'rules of the game' are not yet clearly defined, while the investments might be in multi-billion scales. Other commonly debated topic in nanoscience is the 'nanosafety'. The issue might be of certain (but not yet clearly identified) importance in cosmetics, medicine, textile and other applications involving contact of nanoparticles with humans. In nanoelectronics the safety issue is presumably of less importance as the corresponding elements are confined to on-chip electronic circuits. The fabrication typically happens in a clean room environment with minor danger of contamination.

Emerging policy issues

There is a need to support research in *'more than Moore'* as the conventional approaches had demonstrated their limits.

World electronics industry value chain, 2012



	PROD. EUROPE (€B)	% EU / World
Level4: *Systems*	225	16%
Level3: *Boards and Modules*	80	12%
Level2: *Components*	30	9%
Level1: *Equipment & Materials*	20	20%

Source : DECISION

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Nanomaterials

Keywords: Nanomaterials, nanoscale, Key Enabling Technologies[3].

Current status

Nanomaterials exploit changes of material properties by manipulation of its particle or constituents' shape and/or surface functionalization at the nanoscale (10^{-9} m). The total annual quantity of nanomaterials on the market at the global level is estimated at around 11 million tonnes, with a market value of roughly 20bn €. Carbon black and amorphous silica represent by far the largest volume of nanomaterials currently on the market. Together with a few other nanomaterials, they have been on the market for decades and are used in a wide variety of applications. The group of materials currently attracting most attention are nano-titanium dioxide, nanozinc oxide, fullerenes, carbon allotropes such as nanotubes or graphene, and nanosilver. Those materials are marketed in clearly smaller quantities than the traditional nanomaterials, but the use of some of these materials is increasing fast.

Other new nanomaterials and new uses are being developed rapidly. While some nanomaterials offer improvement in established uses e.g. in automotive or construction sector, many are used in innovative applications such as catalysts, electronics, solar panels, batteries and biomedical applications including diagnostics and tumour therapies. Some, due to their unique properties exclusively originating from nanoscale phenomena, can be used for specific applications which cannot be attained by conventional macroscale materials.

Safety issues

Possible risks are related to specific nanomaterials and specific uses. There is still a considerable lack of data on exposure to nanomaterials via the environment. Therefore, nanomaterials require a risk assessment, which should be performed on a case-by-case basis, using pertinent information. Current risk assessment methods are applicable, even if work on particular aspects of risk assessment is still required. Current knowledge about nanomaterials does not suggest risks which would require information about all products in which nanomaterials are used. Experience so far shows that, if risks were to be identified, they could be handled with the existing tools such as the General Product Safety Directive.

Future trends (~2030)

The use of nanomaterials is expected to increase substantially over the coming years in virtually all areas of applications; some examples are smart polymers for environmental biotechnology and smart irrigation;

[3] In 2009, the EC identified nanotechnology, micro-nanoelectronics, advanced materials, photonics, industrial biotechnology and advanced manufacturing systems as the EU's six key enabling technologies KETs are defined as knowledge and capital-intensive technologies associated with high research and development (R&D) intensity, rapid and integrated innovation cycles, high capital expenditure and highly-skilled employment. They enable process, goods and service innovation throughout the economy and are of systemic relevance. (COM(2009)512).

multilayer materials for ICT and transport, Advanced smart multifunctional foams with enhanced structural integrity, sound absorption and dielectric loss; Nanoporous materials in assembled products (gas storage, batteries); Exploitation of quantum phenomena in nanomaterials for various nanoelectronic and nanophotonic applications; Incorporation of nanomaterials in well-established products to improve their performance and durability, as well as development of qualitatively new applications exploiting quantum effects at nanoscales.

Expected overall impact in/for Europe

The benefits of nanomaterials range from saving lives, breakthroughs enabling new applications or reducing the environmental impacts to improving the function of everyday commodity products. Products underpinned by nanotechnology are forecast to grow from a volume of 200 bn € in 2009 to 2 trn € by 2015. These applications will be essential for the competitiveness of a wide area of EU products in the global market. There are also many newly founded SMEs and spin-off companies in this high technology area. Currently, the direct employment in nanotechnology is estimated at 300 000 to 400 000 jobs in the EU, with an increasing tendency.

High-level generic references

COMMUNICATION SWD(2012) 288 final , Second Regulatory Review on Nanomaterials.

For more information on Responsible Research on Nanoscience and Nanotechnology see also NANOCODE project: http://ec.europa.eu/nanotechnology/pdf/nanocode-rec_pe0894c_en.pdf http://www.nanocode.eu/content/view/245/117/

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Photonics and light technologies

Keywords: Photonics, Key Enabling Technologies[4], light technologies, science, engineering, technology and innovation trends.

Current status

Since the invention of the laser in 1960, photonics technologies have been further developed and have emerged in applications like communications, lighting, displays, health, manufacturing bringing about major improvements and innovations. Photonics is now everywhere around us and in everyday products like DVD players and mobile phones.

In 2005, the European Commission established the European Technology Platform in Photonics: "Photonics21". In 2009, the European Commission recognised Photonics as one of the Key Enabling Technologies and in 2013 it created the Public Private Partnership in Photonics. In Photonics21 the stakeholders develop a vision and a roadmap of photonics as a well-defined science leading to disruptive breakthroughs in telecommunications, life sciences, manufacturing, lighting and displays, sensors and education.

Future trends (~2030)

In science, engineering, technology

New developments can be expected coming from fundamental science and based on novel concepts and approaches for materials and processes. These could lead to major breakthroughs in existing but also in new yet unknown applications. Examples falling within this category include: Photon-photon and photon-phonon interactions; Light-matter interaction in 'extreme' conditions; new materials (engineered materials, new organic materials); new aspects of photonics at the nanoscale; and unexplored new material systems (graphene, silicene).

For innovation/applications aspects (and possible fading out of other areas)

New advances in photonics will move communications into the terabit era by dramatically increasing data capacity and data transmission speeds. It will help overcome the limitations of electronics in computers through all-optical computing or even quantum computing.

In manufacturing, laser processing will be a basic prerequisite for high-volume, low-cost, zero-defect manufacturing.

Photonics will revolutionise healthcare and provide new ways of detecting, treating and even preventing illness.

[4] In 2009, the EC identified nanotechnology, micro-nanoelectronics, advanced materials, photonics, industrial biotechnology and advanced manufacturing systems as the EU's six key enabling technologies KETs are defined as knowledge and capital-intensive technologies associated with high research and development (R&D) intensity, rapid and integrated innovation cycles, high capital expenditure and highly-skilled employment. They enable process, goods and service innovation throughout the economy and are of systemic relevance. (COM(2009)512).

By 2020 it is expected that more than 70% of the lighting will be LED based in Europe. OLEDs represent the next wave of disruptive lighting technology: their development and large scale deployment, expected after 2020, will permit to provide large-area, large uniformity lighting solutions over flexible substrates. This will enable their integration over any kind of surface (furniture, walls, windows, etc.), which will completely change the way we will experience lighting in the 2020's. 3D display technologies together with large bandwidth access technologies and progress on communication system latency will enable the provision of truly immersive experiences.

Many other application sectors will also be affected by photonics S&T advances, such as information processing and consumer goods, metrology, holography, magnetic storage, etc.

Expected overall impact in/ for Europe

Society

Major breakthroughs in biophotonics are expected over the next 10-15 years that will allow developing easy-to-access, minimally invasive, low-cost screening methods of major diseases as well as their better monitoring and treatment.

Laser processing is also expected to make a significant contribution in tackling the societal challenge presented by the ageing population in Europe. This will result from the wide range of innovative new products enabled by future photonic manufacturing technologies, including such varied products as pace-makers, synthetic bones, endoscopes, and micro-cameras used for in-vivo health care processes.

The economy

Photonics is a fast-growing business sector, experiencing ~8% growth per annum, with a global market of around € 350 billion (2012). This market is projected to reach over € 600 billion by 2020. The European photonics industry employs more than 300 000 people directly, many of these in the over 5 000 photonics SMEs often structured in national and regional innovation clusters which represent a highly educated workforce.

Governance and policy issues

The EU is currently a global leader in several photonics technologies. This is expected to grow, provided that sufficient research and innovation investments are undertaken in the coming years by the public authorities and the private sector. It will require pooling resources to finance for example large scale demonstration actions around ambitious targets which could stimulate the collaboration between different scientific communities and industrial sectors needed along the value chain to come up with more effective and successful solutions for the major societal challenges facing Europe, in particular for healthcare, the aging society, food safety, security, and energy efficiency.

Environment and climate

Photonics will play a key role in addressing the challenges of energy efficiency and moving to a low-carbon economy. In the future, solid-state light (SSL) sources are expected to outperform almost all other sources in terms of efficiency, offering potential energy savings of 70% or even more. Sensor applications in smart power grids, smart buildings and smart industrial process control will contribute significantly to more efficient use of resources and meeting environmental challenges.

Lasers will play a major role in facilitating green manufacturing, since laser processes allow for very precise, well-controlled and therefore resource-efficient and energy efficient deposition / processing on the work piece(s).

Opical technologies for communications, information storage and computing will reduce the carbon footprint of data centres and networks and the overall cost per bit.

Safety and security

Multi-band photonic and spectroscopic methods and techniques are employed for monitoring the environment and the quality and safety of water and food. It will be possible to provide reliable, high-performance diagnostics measurement methods and systems for professional and consumer use, such as for food inspection (e.g. moisture sensing, detection of foreign particles in food, etc.) and recycling and waste treatment, for detection and identification of numerous volatile organic compounds in gases and therefore potential microbial food contaminations, and for reliable detection of potential hazards or dangerous situations through deep penetration in standard packaging materials.

3D printing

Additive manufacturing or 3D printing is a process for making three-dimensional solid objects of virtually any shape and any size from a digital model, under the same way as an inkjet printer creates images on paper. 3D printing has many advantages over conventional manufacturing methods as it skips many traditional manufacturing steps, reduce the amount of material wasted and energy consumption and enables more complex, lighter and more solid manufactured products. Moreover, 3D printing enables the mass-customization of goods adapted to consumers' needs through online 3D marketplaces and personal 3D printers. Overall, 3D printing has the capacity to impact the current value chains and wholesale/retail business models of many sectors both at global and local levels. As many disruptive technologies which have the capacity to transform our life and business, 3D printing comes along with a number of risks and policy challenges which will have to be tackled in the medium term.

In economic terms, 3D printing is still a niche, but the market is growing fast. It is expected that the global market volume will increase from $2 billion in 2012 to $11 billion in 2021. However, according to a McKinsey Report on disruptive technologies, 3D printing could generate economic impact of $230 billion to $550 billion per year by 2025 in relation with the vast and always expanding number of applications of 3D printing. The largest source of potential impact among sized applications would be from consumer uses, followed by direct manufacturing and the use of 3D printing to create tools and molds.

Keywords: Additive manufacturing, 3D printing, 3D modelling, 3D scanner, Mass customization, Advanced manufacturing, Key enabling technolgies.

Current status

The first working 3D printer was created in 1984 in the US by 3D Systems Corp. The technology is already used for both prototyping and distributed manufacturing in a vast number of industries, including medicine and nano-technologies. Over the last three years, 3D printers have been shipped in the electronic consumer market at very affordable prices (below €1000), while at the same time more sophisticated 3D printers are being increasingly used in the manufacturing industry to produce bigger objects (e.g. for prototyping cars), but also nano-scale objects and for mass production.

Future trends (~2030)

On the science

The main developments in 3D printing are expected to take place at the level of the various additive processes applied, both regarding the layering technologies and the material employed (e.g. granular materials binding, photopolymerization, laser beam and electron beam to melt metallic powders) which will allow to print out increasingly complex goods including nanotechnologies and genetically engineered bio-materials, while lowering the unit costs of 3D-printed objects.

Under the double impact of technological progress and market take-up, the unit cost of 3D printers is expected to decrease with consequence to see in the medium to long term 3D production units of complex goods being decentralised at local level and even in the household.

On the applications

The field of applications of 3D printing is extremely vast and keeps increasing rapidly. A useful distinction can be made between industrial and bio-medical applications and domestic uses.

Regarding industrial applications, a first distinction can be made prototyping, rapid manufacturing and mass customisation.

Prototyping: this implies the use of large industrial 3D printers for rapid prototyping of cars, airplane etc.

Rapid manufacturing: is used for the manufacturing of finished components in the automotive and aeronautic industries but also in other sectors such as industrial commodities. In these sectors, 3D printing enables to produce components that are lighter and more resistant, and which require 90% less material, 90% less energy and 90% less emissions, while inducing less labour costs.

Mass customisation: companies have created online services, e.g. 3D marketplaces, where consumers can customise objects using 3D files to which they can make adaptations and order the resulting items as unique 3D printed objects (e.g. furniture, cases for smartphones etc.)

Regarding bio-medical applications, 3D printing is used for the prototyping and design of unique pieces adapted to the human body, for instance hearing aids, parts of bones (skull, hips), at relatively low cost.

The development of domestic uses of 3D printing have been fuelled by the shipment of very affordable 3D printers in the consumer market over the last 4 years (prices below €2,000). 3D printing communities have emerged as well as a surrounding ecosystem of software tools enabling dissemination of 3D files.

Additive manufacturing in combination with cloud computing technologies allows decentralized and geographically independent distributed production (Cloud Producing).

Other field of applications include building construction, food making, clothing, jewellery etc.

Expected overall impact in Europe

Society

3D printing will enable mass-customization of goods, leading to change of consumption patterns with unique products being delivered to individuals to the point that it could impact the sense of ownership of goods by individuals.,3D printing will also increase the democratisation of digital manufacturing, as Internet-connected PC democratized the use of computing power over the last decade, and should see the development of 3D printing communities.

The economy

3D printing will reduce the labour cost of manufacturing to near-zero%, thereby completely modifying the existing international division of labour and the resulting globalisation of our world. The likely consequences will be, in a first stage, repatriate a significant fraction of the manufacturing capacity from low labour cost countries and in the longer run the demise of low-skilled assembly and operational jobs in manufacturing as a consequence of the diffusion of this technology. The democratisation of 3D printing is also likely to impact on logistic costs, in particular maritime freight of finished or semi-finished products and parts may well decrease although bulk freight of raw materials may be increase. This will have a considerable impact on the shipping industry, as well as on the carbon footprint of that industry although the net impact is unclear since the diffusion/democratisation of the technology could lead to the growth of small consignments of raw materials (costly , dedicated and/or dangerous to handle) to homes or local printing centres.

Moreover, 3D printing's potential to enhance the demand for innovative designs and technologies and their embodiment in software offers enormous opportunities for growth in tailor-made engineering and design services.

Governance and policy issues

The ability to rapidly identify the disruptive nature of the 3D printing revolution and to ensure that the incentives for the development of new services and manufacturing processes are in place so as to maximise the interests of citizens and businesses will be a source of international competitiveness and societal welfare. Moreover, education systems and labour markets will have to respond to the needs and challenges posed by 3D printing, while a continuous effort in R&D in that area will also be necessary at European level (H2020/Factories of the future/services of the future). The democratisation of 3D printing and its spur towards the development of new employment opportunities in terms of the engineering, design and specialised retail/production services all depend crucially on the secure distribution over the internet of authentic process code/software to local printing centres. This poses a major challenge in terms of ensuring the security of the internet. There will also be a need to both adapt the IP policy framework. Preventive security systems and dissuasive redress systems against trade secret misappropriation will be key and existing product safety regulation (which is enforced on shippers, distributors of finished or semi-finished products handlers of final products under the current regime rather than on final users) will need to be reviewed, Health and safety rules and marketing rules will also need to be revised. In addition, the emergence of potential bottlenecks around new printing materials will have to be addressed.

Environment and climate

3D printing enables to tackle major inefficiencies in traditional manufacturing in terms of energy and resource consumption while reducing CO2 emission associated with global logistic of semi-finished goods. The delivery of raw materials possibly all the way to the final consumer will somewhat counter this positive effect but could again be considered as an opportunity to modernise and “green” the environmental performance of local transport networks.

Safety and security

The implications for consumer safety policy will need to be considered, i.e. how can it be ensured that products produced by or for consumers are safe for their intended use? Indeed, 3D printing could potentially allow the manufacturing at home of weapons (e.g. guns), personalised food or any other goods that creates potential risks for life, health and the environment (e.g. toys, electrical fittings, spare parts of motor vehicles or even personalised medicines), Product liability regulation and health and safety rules will need to be reviewed fully in view of this and at an early stage so as to ensure that the technology's diffusion is not stifled by powerful interested parties (typically incumbent industry) who would exaggerate these risks to maintain the status quo, but also to promote acceptance by consumers.

The disruptive potential of this technology is such that the policy challenges should not be underestimated in a broad range of areas. For instance, health and safety regulations apply at the work place but not in the home, which however could become a local manufacturing unit. Likewise, the roll out of personalised medicines could be largely enhanced by the diffusion of low-cost 3D printing. However, many incumbents (not least large parts of the pharmaceutical industry and the pharmacy lobbies (who have so successfully prevented the roll out of licit on-line pharmacy services in the EU) are likely to be totally opposed to this possibility and will no doubt exaggerate the health risks. This suggests that a one size fits all policy solution is unlikely to be sufficient and the policy-makers will have to move rapidly to set the positive tone of the debate on this disruptive technology.

Synergies and conflicts with other fields

3D printing is a horizontal technology which can be applied in many other areas, and is expected to have interaction with and contribute to technological progress and innovation in particular in the following areas:

* Cloud computing;
* Nanotechnologies, including nano material and nanoscale devices & systems;
* regenerative medicine and tissue engineering;
* Prosthetic body implants;
* Food science;
* Robotics;
* Deep space travel;

Emerging policy issues

An inter-service meeting organised on 16 June 2014 enabled to identify a number of policy issues triggered by the widespread diffusion of 3D printing in the economy and society at large, as follows:

Consumer protection

From the moment the production would shift to consumers, the lack of quality check could be an issue, in particular with respect to authorisation and enforcement of EU legislation in the field. Moreover, if the transaction consists in buying a file for a 3D print out, it corresponds to the buying a service, which raises different type of legal issues as compared to the buying of products.

Industry

3D printers should normally fall under the Directive on machinery. An issue will be to assess how these machines will make inroads in consumer markets. Standardisation is important aspect in that context, but should not be seen as the only answer to the new challenges raised by 3D printing.

Competition

Certain vested interests could go against the lowering of 3D printing technology cost with the view to raise barriers to entry into the domestic 3D printer market.

Intellectual property

The use of 3D printers at home raises the question of liability (on IP, safety etc) within the distribution chain (role of the retailer).

Environment

The environmental impacts are not so clear-cut as presented by the 3D printing industry, in particular with respect to the access to resources and the longer term developments combined with the spreading of that technology.

RTD

The 'advance manufacturing system unit' of DG RTD runs 60 projects in that area. The experience is showing that in terms of development of new business models, Europe is lagging behind the US, and additional efforts would be required to ensure that the European industry will be able to take advantage of that technology.

High-level generic references

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Sustainable consumption and production

We are used to see consumption as a key driver of economic activity. Its current level, composition, associated production methods and resource use are not sustainable though. The distinction between consumers and producers is becoming increasingly blurred together with the dichotomy of goods and services allowing efficiency gains through shifting from ownership of products to use of services. Monitoring technologies will make citizens more aware of resource use and could change behaviours. Advanced manufacturing helps to pave the way towards an industrial renaissance in Europe while aging populations will be a driver for new products and services across various sectors. There may be trade-offs between environmental issues and new ways of accessing and using resources for an increasingly urbanised population.

Keywords: Sustainability, Life-cycle Approach, Beyond GDP, Resource, Efficiency, Consumption, Production.

Current status

Consumerism has been the root of our prosperity and has been considered the counterpart of the protestant work ethics.

Being green is fashionable but often not affordable for people with low incomes.

Sustainable and unsustainable modes of consumption and production co-exist.

Adoption of unsustainable occidental lifestyles and consumption patterns by a growing global urban middle class increases pressures on resource systems.

Strong rebound effects have prevented absolute decoupling until now.

Few incentives for sustainable consumption and production exist.

Imports and exports make assessment of environmental effects of consumption increasingly difficult.

Future trends (~2030)

Science, engineering, technology

Technological progress continues but remains diffuse.

Some particular resource challenges generate new technological answers and foster innovation and creativity.

Consumption and production become dislocated at global scale.

Distinction between hardware and software is increasingly blurred.

Connectivity through ICT solutions gradually replaces mobility.

Alongside mass production, custom-made production just-in-time allows more sustainable consumption through production "only on demand" (e.g. 3 D-printing) but also lowers real prices and hence boosts demand.

Tendency of a shift from primary use of resources to recycling and reuse (e.g. secondary mining).

Waste streams and sustainably sourced biomass complement and to some extent replace fossil and non-renewable resources.

Increasing pressure from global demand to make farming and food systems more efficient and reduce food waste throughout the food chain.

New production technologies for already existing products such as meat, e.g. artificially grown meat, alter their environmental and social footprint.

Urban and peri-urban agriculture creates potential for shorter food supply chains.

Distinction between consumers and producers becomes blurred: citizens can both produce and consume resources (prosumers).

Agricultural technologies, innovative foods using alternative protein sources, aquaculture and urban farming will become more prominent and will provide for more alternatives alongside traditional agriculture thus creating a diverging urban landscape.

Smart grids and cities, renewable energies and energy storage and wireless energy transfer are key elements of a shift towards a sustainable supply of energy and lead to more decentralised market structures.

Advanced manufacturing, for example 3D printing, robotics, complex systems modelling, sensors, synthetic biology, "the internet of things", and the miniaturisation of technologies facilitate an industrial revival in Europe and increasingly blur the distinction between goods and services.

Space and sea-based services and technologies, for example deep-sea mining allow access to new resources.

Institutional, social and behavioural

Efficiency gains through shifting from ownership of products to use of services.

Changing attitudes towards consumption as a means of politically and/or ethically correct behaviour, e.g. fair trade or conscious consumption, and emergence of new role models for (sustainable) consumption.

Corporate social responsibility and environmental concerns become criteria of successful “business models”.

Fiscal systems are reoriented towards supporting sustainability as social and environmental risks are increasingly priced in.

Services (and on demand manufacturing) require consumers to become increasingly involved actively in design and production.

There are fewer differences between countries and continents, but greater disparities within countries. Future divisions in society will be more than rich-poor divisions, e.g. also about those who have access to knowledge and those who don’t.

Interdependence between changing global income developments and consumption patterns (e.g. rising income can lead to a shift from mainly carbohydrate to a more diverse diet which includes vegetable oils, animal products, meats, dairy and sugar) will impact production both inside and outside the EU.

Monitoring technologies will make citizens more aware of resource use and could change behaviours.

Complex systems modelling and simulations will help us to understand what is happening and what could happen.

Urbanisation will increase citizens' desires for healthy environments in confined spaces.

The ageing population (in Europe) will be a driver for new products and services, across various sectors such as healthcare and living environments.

Human-human interactions will remain important but are already seeing increasing acceptability of online interactions as a substitute for real-life interactions. This will change citizens' perceptions of what community means.

Need for an increased availability of information on production processes in order to better guide consumer choices.

Expected overall impact in/for Europe

Society
Consumption as social interaction declines; more emphasis is put on community based production and consumption methods.

The economy
New opportunities and new sources of growth through sustainable and future-proof solutions and through niche products and small scale production emerge, greater recognition of eco-system services by sectors depending on these services.

Governance and policy issues
Increasing complexity and declining visibility of economic activities increased calls for responsible public leadership due to close links between well-being, inclusiveness, environmental stewardship and intergenerational fairness.

Environment and climate
Impact of trends uncertain, but positive if a new behaviourally significant consumption ethics emerges and if technological breakthroughs and responsible innovation permit continued and increased prosperity within the boundaries of the planet.

Safety and security
Political conflicts over scarce resources become increasingly common and spill over into Europe while threats from natural hazards become more frequent.

Synergies and conflicts with other fields

Interactions between environmental (product policies, mainly ecodesign) agricultural, health, food, consumer and trade policies are important for shaping the future of European production and consumption patterns: how can environmental footprints be used for shaping these policies?

Can we decouple work (jobs) and production/consumption?.

There will be trade-offs between environmental issues and new ways of accessing and using resources for an increasingly urbanised population.

Emerging policy issues

Can we produce green at zero environmental cost, or even combine production with environmental restoration?

Can the dematerialization of products catalysed by ICT (e.g. e-books) spill over to other sectors?.

(How) can going green be mainstreamed and become affordable for everyone?.

How can green solutions be made profitable and become the obvious or preferred choice of enterprises?.

What are the 5 top scientific or innovative breakthroughs we need to survive the next century? Energy?. Food? Mobility? Housing?...

Should we move to a service based society instead of product based and a greater role of eco-system and society services?.

How important will rebound effects be and how can they be avoided?.

Is *downscaling* (certain) consumption activities an option in order to meet sustainability targets? Consequently, should targets be set for consumption patterns in Europe, e.g. for selected groups of products?.

Should Europe strive for knowledge and value based world leadership in sustainability and if so what does that aim imply and require?.

How can reuse, recyclability and better use of waste turn discarded products into a resource? Which technologies are needed for that and how can they be assessed vis à vis technologies mainly geared towards improving resource efficiency in production?.

Education and awareness about sustainability must improve because the concept is not always well understood by citizens or even by experts. The current economic system is based largely on private costs and often fails to fully take account of the public costs related to economic activities and the pressures on resources. Achieving sustainability may require a move towards economic systems with different values.

Better governance of emerging technologies is needed to balance insufficient regulation with over-regulation that stifles innovations.

In line with the obvious interference between income developments and production/consumption trends a major policy issue should remain to address global poverty by (sustainable) economic growth.

High-level generic references

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SEAS: a new space for opportunities

Oceans, seas and coasts are an integral part of Europe's identity and culture, with 23 of the 28 Member States having a coast, and two thirds of European frontiers being bounded by the sea. The European Union, the global leading maritime power, has the world's largest maritime territory, with an Exclusive Economic Zone covering 25 million km^2 including the associated Overseas Countries and Territories of the Member States.

Oceans, seas and coasts can offer an essential contribution to tackling the scarcity and vulnerability of strategic resources, including food and energy and material resources, and provide recreational and industrial opportunities. All developments have to be responsible and in line with sustainable development especially because seas and oceans are already under much pressure and marine ecosystems and processes remain largely unknown.

A better understanding of what is happening in the sea will provide a better knowledge of ocean resources and underpin better policies for their sustainable development. Research and innovation are progressing towards exploring the best possible ways that the seas can continue to be a healthy and productive life support system. Generating and capturing synergies among the various blue economy activities and addressing conflicts will be critical for unlocking the potential of the largely unexplored seas.

Keywords: Seas, Oceans, coasts, ecosystems, offshore wind energy, fisheries, aquaculture, blue biotechnology, seabed mining.

Current status

The EU's "blue" economy is vast and embraces a broad array of marine and maritime activities at various stages of development, including established mature activities such as shipbuilding, shipping, fishing, aquaculture and tourism, as well as emerging activities such as renewable energy, biotechnology and sea bed mining. Europe is the global leader in offshore wind energy with more than 90% of the world's installed capacity. In 2012, offshore wind represented 10% of the annual wind capacity installed in the EU, and employed, directly and indirectly, 58,000 European citizens.

The EU Blue Growth strategy is the long term action framework to support smart, sustainable and inclusive growth across the marine and maritime sectors. The EU is stimulating action to provide better knowledge, spatial planning and management and better surveillance. Despite increasing efforts, the properties and functioning of marine eco-systems remain largely unknown. Around 30% of the seafloor surrounding Europe has not yet been surveyed. This varies from 5% of the Bay of Biscay and the Iberian Coast to more than 40% of the North Sea and the Ionian and central Mediterranean. A better knowledge basis of what is happening in the sea will provide a better assessment of the potential and help devise better policies for the sustainable development of marine resources. Skill gaps are already apparent, as for instance in the offshore wind energy sector, and transparency, trust and societal acceptance are crucial issues, as seen with seabed mining. The world has however moved significantly closer to deep ocean mining as a Canadian company concluded an agreement with Papua New Guinea to start digging up and extract precious metals from a depth of 1,500.

Future trends (~2030)

It is expected that global knowledge on marine ecosystems will considerably increase as developments in fields such as information technology, underwater technology, and molecular science provide better tools to explore, analyse and model the abiotic and biotic properties of the seas. New technologies such as robotics and materials that can withstand corrosion or biofouling developed primarily in the offshore oil industry, as well as better understanding of genetic processes offer more possibilities for realising the potential of marine resources.

Overall, blue activities are expected to expand if developments do not compromise the capacity of the ecosystems. The various value chains are at different stages of their development and innovation is vital for extracting more value from healthy ecosystem services. The tourism and leisure sector is already one of the largest sectors and this is set to expand still further as Europe is a confirmed first tourist destination of the world. The naval industry which dominates shipbuilding activity in a number of countries may well consolidate to fewer yards in a similar way to the aerospace industry and an increasing proportion of the industry could be devoted to specialities such as leisure craft, yachts, cruise ships and vessels able to sail through the newly navigable north-east passage or service extraction activities in extreme environments.

Globally, aquaculture could provide two thirds of fish products by 2030, but it faces particular challenges in the EU, due to lack of available space, competition in the global market and administrative constraints in particular concerning licensing procedures. Aquaculture could further move offshore in order to take advantage of cleaner water, less environmental impact and disturbance of other coastal activities. Many projects could be associated with offshore platforms that also host renewable energy machinery. Sustainable aquaculture must also consider potential impacts on wild fish stocks and water quality.

The European Union, the world forerunner in green energy and sustainability eco-systems has a great potential in offshore wind energy. Two landmark projects reached financial close in 2013. 12 offshore projects currently under construction will bring cumulative capacity to 9.4 GW. Electricity generation from wind and the offshore fraction will increase. The European Wind Energy Association expects the percentage of new offshore installations to rise to 60% by 2030. These developments might be followed by tidal energy and maybe in a later stage by wave energy. Most of the existing ocean energy technologies are still in the demonstration phase. The sector could also see a skill shortage growing from 7,000 now to 14,000 full-time equivalents if the future workforce is not equipped with skills in maintenance and manufacturing for example. Biofuel from algae could be added to the energy mix once ways of extracting the oil are improved. It uses fewer resources of land or freshwater than terrestrial sources.

Biotechnology products based on the highly diverse range of marine organisms will be increasingly used in pharmaceuticals and industrial enzymes. It is hard to predict the extent of seabed mining. It will largely depend on the abundance and location of terrestrial supplies, geopolitical stability, trade conditions, evolving evidence on environmental impacts and societal acceptance.

A cleaner marine environment in Europe and healthier ecosystems is the sine qua non condition for the development of all blue economy activities. The Marine Strategy Framework Directive establishes a framework within which Member States shall take the necessary measures to achieve or maintain good environmental status in the marine environment by the year 2020 at the latest. In 2014, the mid-term review of the Directive highlighted that progress was made but the way to the 2020 target is longer than the distance already travelled.

Expected overall impact in/for Europe

A better understanding of the sea and how it is changing will benefit all activities in the blue economy. The mapping of the seabed of the European seas by 2020 will be a major step towards safeguarding the integrity of marine ecosystems and the provision of their goods and services.

The potential and impact of the blue growth depends on resources that have not been fully explored and enhanced. Its realisation will vary across Europe as each of Europe's sea basins has its own economic, social, environmental, geographic, climatic and institutional characteristics that will contribute to a differentiated path. Maximising synergies through context-specific coordination and planning is of high importance.

Coastal populations are expected to be more numerous, ageing and more city-dwelling. Living conditions may be impacted by advancing climate change, depending also on adaptation policies, and scarcity of resources. There will be fewer but more highly skilled jobs in shipbuilding and fisheries. The education-level required to be competitive in tourism will increase as regions begin to specialise in active, cultural, or health and green leisure. There will be significantly more jobs in renewable energy. Other activities which could hold a special potential for the EU could develop, such as underwater archaeology.

Inter-relations with other fields

Expected synergies

Multi-use offshore platforms can support multiple synergies among blue growth activities;

Products of synergies include biofuels from cultivated algae in integrated multi-trophic aquaculture;

The integration of activities such as angling and tourism in extensive aquaculture ponds could add environmental and landscape management services.

Possible conflicting aspects

Shipping, tourism and recreational activities are often seen as antagonistic to aquaculture, while some farming practices are also detrimental;

Adverse environment impacts of aquaculture include localised eutrophication events, changes in benthic communities, contamination from antibiotics and introduction of non-indigenous species.

Emerging policy issues

Security of food supply, internationally and in the EU, also linked to the recession;

Security of energy supply, internationally and in the EU, also linked to the recession;

Security of supply of raw materials and rare earths;

Resource efficiency and marine litter;

Marine / land circular economy (up-cycled marine waste into resource and energy);

Food safety and competition in relation to imported in the EU aquaculture products;

Trust and transparency in enhancing marine resources;

Social acceptance of sea mining and levels of irreversible disturbance of the ecosystems;

Biofuel-oriented aquaculture;

The impact of climate adaptation on blue growth activities.

Valuation of marine ecosystems.

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Chapter 7
Aeronautics and Space applications

Introduction

The **space and aeronautic** sectors are certainly at the forefront of **progress**, technologically as well as from a fundamental research point of view.

The space sector in particular is an example of success by pulling together competencies, policies, and financial means between Member States and the European Union. **Space is multifacetted**, from discoveries to daily life applications, to the fascination of the exploration of the solar system and beyond. It is therefore a means to **boost citizens' engagements** in science and technology.

Like satellites and drones are the **next frontiers**… The world of **'sensors everywhere'** is in front of us: satellites, drones, smartphones, you…

Space-based services

Satellite navigation, Earth observation, telecommunication satellites are giving rise to an increasing number of services down on Earth. These services are pervading the daily life of citizens at unprecedented levels and will continue to do so.

1 tn GNSS chipsets in 2024 – Space data and space-based services data counting for an increasing part of the Internet broadband.

Keywords: Space-based services, GNSS, Earth Observation, Big Data, GPS, Galileo, Landsat, Copernicus, Privacy, Open Data, in situ, geo-tagging, geo-location.

Current status

Space-based services encompass services using satellites: telecommunications, Global Satellite Navigation Systems (GNSS) like GPS and Galileo, Earth observation like Copernicus and meteorological satellites. Space-based applications have rapidly developed over the last decades moving from research to operational commercial and public domains. This evolution was facilitated by the development of mobile technologies, Internet, IT processing capacities and the miniaturisation of chipsets and sensors integrated in smartphones and handheld devices. Decisions by the US government to give free access to Landsat data and GPS civil signals have also fostered the democratisation and wide-spread use of space-based information and services. In parallel, the processing power and storage capacity of receivers have tremendously increased. The importance of the space-based services for European competitiveness is recognised at European and national levels.

Future trends (~2030)

New applications on smartphones and personal computers through the Internet combining GNSS and/or Earth Observation are developing fast. There are already very interesting applications providing Near Real Time information to the end users on air quality, mobility, navigation, etc. Lower costs for broadband communications for airborne and seaborne vessels with possible extension to polar latitudes will lead to new services and applications. The continuous tracking of airborne and seaborne vessels is becoming of utmost importance as underlined by the disappearance of Flight MH370 in 2014 and the resurgence of maritime piracy in East Africa. Space operators already propose the scanning of Automatic Identification System signals (electronic identification of maritime vessels) by low earth orbit satellites. GNSS data could be cross-checked and embedded (geo-tagging) in Earth observation data (radar, optical and hyperspectral). Transport will evolve to connected mobility allowing users to better organise their trips according to forecast and real-time traffic and traveller information. Real-time mobility information will also improve the delivery of goods and optimise infrastructures. The access to space data in near real-time combined with 'in situ' observation will generate many new applications, being for professional or private purposes and will improve our knowledge in the field of environment (air quality, land and marine monitoring), crisis management (e.g. rapid mapping in response to earthquakes, forest fires tsunamis, floods, etc), agriculture (precision farming) etc..

The volume of available space data is growing exponentially, which becomes a challenge in terms of mass storage, processing capacities and communication for disseminating data (cloud computing). **'Big data'** has already become a challenge for space-based services but constitutes also opportunities for enhanced services. The combination and integration of data from various sources (space data from various sensors, aerial photos, UAVs, space and in situ or ground observation, including citizen science) will lead to models and other processing tools including web-based services that can create new services. EU open data policies will facilitate the access to free data and the development of added-value services offered by small companies and greater availability of data for monitoring the state of ocean, land and atmosphere.

The **Internet of Things** is expected to connect in 2024 one trillion human-made objects in real-time. Beyond this, most of these connected objects will be likely also equipped with GNSS chipsets (today the cost of a GNSS chipset is 1 USD for mass market usage, in 10 years it may be less than 1 cent), and most will be connected to the Internet through space and/or RFID chipsets.

The precision of navigation and resolution of images will continue to increase (maybe 1 cm precision for GNSS and 10 cm resolution available to the public by 2030 compared to up to 1 m precision by GNSS only and up to 1 m resolution for civil optical images today). Moreover, data from space will be more and more transferred and processed in real-time (which is still not completely optimised today for Earth observation).

Expected overall impact in/for Europe

Society

Today our daily life already crucially depends on space systems and space-based services. Society has seamlessly integrated satellite telecommunication, navigation and remote sensing facilities in its terrestrial networks and services:

- Direct TV coverage around the globe;
- Traffic management systems (Land, air, sea);
- Reliable weather forecast for increasingly longer terms;

Precise time signals for the synchronization of major communications networks, banking systems, financial markets and power grids.

Privacy appears to be a growing concern for citizens. Real time availability and the increasing resolution of space imagery as well as the high precision of satellite-based localisation services are likely to create more opportunities to invade into the private lives of citizens; an aspect to be taken into account in prospective discussions on the impact of space-based services.

The economy

Space is now widely recognised as an enabler creating a wide range of benefits and is considered a highly strategic sector for governments, businesses and people, globally and in Europe. Space-based services constitute a driver for growth and innovation, thus contributing directly to Europe's growth strategy for a smart, sustainable and inclusive economy. As a result of past investments over decades, Europe holds a strong competitive industrial and scientific position in space globally, with European space industry upstream revenues estimated at around € 8 bn in 2012 - around 20% of which exports - or roughly 45% the global estimated upstream market. Overall space industry revenues in 2012, including the mid- and downstream segments, are conservatively estimated in Europe around € 50 bn, out of a global market estimated around EUR 160 bn. Space activities in Europe generate around 330 000 jobs, a majority of them stemming from the downstream sector in particular the satcom media industry, including large satellite TV networks that took advantage of satellites' inherent broadcast features.

With emerging and fast developing applications further direct impact is expected on growth and jobs, in the space industry, downstream sector (including SMEs), IT sectors and derived markets. The market for geospatial products and services will continue to grow, benefitting decision makers in various sectors (precision farming, geo-location for maritime, aerial, terrestrial transport etc.). It will also stimulate the "blue" economy.

The free full and open data principles promoted in EU programmes and GEO should largely contribute to the development of new applications (the 'downstream' sector) including by SMEs.

However, the European space industry has to face increasing competition from developed and emerging countries, such as the USA, China and India. Thus the European space industry needs to aim at strengthening its competitiveness at the global level. The European space industry is well positioned to compete in the global market, but a bigger emphasis should be given to the role of innovation and technology and on granting access for SMEs ensuring the strengthening of the sector.

Inter-relations with other fields

Expected synergies

* Big Data;
* Ubiquitous connectivity to the Internet;
* Miniaturization and improvement of receivers/smartphones;
* *In-situ* sensors.

Possible conflicting aspects

* Satcoms vs broadband fibres and ground-based or airborne broadcast;
* GNSS vs Wifi positioning;
* Earth Observation vs sensors embarked on drones or balloons.

Emerging policy issues

Governance and policy issues

Space-based services are not yet benefiting from a European homogeneous legal environment and thus from the full effect of the internal market to unleash the innovation potential in the downstream segment. There is thus a risk that nascent and innovative markets for space-based services become fragmented.

Environment and climate

Space applications will contribute to a better understanding of the Earth system, its weather, climate, ocean, land, natural resources, ecosystems and hazards. Information on the state of environment and its changes are crucial for protecting environment, health and achieving sustainable development. Access to timely, accurate information on the state of environment across borders and at global level is also crucial for policy makers and for better implementation of EU policies. Access to space data and information through worldwide Internet and social networks will bring also science closer to the citizens contributing to more participative initiatives (e.g. crowd sourcing and citizen observatories).

Safety and security

Surveillance satellites allow the verification whether movements of other powers in the world are peaceful or not.

Regarding safety, satellite-based systems are playing an increasing role to keep airspace open during volcano eruptions by analysing detailed satellite observations and weather models using lessons learnt from Eyjafjallajökull and subsequent eruptions of other volcanos.

Earth Observation is extensively used for security purposes (military and civil security) primarily at national level. Some security services have also been developed at EU level e.g. in support to maritime surveillance (EMSA and Copernicus), border surveillance and external actions (EUSC, Copernicus).

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Space-based services

The space sector is entering a new era with the inclusion of new technologies, operational concepts, manufacturing processes that in turn can enable new applications and services. International competition is increasing with new entrants (both new countries and new companies) and is challenging Europe's position.

Keywords: Space, innovation, R&D, applications, citizens.

Current status

The space sector is entering a new era with the inclusion of new technologies (IT, novel energy production and storage, advance robotics, new propulsion systems, miniaturisation, optics, lightweight structures, etc.), operational concepts (fragmented spacecraft etc.) manufacturing processes (3D printing, IT procedures etc.), interoperability among systems in space and on Earth, that in turn can enable new applications and services, notably through the mutualisation of space assets, ground assets and space data. In addition, the frontier between civil and military satellites may disappear progressively due to the greater accessibility and lesser cost of high resolution sensors. This is changing the space sector from an high-end sector with high entry barriers to a sector that provides new applications and services (most still unknown today) to citizens, essential for the functioning and security of our society. International competition is increasing with new entrants both new countries that are developing new capabilities in the fields mainly in Africa, Latin America and Asia, as well as new companies such as start-up in the United States (and even Google). The changing geopolitics of space is challenging Europe's position.

Future trends (~2030)

With the advance of commercial-of-the shelves (COTS) technologies and spin-ins from other major technological sectors, satellites will be more capable, versatile and cheaper. The decrease cost of space technology and of access to space will bring the use of space assets within reach of a much wider community, i.e. new countries and commercial enterprises, including SMEs. Furthermore there will be fewer differences between civilian and military space technologies.

On the science

The advances for space technologies will benefit the domain science research including 'science of space' that tackles some fundamental questions about the origin of, and our place in, the Universe (How did the Universe begin? How did our Earth and our Solar System evolve? Where are other Earth-like planets? Is there life anywhere else?), 'science from space' that helps us to understand phenomena such as climate change and its consequences, as well as other environmental factors on Earth), and 'science in space' that studies the effects of microgravity on humans, other living organisms but also new fields of research linked to physical sciences such as new materials etc.

On the applications

The advances for space technologies will benefit the overall space sector and will lead to new applications of space-enabled applications and could enable technological spin-offs and new services being fostered. With Galileo and Copernicus the EU has the autonomy over two essential programmes geared to future space-enabled applications: Copernicus provides geo-spatial information, Galileo provides positioning, navigation and timing services. By the 2020s these two infrastructures will start to be upgraded providing increased capabilities.

Expected overall impact in/for Europe

Society

A deep space venture will appeal to younger generations and incentivise them to study STEM and engage into scientific and engineering careers. Human ventures beyond Earth orbits and potential colonisation of Mars will be one of the major challenges of the century.

The economy

Decrease cost of accessing space and developing and operating space missions. This would bring space assets within reach of many more countries and also diverse commercial companies, including SMEs.

Governance and policy issues

Internationalisation of actors with more and more countries engaging in space activities, as well as NGOs such as companies, research organisation, scientific societies or even citizen scientists.

Environment and climate

In the space environment there is a risk of increasing debris proliferations and spectrum interference. The monitoring of the Earth environment might however benefit from new data provided by new missions.

Safety and security

The unique vantage point from satellites means that a large area of the Earth's surface can be monitored (for example for Search and Rescue operations, or for detecting lost airplanes) and controlled. Space technology is also an essential element of any modern military operation, where imaging, navigation, and communication rely heavily on satellites.

Synergies and conflicts with other fields

The space sector is a domain allowing strong linkages between large companies and SMEs, academia and research centers and fostering European industrial leadership to support fundamental and applied research and business applications. Furthermore, space is a cross-cutting domain by sheer nature and is a tool providing solutions to terrestrial issues in various areas such as telecommunications, transportation, environment, security, etc.

Emerging policy issues

Space technologies development might be considered as specific to the sector. However, the requirements for high reliability, low mass, low consumption and resistance to harsh environment have often been a driver for major technological steps forward and for applications in many non-space sectors. In this respect, investments in space technologies benefit the overall European industrial competitiveness and leadership as well as it enables space missions and technologies developments addressing many societal challenges such as security, raw materials and excellence in science. Furthermore critical space components are also related to Key Enabling Technologies (KETs), which generally touch on varios technology domains (electrical, mechanical, software) and have a variety of space and, in many cases, non-space applications (e.g. Field-

Programmable Gate Array). In the same way, some of these technologies have progressed thanks to COTS available technologies and products, fostering capabilities exchange with non-space sectors. The security of supply, industry capability and technology readiness of European technologies and products need however to continue to be supported to guarantee future autonomy of Europe in the space sector.

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Asteroid mining

Exploitation of non-terrestrial resources has been predicated for quite some time. However tools and hardware have been developed notably in the USA (both by NASA and private companies) to characterise and identify appropriate Near Earth Objects (NEOs) to eventually dock with them and exploit their resources. Asteroid mining is also linked to the protection of Earth from geocruisers and thus to the detection and tracking of such dangerous space objects.

Keywords: Space, innovation, R&D, applications, citizens.

Current status

Exploitation of non-terrestrial resources has been predicated for quite some time. It started long-time ago with the search of meteorites for scientific research on Earth (e.g. in deserts and Antarctica). Robotic and human missions to the Moon have also brought back lunar rocks and soils. However nowadays with the increase price of rare Earth elements and other minerals, private companies in the USA (backed by wealthy entrepreneurs) have in recent months been able to raise capital to develop tools and hardware to characterise and identify appropriate Near Earth Objects (NEOs) to eventually dock with them and exploit their resources. These private sector endeavours are based on robotic missions/concepts. Complementing this trend, NASA has proposed an Asteroid-capture mission and deviation to the Moon involving Astronauts to test and develop new technologies for both future deep space missions, as well as planetary protection. Europe is also been involved to characterise NEOs through European Space Agency (ESA) missions and projects funded by the EU framework programme for research.

Future trends (~2030)

By the early 2020s NASA should have performed its Asteroid-capture and the first private space telescopes will be operational. Later in the decade the first missions to extract resources will evolve from concept to realisation.

On the science

New knowledge on NEOs will be gathered allowing understanding better the formation of the Solar System and the existence of life.

On the applications

The advances for this sub-field of space activities will benefit the overall space sector. With the advance of commercial-of-the shelves (COTS) technologies and spin-ins from other major technological sectors, satellites will be more capable and cheaper. The decreased cost of the access to space will also favour private missions beyond Geosynchronous Earth Orbits.

Technologically, a successful output may include commercial interests. In the future, asteroids may be mined for water and other volatiles for serving manned space exploration or used as propellant, portable water, and breathing oxygen depots to dramatically lower launch mass. Asteroids may also be mined for precious metals for direct use on Earth (especially platinum group metals which are central to many ground-based clean technology development efforts) as well as for other metals and rare-earths for in-space construction of space vehicles.

Expected overall impact in/for Europe

Society

Inspire younger generations using the appeal of the space sector to study STEM and engaged into scientific and engineering careers.

The economy

Potential decrease of price of rare Earth elements and other minerals and lower the cost of entry of space, including exploration, activities through the increase in the number and rate of exploitation missions. However, our current knowledge of asteroids does not make the case yet for this kind of missions. To generate real benefits within this field, dedicated asteroid-prospecting campaigns should be launched

Governance and policy issues

The 1967 Outer Space Treaty that precludes exploitation of celestial bodies ratified by most space-faring counties will need updating.

Environment and climate

While pressures on the Earth's environment could be alleviated by extracting non-terrestrial resources, bringing back mining materials from space could however cause severe environmental impacts due to man-made collisions of asteroids with Earth.

Safety and security

Potential dangers of deviating NEOs towards Earth and the import of extra-terrestrial living materials onto Earth (potential contamination).

Synergies and conflicts with other fields

The space sector is a domain allowing strong linkages between large companies and SMEs, academia and research centres and fostering European industrial leadership to support fundamental and applied research and business applications. Furthermore, space is a cross-cutting domain and is a tool to provide solutions to terrestrial needs and issues in various areas such as telecommunications, transportation, environment, security, etc.

Emerging policy issues

Asteroid mining will pose legal issues and compliance with the 1967 Outer Space Treaty that has been signed and ratified by all space-faring countries. This treaty states that "outer space is not subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means". This policy question is expected to be raised soon by the USA in light of their institutional and commercial plans.

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Deep space travel

U.S. President Obama has indicated that the USA, and mandated NASA, to send a human mission to Mars by mid-2030 with intermediary steps to Lagragian points in 2020s. NASA is consequently developing appropriate capabilities with the SLS launcher and the Orion crew capsule that should be ready by early 2020s. This would allow human to ventures farther into deep space compared to previous endeavours in the last century.

Keywords: Space, Innovation, R&D, Applications, Citizens.

Current status

U.S. President Obama has indicated that the USA would send a human space mission to Mars by mid-2030 with intermediary steps to Lagragian points in 2020s. NASA is consequently developing appropriate capabilities with the SLS launcher and the Orion capsule that should have its first crewed flight by the early 2020s. This would allow humans to venture farther into deep space compared to previous endeavours in the last century. The U.S. private sector is also advocating for a fly-by of Mars before 2020 in order to develop and test new technologies and demonstrate the U.S. leadership in space exploration. In Europe, the European Space Agency (ESA) is supporting research (i.e. Mars500) and technological developments for deep space travel? in particular with a cooperation with NASA on the MPCV-SM (cargo capability to go beyond LEO). A Dutch company (Mars One) is also pushing for one-way Martian trips in 2024 as launched a media campaign to attract candidates.

Upon the initiative of Europe, an international mechanism of coordination and cooperation in space exploration matters has been created in recent years with the objective to further advance the international dialogue on space exploration.

Future trends (~2030)

By the early 2020s NASA should have performed its first crewed mission of Orion and SLS. These two elements are among the major building blocks missing today (large rocket to access to space and new space vehicle). Later in the decade the International Space Station (ISS) should be de-orbited (current life time expected until 2024 but could be extended to 2028) and the preparation of the first Mars missions ongoing with intermediary steps to Lagragian points in 2020s and further into deep space.

On the science

The International Space Station (ISS) provides a unique resource for exploration preparation. Questions that need to be solved to enable exploration are related to psychosocial, health/medical, nutrition, human automation/robot interaction, training and life support issues, in association with ground based facilities where appropriate. The ISS investigations include psychosocial, health and life support aspects that provide most integrated and cross cutting benefits. Preparation for deep space travel will lead to better understanding of life in environments outside the known terrestrial envelope and better understanding of the origin and early evolution of life. The search for extra-terrestrial life is perhaps one of the most integrative disciplines, linking science, technology and society (even philosophy and religion).

On the applications

A new that will push for technological developments in many domains (e.g. new materials, human-machine interface, life support systems etc.) akin the Apollo era of the 1960s could be created. Spin-offs in non-space domains are also expected to provide benefits to citizens in many unknown domains today.

Expected overall impact in/for Europe

Society

A deep space venture will appeal to younger generations and incentivise them to study STEM and engage into scientific and engineering careers. Human ventures beyond Earth orbits and potential colonisation of Mars will be one of the major challenges of the century.

The economy

Lower access to space (for crew and cargo) can lead to new activities in space providing new applications for citizens on Earth.

Governance and policy issues

The 1967 Outer Space Treaty that precludes exploitation of celestial bodies ratified by most space-faring counties will need updating.

Environment and climate

Deep space mission and in particular a return to Earth raise the issue of both forward and backward planetary contamination.

Safety and security

Potential dangers of import of extra-terrestrial materials on Earth (potential contamination) can arise.

Synergies and conflicts with other fields

Space exploration is an engine of innovation that allows the synergies between many different non-space sectors that can provide increased benefits to citizens. The space sector is a domain allowing strong linkages between large companies and SMEs, academia and research centres and fostering European industrial leadership to support fundamental and applied research and business applications. The health and the growing personal health industry provide some of the key capabilities here. The effects of spaceflight are akin to accelerated ageing providing valuable spin-off knowledge for terrestrial applications and society.

Emerging policy issues

Space exploration is a strategic political sector of high visibility as well as a landmark of international cooperation and soft power. The process towards what has been called a “high-level political platform” for space exploration was launched by Europe at the informal ministerial Council held in Kourou in 2008. It was followed by three dedicated international high-level political conferences at ministerial level organised by the Commission, ESA and Member States (Prague on 23 October 2009, Brussels on 21 October 2010, Lucca on 10 November 2011). This cycle of European conferences has laid the ground for the establishment of an enlarged, international mechanism of coordination and cooperation in space exploration matters. The United States offered to continue the process started in Lucca, by hosting the subsequent meeting. The International Space Exploration Forum (ISEF) took place in Washington, D.C. on 9 January 2014. Japan announced on that occasion that it would host the next forum meeting (in 2016 or 2017) and proposed to prepare it in collaboration with the USA and Europe (Commission and ESA). The objective of these events is to further advance the international dialogue on space exploration.

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Drones

Drone technology is now expanding quickly into the civil market, generating an increasing number of innovative services, new businesses and jobs. These emerging services have the potential to substantially increase productivity in a wide range of sectors (agriculture, energy, construction, etc.) and so support the competitiveness of European economy. As the drone industry is a crossroads of technologies, drone services will improve many aspects of the daily life of citizens.

Hundreds of innovative services[1] and 150.000[2] new jobs by 2050.

Key words: Drone, Unmanned Aircraft System (UAS), Remotely Piloted Aircraft System (RPAS), innovation, privacy.

Current status

The development of drones (or Unmanned Aircraft Systems[3]) started in the 50's and matured rapidly in recent years. Recent conflicts and peace-keeping operations around the world have demonstrated their military capacities and led to a quasi-exponential increase of military applications. Today many European armed forced are equipped with drones, mainly for intelligence and surveillance purposes. So far only UK has used armed drones in operations. These drones are mainly procured abroad (US and Israel) as no competitive European product exists yet and the European industry is lagging behind its international competitors. In order to address this issue, the European Defence Agency is developing a European strategy for military drones and their insertion into the airspace, including a next generation military large drone programme (MALE). This strategy has been supported by the European Council in 2013.

At the other end of the market, thanks to progress in robotics and IT, drones are becoming a reliable new technology for civil use. There are hundreds of drones' types from miniaturised platforms to drones of the size of an aircraft. The development of civil applications is driven by state applications (mostly for larger drones) and commercial services. The use of civil drones by governmental agencies is often based on the re-use of military assets withdrawn from military operations while an emerging market of commercial applications is based on small drones produced and operated by SMEs and entrepreneurs. In order to unleash the full potential of civil drones, they should be able to fly like 'normal' air traffic and be integrated among 'normally piloted' aircraft in non-segregated airspace, i.e., airspace open to all civil air transport. Over the 3 last years, 10 member States have issued partial regulation allowing limited operations. This significantly stimulated the market but rules remain partial and fragmented between States, which does not provide for an optimal business climate.

[1] See "UAS Panel Process - Workshop 1 - Discussion Paper", UAVSI, Annex 5 and EC/EDA high level conference held on July 1st 2010.

[2] Estimate provided by ASD, the AeroSpace and Defence Industries Association of Europe.

[3] Remotely Piloted Aircraft Systems (RPAS) are those UAS which are not fully autonomous, but have a pilot in command (on the ground).

Future trends (~2030)

On the technology

Up to now civil and military drones are operating in segregated airspace outside the main aviation traffic (i.e. airspace closed for rescue operations). In order to allow drones to fly amongst the other aircrafts, a number of key technologies have still to be developed and validated. They include the capacity to detect and avoid other aircrafts, secure command and control data links or autonomous decision capabilities for flight control.

As civil aviation is evolving itself towards more automation, the development of these technologies is also crucial for the competitiveness of the European aeronautics industry as a whole.

On the applications

Drones represent a key asset for armed forces and will become the centrepiece of modern Air Forces in the medium term.

Drones have also a huge potential for civil applications. Being remotely piloted, drones can perform tasks that manned systems would not be able to perform. They are well suited to perform long monitoring and surveillance tasks or risky flights into ash clouds or in proximity of nuclear or chemical plants after major incidents. Small drones are already used to provide aerial views. They can fly lower than a helicopter with less intrusion and less cost. Drones present a high flexibility and are often cheaper than alternative solutions. They efficiently complement existing airborne and space borne platforms to support governmental applications like law enforcement (fisheries or environmental control), firefighting, and crisis management or border control. They can also deliver profitable commercial aerial services in various areas. Applications are, for instance, emerging in precision agriculture and fisheries, power/gas line monitoring, infrastructure inspection, communications and broadcast services, wireless communication relay, natural resources monitoring, environmental inspections, surveillance, journalism, cinema, aerial photography, digital mapping, land and wildlife management, air quality management/control. Hundreds of potential civil applications have already been identified. Many more are expected to emerge once the technology is widely disseminated. Drone technologies combine robotics, software development and management of systems, miniaturisation and new material developments. Creativity, innovation and entrepreneurship will play a major role in the development of commercial aerial services where SMEs will have their role in parallel to major aerospace companies.

Expected overall impact in/for Europe

If the full potential of civil drones is unleashed, they will bring important benefits to European citizens and the European economy as a whole. They will support governmental applications and commercial services, creating new businesses and jobs. The precise scale of the potential market is difficult to predict. However, the growing civil drones' activities will translate into a substantial number of new jobs. For Europe, about 150,000 jobs by 2050 are forecast, in addition to the employment generated through operator services.

As civil aviation is evolving towards more automation, drone technologies are crucial for the future competitiveness of the European civil aviation, for large commercial airliners (with reduced crew on-board), for cargo operators (which could be early adopter of drones) and for small aircraft (paving the way for personal unmanned planes in the future).

Synergies and conflicts with other fields

The development of civil applications of drones requires their integration into the European aviation system in close relation with the development of the Single European Sky.

The use of governmental drones for military and surveillance missions is controversial and raises ethical questions that require public debates. Commercial applications may, on their side, involve the use of cameras and recording devices which potentially allow them to collect and process a substantial amount of personal data. While the overall privacy and data protection framework applies to civil drones applications, they might raise issues requiring specific attention.

Emerging policy issues

The civil market can only develop if civil drones can fly in non-segregated airspace without affecting the safety and the operation of the wider civil aviation system. To this end, adequate safety regulation must be developed. The development of national regulations, while instrumental in launching drone activities, will lead to a fragmented market, hampering the development of the European industry in view of global competition. The Commission will consider the relevance to extend EASA competences in order to develop common European rules for light drones and will consider actions to support the development of the market and ease public acceptance.

High-level generic references

Future mobility and autonomous systems.

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Conclusion

Foresight is coming of age[1] [2]. Within the European Commission several significant initiatives came to fruition in 2014, such as the Science and Technology Advisory Council's foresight report[3], the European Strategy and Policy Analysis System (ESPAS)[4], an expert report on a new way to address policy-making by "concurrent design foresight"[5] and many other initiatives and reports specific to Commission DGs. In addition, a quantitative Special Eurobarometer survey[6] performed in June 2014 has questioned[7] the mantra that Europeans are lukewarm or even risk averse about science and technological innovation, with an outlook to the next 15 years. Finally, a focus group Eurobarometer study, using foresight scenarios, will be performed before the end of 2014 in 16 EU Member States to address the qualitative aspect of science and technology acceptance.

So, there is ample hope that this 'Foresight Network Fiches 2014' report will be a valuable resource for policy makers and stakeholders.

We need to know where innovations and breakthroughs will come from. But science and technology cannot have a positive impact on society unless our citizens accept it. It is crucial that foresight fully integrates the societal dimension and public views about novel science and technology. For this to happen, a document that is accessible to non-specialists should be the next step, as well as other activities to engage citizens.

We also need more co-disciplinary work to propose initiatives that are not only scientifically and technologically feasible but also ecologically responsible, climatically durable, ethically defendable, culturally acceptable, even philosophically compatible, aesthetically pleasing, and *de facto*, socially acceptable. It also goes without saying that financial and economic viability is important as well as political feasibility.

1 http://europa.eu/espas/orbis/

2 http://www.latribune.fr/opinions/tribunes/20131206trib000799729/la-prospective-comme-un-jeu-d-echecs.html

3 http://ec.europa.eu/commission_2010-2014/president/advisory-council/documents/the_future_of_europe_is_science_october_2014.pdf

4 http://europa.eu/espas/

5 To be published in December 2014 by DG RTD and CSA/BEPA

6 http://ec.europa.eu/public_opinion/archives/eb_special_419_400_en.htm#419

7 http://www.latribune.fr/opinions/tribunes/20141006trib17b1bffa3/non-les-europeens-n-ont-pas-peur-du-progres-technique.html

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