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REINVENTING TOGETHER SOCIETY, ECONOMY AND SCIENCE**

Abstract: The great challenges of our time in environment (climate change and environmental sustainability…), science (Science 2.0, the data revolution…), society (demography, migrations, inequality, communication, internet of everything…) and economy (employability, open innovations, circular economy…) cannot be understood and tackled by any one academic field alone. The problems we are facing are large-scale socio-technical problems of such immensity, complexity, and urgency that to neglect a single aspect could be very "costly". But the future is not predefined, it very much depends upon the policies taken. EU policymakers are increasingly confronted with a wide array of problems. They often need their decisions to be informed by the best available science from across disciplines as these challenges no longer arrive in neat discipline-shaped boxes. The mission of the Directorate General Joint Research Centre as the Commission's in-house science service and *honest broker* is to provide EU policies with independent, evidence-based scientific and technical support throughout the whole policy cycle.

Key words: *future trends, key technologies, data revolution, disruptive new technologies or events, evidence-informed policy-making, knowledge management, Directorate General Joint Research Centre*

INTRODUCTION

The history of Earth as well as the history of human society is a combination of slow evolutionary processes and disruptive events. But our world will change more this century than during any other time in human history. Change will happen faster than ever before. It will also affect more people than ever before. [1] The 21st century could be our best century ever, or our worst. The outcome will depend on our abili ty to understand and harness the extraordinary opportunities as well

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as manage the unprecedented uncertainties and risks. While the future is full of opportunity arising from the extraordinary advances of recent decades, it is also highly uncertain and characterised by growing systemic risks. The changes created by globalization, demographics, technology, economic growth, systemic risk, and governance should serve as a guide to 21st century businesses, investors, and governments. The scale of the opportunities and risks require more attention in the future and a more far-sighted attitude.

FUTURE TRENDS

Analysis of future trends, whether derived from extrapolations, simulations, projections or scenarios, can provide important insights for the future. They can offer support and guidance for decision makers and investors, and forewarn policy makers, the business community, researchers and society more generally to important upcoming issues. Interpretation of future trends, however, always needs to be done with care: they do not foresee the future, they merely indicate how the future might evolve under certain conditions and in a given subject area. A somewhat fuller picture of possible futures can be assembled by bringing together numerous trends from different subject areas. This can strengthen the basis for developing narratives, which in turn can enrich our view of where the world is heading and what challenges and opportunities may lay on or beyond the longer-term horizon.

In reality, our future is being shaped by a multitude of powerful, highly complex and interconnected forces and any attempt to peer into the future seems destined merely to enhance our sense of uncertainty. Yet, seen over a time horizon of one or two decades, some of the big trends we see unfolding before us are in fact quite slow-moving. These are megatrends — large-scale social, economic, political, environmental or technological changes that are slow to form but which, once they have taken root, exercise a thorough and lasting influence on many if not most human activities, processes and perceptions.

What often tends to shake that confidence, at least temporarily, are *disruptive* events. They come in a multitude of forms

— from global financial crashes and pandemics to wars and sudden waves of immigration and from continental-scale natural disasters to sudden shifts in population fertility. Such events are difficult to build into trend projections, and so are often treated in foresight exercises as “wild cards”. Potentially disruptive scientific and technological innovations, on the other hand, frequently find a place in forward trend studies, not least because they often occur as an extension of or as a marked departure from existing science and technology trends. Ultimately, it is how megatrends and disruptive trends — especially in the field of science and technology — interact that will set the scene for the coming decades. It is for gov- ernments, business, researchers and citizens in general to reflect on what the interplay of such trends means in terms of opportunities to be grabbed and challenges to be met. [2]

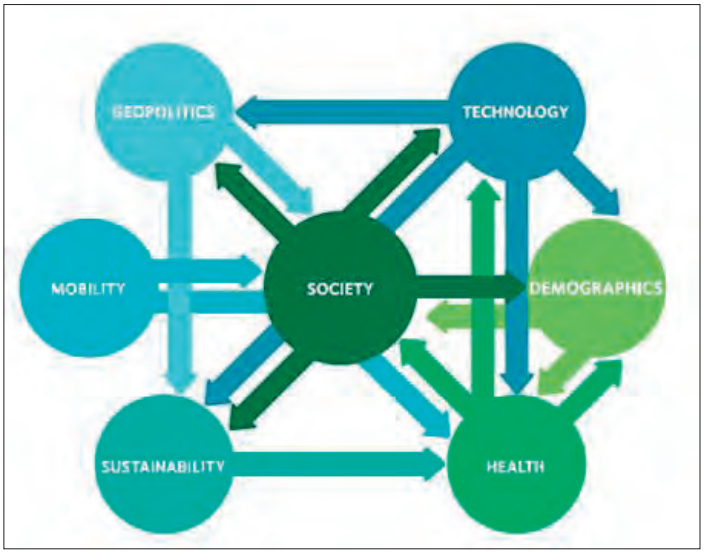

Figure 1. Global megatrends in the 21st century (Source: Oxford Martin Commission for Future Generations [3])

As identified by Oxford Martin Commission for Future Generations: Challenges or interacting megatrends that are expected to have significant socio-economic impacts over the next 10-20 years and beyond are:

The European Strategy and Policy Analysis System (ESPAS) project in its aim to help the European Union (EU) to identify the main global trends, assess their implications and review the resulting challenges and policy options, published the document Global Trends to 2030: Can the EU meet the challenges ahead? [4]

Those challenges pose questions like: How to make growth and development more sustainable and inclusive? How can different stakeholders (businesses, institutions and governments) contribute to more inclusive and sustainable growth? How to ensure enough food, energy, water and biodiversity? How public health infrastructure and processes would be able respond to the needs of all? Whether power transitions would be the basis for new forms of collaboration?

These challenges cannot be understood and tackled by any one academic field alone. So no one sector of society can make our sustainable dreams come true—not science, government, business, industry, civil society, academia, or the arts. All sectors need to share their concerns and perspective about these issues to ensure the best possible outcomes.

TECHNOLOGY AS A SOLUTION (?)

A dramatic megatrend of the last half-century has been the pace of technological change. Very often we turn to *technology* as a solution. Nearly every country—from low to high income—has been convinced that it must engage on a world-class level in science and technology to become more innovative in a highly competitive

and interconnected world. They also have taken into account the understanding that *human capital development* through scientific research is one the essential elements of innovation success and technological advancement.

EU is strongly supporting Key Enabling Technologies (KETs) and Future and Emerging Technologies (FETs). Key Enabling Technologies (KETs) are investments and technologies that will allow European industries to retain competitiveness and capitalise on new markets. The Industrial Technologies Programme (NMP) focuses on four KETs: nanotechnologies, advanced materials, and advanced manufacturing and processing (production technologies) and biotechnology. The Future & Emerging Technologies (FET) programme invests in transformative frontier research and innovation with a high potential impact on technology, to benefit our economy and society. FET Open supports the early-stages of the science and technology research and innovation around new ideas towards radically new future technologies. It also funds coordination and support actions for such high-risk forward looking research to prosper in Europe. [5]

This should continue and public and business investment into integrated research and development and long-term systems approaches uniting food, energy, water and land use and biodiversity preservation need to increase considerably. A consideration of possible pathways to tackle new challenges requires an awareness that technology is deeply embedded in existing institutional and societal structures. To some extent, this can act as a barrier to more sustainable innovation, and favour incumbent technologies against newcomers or more radical interventions. Stimulating new technologies that offer alternatives to existing resource-intensive "locked-in" technologies (scholars point to our current carbon based energy and transportation systems as evidence of "technological lock-in", reinforced by regulatory and incentive structures with substantial environmental consequences), and measuring available potential of renewable energy would make a significant contribution.

The Digital Technology Revolution, in the second half of 20th century enabled the Data Revolution [6] and marked the beginning of the Information Age. New technologies are leading to an exponential increase in the volume and types of data available, creating unprecedented possibilities for informing and transforming society and protecting the environment. Governments, companies, researchers and citizen groups are in a restlessness of experimentation, innovation and adaptation to the new world of data, a world in which data are bigger, faster and more detailed than ever before. Digital technologies—the internet, mobile phones, and all the other tools to collect, store, analyse, and share information digitally—have spread quickly. The number of internet users has more than tripled in a decade—from 1 billi on in 2005 to an estimated 3.2 billi on at the end of 2015. This means that businesses, people, and governments are more connected than ever before. The digital revolution has brought immediate private benefits—easier communication and information, greater convenience, free digital products, and new forms of leisure. It has also created a profound sense of social connectedness and global community. But have massive investments in information and communication technologies generated faster growth, more jobs, and better services for everybody? [7] One of

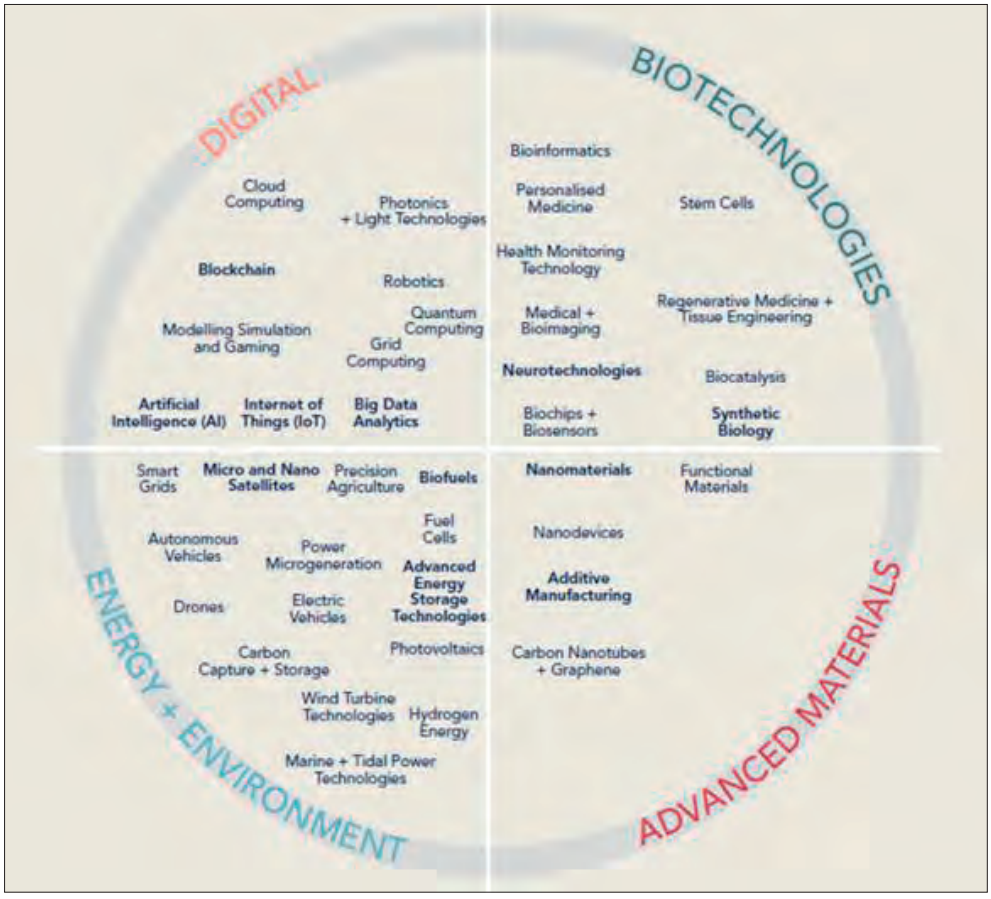

Figure 2. Forty key technologies for the future (Source OECD [2])

the strongest trends for the 21st century may be the ascent of the emerging middle class. According to a paper by Homi Kharas [8] the emerging middle class could almost double by 2020 and triple by 2030. Based on the rapid growth, scholars expect the global middle class to be the driving force for sustainable development. This assumption, however, is contested and *technological unemployment* is discussed [9].

Computing power has been doubling almost every 18 months. This appears likely to continue for at least the next decade or two, and will continue to revolutionise the way we lead our lives and the way societies are governed. Such is its reach and nascent speed, the World Wide Web has been declared "the most powerful force for globalisation, democratisation, economic growth, and education in history". The information revolution has penetrated our lives in ways not entirely understood, and created a faster, smarter, "more personal and participatory" world.

On the other hand, new information technologies are reaching the world's poor much faster than food and toilets. A recent UN report suggested six billi on people have access to mobile phones, while only 4.5 billi on have access to working toi-

lets. More households in developing countries own a mobile phone than have access to electricity or clean water, and nearly 70 percent of the bottom fifth of the population in developing countries own a mobile phone. There are around one billi on mobile phones in both China and India. Africa is home to twice as many mobile phones as the United

States and is the most advanced continent when it comes to "mobile money". Developing countries accounted for 80 percent of new mobile subscriptions in 2011, with the number of Internet users doubling over a four year period. Technology offers great potential to enhance education opportunities, dramatically improve health outcomes, promote free speech and democracy, and offer greater access to global markets.

The Internet is the key driver of global connectivity and opportunity, but different bandwidth speeds, limited access, and contrasting levels of openness can mean that the Internet aggravate rather than offsets inequality. The WTO's Agreement on Trade-Related Aspects of Intellectual Property Rights commits developed countries to providing incentives to the private sector for technology transfer to developing countries, but implementation remains weak. Once online, the inequalities persist.

The technology-enabled shifts, at their core, are potentially providing two things: (1) digital connectivity for everyone to everything, anywhere and at anytime; and (2) the tools for analysing and using digital data in new ways.

By 2020, there are expected to be four billi on people online, 31 billi on connected devices, 450 billi on online interactions performed per day, and up to 50 trillion gigabytes of data. The notion of the cyber world as a separate "space" is increasingly redundant as technology becomes omnipresent and we become more dependent through our business

models, our working and social practices, and in the delivery of key services. Digital technologies hold great promise. The growing maturity and convergence of digital technologies are likely to have far-reaching impacts on productivity, income distribution, well-being and the environment by 2030. Firms will be predominantly digitalised, enabling product design, manufacturing and delivery processes to be highly integrated and efficient. Additive manufacturing technologies will allow certain products to be tailored to specific user needs using computer-assisted drawing software. The Internet of Things, big data analytics, artificial intelli gence and machine learning tools will enable the emergence of smart machines that will be increasingly adjustable through sensor technologies, cheap computing power and the real-time use of algorithms. These impacts will however vary across industries, countries and sections of the workforce.

But this is all somewhat predictable. Similar importance is the potential of truly disruptive new technologies or events like quantum computing, artificial intelli gence or disruptive cyber crises in society in coming decades. [10] Whilst technological advances have revolutionised our lives, and offer profound possibilities for tackling challenges, they also maximise vulnerability. Our everyday li fe is highly dependent upon different *Critical Infrastructures* and their information networks: internet, smart grids (electricity, oil, gas), road — rail — air transport, flight con-

trol, water, environment, food, health care, financial systems… Individual hackers now have the capacity to damage public and private services, or cause widespread destruction through the deliberate or unintentional spread of misleading information. Risk management processes is becoming more and more important. It should be protecting the organizations and their abili ties to perform their missions, thus reducing the vulnerabilities of Critical Infrastructures and increasing their resilience.[1] [11]

All of these massive changes underline that technology not only provides solutions but also brings its own set of challenges. Even in 1955 John von Neumann asked: Can we survive technology? and stated [12]: "Technological evolution is still accelerating. Technologies are always constructive and beneficial, directly or indirectly. Yet their consequences tend to increase instabili ty–a point that will get closer attention after we have had a look at certain aspects of continuing technological evolution…All experience shows that even smaller technological changes than those now in the cards profoundly transform political and social relationships."

THE FUTURE IS NOT PREDEFINED, IT VERY MUCH DEPENDS UPON THE POLICIES TAKEN

Now in the 21st century we are beginning to understand the natural world to such an extent that we can manipulate it to our own ends. But we have to understand also that climate change produces controversy in established ways of understanding the human place in nature. For the first time in human history our activities are influencing the biosphere in a such a (dramatic) way to be able to shift the course of its evolvement.

The lesson mankind should learn is that technology alone can't solve problems — it's most effective when it's paired with capable underlying human forces. But after ages of designing technologies for humanitarian causes, we must conclude that no technology, however dazzling, could cause social change on its own. I t is human wisdom, not machines, that move our world forward.

Technology advances will continue to change the ways in which people live and interact with each other and their governments. Governments and societies will deal with complex, interconnected issues like data security, intellectual property rights, automation, privacy and identity concerns, and job displacement. Technol-

[1] DG Joint Research Centre (JRC) is one of the Directorate Generals of the European Commission. One of its seven Scientific Institutes the IPSC Institute for the Protection and Security of the Citizen in Ispra-Italy. The scientific research areas of IPSC include the area of Safety and Security. Among other things, specific area of its expertise is critical infrastructure protection, cyber security, global safety and security, nuclear safety, security for privacy and data protection, surveillance and transport safety and security. The power grid, the transport network and information and communication systems are among the so-called "critical infrastructures", which are essential to maintain vital societal functions. Damage or destruction of critical infrastructures by natural disasters, terrorism and criminal activity may have negative consequences for the security of the EU and the well -being of its citizens.

ogy advantages once held by developed states and large corporations will continue to devolve rapidly to all states and non-state actors alike.

The choices of people—along with governments, organizations, and elites—will shape the 21st century and challenge many 20th century ways of li fe. The future can therefore evolve in different directions, which can be shaped to some extent by the actions of various players and the decisions taken today.

For policy responses to address all the pressing current global challenges, especially when these are seen separately from one another, is clearly a demanding task. Institutions face greater complexity and difficulty in providing solutions in due time if the policy focus extends beyond the challenges that societies face today, seeking to anticipate future challenges and transform them into opportunities. Policy problems no longer arrive in neat, isolated boxes but increasingly inter- connect, presenting themselves as "system" problems. At the same time, the explosion of new scientific knowledge, information and data, including big data, means that policymakers face a problem of abundance, rather than scarcity of information.

While complexity and uncertainty are growing and a lot of developments cannot be predicted as such, a stronger anticipation culture would strengthen preparedness and resilience of our societies.

EVIDENCE-INFORM ED POLICY-MAKING

Policymakers are increasingly confronted with a wide array of problems, such as climate change, economic inequality, ageing populations, energy and food security, and water scarcity. They often need their decisions to be *informed* by the best available science from across disciplines as these challenges no longer arrive in clean-cut discipline-shaped boxes. This is crucial because the wrong policy can result in grave economic and social costs, and erode trust in governing institutions.

The good news is that never before in human history has so much scientific information been produced and it has never been so easily accessible. We now have a better understanding of our planet, our economy, our society and of ourselves than any other time in history. With all this, we face the challenge of mobilizing these accelerating trends of scientific enterprise, knowledge, mobility and international co-operation to inform policy and take the world on a more sustainable path. (At the same time science itself and the way that scientific knowledge is being produced, distributed or transferred is undergoing change due to new technologies. One has also to seriously consider the quality of the scientific data and information being produced. There is a multiplicity of actors, with scientists no longer only based in universities or research institutes; citizens are now also actors in scientific evidences production.)

However, the process of translating this scientific information into policy relevant evidence is not simple. The science- policy interface is a very specific field with its own framework requiring specific approaches. The supply and demand for scientific evidence will be best handled by bringing policy and science as close as possible. Scientists need to be an accepted (and trusted) part of the policy cycle, regularly consulted at different stages of the policy cycle, from the initial discussions

about potential new policy through to the ex-post assessment of the policy impact. Scientists could then provide their input in formal reports, but also in informal discussions as policy is developed. Format of the evidences presented is very important in order to provide policymakers with concise and visually obvious input so that they can quickly understand the main messages arising from the scientific evidence. Scientific evidence should be provided in a timely manner and usually as early as possible in the policy cycle, before important policy positions are taken. [13]

The problems policymakers are generally facing are large-scale socio-technical problems of such immensity, complexity, and urgency that to neglect a single aspect could be very "costly". These are not just problems per se, but problems with all the associated factors and concepts they encompass. These problems commonly cause different behaviour in different people. Narrowly focused, single-disciplinary science alone (usually hard science, forgetting importance of social sciences and humanities) cannot adequately underpin policies and solutions to resolve those challenges. For science to play a decisive role in addressing these problems in their full complexity, one must focus efforts toward multi-scale, integrated, interdisciplinary approaches that consider social, economic, and environmental aspects, that look between and beyond borders and sectors, and that identify feedbacks or the advantages of a policy or management decision, before it is made.

This is the area which is occupied by the *Directorate General* (DG) *Joint Research Centre* (JRC) of the European Commission [14]. As the Commission's *in-house science service,* the Joint Research Centre's mission is to provide EU policies with independent, evidence-based scientific and technical support throughout the whole policy cycle. Its work has a direct impact on the lives of citizens by contributing with its research outcomes to a healthy and safe environment, secure energy supplies, sustainable mobility and consumer health and safety. As the *honest broker*, the JRC tries to identify and overcome biases, to present what is known, what is not known, what is the scientific consensus, what are the implications for policy and action and the trade-offs of various options.

DG JRC draws on over 50 years of scientific work experience and continually builds its expertise based on its seven scientific institutes, which host specialist laboratories and unique research facili ties. They are located in Belgium (Brussels and Geel), Germany, Italy, the Netherlands and Spain. While most of its scientific work serves the policy Directorates-General (DG) of the European Commission, the DG JRC addresses key societal challenges while stimulating innovation and developing new methods, tools and standards. We share know-how with the Member States, the scientific community and international partners. DG JRC collaborates with over a thousand organisations worldwide whose scientists have access to many DG JRC facili ties through various collaboration agreements.

DG JRC enhances the development of 'better regulation' tools, in particular to contribute to high quality impact assessments of policy proposals and policy options, and promote their application at EU and Member State level. It also provides scientific and methodological support to the impact assessment process. DG JRC strengthens its modelling capacity. This includes further development of sectorial models and their links to or integration with cross-sectorial analysis and sensitiv-

ity analysis. DG JRC continues its work on ensuring the consistent use of data and assumptions in its modelling across different policies, and the use of shared baseline scenarios.

Of course, the reality is that in a democracy, policy formation and political decision-making are and should be based on more than scientific advice alone. Science alone cannot decide whether or not a society should accept a particular tradeoff between economic growth and environmental protection. But science can and should certainly inform the choices that society makes. But one place where science can play a much greater role and particularly assist the policy maker, and indeed the politician, is in developing greater insights and evidence about how citizens and users of services might respond to any particular option. There are many facets to how this can be achieved including behavioural insights and the use of controlled trials and so forth.

KNOWLEDGE MANAGEMENT

In his book Megatrends (where the shift from the industrial society to the information society was envisaged) published in 1982, John Naisbitt stated: "We are drowning in information and starved for knowledge". Indeed information and information resources are exponentially increasing and it is now a universally recognised true, again talking with Naisbitt's words, that unorganised information is no longer a resource, but an enemy to knowledge building.

Every stakeholder comes armed with their own knowledge, making it harder to detect the "signal" in the "noise". Science is also increasingly suffering from fragmentation and hyper-specialisation, as disciplines become ever more focused at the time when policy-makers need multi and inter-disciplinary advice. The socio-biologist E.O. Wilson summed up this situation: "We are drowning in information, while starving for wisdom. The world henceforth will be run by synthesizers, people able to put together the right information at the right time, think critically about it, and make important choices wisely."

As a response to the changing nature of both the supply and demand for knowledge for policy DG JRC is organising Knowledge and Competence Centres in certain priority policy areas, the central part of its knowledge management system. [15] In these areas, they should ensure that DG JRC provides more timely, important and useful knowledge but also that it achieves real impact on the policy process. Their key role will be to better coordinate the supply of knowledge and also the demand. Due to changing nature of relations between science and policy, collaboration between scientists from different disciplines and policymakers from different Directorate Generals (DGs) in co-creating policy questions and research answers, is needed. Knowledge and Competence Centres will be virtual entities, bringing together experts and knowledge from different locations inside and outside the Commission. They will facilitate knowledge management across DGs and will put in place new collaborative working methods. They will develop core knowledge management skills — systemic reviews, meta-analysis, data visualisation, web design, data analytics, infographics and management of communities of

practice. They will also put this knowledge into context and make it comparable and easily accessible. Their job will be to inform policy makers, in a transparent, tailored and independent manner, about the status and findings of the latest scientific evidence. Where there are legitimate disagreements in the scientific community, these will be clearly presented. The Knowledge Centres will not overstate what is known; they will fully acknowledge scientific limits and uncertainties.

While scientific evidences are plentiful, gaps do, of course, still exist. The Knowledge Centres will be able to map these gaps. They can then be fil led by DG JRC, if it is best placed to do so. If DG JRC does not have the knowledge, it should be connected to the best available person or body, so that it "knows who" as well as "knows what", which is the essence of knowledge management. Knowledge centres will create, collate, validate and structure internal and external scientific

knowledge for a specific policy field or across policy fields. Pilots will be set up for territorial policies and disaster ri sk management in collaboration with the relevant DGs. Competence centres will bring together analytical expertise such as modelling or data mining which are independent of theme, and can be applied across policy areas. The Centres will become the "synthesisers" referred to E.O. Wilson.

DG JRC would hope that the knowledge centres also take care of the preservation of knowledge in the respective priority areas of DG JRC in the form of constructing added-value resources (ready-to-use information evaluated and selected by experts) or group them as appropriate for their use by stakeholders, which could also be available to the general public. The Centres should therefore become the place both for policy questions and policy answers, a one stop shop where the most important questions and answers can be identified by the best policymakers and scientists from inside the European Commission but also ultimately around the world. DG JRC will launch three pilot Competence Centres: a Competence Centre on Composite Indicators, a Competence Centre on Microeconomic Evaluation and a Competence Centre on Modelling. While they operate in a similar way, Knowledge Centres are organised around a specific policy challenge, while Competence Centres are organised around a cross-cutting policy tool. This approach is also more likely to enhance the impact of evidence on policymaking. Closer engagement between policymakers and scientists means scientists are better able to provide useful, timely advice and policymakers are better aware upstream of emerging issues.

DG JRC also carries out high quality exploratory research to develop in-house the skills and knowledge necessary to better anticipate the science needed for EU policymaking. Exploratory research accounts for approximately 5 % of DG JRC's scientific activities and is integrated throughout the work programme.

DG JRC also continues to develop its capacity to monitor significant upcoming trends through horizon scanning, anticipate societal challenges and their impacts on policy, analyse complex problems with a system thinking approach and identify forward-looking solutions through foresight processes. DG JRC's competences in relation to socioeconomic research and behavioural sciences will be further developed. [16] DG JRC recently has established the EU Policy Lab as a collab-

orative and experimental space for innovative policy-making. [17] It is both a physical space and a way of working that combines foresight, behavioural insights, design thinking to explore, connect and find solutions for better policies. By accessing diverse areas of knowledge, EU Policy Lab strives to co-create, test and prototype ideas to address complex social problems and to enable collective change (citizens science, fab labs, sharing economy…[18]).The lab setting facili tates collaboration between policy-makers and society in order to place people [19] more at the centre of policy making.

CONCLUSIONS

Abraham Lincoln and countless others have articulated some variation of the quote: "The best way to predict your future is to create it." This statement is even more true today, when the world is a whole lot less predictable than it was.

As the world embarks on an ambitious project to meet new Sustainable Development Goals (SDGs), governing requires a dual vision: a commitment to address current needs and to build the foundations for vibrant generations in the decades ahead. So creating future means adopting forward-looking policies today and taking innovative actions. But taking a longer view is no panacea; striking a sustainable balance between short-term and long-term interests is key.

Given extraordinary advances in knowledge (information) and scientific understanding, today we are more aware than ever of the implications of our actions on future generations, not least in areas like climate change. This requires more and more science informed policy making but also better understanding of science-policy interaction. Indeed, the science/policy interface should perhaps be seen as a specific field or discipline in itself, requiring a particular set of methodologies and skill s.

So, DG JRC, in its strategic orientation, is positioning itself and rethinking its organisation, to be able to fulfil its task. It constantly interacts with policy makers in more diverse way and with multiple starting points, providing integrated (in the right form and format), timely and trustworthy information and knowledge management based on multiple perspectives which can lead to better decision-making and real-time citizen feedback.

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