



FORESIGHT

New Horizons: Future Scenarios for Research & Innovation Policies in Europe

Extended Summary



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Extended Summary

A report from project BOHEMIA

Beyond the Horizon: Foresight in Support of the Preparation of the
European Union's Future Policies in Research and Innovation

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This document is an extended summary of the BOHEMIA scenarios report.

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Abstract

The growing complexity of the world will require that society develop more options for coping and flourishing. Those options will come, primarily, from new discoveries, inventions, ideas – in short, from research and innovation. This foresight report, commissioned by the European Commission's Directorate-General for Research and Innovation, draws on a broad range of sources about megatrends shaping the world today and projects them forward into the 2030s. It describes two possible outcomes: That the trends go on unmanaged and uncontrolled, or that society takes action. The first outcome would be negative: climate change, environmental degradation, explosive migration, an unhealthy population, crowded and dangerous cities, mass unemployment and global strife – and Europe a victim. The second outcome would be positive: climate control, sustainable land and sea management, a circular economy with greater productivity, a healthier and longer-lived population with fulfilling work and leisure, peace – and Europe a leader. The report goes on to illustrate specific ways in which research and innovation could help Europe realise the positive scenario or at least minimise the harm of the negative.

Résumé

La complexité croissante du monde exigera que la société développe davantage d'options pour s'adapter et prospérer. Ces options résulteront, essentiellement, de nouvelles découvertes, d'inventions, d'idées — en bref, de la recherche et de l'innovation. Ce rapport de prospective, mandaté par la Commission européenne, direction générale de la recherche et de l'innovation, s'inspire d'un large éventail de sources pointant vers les grandes tendances qui façonnent le monde d'aujourd'hui et les projette dans les années 2030. Il décrit deux résultats possibles: les tendances se poursuivent, mal gérées et incontrôlées, ou bien la société prend des mesures. La première approche serait négative: le changement climatique, la dégradation de l'environnement, une migration explosive, une population en mauvaise santé, des villes densément peuplées et dangereuses, un chômage de masse et des conflits dans le monde — l'Europe devient une victime. La deuxième approche serait positive: contrôle du climat, gestion durable des terres et des océans, économie circulaire avec une plus grande productivité, une population en meilleure santé et jouissant d'une plus longue vie avec un travail satisfaisant et des loisirs, la paix — l'Europe joue un rôle de premier plan. Le rapport se poursuit en illustrant les moyens concrets dans lesquels la recherche et l'innovation pourraient aider l'Europe à concrétiser le scénario positif, ou du moins minimiser les effets délétères du scénario négatif.

1. Creating options for the future

'It is a very interesting point in time. We either go for the bright side of a sustainable future, or we might go for the Dark Ages again.'

Prof. Hans Joachim Schellnhuber, founder of the Potsdam Institute for Climate Change Impact Research¹

The world, it seems, is getting more complicated. A confusing mix of positive and negative trends, constructive and destructive forces, vie for our attention every day.

On the scary side: international conflicts are multiplying, a large European Union member has vowed to leave, and immigration and terrorism have risen in just five years to be the No. 1 and 2 concerns among European citizens.² The stubborn persistence of slow economic growth, high unemployment and steep income inequality disturbs many. Climate change, disruptive technologies, cyber-espionage, a demographic time bomb – the list of frightening developments seems endless.

But on the brighter side: We have ever-lengthening life spans, the lowest hunger and poverty levels in human history, and the highest literacy rates. Our scientific knowledge, cultural interchanges and international trade have grown as never before. Our ability, with robust public institutions and a vibrant civil society, to organise industry, technology and people to do the right thing has never been stronger – even if our will to do so often falls short. We do, as Charles Dickens put it, live in the best of times *and* the worst of times.

How will this story turn out, for the world and for Europe, over the next 20 or 30 years? Of course, we cannot know today. But we can create options – new sources of technology, wealth or wisdom to cope with whatever may happen. Options permit a company to adapt, employment to adjust, the environment to recover, a city to stabilise. Options are what a government needs to manage a crisis effectively. Any policy maker, with the foresight to imagine nightmares or dreams for tomorrow, will want to take steps that maximise options today.

Why research?

And that is one of the primary roles of research and innovation: To create and enable options for society. This report, commissioned by the European Commission, summarises a range of realities we might be facing in the 2030s, and suggests ways research might create options to cope and flourish. We could be facing a fragmented, fractious future, with hostile nations, class warfare between rich and poor, and a workforce hollowed out by technology. Or, we could be enjoying a peace in which we strengthen supra-national structures to resolve disputes, harness technology to create jobs, and manage our planet to support an educated, fulfilled population.

Our policy choices will decide which scenario proves closest to the truth – but, again, the options before policy-makers at each step along the way will be shaped by the tools they have available. Will they have the technology to feed and provide energy to growing cities, without risk of climate-induced flooding or desertification? Will they have the medicines, treatments and preventive measures to prolong productive lives at reasonable cost, or will their health systems be bankrupt by an ageing, ill and increasingly distressed population?

Research and innovation are about creating solutions, opportunities and options – across the entire economy. Agriculture, health, justice, monetary policy, the economy, manufacturing, resource management: There isn't a single sector of EU and member-state policy that would not be aided by more and better options. Drafting a new Framework Programme, an exercise on which the EU is about to embark, is thus not a narrow issue of how to spend R&D money; rather, it is a process of

1 Deighton, Ben. "We need an Apollo-style programme to tackle climate change – Prof. Hans Joachim Schellnhuber". *Horizon Magazine*, 19 December 2016
https://horizon-magazine.eu/article/we-need-apollo-style-programme-tackle-climate-change-prof-hans-joachim-schellnhuber-en.html?utm_source=HORIZON&utm_campaign=781763c4f0-News+Alert+20161209&utm_medium=email&utm_term=0_bdcf6f64ca-781763c4f0-105613157

2 Eurobarometer, cited in EPSC (2016b) "EU 2016: From Trends to Policies."
http://ec.europa.eu/epsc/sites/epsc/files/eu2016_from_trends_to_policies.pdf

agreeing on a common vision of the problems we may face, the opportunities we could seize, and the tools we will need for either eventuality.

The Sustainable Development Goals

Of course, we know which outcomes we would prefer – in fact, they are codified already in the Sustainable Development Goals of the United Nations, to which EU members and most other nations in the world committed themselves in a 2015 UN resolution.³ These 17 goals are high-minded: end hunger and poverty, assure clean water and sustainable energy, reduce inequalities and promote justice, ensure healthy well-being and inclusive education for all. All of these goals are, already, reflected in one way or another in EU policy and that of the member-states. Through Horizon 2020, researchers are working to keep the oceans alive and the air clean, to make the electricity grid more efficient and energy-generation carbon-neutral, and to help doctors target treatments to the individual and researchers move their ideas faster to market.

The Sustainable Development Goals are reflected in the positive scenarios in this report, and, by their absence, in the negative scenarios as well. The scenarios were developed during 2016 as part of the BOHEMIA project set up by the Commission's Directorate-General for Research and Innovation. The study involved experts in varied fields from across the EU, interacting extensively with Commission services and participating in two workshops. This study is part of a multi-year process of reflection and consultation that will, by 2021, result in a new programme for EU research and innovation – the ninth such multi-year Framework Programme.

The scenarios are of two sorts:

- a) Perseverance Scenario. In this, the future is driven by a set of well-recognised megatrends. For instance, the OECD describes several long-term, documented trends in natural resources, climate change, globalisation, demographics, employment and productivity, among others.⁴ The scenario assumes that the basic principles and structures of our economies and societies remain largely unchanged. Hence the name, perseverance: Things just kind of go along as they are now – in a not very happy direction.
- b) Change Scenario. This reflects what might happen if, as a society, we consistently acted on our values. In these scenarios, we work towards the Sustainable Development Goals. Our leaders act wisely, in the interest of all people. In Europe and globally, we work together. And, due to the fruits of research and innovation, we have the necessary tools to act effectively. In this scenario, we see Europe as a moral, social and technological leader – punching well above its weight on the world stage, even as its share of global population diminishes.

By 2030 or 2040, the ninth Framework Programme will have already ended – but the tools it was created to develop will by then be at the disposal of society. And, in the shorter term, those tools throughout the 2020s will already be creating jobs, stimulating growth, improving our health, and helping keep the peace at home and abroad. The economic evidence for this is strong. From 1995 to 2007, investment in research and innovation by all parties – government, corporate, in every EU member-state – drove two-thirds of economic growth in Europe, according to UK innovation foundation Nesta⁵.

At the same time, this planning process provides us all a way to think through, together, what we would like Europe to be a generation from now. Will we have a Europe driven into irrelevance by forces beyond its control, or a Europe leading a global march towards a future we all want?

³ UN: <https://sustainabledevelopment.un.org/post2015/transformingourworld>

⁴ OECD (2016) Science, Technology and Innovation Outlook: Megatrends affecting science, technology and innovation
<https://www.oecd.org/sti/Megatrends%20affecting%20science.%20technology%20and%20innovation.pdf>

⁵ Nesta (2013) *Plan Innovation for Europe: Delivering Innovation-led Digitally-Powered Growth*. Nesta and the Lisbon Council, think tank for the 21st century.
<http://www.lisboncouncil.net/publication/publication/99.html>

2. A turbulent tomorrow

The 'perseverance' scenario, in short

By the 2030s, Europe's population is ageing and shrinking, while immigration pressures rise from younger, poorer neighbours. A generation gap, between the many retired and the fewer working, widens. Health problems multiply, but the rich have better access to new medicines and care than do the poor. More people crowd into sprawling, polluted cities. Technology is rushing ahead, changing the way we work and live; but it mainly benefits the biggest companies with the top labs, most patents and best distribution and supply chains. Small companies have trouble breaking through, and many people struggle to make ends meet in the 'gig' economy. Despite their green promises, governments never managed to act decisively to prevent climate change, and the effects are visible: conflicts and critical shortages in resources. Europe, no longer a leader in the world, is just one among many unhappy voices.

Inequality is the key word, here – and a failure of our leaders to make the right choices, develop the right technologies, and work together within Europe and across the globe.

How bad could it get, by the 2030s? Based on current trends, pretty bad. For Europe and the world, we will face a series of daunting challenges– growing urban populations, climate change, environmental degradation, health and social problems. Of course, foresight is not destiny; as a society, we have the capacity to pick a different outcome, to manage the challenges rather than succumb to them. And, as firm Europeanists and optimists – that is the nature of the research and innovation community, after all – we believe this story will end fairly well. We are optimists because we believe in the power of education, science and technology to make the world better.

But, purely as a policy exercise, let us imagine for a moment what the world would be like if we do not make the right decisions. What happens if we just let current trends take their course?

Population and the youth bulge

Our story begins with demographic trends. The UN projects that by 2030 the global population will reach 8.5 billion, and by 2050, 9.7 billion before starting to fall back again. This shorter-term growth will take place almost entirely in less-developed countries. Africa alone will account for more than half the population increase; as it grows, it will experience a "youth bulge" with the population aged 15 to 24 due to double by 2050.⁶ This could be good, if well managed: it means more people arriving at a working age, to support their society. But if badly managed – the basic assumption of this scenario – this will mean a reservoir of disaffected young people with few job opportunities. Europe's southern neighbours will become less stable. There will be more pressure for migration to wealthier countries. This could be bad for Europe, if it fails to integrate migrants into their new homes. But it could be good for Europe in handling its own demographic problems – which are substantial.

⁶ UNDESA (2015): "Youth population trends and sustainable development", Population Facts, No. 2015/1, UN Department of Economic and Social Affairs, Population Division, New York. <https://esa.un.org/unpd/wpp/>

Can science help immigrants feel at home?

As immigration rises, a serious policy question is how best to integrate new arrivals into society. Maurice Crul, a researcher at the Free University of Amsterdam, received a European Research Council grant to help answer that question.

So far, his research group found in studies across nine EU countries that enrolling immigrant children in school before age 6 – and in mixed classes – is especially important, providing them a base in both their old families and their new countries. “What we learned is that the children who are successful are those who live not just between cultures, but in two cultures at the same time,” Crul wrote recently in *The Guardian* newspaper.⁷

Within the EU, a poisonous cocktail of low fertility rates and longer lifespans has been brewing for years. The population of Europe, after decades of growth, will slip from 738 million in 2015 to 734 million in 2030⁸ – and fall further after that; in much of central and eastern Europe, the population is expected to drop by more than 15% by 2050. Yet average life expectancy in developed countries is projected to reach 83 years by mid-century. By 2050, there will be about as many over-60s as under-15s. An older, less-productive population results. The generation gap, with social tensions between older and younger citizens, widens. People delay retirement – but that still does not produce a large enough workforce.

Clearly, there are health problems. The focus, for such an ageing population, is on non-communicable diseases – for instance, cardiovascular disease, cancer and diabetes; this is true around the world, with deaths from this kind of ailment climbing from 60% in 2000 to 74% by 2030.⁹ The sick baby

boomers value individual freedom and autonomy, and rely heavily on the market for new treatments – so the private healthcare sector is booming. Personalised healthcare, tailored to the individual’s genome or other characteristics, is hot. Governments are under pressure to let new drugs rush out into the market; but it is easier to get them in private rather than public clinics. Those who can pay, do pay; the rest suffer. Many elderly are bankrupting themselves to get the latest, best care. At the same time, for old and young alike, obesity and its diseases are rife. The poorest, least educated and homeless have the worst care; but it is difficult, also, for young couples seeking jobs or homes. Online self-diagnosis and nutritional supplements are popular and cheap. The divide between rich and poor, urban and rural, well and ill, is wider than ever.

Urban sprawl and decay

For some in the city, care is better; smart cities have good health and diagnostic services. But generally, with 85% of the world projected to live in cities by the end of the century,¹⁰ urban life is stressful. The fastest-growing cities are in the developing world; by 2030 there are 40 megacities of more than 10 million each. Europe has its share of them – and they are sprawling, with bigger slums and bad pollution; there are also many more medium-size, million-person cities. Infrastructure is over-stretched. Extreme weather disrupts transport and work. People move a lot – pushed by housing and income pressures into the suburbs, leaving behind swathes of urban decay.

Indeed, the tattered fabric of these cities starts to look like the 1970s all over again, but on a bigger scale. In retrospect, the 2020s were a missed opportunity. As the cities grew, society could have invested in better infrastructure, environmental protections and social support. Instead, it bought a lot of expensive technology, without enough money or sense to make it worthwhile.

For instance, transport in and between these cities is getting automated. Connected and autonomous vehicles are being deployed, pushed by ICT companies that pioneer these new technologies. These come with big infrastructure and data projects; but poor governance and insufficient investment mean the much-vaunted improvements in lifestyle and environmental quality do not materialise. Europe’s auto industry, meanwhile, is focusing on exports to the rising, developing world; at home, the shrinking, ageing population is not as tempting a market. The freight sector has yet to innovate; its business models have not changed much, and most goods

⁷ Crul, Maurice. «Early education is key to helping migrant children thrive.» *The Guardian*, 18 September 2016. <https://www.theguardian.com/commentisfree/2016/sep/18/early-education-key-migrant-children-thrive-integration>

⁸ UNDESA (2015), *op.cit.*

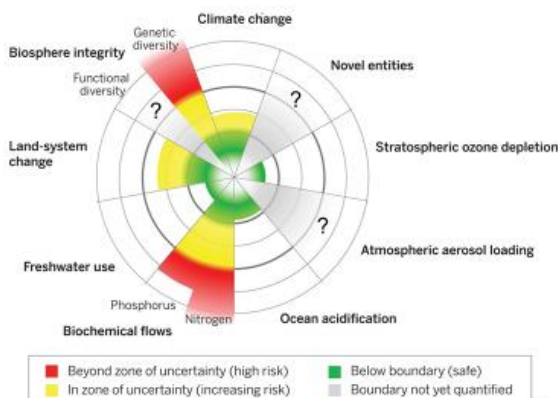
⁹ EEA (European Environment Agency) (2015) *The European Environment: State and Outlook 2015 – Assessment of Global Megatrends*, European Environment Agency, Copenhagen

¹⁰ OECD (2015a): *The Metropolitan Century report*, OECD (2015)

continue to move inefficiently over long distances. And the European airline industry, lulled into complacency by the slow pace of change in transport generally, now finds itself unprepared for a new era of cheaper, quieter all-electric aircraft.

You are now crossing a planetary boundary. Can science help?

Current status of the control variables for seven of the planetary boundaries. The green zone is the safe operating space, the yellow represents the zone of uncertainty (increasing risk), and the red is a high-risk zone.



Will Steffen et al. *Science* 2015;347:1259885
Published by AAAS



Four of nine planetary boundaries have now been crossed as a result of human activity, an international team of 18 researchers recently reported in the journal *Science* (16 January 2015).

The four are climate change, loss of biosphere integrity, land-system change, and altered biogeochemical cycles (phosphorus and nitrogen). Two of these, climate change and biosphere integrity, are what the scientists call "core boundaries"; significantly altering these would "drive the Earth System into a new state" – one less hospitable to human life.

Can we reverse these transgressions? What will happen if we do not? In 2010 Frank Fenner, one of the leaders of the effort to eradicate smallpox, said *homo sapiens* could be extinct in 100 years.¹¹ But if we can reverse the transgressions, would that not increase our incentives to transgress again?

Tech and its discontents

Technology in general has roared ahead since the Millennium. The pace of innovation keeps accelerating across most fields – spinning off a bewildering number of new opportunities and problems. Ubiquitous sensing, big data analytics, machine learning, advanced robotics and service bots are routine in big companies. For the dominant companies – and there are many of them, as technology opened new occasions for monopoly – this permits hyper-efficient chains of supply, design, manufacturing and delivery, spanning the globe. These companies can design a product for the individual customer, and deliver it direct. Of course, they control these processes from outside Europe; it is too expensive at home. But their technology-related efficiency makes them larger, more profitable, and more likely to develop more new technologies and get them patented, so their tech-fed growth cycle can start all over again.

As a result, the profit and productivity gap between multinationals and smaller companies is widening. Network effects lead to more concentration, and Europe's retention of strict IP protection makes it harder for new challengers to break through. Agriculture is a good example. Big data, genetics, 'precision agriculture' using wireless sensors, and other technologies have permitted multinationals to grow in the food sector. Their innovations in seeds and breeding are strongly protected. They are integrating vertically, buying food distributors and retailers. Investing in infrastructure is risky, because technologies depreciate fast. This is Agroindustry 4.0.

A similar story can be told throughout the economy. Result: Structural unemployment, especially on Europe's periphery. The new tech toys are fun: delivery by drone, driverless cars, the online doctor, automated factories, self-serve kiosks, computerised lawyers and accountants – even automated journalism, the inevitable next step after 'fake news.' But they are destroying more jobs than they create. Only those jobs requiring real human contact, creativity or complexity are safe – for now; artificial intelligence is advancing fast. This polarises the labour market between high-income cognitive workers and cheap manual labour. The 'gig economy' of temporary, part-time work on demand is spreading. Jobs are broken into projects for outsourcing. The social security systems cannot cope; they were designed for full-time jobs for life. That is a distant memory.

¹¹ Jones, Cheryl. "Frank Fenner sees no hope for humans." *The Australian*, 16 June 2010: <http://www.theaustralian.com.au/higher-education/frank-fenner-sees-no-hope-for-humans/news-story/8d77f0806a8a3591d47013f7d75699b9>

Seas rising, crop yields falling

The environment is the silent, but sickest, victim in this scenario. For climate, the adaptations required to hit the “mitigation” targets set out at the COP21 conference in Paris in 2015 proved too difficult. CO2 emissions are rising more slowly, but they are still rising. Renewables have become the leading source of electricity by 2030, but coal-fired capacity has declined only marginally and the global economy continues to exploit fossil fuels. Scientists predict a rise in global temperature of between 2.9 and 3.5 °C by 2100.¹³

The ice sheets of the North Pole are disappearing at an ever-faster rate. Sea levels are rising and are projected to reach, on average by the end of the 21st century, 1 metre higher than at the beginning of the century. Extreme heatwaves and rainfalls are more frequent and severe in most parts of the planet. Dry subtropical regions, however, have become dryer. All this is having profound effects on the abundance, distribution and composition of plant and tree species and animal populations, with a cascading effect for whole ecosystems. Average crop-yields are falling, while the growing human population is raising demand for crops by 25%.¹⁴ Coral reefs have died and all kinds of marine populations have collapsed.

This is bad for people, too. Building resilience to disasters has become the largest sector of the economy. Surveillance and early warning systems for heatwaves or other problems are multiplying. New agencies, with multifunctional teams ready to intervene across the world, stand by, 24/7. Social and international tensions are rising, too. Rich countries can get the energy they need, but poor countries with restive young populations cannot. Local problems quickly become global conflicts.

This is the age of over-exploitation. Water use in manufacturing has risen five-fold, and use at home and in electric plants has more than doubled.¹⁵ At the same time, the ocean is stressed by pollution, micro-plastics, declining biodiversity and climate-induced warming. Likewise, more forests and other natural habitats have been turned to raising animals for a meat-eating population, and growing maize, sugar cane, palm oil and other crops for biofuels and cosmetics. Native species are dwindling. Burning forests and clearing land is worsening pollution and the climate. It is also degrading soil. Intensive agriculture is raising nitrogen and phosphorus concentrations. Global chemical sales, rising since 1950, have climbed by about 3% per year since 2015, while production has been shifting from richer to poorer countries.¹⁶ The food supply is threatened – by waste as well as pollution. Already in 2013, the Food and Agriculture Organisation had warned that, if food waste were a country, it would be

What if: A new agriculture in Europe

Farming has a growing range of uses beyond producing food: agricultural by-products can go into biofuel, fibres into raw materials, rare plants into medicines. We can use plants to mine fields for metals, sow crops in wasteland to remediate the soil, plant forests to store CO2. At the same time, food is coming from a lot of places besides wheat or cows: new products are coming from algae, yeast, bio-refineries, aquaculture.

Exploiting this diversity could prove vital to our future. It could allow more farming in the city (one venture, Ennesys,¹² co-funded by the European Institute of Innovation and Technology is growing algae on the side of glass-windowed office buildings to generate energy and manage the climate inside.) The circular economy paradigm and ICT could strengthen local and regional agriculture.

The countryside will change, as will the systems to support it. There may be fewer cows. There may be greater biodiversity. Exactly where this will lead is impossible to say, but it takes a lot of science, technology and experimentation to generate the options that will enable us to find the right directions.

¹² <http://www.ennesys.com/en>

¹³ United Nations Environment Programme, at <https://web.unep.org/emissionsgap/>

¹⁴ IPCC (2014): “Impacts, adaptation, and vulnerability. Part A: global and sectoral aspects. Contribution of Working Group II to the fifth assessment report of the Intergovernmental Panel on Climate Change”. In: Field CB, Barros VR, Dokken DJ, et al, eds. Climate Change 2014. Cambridge, UK and New York, USA: Cambridge University Press, 2014: 1132

¹⁵ DASTI - Danish Agency for Science, Technology and Innovation (2016), An OECD Horizon Scan of Megatrends and Technology Trends in the context of future Research Policy, available at <http://ufm.dk/en/publications>

¹⁶ UNEP (2013). Global chemicals outlook—towards sound management of chemicals. http://www.unep.org/hazardoussubstances/Portals/9/Mainstreaming/GCO/The%20Global%20Chemical%20Outlook_Full%20report_15Feb2013.pdf (accessed Dec 23, 2014).

the third biggest CO² emitter after the US and China. In the past 15 years, we consumed more copper, aluminium and steel than in all of human history, as demand from China, India and other developing economies soared. Materials prices are a constant worry, spiked by scarcity and strife

War and peace

Conflict is the one factor not in short supply. Mounting social tensions plague city life. Ethnic and religious conflicts, and radicalisation, continue. As migration and terrorism rose in the past few decades, governments responded by investing huge amounts in safeguarding borders; this goes into police and military budgets, and new technologies to anticipate, detect and neutralise threats. But many of these new security technologies raise problems of their own: what is the proper way to handle and regulate drones, biological tools, cyber-weapons and – a new category – social engineering? To manage, governments lean heavily on the private sector for new security tools and services. But these companies operate with little oversight, essentially regulating themselves. And most of the money goes into minimising the effects, rather than fixing the causes, of conflict.

The wealthy protect themselves, as far as possible. A new kind of inequality results: The rich can be safer than the poor. That goes for individuals, as well as communities and countries. This divide makes it even harder for the EU to coordinate security among its bickering member-states.

And where does Europe fit in this sad world? It doesn't, much. The world's economic centre of gravity has shifted firmly east and south. By 2030, developing countries are contributing two-thirds of global growth and half of output, and are exercising greater political influence. Europe remains important for culture, ideas and perhaps leadership in specific sectors. But it is just one among many voices in a new, and unhappy, world order.

Can we engineer a solution?

Geo-engineering against climate change is a controversial topic. Experiments have shown that it is possible to engineer various aspects of the weather, and some claim this could mitigate global warming.

But the impact is unpredictable. Local effects can generate global problems, and global effects could generate local problems. Questions about authority and responsibility, who decides and who is affected, make geoengineering a difficult choice. As the impacts of climate change show more and more, the promise of geoengineering becomes more and more appealing, pushing humanity to take on further systemic risks.

3. Transition to a better age

The 'change' scenario, in short

By the 2030s, Europe and the world have made progress towards the UN Sustainable Development Goals. A rapid switch to low-carbon energy is reducing the risk of climate change, and society is adopting the models of the circular economy: Recycle and re-use, rent and share rather than buy and toss, design for sustainability. A new social contract, funded by resultant productivity gains, provides a basic income and a 'social budget' for all. Living a productive, healthy 100 years is growing common, as healthcare now prevents and manages disease holistically, and regulation permits a healthier work-life balance. Education, digital job markets and productivity-enhancing technologies create new work opportunities. The growing cities have become laboratories of good governance, and transport is more efficiently organised. All this has made society, and the world at large, more secure.

Fairness is the key word, here – and the ability of our leaders to make the right choices, develop the right technologies, and work together within Europe and across the globe.

Do nations stand alone in a fragmented world, or will they work together for the benefit of all? The negative scenario assumes fragmentation, inequality and strife. This next, positive scenario assumes cooperation, solidarity and peace. Research and innovation have always been driven by what could and should be, rather than by what is.

A propitious climate

With the 2015 adoption of the UN's Sustainable Development Goals, the EU joined other nations in a commitment to make the world better – and by the 2030s, great progress has been made. We are indeed eradicating poverty, ending hunger, providing healthcare, protecting the environment, controlling climate change. In most of the world, these goals are reflected at every level of government – from city to region to nation. The EU is a leader, drawing on the strength of its society, technology, culture and diversity. It is an open society, within its own borders and in its relations with the rest of the world. It is less fragmented – as is the world overall; people accept now that global problems need global solutions. As a result, around the world, differences between rich and poor, haves and have-nots, have diminished.

This happy state required several challenging transitions. Climate policy is one. To achieve the climate goals, governments, consumers, industry – all had to change the way they think about energy. Low-carbon energy sources, including onshore wind and solar photovoltaic energy, were deployed rapidly across the world, and are now projected to supply 80% of electricity by 2050, up from 30% in 2015. The sector is better now at storing energy, and distributing it over smart grids. At least as important as the technology have been incentives, such as a revised emissions-trading scheme and energy-saver tax breaks for consumers. New ways of managing raw materials were found. For instance, in 2015 platinum was a bottleneck. To build low-carbon fuel-cells, automakers needed platinum – but at that time, there was only enough to supply 5% of the world’s car fleet.¹⁹ The solution came through substitution, recycling, sustainable production and international cooperation – not one magic bullet, but a series of small measures with collective impact.

The circular economy

Of course, climate risk is not gone; it is just reduced. Extreme weather and environmental catastrophes have raised the importance of adaptation and resilience across the globe. Demand from investors, shareholders, civil society and government led to sustainable business models that address social, environmental, and commercial goals – the ‘triple’ bottom line. There was a major change in the way we all work, play and live. Energy efficiency is up; waste is down. Re-cycling, re-using and repairing are rewarded. Hazardous materials are being replaced. Product design and manufacture is changing. New kinds of services exploit network economies; each new consumer is added at near-zero marginal cost. Automation advances. The fossil-based chemical industry has been replaced by a smarter, more resource efficient bio-based industry. Today the economy uses between 17% and 24% fewer materials than it did in 2015.

In short, the “circular economy” is working. A change from ownership to sharing has created a flourishing re-use and rental market, with new jobs for maintenance, distribution and installation. Electronic tags record the history of each appliance and help set rental prices, while 3D printers produce replacement parts. Many producers concentrate on top-end designs with the latest technologies and most durable materials; they fetch the highest price and profit. They are often rented, used many years, and finally disassembled and recycled. There is a new focus on local rather than long-distance trade. Cities are creating their own regional markets for food and materials, rather than relying on imports. Globalisation is not gone, but it is different: it is more about trading knowledge and intangible services, and less about goods travelling long distances. The freight system is smaller than in the past. Transport networks, thanks to new sensors and

Global collaboration for global markets

We come from an era in which global collaboration was about opening national markets. We are entering an era that requires global collaboration to build global markets.

The leading example is space – “the final frontier”. What started as a journey of exploration has led to important economic activities in near space. This is already part of the world’s telecommunications and earth-observation infrastructure; smartphones, GPS, accurate weather forecasting and crop prediction – all would be impossible without it. Far-space, to other planets or star systems, is the next frontier. Cooperation in this field – with Russia, China, India, the US and others - could make a great contribution to building a stronger climate of peace and security across the globe, and can generate new markets.

The next frontier could be the oceans. Ocean pollution is a huge problem requiring urgent attention. While coastal fishing communities worldwide suffer from depletion of fishing stocks and unemployment, plastic waste accumulates in the sea with terrible consequences for ocean ecosystems. Cleaning it all up, some say, “would bankrupt any government”.¹⁷

But many governments together could finance it. And once the project is set up, the materials recovered could pay for its running – until the oceans are clean from litter. So thinks one Dutch not-for-profit, The Ocean Cleanup.¹⁸ Their idea is to install what are, in essence, enormous sieves in a few strategic locations in the ocean to collect floating plastic waste. It was started by one young man: Boyar Slat of Delft University of Technology, who crowd-funded enough money to get his idea off the ground. Nobody knows if it is the right answer yet, but it is certainly worth the effort to find out – and in recognition, the UN Environment Programme award him prize.

¹⁷Stone, Daniel. “Can the Pacific Garbage Patch Be Cleaned Up?” *Newsweek*, 10 December 2009. <http://europe.newsweek.com/can-pacific-garbage-patch-be-cleaned-75657?rm=eu>

¹⁸ <https://www.theoceancleanup.com>

¹⁹ EC (2012) “Global Europe 2050”, https://ec.europa.eu/research/social-sciences/pdf/policy_reviews/global-europe-2050-report_en.pdf

materials, need very little maintenance. The average cost per passenger-kilometre is due to fall as much as 80% by 2050. By then, the transport sector could be 95% decarbonised.

Technology and people

New technologies have been key to many of these changes; they improve society, rather than destabilise it. For this, a change in mindset was needed. Whereas people previously feared disruptive technologies and tried to regulate the danger away, now they engage with change and plan ways to benefit from innovation – and lead from Europe. Productivity gains from these technologies, and from the circular economy, have financed a social contract for a basic income for all. Also, a life-time social 'budget' for education, health and skills is provided for each citizen, often delivered online. Social insurance has adapted to the labour market of mobile, part-time, flexible employment. New forms of child benefits help bridge the generation gap. More women participate in the new, flexible workforce, so lifestyles are changing. And entrepreneurship is "in", as more people feel secure enough to embark on a risky venture in the volatile, digital economy. This generates more wealth for society, in a virtuous cycle.

A starting point was investment in knowledge infrastructure. Supercomputers, satellites, smart cities, autonomous transport systems, more universities and hospitals – all were seen as the bedrock of Europe's future. Bigger and better research facilities clustered talent to help cities become innovation hubs. A consistent policy of openness in science and innovation increased technological productivity and strengthened the EU. Governments established a Grand Coalition for Digital Jobs, using real-time employment data and analytics to match individual skills with employer needs; it broke down the walls between sectors and regions that hindered job mobility.

The new well-being

Also important has been a shift in health policy – to a broader view of what 'healthy' means, affecting every area of policy. Education helps people learn how to preserve their health as long as possible. Employment regulation promotes a healthy work environment and work-life balance. Environmental management makes cities safer, water and air purer, food more wholesome. A stronger EU has written stringent health clauses into all trade agreements.

At the same time, the EU has coordinated public health research to fix population-level problems. So it has stimulated innovations in community-based healthcare, getting more people out of hospitals as they get better at home. There are new systems for early diagnosis, personalised medicine and health promotion; better patient-data systems so specialists can collaborate on treating people with multiple diseases or frailties; more training of less-skilled health workers so they can take work away from over-stretched doctors; and a 'health by design' approach to planning cities, cycle paths and walking routes. Health literacy has improved. Wearable devices let people check up on their own health and habits. Many people are now active and productive to the grand old age of 100 or beyond. All this is paying off in lower losses to the economy from illness, and greater competitiveness of the health industry.

What if nuclear energy were safer, cleaner?

Nuclear energy is politically charged. Worries about safety, waste disposal and security have led half of Europe to shun it. But other countries have kept at it – in Europe, China, India and elsewhere. Could new technologies help?

Already, smaller and safer reactor designs are being developed. Others suggest that thorium reactors could be built, using a fuel source more available than uranium, more controllable in operation, and more easily disposed of. And a very futuristic possibility is small fusion plants, to go underground on the sites of decommissioned coal stations.

Under the 1957 Euratom treaty, the EU continues researching nuclear energy; and it is a leading funder in the ITER fusion reactor now under construction in Cadarache, France.

But where is most of this good progress happening? In cities – to which more and more people are moving. Already by 2016, cities produced 80% of global GDP and emitted 70% of greenhouse gases; so, it was always clear that urban planning was a first step to a better future. Better data management, resource planning, energy efficiency and transport systems have developed. Governments have reclaimed inner-city land to create nicer spaces for people to live, work and play, integrating parks with mixed-use buildings, modular designs and eco-friendly materials. Buildings do not just house people and things; they also generate power and food, recycle water and nutrients. This 'urban bloom' will reduce city sprawl in Europe by up to 30,000 square kilometres by 2050. CO2 emissions can fall 85% below 2012 levels. And it is good for business: European innovators are selling their green expertise across the globe.

What if: The ultimate e-health manager²⁰

An excerpt from a health blog, in 2030:

The I-Pocrate is this little chip on my wrist. It is linked to my health App, using data on my genes, fitness, diet and lifestyle. It also watches the environment around me – pollution, noise and the like. Anything I do, it registers and calculates implications for my body. And it learns.

My I-Pocrate last year detected a predisposition to lung cancer (I used to smoke). But I followed its advice and improved my life style. Hence, earlier this year, I-Pocrate forecast with 90% confidence that I will live disease-free until 90 years... and I could negotiate a 20% rebate to my health-wellbeing insurance!

This is a global App, too. The WHOPP (World Human Operational Programme for risk Prevention) lets anyone voluntarily upload (and anonymise) their data, and fuses it with data from environmental sensors and -omics databanks. Such anonymised hyper-massive data and analysis has allowed tremendous progress in medicine, personalised vaccination and better life styles, anywhere in the world.

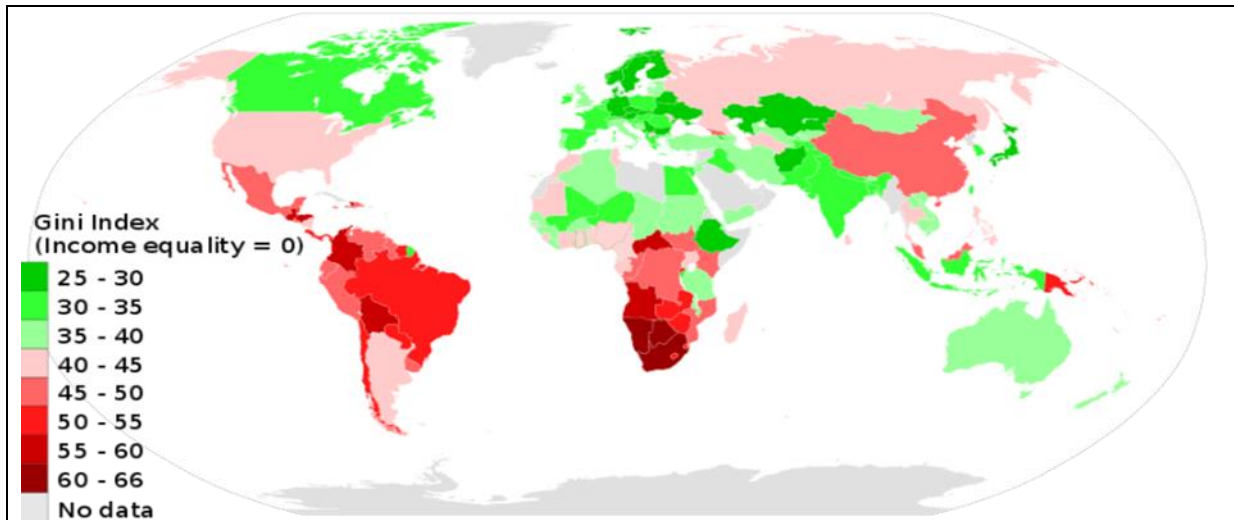
A safer, equitable world

With all these improvements has come greater security. Inequality breeds strife; fairness makes peace. The terrorism and conflicts earlier in the century forced a change in mindset: Security policies were broadened, to include employment, education, resources and other domains. Better to fix social disaffection and its causes, at home and abroad, than to build walls and buy more tanks. Predicting, identifying and neutralising potential threats also matter, as does involving citizens in planning their own security. Cities are now designed to be secure, in lay-out, ICT infrastructure and community organisation. Cyber-security remains a threat, but companies integrate security policies into their Corporate Social Responsibility objectives and governments launch public-private partnerships with industry for that purpose. Indeed, one can say that

security has moved from a siloed concern of the justice and defence ministries to a cross-cutting policy area that affects all.

The EU's role in this has been crucial. Security requires coordination across borders – within Europe, and without. Indeed, relations with Europe's poorer neighbours have improved. Development aid is one tool; though more than double the level of 2015 – an average 0.47% of GDP in the EU – it is still affordable. But it is not just about money. By the 2030s, open science, open access and an open view of intellectual property have prevailed: for instance, the developed countries have renounced IP rights to important chemical or biological innovations so that they are more freely available in the developing world. Reducing inequality, at home and abroad, is now a top priority of governments everywhere. Whereas in the past politicians aimed to grow the economy at any reasonable cost, now they seek growth with equality. All recognise that a flexible, educated workforce requires equal opportunity for every individual to learn, retrain and seize new opportunities. Indeed, the human race may be faced with an unprecedented period of peace.

²⁰ Inspired by Schmitt, Didier (2016): "Antéversion. Ce qu'il faut retenir du futur: Entre science et fiction." Editions Fauves



Can we solve the equation for growth and equality?

The Gini index, 2014. In this index, invented by Italian statistician Corrado Gini a century ago, a high number (red) means high inequality of income. An index of zero – achieved nowhere – means equality.²¹

The need for economic growth is often asserted by economists and policy-makers. With it, people feel optimistic; living standards rise; there is progress. Without it, people get restive; they move elsewhere; inequality rises. Indeed, conventional economists say, we need some inequality to propel growth. Without the carrot of large financial rewards, risky entrepreneurship and innovation would grind to a halt.

But there seems to be a limit. Over the past few generations, inequality has risen most in places where progressive policies, such as high top tax-rates, have weakened. New OECD analysis suggests that income inequality has a negative and statistically significant impact on medium-term growth. Thus the question is not whether inequality can be reversed, but rather whether inequality will be allowed to harm our economies.

“We have reached a tipping point,” said OECD Secretary-General Ángel Gurría.²² “Inequality in OECD countries is at its highest since records began. The evidence shows that high inequality is bad for growth. The case for policy action is as much economic as social. By not addressing inequality, governments are cutting into the social fabric of their countries and hurting their long-term economic growth.”

²¹ Source: Tracy Hunter in Wikipedia based on GINI index 2014 based on Table 2.9 of The World Bank: Word Development Indicators <http://wdi.worldbank.org/table/2.9>

²² Hannon, Paul. “OECD Sees Continued Rise in Growth-Harming Inequality.” *The Wall Street Journal*, 21 May 2015: <http://www.wsj.com/articles/oecd-sees-continued-rise-in-growth-harming-inequality-1432198801>

4. An opportunity for Europe

The Union 'shall contribute to peace, security, the sustainable development of the Earth, solidarity and mutual respect among peoples.'

From Article 5 of the Treaty of Lisbon

From 2014, the Juncker Commission has launched many new initiatives to strengthen Europe's economy, boost its competitiveness, and improve the well-being of its citizens.²³ It has also reached outward with, for instance, an external investment plan to complement its internal European Fund for Strategic Investment. The international community has also made progress, with a global climate agreement in Paris and the UN Sustainable Development Goals in New York.

So there are some positive signals that Europe and the world may lean towards the better of the two paths just outlined. In the worst path, we would see major environmental, economic and security risks, and an alarming degree of social inequality and strife at home and abroad. A strong and united Europe could stand its economic ground and minimise the damage, but at what cost? In the best path, we could move peacefully towards an economic and social system that is sustainable for both people and planet. Of course, for this to happen, a lot of things must go right.

And that is exactly where research and innovation can help. They have a funny way of making the impossible become possible – throwing up new opportunities, new ideas. A century ago, no politician could have dictated that everybody in the world should be able, if they want, to share knowledge; today we have the Web and cloud. No past politician could have outlawed smallpox and polio; today most of the world is vaccinated against them.

In these scenarios, we have suggested several areas in which research and innovation could help us find new solutions to old problems. The migrant crisis: Let social science tell us, from evidence, what policies are best at integrating a new population. Financial market crises: Can data analytics and economic modelling find better ways to manage the economy? Ocean life is choking on pollution: Find a cheap, safe way to clean the water up. The climate is warming: Figure out how to manage the grid, expand solar and wind power, make nuclear energy safe. The demographic time bomb of ageing: Invent tools for people to keep themselves healthy, prevent disease, and work longer. Unemployment: Use the Internet to match jobs and people, and devise forms of automation that can create, rather than destroy, jobs.

These and any number of other possibilities one can list fall into three categories of research and innovation. First, we must find novel solutions for the challenges identified as critical to Europe's future ("solutions-oriented R&I"). Second, we often lack knowledge of the challenges we face, and thus need research to better understand them ("understanding-oriented research"). Third, we must explore scientific frontiers to make society more resilient in the long term ("frontier research"). The EU Framework Programmes, as many Member-State programmes, are already organised along these lines – so that is a good sign for the future.

But it is not our intention here to propose any specific policy or project. Rather, the point is simpler: Let research and innovation invent opportunities for society. Indeed, this idea is first in our list of basic principles for research and innovation that emerge from our scenarios:

- **Build resilience by developing options before, rather than after, a crisis strikes:** As climate or security crises mount, we will face more difficult policy choices: nuclear or not, geo or bio engineering, collective security or individual privacy. The history of technology is full of ideas that were tried and rejected, and then revived and made to work by a later generation that needed them to solve some urgent, unexpected crisis. Whatever policy choices we make today, they should not cut off or otherwise restrict research and innovation that could provide answers for tomorrow and make our world more resilient to crisis.
- **Experiment in real world settings:** The level of the challenges faced, the complexity of the transitions that need to happen, and the speed of change in innovation will force our leaders to make major decisions fast, with little information and great uncertainty. How will

²³ https://ec.europa.eu/commission/2014-2019/president_en

they know which solutions work, and which do not? Experimentation, rapid prototyping and testing solutions need to become an important part of policy everywhere.

- **Learn from the best:** Right now, in policy areas from agriculture to security, there are hundreds of social and technological experiments going on across the EU regions and cities. Each, from Apulia to Lapland, has its own strengths in individual sectors, successes in social inclusion, new ideas to improve city life or gender equality. The rest of Europe can learn from these best-of-class models – but it takes systematic research to identify them and figure out which of their features can be transplanted elsewhere.
- **Get the governance right:** Developing great technology requires both support from the public sector and appropriate regulation of the private sector. But it especially needs support from the citizen. Increasingly, people are concerned about technology (will this new thing harm me or my job prospects?). They also expect much from it (will they invent a cure for my disease?). This trend will reshape the relationship between technology and government in fundamental ways. Medicines regulation will get faster. Product and substances regulation will get more thorough. Scientific equipment will be more regulated; after all, gene-editing kit can be used to make pathogens as well as medicines. More and more, the people affected by these technical questions will want to have a stronger voice in the decisions. As a result, in this century, a major challenge of government everywhere will be devising the right ways to make policy for and regulation of innovation and technology more inclusive, more participative and fairer in its societal outcomes whilst promoting a vibrant innovation ecosystem.
- **Look to the cities as laboratories:** As outlined in the scenarios, cities – big or small – are where most of our citizens, opportunities and challenges will be found in this century. Each one is unique. That means each one can be a laboratory for policy, technology, social cohesion, employment and more. Result: With hundreds of simultaneous experiments in the future underway, we can more quickly identify the right solutions and scale them up across the EU. Planning research and innovation should take this local dimension into account.
- **Connect and collaborate, across sectors:** There are no islands in policy. Our scenarios cut across each other, with synergies and trade-offs. For instance, we will not get a digital society or a liveable city if we do not have security. We will not have healthy citizens if we are still using 19th century fossil-based energy. Research and innovation, across all sectors, can help find ways to resolve seemingly intractable problems.
- **Openness, inclusiveness and fairness as policy principles:** Openness improves quality and productivity in science and technology; it does, as well, in public policy outside the lab. The spread of open data and e-government can improve public administration. Scientific collaboration with other nations can spread to collaboration in regulation, trade, education, energy and other seemingly disparate policy areas.

Science, technology and innovation have been the basis of many of Europe's greatest achievements, and continue to be fundamental to its performance in the world. Whichever scenario prevails, we will need strong universities, laboratories and technology-based companies. That will require a step-change in the levels of investment we deploy; the EU has yet to hit its oft-stated goal of spending at least 3% of GDP on R&D (we have been stuck below 2% for years.) As we invest, we should continue betting on R&D with the greatest potential impact, but also recognise that is affected by the framework conditions: market regulation, the skill of the workforce, the supply of capital and more. And as we invest, the scientific and technical community must be sure that what it does is, and is seen as, responsible – for society at large. Responsible research and innovation are watchwords.

These characteristics can, operating together, ensure our science and technology base is strong, flexible and responsible enough to build a better future. It can spark an innovation revolution that is Europe's to lead.

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The growing complexity of the world will require that society develop more options for coping. Options will come from new discoveries, inventions, ideas – in short, from research and innovation. This document summarizes a foresight report, commissioned by the European Commission's Directorate-General for Research and Innovation, draws on a broad range of sources about megatrends shaping the world today and projects them forward into the 2030s.

The report describes two possible outcomes: That the trends go on unmanaged and uncontrolled, or that society takes action. The first outcome would be negative: climate change, environmental degradation, explosive migration, an unhealthy population, crowded and dangerous cities, mass unemployment and global strife – and Europe a victim. The second outcome would be positive: climate control, sustainable land and sea management, a circular economy with greater productivity, a healthier and longer-lived population with fulfilling work and leisure, peace – and Europe a leader. The report goes on to illustrate specific ways in which research and innovation could help Europe realise the positive scenario or at least minimise the harm of the negative.

Studies and reports