



Foresight

The Junction of Health, Environment and the Bioeconomy:

Foresight and Implications for European
Research & Innovation Policies



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Innovation

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The Junction of Health, Environment and the Bioeconomy:

*Foresight and implications for European
Research & Innovation Policies*

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Foreword



More and more, we find that the solutions to global challenges appear at the intersection of disciplines, whether it is the merger of the digital and physical worlds – creating new possibilities for us to monitor the effects of climate change – or social scientists cooperating with medical researchers to create solutions to public health problems like diabetes. The lines between one area of research and another are becoming increasingly blurred.

Equally important to consider is that the sheer complexity of many global challenges calls for new ways of dealing with them. Research, science and innovation can provide many of the answers we need, but the more challenging the problem the greater the need for foresight.

We must make efforts to predict how to support research and innovation for the greatest possible impact on humanity's progress and prosperity. Increasingly, this will mean departing from the way we are used to doing things, like running our cities on clean energy instead of polluting fuels.

Horizon 2020 is the European Union's biggest researching funding programme yet and, as part of the Commission's efforts to inform its strategy, this report brings together the work of twelve experts recommended by DG Research and Innovation and supported by the Joint Research Centre Foresight & Behavioural Insights Unit.

Their objective was to identify emerging trends across three Horizon 2020 challenges – health, environment and the bioeconomy – and, wherever possible, to identify areas of innovation with the potential to benefit all three. Particularly interesting in this regard are the explorations of sensor technology development and user engagement highlighted in this report.

I would like to convey my thanks to the experts whose work informed this report. It provides many interesting insights into areas for European research, science and innovation for the near future and will be taken into account in the future design of Horizon 2020 programmes.

A handwritten signature in blue ink, which appears to read 'Carlos Moedas'.

Carlos MOEDAS
Commissioner for Research
Science and Innovation
European Commission



Summary of conclusions

A 12-member expert group was formed in June 2014 to identify emerging, but not necessarily widely recognised, trends at the Junction of three interdisciplinary Horizon 2020 challenges: Health, Environment and the Bioeconomy (JHEB) and to draw implications particularly for the Research and Innovation strategy in Horizon 2020.

Systemic challenges require systemic responses

A rapidly increasing world population, unsustainable production and consumption patterns, and environmental change form complex and interdependent systemic challenges for our societies, threaten the biosphere and humanity as a whole. The key message from the exercise of identifying trends at the junction of health, environment and the bioeconomy is that a systemic approach to challenges is necessary, often going beyond the three areas, for example to encompass issues of energy and mobility.

Taking a broader view of the global crises and trends such as climate change, threats to food security, biodiversity loss, rise in non-infectious diseases (e.g. cardiovascular diseases, cancers, obesity and psychiatric disorders), creates opportunities to develop systemic solutions delivering co-benefits across health, environment and the bioeconomy.

Systemic responses need to connect global and local level understanding and action, from planetary boundaries to the resilience of local systems. This creates specific pressures on the existing institutional structures and requires that policies provide appropriate incentives to all actors (e.g. individuals, research institutions, industry, civil society organisations...) to guide innovation and creativity towards sustainability and better quality of life.

Observing the intersection between health, environment and the bio-economy gives the opportunity to identify and exploit the synergies that facilitate the emergence of 'triple wins' (i.e. research delivering benefits across the three fields) as behaviours, knowledge and technologies advance. **It offers a unique occasion to ensure a safer and more sustainable society through the development of a green, circular economy.**

Four issues cut across health, environment and the bioeconomy

The expert group confirmed the pertinence of the broad areas of research already identified by Horizon 2020. However, **they highlighted the particular importance of four issues across health, environment and the bioeconomy.**

1. Sustainable food: developing multi-pronged solutions

A rapidly developing narrative concerns the opportunity to improve human diets, to provide appetising and nutritious food that not only meets caloric needs, but **minimizes the health and environmental risks** associated with overconsumption, waste and unsustainable farming practices. Changing diets also affect the opportunity space for emerging and re-emerging trends such as urban farming and organic agriculture.

Reducing excess intake of resource-intensive food types (such as meat and dairy products) also reduces the need to use arable land for the production of livestock feeds, potentially freeing it up for carbon sequestration supporting climate change mitigation, or bio-based products replacing fossil inputs. However, all these options require systemic approaches to evaluate their global and local impacts and potential unintended side-effects.

Similar challenges apply in fisheries and aquaculture, with rates of fish consumption increasing substantially, while land limitations push for improved methods to conduct agriculture in salt rich environments.

The bioeconomy, including oceans, is one of the key areas in the area of environmental remediation. There is much promise that through the bioeconomy we can overcome some of the problems of toxicity and resource scarcity of non-biological materials and processes. At the same time, the bioeconomy brings its own health and environmental risks and resource issues. These require integrated assessment, linking citizens' choices with options for better systems management. It is very important to draw lessons from experience with different governance systems in order to develop appropriate conditions for a sustainable bioeconomy. Outside the bioeconomy *per se*, advances in materials and processes are generating new ways of production, including remanufacturing, refit and reuse of existing stocks of durable goods and infrastructure.

While avoiding degradation is the cheapest option of all, environmental remediation becomes an increasingly important part of the bioeconomy discussion. Thanks to a combination of technological innovation and political will, it may be possible to successfully address large scale environmental problems such as rising soil salinity or desertification.

2. Circular economy: an impetus for all

On the economic side, **the challenge is to make the Green Economy work in practice, which requires placing the right values on environment and health outcomes in actual policy and economic decisions.** The value of a healthy environment is still largely invisible in national accounting practices. However, efforts are witnessed to improve measurements and to link

economic performance, environmental quality, social progress and health and well-being. Achieving healthy environmental and socio-economic conditions will require concerted effort from all parts of the world and will provide important innovation opportunities. **European companies could and should play a leading role in this field of innovation.**

Some evolutions in the **bioeconomy that link circular and green economy thinking, and in energy savings, favour developments at local scales, thus giving a new impetus to local, small scale, enterprises.** This is the case for small bioeconomy business, e.g. in urban farming, or in nutrient recycling as well as for non-bioeconomy processes such as 3D printing. Emphasis on green economy elements at a local scale can be important to progress towards global sustainability. There is a hope that large scale environmental problems such as desertification, ecosystem eutrophication, soil degradation and depletion can be successfully addressed, through a **combination of technological innovation and political will.** Emphasis on circular green economy elements at a local scale can be important to progress towards global sustainability. The circular economy has also important potential for improving local employment conditions and strengthening the resilience of local communities and systems in environmental as well as social terms.

In addition, 'non-bioeconomy' activity may follow the same evolution such as local manufacturing or local repair. The circular economy has also important potential for improving local employment conditions and strengthening the resilience of local communities and systems in environmental as well as social terms.

3. Cities: a key entry point where local action offers enormous potential

Cities emerge as key areas for testing and demonstrating these systemic responses. Involvement of all relevant actors, in particular through community and business initiatives, holds enormous potential. European companies could and should play a leading role in this.

Cities, home to two thirds of the European population, emerge as an important level for governance interventions. As cities develop new roles, there is potential to combine benefits in health, environment and the bioeconomy, taking into account the organization of society (i.e. consumption, transportation, production, waste management, and infrastructure). Infrastructures for the circular economy, regulatory practices, citizens' involvement, deployment of new technologies, urban and local farming, urban planning for healthy spaces and mobility, and approaches to foster social cohesion, are some of the ways the cities are involved in the junction between health, environment and the bioeconomy.

Sensor technology development will open massive opportunities for understanding and change in cities. Developments in IT and governance systems are promising tools to manage complex environments such as cities and for developing systemic understanding in all fields (dealing with opposing constraints, regulations to limit exposure, monitoring exposure). **Recent developments include IT-based governance and surveillance systems integrating new sensor technologies. The importance of harmonious development of appropriate institutional frameworks for widespread deployment of sensors and responsible use of associated data (e.g. privacy) cannot be understated.**

4. Holistic health: Exciting new avenues in the prevention and treatment of diseases

New Omics¹ technologies allow the identification of special molecules in humans and plants or bacteria, many of which could be interesting as facilitating nutrients use or as pharmaceuticals, or open up new opportunities in plant breeding. Technologies for monitoring, detection and diagnostics relevant for health are booming. **Thanks to the Internet of Things² and better data semantics, the ways people deal with their own health and the ways health care systems will be organised are undergoing a major shift, potentially bringing environmental co-benefits.**

More emphasis on disease prevention is urgently needed by building on the recognition of the positive links between healthy environments, healthy societies, human health and well-being. In particular, the integration of urban and transport planning, environment and health is essential to improve health and well-being. **Medical research (on pharmaceuticals but also radiotherapies, prostheses etc.) should strive to integrate environmental issues, including development and testing strategies.**

Some of the most exciting developments come from medical advances in biosciences and their convergence and combination with Information and Communication Technologies (ICTs). Sensors and developments in data analysis will allow **new prevention strategies and new treatments for disease, based on a holistic view of health, i.e. integrating life-style, environment and well-being.** OMICs promise the identification of new treatments and prevention opens new horizons for medical research, including foods, environmental conditions and other forms of preventive approaches.

However, institutional innovation are needed to provide the right incentives

Responsible research and innovation

In conjunction with technological research and development projects, sufficient emphasis must be put on studying potential environmental and health risks of these new technologies. This is especially the case when they involve possibly irreversible and/or widespread consequences (e.g. gene diffusion, persistent pollution, invasive species). The comparison of risk and benefits of innovation often requires a systemic approach, as it may raise complex questions. For instance beneficial processes in terms of sustainability can also lead to chemical or biological contaminant recycling with potentially adverse health effects (for instance wastewater nutrient recycling for agriculture). Another example is the development of green cities: these can be beneficial for health (e.g. increased level of physical activity or cleaner air), but also may bring more allergies (e.g. from pollen) or more vector borne diseases (e.g. from ponds). Equally, generalization of sensors and personalized prevention has a positive impact at the level of the population but may infringe on privacy at the individual level.

¹ Omics refer to the collective set of technologies used to explore the roles, relationships and actions of the various types of molecules that make up the cells of an organism. These technologies include Genomics (the study of genes and their function) and Proteomics (the study of proteins).

² The Internet of Things (IoT) refers to the capability of everyday devices to connect to other devices and people through the existing infrastructure and communicate with each other (Available at: <https://epic.org/privacy/internet/iot/>).

The Late Lessons from Early Warnings reports published by EEA³ have extensively illustrated how insufficient attention to risks often leads to irreversible damage and rocketing societal costs, which could have been avoided had a precautionary approach been chosen. It also shows that precaution can actually lead to more innovation.

Horizon 2020 responds in varying degrees to these opportunities and challenges. However, institutional innovation is needed to provide the right incentives. Institutional structures need to be responsive and to **provide appropriate incentives to individuals, corporations, and public managers to guide innovation and creativity (including social innovation) towards sustainability and improvement of quality of life.**

The appropriateness of incentive structures depends on the state-of-the-art in knowledge and technology. The junction between health, environment and the bioeconomy is full of synergies and trade-offs that become continuously reconfigured as knowledge advances. It is important for regulation and institutions to keep-up with advances in knowledge and technology, so that the 'triple-win' benefits can be obtained.

The road to sustainability opens up opportunities

The bioeconomy offers important potential to overcome some of the problems of toxicity and resource scarcity of non-biological materials and processes, as well as potential for medical applications. It is important to **draw lessons from EU and international experience in order to improve governance systems ensuring appropriate conditions for a sustainable bioeconomy. Such lessons can be, for example, learned from the field of biofuels, where a holistic view could help to foresee potential bottlenecks and contradictions between land use for biofuel, food and biodiversity.**

The bioeconomy coexists and interacts with other parts of the economy. **Advances in materials and processes, as well as fulfilling local needs generate opportunities in remanufacturing and refit, reuse of existing stocks of durable goods, materials and in infrastructures.** A circular economy is based on value preservation in a regional economy, such as reuse and service life extension of stocks. It thus reduces environmental impairments in industrial throughput that is mining and manufacturing and related transport as well as recycling and waste management.

The value of a healthy environment is at present still largely invisible in current national accounting practices. National accounting at present is focused on flows (throughput). Natural capital and health are stocks. Measuring increases in the quality and quantity of stock would enable to redefine growth as increase in stock. Signals are pointing **to better measurement linking economic performance, environmental concerns, social progress and health and well-being.** Until the value

³ EEA 2001. Late lessons from early warnings: the precautionary principle 1896-2000, Environmental issue report 22 & EEA, 2013, Late lessons from early warnings: science, precaution, innovation, EEA Report, 1/2013, European Environment Agency, Copenhagen, Denmark.

of a healthy environment can be incorporated in metrics that provide incentives across society, it is likely that substantial barriers-to-change will continue to block the path towards sustainability.

The road to sustainability opens up a myriad of possibilities. The European Union and its partners in research and innovation should not miss the opportunities entailed in a genuine transformation towards living well, equitably and within the limits of the planet. **Behavioural and institutional changes will also be fundamental in improving sustainability.**

Horizon 2020 could become a game changer: kicking-off a real change

There are substantial opportunities for Horizon 2020 to respond more effectively to the challenges at the junction of health, environment and the bioeconomy. The horizon scanning reported here by the Foresight Expert Group is targeted at the European Commission and member states of the European Union and encourages them to reflect on these emerging challenges. To enable the benefits of the junction approach we identify three specific policy recommendations:

- First, it is important to **provide open spaces for cross-cutting themes and collaborations across societal challenges** in Horizon 2020. Developing cross-programme and cross-field cooperation remains an important challenge for research funding organisations as well as for researchers. For the funders it requires agility and a willingness to strategically reassess opportunities and challenges and to develop programme management processes that support the cooperation at the research end. For the researchers it requires willingness to reach beyond one's comfort zone and open up to other disciplines and ways of thinking.
- Second, addressing societal challenges effectively requires **the conditions to be provided for collaboration between researchers, policy makers, entrepreneurs and broader stakeholder communities at all levels, enabling information dissemination**. Political leadership is necessary to lessen barriers to creativity and innovation. Transdisciplinarity offers new approaches in bringing together scientific and non-scientific research to support active transformation towards sustainability.
- We also urge **the Commission to build on its leadership regarding the Investment Plan⁴** and create an environment in which the research community and Europe's innovators find the opportunity to claim global leadership in the junction of health, environment and the bioeconomy.

The great complexity of issues at the junction of health, environment and the bioeconomy also points to **the need for very large scale collaborative research if European innovators should achieve this global leadership and if real transformational change towards sustainability should be achieved**. This implies a need to make space in programmes for a significant part of the budget to be allocated to major collaborative initiatives on a much larger scale than the norm of Horizon 2020 (e.g. €20-30 million). With this scale of action, key areas of European leadership will be empowered with huge benefits, not just for the European economy, but for the health of the world's citizens and planet Earth as a whole.

⁴ http://ec.europa.eu/priorities/jobs-growth-investment/plan/index_en.htm



1. Introduction

The Horizon 2020 Programme reflects the policy priorities of the Europe 2020 strategy and addresses major concerns shared by the citizens in Europe and elsewhere across the globe. Widely shared concerns are encapsulated in Societal Challenges. Health, environment and the bioeconomy⁵ are covered by Horizon 2020 in three separate societal challenges (SC):

1. SC1 - “Health, Demographic Change and Well-being”
2. SC2 - “Food Security, Sustainable Agriculture and Forestry, Marine, Maritime and Inland Water Research and the Bioeconomy”; and
3. SC5 - “Climate Action, Environment, Resource Efficiency and Raw Materials”.

Horizon 2020 addresses also important cross-challenge concerns, including sustainable development, for which an overall target is set of 60% of Horizon 2020 budget, while climate-related expenditure should exceed 35 % of the overall Horizon 2020 budget, including mutually compatible measures improving resource efficiency.

However, each societal challenge defines its own scope and approach to the issues involved and sets its specific agenda, within a general coordinated strategic programming exercise. Yet, the interdependence between health, environment and the bioeconomy is evident as each of these fields has important implications for the other two. There are '**triple-wins**' at the junction of the three fields, i.e. areas of research in one of the three fields which would benefit the two others.

To support cross-challenge strategic programming in Horizon 2020, **an expert group was set up with the aim of:**

1. **identifying important emerging, but not widely recognized, trends** in science, economy, society and lifestyles, cutting across the fields of environment, health and the bioeconomy;
2. **assessing their implications for the three fields health, environment and the bioeconomy**
3. contributing to the identification of the most promising scientific fields and research areas **that offer potential co-benefits across the three fields.**

To build on the synergies and complementarities between health, environment and the bioeconomy and support a strategic approach using foresight, the expert group was tasked to:

- Identify potentially important trends that are not widely recognised; and
- Identify emerging opportunities for research and innovation (technological and social) at the cross-roads of the three fields.

⁵ The bioeconomy is here to be understood in its broader sense of a sustainable use of living resources from land and sea for food, industry and energy.

Methodology

The expert group began its work on the basis of material ('signals') derived from two complementary sources: First, a list of 186 abstracts identified through contributions from programme officers of the European Commission, second, a bibliometric analysis of scientific publications in the Web of Science database. The scanning phase of the study was followed by three one-day workshops, which took place between September and November 2014. The material from both sources was organised, reflected upon and discussed by the group, in order to derive its conclusions and recommendations.⁶

The scanning and bibliometric exercises provided clusters of issues, which collectively provide a possible mapping of the scope of work at the Junction of Health, Environment and the Bioeconomy (JHEB). Those clusters are presented in Table 1.

Table 1: Consolidated clusters from scanning and bibliometric analysis

Scanning clusters	Bibliometric clusters	Group No
Circular economy Interconnected & multiple crises Environmental governance & empowered green economy From citizen science to public engagement & cultural change, centrality of cultural change for sustainable development	Circular economy Sustainable development Governance (global, national, regional) Economy, finance, banking	1
Cities and infrastructure Green cities & urban farming	Cities Land use	2
Sustainable food Food security for industrialised countries	Sustainable food Agriculture	3
Complex systems thinking Holistic approach to agriculture	Energy	4
Water in the blue and green economies	Water	5
Holistic approach to health Public health & social issues related to individual diagnostics	Health Ageing and population	6
Digital revolution & industrial production	Materials Production	7

The clusters identified in both exercises, have considerable correspondence with the structures of implementation of Horizon 2020. Societal Challenge 1 incorporates group N° 6. Societal Challenge 2 incorporates group N° 3 and 4 as well as parts of groups 1, 2 and 5. Societal Challenge 5 incorporates large parts of groups N° 1, 2 and 5 and parts of N° 4 and N° 7. The clusters also include themes that are under dealt with in Horizon 2020 under Societal Challenges 3 and 4 (respectively 'Secure, clean and efficient energy' and 'Smart, green and integrated transport').⁷

⁶ The methodology is detailed in Annex 1

⁷ All details pertaining to cluster identification are given in Annex 2

The Expert Group considered that a number of elements in topic group N° 1, which are linked to socioeconomic, cultural and policy considerations, as well as group N° 7 (relating to ICTs, materials and production technologies) are of prime importance from an integrated perspective to the junction of health, environment and the bioeconomy. These elements include trends of change as well as barriers to innovation and are discussed in section 2 of this report.

Section 2 presents the trends and barriers at the junction of the three fields of health, environment and the bioeconomy.

Section 3 presents the emerging important themes and opportunities identified by the group in four main areas:

1. **Sustainable food**
2. **Circular, bio- & blue- economy**
3. **Integrated visions for cities**
4. **Holistic health**



2. Integrating health, environment and bioeconomy: trends and barriers

The interdependence between health, environment and the bioeconomy is increasingly apparent and offers **growing opportunities for a perspective for integrating the three fields as well as addressing major barriers**, which are summarised in the following sections.

2.1 Institutional barriers to integrating health, environment & bioeconomy

The existence of different **administrative divisions in government policy** dealing with health, environment, agriculture, fisheries, energy, land use and transport **generates barriers to integration**. It is understood that, whilst these divisions generate efficiencies in the individual domains, they inhibit systemic understanding of problems and systemic solutions, and thus they often fail or underperform when dealing with complex problems, as the responsibility/liability is spanned over many different administrative divisions. The interactions between health, environment and the bioeconomy are intensified by population growth and other global megatrends (see e.g. SOER 2015 - European Environment – state and outlook 2015⁸)

The barriers imposed by administrative divisions in government have a corollary in the **barriers posed by the structures of science**. Disciplinary science and analytical approaches have great merit to some scientific issues, but fail when confronted with complex socio-ecological system challenges for which **more holistic trans-disciplinary approaches are warranted**. Disciplinary boundaries are reinforced by administrative divisions between academic departments and faculties, as well as by the whole system of publications, careers and evaluation in science.

One promising way forward, in science⁹ as well as in government, is to act both at the institutional level by modifying institutional arrangements so that they allow for more cross-cutting operations, and at the individual level, to develop a culture of cross-sectorial cooperation amongst policymakers and inter- or transdisciplinary research amongst scientists, as well as effective science-policy interfaces bridging the two domains.¹⁰

A different set of institutional barriers is associated with market failures. Market failures may be due to powerful vested interests preventing the markets from operating efficiently, and generating high transition costs and lock-ins. **Market failures may also be due to lack of knowledge and mismatches between societal visions, regulations and technologies**. Where there are **multiple trade-offs and complex interactions** markets can also fail to internalise all the externalities and generate perverse incentives or effects. Examples of such perverse incentives apply when key

⁸ <http://www.eea.europa.eu/soer>

⁹ The Paris-Saclay University has the explicit goal to foster encounters of scientists and engineers from various disciplines, through planning of building location and local common actions.(see <http://www.campus-paris-saclay.fr/en/content/download/2667/16571/version/3/file/A4-GB-international-V4.pdf>) Active networking of scientists around multidisciplinary themes can be pursued also by modern communication tools.

¹⁰ van den Hove, S. (2007). A rationale for science-policy interfaces. *Futures* 39(7):807–826

sectors of society benefit from larger numbers of sick people, from higher levels of food waste, and from higher rates of natural resource use. Each of these examples result from only partial valuation, with issues related to health, environment and well-being not being attributed sufficient value in decision-making by society as a whole.

There is thus a strong need to find appropriate incentives and regulations for private actors to work in-line with the common interest. This includes reconsidering how legislation, subsidies, incentives and disincentives and overall tax systems are functioning, strengthening social responsibility and accountability of private actors and creating new business environments which favour responsible business models and responsible research, as well as encourages transformation towards sustainability. **'Triple wins' (innovations that improve health, environment and the bioeconomy) can emerge in the economy if incentives and economic values are oriented towards taking into account the totality of interactions between people and the planet.**

Appropriate metrics and data are needed to measure synergies and trade-offs between health, environment and the bioeconomy (including those of energy and transport). **Capturing the complexity of these interactions is an important prerequisite** for the development of systemic understanding that can underpin good regulation and enable “triple winners” in health, environment and the bioeconomy to become commonplace in Europe's industry and society.

Examples of trade-offs between health, environment and the bioeconomy

Whilst there are synergies between health, environment and the bioeconomy, there are also important trade-offs. For example, , there is an important debate in the scientific community on whether certain crops are effective in achieving net greenhouse gas reductions, once the trade-offs are considered (such as nitrous oxide emissions from fertilizer use in bioenergy crops which compensate the fossil-fuel carbon savings provided).

For another example, consider how the use of antibiotics as growth promoters for livestock is no longer allowed in the EU. However, the legal use of antibiotics in livestock to manage animal health still implies a trade-off. Better animal health improves the productivity of livestock: less feed is needed per kilogram of product, reducing the environmental impact of meat. However, their use also increases the occurrence of multi-resistant bacteria which may cause a large public health risk.

Devices and medicines generated to improve health can also often cause pollution when released in the environment.¹¹ Cooling and cleaning of foods has environmental costs, but it keeps food safe. Food safety regulations increase the amount of food that is thrown away. In the UK, it has been estimated that the 'best before' indication is responsible for a third of household food waste¹². The use of pesticides may improve agricultural productivity, but leads to environmental pollution and risks for health and ecosystems.

Such trade-offs can operate at different scales. For example, at a global scale the use of food crops for biofuels to reduce climate change has been shown to affect prices on global markets, while limiting access to food in less privileged countries. Sudden changes in Western diets due to health fashions (e.g. consumption of alternative grains, increased consumption of salmon or giant shrimps) can also affect food availability in poor countries and create severe environmental degradation.

¹¹ http://www.who.int/water_sanitation_health/publications/2011/pharmaceuticals_20110601.pdf

¹² Quested, T. and Murphy, L. (2014). Household Food & Drink Waste – A Product Focus. Available at: <http://www.wrap.org.uk/node/23379>

2.2 One Planet sustainable economies

We live in an increasingly globalized economy, where key decisions are taken at a global scale by multi-national companies, and where national financial interests of different countries and companies have global implications.

With technological change, the global economy finds new resources and increases its exploitation of existing resources. There is a continuous search to push the limits of resource availability, and for solving bottlenecks caused by individual resources. Water, energy, or nutrients, such as nitrogen, phosphorus, potassium and micronutrients are increasingly seen as limiting resources. Complex feedback loops result from the exploitation of these resources (including effects on health and the environment).

For example, through climate change, there are feedbacks from one set of resources (e.g. energy sources) to other sets of resources (e.g. water availability).^{13 14} A concern about ‘**Peak Phosphorus**’ with implications for future global food-security, became translated into a drive to manage phosphorus, which indirectly addressed nutrient pollution.^{15 16 17 18} Although the concern about peak phosphorus subsided through the recent re-estimation of global phosphorus reserves (290 years rather than 60 years), there is increasing recognition of the effects of phosphorus overuse on the environment (eutrophication, spreading of contaminants present in phosphate). New ways have to be found to improve the use and management of phosphorus and to constrain pollution;¹⁹ including addressing drivers linked to societal consumption patterns.

Management of resources and pollution requires coordination of incentives at a local and global level, and relates to the globalization of trade in key commodities. Imported food and feed products from abroad are often cheaper, although importing food and feed may have substantial environmental costs which are not born by those involved in the importing process. For example, while there are some actions a farmer in Europe might take to improve his/her business and the environment at the same time (e.g. making better use of manure), there will be other actions that benefit the environment, but are not justified from a farm-business point of view. **There is a wide range of possible solutions to such dilemmas that integrate both environment and health cost-benefits with the financial development of the bioeconomy that need to be addressed and understood.**

The coordination of incentives at local and global levels is at the heart of the challenge to make the ‘Green Economy’ work in practice. **How can approaches be found that really stir us towards increased sustainability?** The current preparation of the Sustainable Development Goals as a follow

¹³ A world without water, Financial Times, a series on the rising water scarcity, first instalment July 15, 2014, p. 8.

¹⁴ <http://www.unwater.org/topics/water-in-the-post-2015-development-agenda/en/>

¹⁵ www.bafu.admin.ch/magazin2014-2-07

¹⁶ http://www.unep.org/unea/working_documents.asp

<http://www.fcrn.org.uk/research-library/climate-change/science-background/unep-report-our-nutrient-world>

<http://www.unep.org/newscentre/default.aspx?DocumentID=2755&ArticleID=9707>

¹⁷ <http://onlinelibrary.wiley.com/doi/10.1111/j.1530-9290.2012.00541.x/abstract>

¹⁸ <http://www.vdi-nachrichten.com/Technik-Wirtschaft/Wertschoepfung-Abwasser-gefordert>

¹⁹ http://www.unep.org/unea/working_documents.asp

up to the Millennium Development Goals represents an important contribution. It is important to overcome the barriers which prevent adoption of a Green Economy. Here it is important to recognize that there are different views of the Green Economy.²⁰ **A key question concerns the extent to which environment and health outcomes presently and in the long term are really valued in actual decisions.** For example, many valuations have been made of the health costs and on environmental costs associated with different actions: in the case of the **multiple impacts of nitrogen on Europe** (health, ecosystems, climate etc.), van Grinsven *et al.* (2013)²¹ estimated a social cost in the EU of €75–485 billion per year. These costs are in general not directly born by the organisations or societal groups which contribute to the different forms of nitrogen pollution included.

In the well-known article called “The Tragedy of the Commons”²², each of those with a right to use the commons gets full benefit from exploiting the commons, but only a share of the cost. The result is the depletion of the "commons" resource. In the Green economy there can be a **distinction between a “Sector Profit oriented View”** (e.g. how can Green opportunities help us maximize our profit?) **and a “Societal View”** (e.g. how can we optimize the whole system, including the value of opportunities to improve environment and health?).²³ The resulting differential represents one of the main barriers to developing ‘One Planet Sustainable Economies’ and **research is needed on mechanisms to address it.** One potential way to reconcile a sectorial view and a societal view may be to reassert the societal purpose of the market economy. In this way, companies are seen as aiming to provide goods and services that are beneficial to society, while profit is not the purpose but a means to ensure that the companies will be able to provide these goods and services.

²⁰ Allen,C.,Clouth,S.,2012.A guidebook to the Green Economy .Issue1: Green Economy, Green Growth, and Low-Carbon Development – history, definitions and a guide to recent publications, UN Division for Sustainable Development.

²¹ Van Grinsven H.J.M. et al. (2013). Costs and benefits of nitrogen for Europe and implications for mitigation, *Environmental Science & Technology*, 47, 3571-3579 (<http://dx.doi.org/10.1021/es303804g>).

²² Hardin, G. (1968). The tragedy of the commons, *Science*, 162, 1243–1248.

²³ Sutton, M.A. *et al.* (2014) Green Economy thinking and the control of nitrous oxide emissions, *Environmental Development* 9, 76-85 (<http://dx.doi.org/10.1016/j.envdev.2013.10.002>).

2.3 Maintaining and (re-)building resilient ecosystems and communities

The rising force of systemic challenges has raised the importance of resilience as a quality of communities and ecosystems. It is understood that our growing population and our increasingly interconnected complex socio-ecological systems imply greater risks of sudden unforeseen high impact events. **Our future will depend on our capacity to maintain and (re-) build resilient ecosystems and communities.**

The resilience dividend

*“Building resilience is about the actions we can take now so that the impact of inevitable shocks and stresses are minimized and the rebound is accelerated. It also makes good financial sense. The collective cost of climate change disasters is estimated at US \$200 billion every year. That's equal to the Gross Domestic Product of Peru. Investing in resilience now can help avoid the devastating financial costs of natural disasters—while making day-to-day life better for everyone. **It costs 50 percent more to rebuild in the wake of a disaster than to build in a way that can withstand the shock.** We call this the resilience dividend. Indeed, building resilience delivers near-term economic benefits and jobs, while making everyone better prepared when a shock hits.”*²⁴

Maintaining and (re-)building resilient ecosystems and communities **require systemic science to support regulatory decisions and practice.** “The Victorians got rid of cholera not by treating people who developed it but by developing the political will to build sewers”.²⁵ Lighthouses and training in simple navigation equipment (for example chronometers) contributed more to the safety of shipping than any technical improvement to ships. Such **systems solutions** may escape a systematic scanning but **could emerge from a holistic analysis.**

To promote resilience, current system design practices and policies have been evaluated and best practices **and factors that hinder transformation towards more sustainable systems need to be identified.** Resilience could be promoted and improved through an inclusive approach to knowledge. This may **involve a broader set of knowledge-holders including citizens.** Together they can help in the early identification of emerging issues or potential disasters, collaborating with authorities in formulating and testing response plans, as well as contributing to long term data collection.²⁶

²⁴ The Rockefeller Foundation - Building Resilience to the Shocks and Stresses of Climate Change.
<http://www.rockefellerfoundation.org/our-work/current-work/resilience>

²⁵ The Economist, Oct 11th 2014, Science and Technology, p. 84

²⁶ <http://www.citizen-obs.eu/>

2.4 From grey tech to green tech

The dramatic progress in the fields of life sciences, information technology and computing science over the last two decades results in new developments at the interface between environment, health, and bio-based process.

New tools for awareness and prevention

One of the most impressive breakthroughs is the development of impressive DNA sequencing capability and more generally **of the “Omics”**²⁷. In addition, the convergence of computing and life sciences is already providing various applications, **using biosensors and bio compounds**, enabling for example rapid identification of specific bacteria, improving our capacity to limit pathogen propagation and to cure diseases. Also such progress allows more and more sophisticated *in vitro* or *in silico*²⁸ investigations **at the molecular level**, thereby reducing the need for animal testing (for instance to investigate adverse outcome pathways). Examples include:

- Illumina, a California-based DNA-sequencing company, created a machine (the HiSeq X Ten system) that can sequence a human genome for less than US\$1000²⁹
- Work at the Fraunhofer Institute for Biomedical Engineering on instant tests for viruses and bacteria using miniaturized biosensors³⁰ : integration of sensors with paper towels and handkerchiefs allows diagnoses to be made simultaneously while cleaning one's nose
- Researchers at Duke University have developed a blood test that was 90% accurate in 'distinguishing between viral and bacterial infections when tested in people with respiratory illnesses'.³¹

Such technologies will also contribute to ensure the safety of many activities at the interface of environment (where pathogens come from or may disseminate), **health** (investigation of toxicity mechanism, detection of pathogens, development of treatments), **and processes involving bio-based substances** (e.g. in agriculture, food processing and bio-based industries).

New bio-based processes and materials

To curb the negative impacts of human development on the Earth's resources and reduce the environmental impacts of human activities, **new technologies need to combine with environmental technology** (*envirotech*), which is also called green technology (*greentech* or *cleantech*). Developing such technologies draws on very diverse fields ranging from genome as a resource, to cloud computing and material sciences. Some of these processes use microorganisms to produce chemicals or harness energy with less impact on the environment^{32 33 34}. Such biotechnologies

²⁷ Omics refer to the collective set of technologies used to explore the roles, relationships and actions of the various types of molecules that make up the cells of an organism. These technologies include Genomics (the study of genes and their function) and Proteomics (the study of proteins).

²⁸ *In vitro* refers to research performed outside living organism, while *In silico* refers to research performed on computer or via computer simulation.

²⁹ <http://www.nature.com/news/is-the-1-000-genome-for-real-1.14530> and <http://www.illumina.com/systems/hiseq-x-sequencing-system/system.html>

³⁰ <http://www.vdinachrichten.com/content/Viren%2Dund%2DBakterien%2Didentifizieren%2Dmit%2DDeinem%2DWisch/65291/1>

³¹ <https://globalhealth.duke.edu/media/news/genomic-test-accurately-sorts-viral-vs-bacterial-infections>

³² <http://www.futurity.org/microbe-battery-gets-power/>

currently benefit from many new developments e.g. using more complex organisms such as insects or plants to synthesize specific proteins or metabolites. For example, Stanford scientists have developed a "microbial battery" that uses a special group of microbes - exoelectrogenic microbes - to generate electricity from wastewater. These microbes are wired by carbon filaments that serve as electrical conductors and allow them to generate useful electricity.³⁵

There is a wide range of possible applications which could allow replacement of some industrial processes with more environment- and health-friendly ones in areas like chemistry, pharmaceuticals, vaccines, materials, and biofuels. Research in this domain includes the development of processes, and their scalability, taking into account needed resources and economic viability concerns.

The safety of new bio-based processes and materials is an important concern. In all the areas mentioned above, it remains crucial that sufficient emphasis is put on studying potential environmental and health risks of these new technologies. This is particularly important if there is significant risk of irreversible consequences (such as gene diffusion, persistent pollution, and invasive species). **Under the EU framework programmes, insufficient public funding is orientated towards research on hazards:** a recent analysis concluded that since 1996 the funding for such research represented just 0.6% of the overall EU funding of research and technological development (RTD). In particular Environmental Health and Safety (EHS) research funding for information and communication technologies, nanotechnologies and biotechnologies was particularly low at 0.09%, 2.3% and 4% of total research, respectively.³⁶

Important research directions concern the development of bio-based, health-risk-free, materials and processes to reduce resource consumption and environmental impact, as well as around the development of tools for better knowledge of the environment (identification of chemicals or of pathogens), and related to health (investigation of toxicity mechanism, detection of pathogens, development of treatments), enabling better risk assessments, and regulation of technology. **Designing incentive systems to enable transitions from established technologies to technologies for higher health, environmental and bioeconomic benefit remains an important challenge.**

³³ <http://mitei.mit.edu/news/microbes-chow-down-latest-fuel-cell-tech>

³⁴ <http://www.nanowerk.com/news2/green/newsid=35684.php>

³⁵ <http://engineering.stanford.edu/news/stanford-scientists-use-microbes-generate-electricity-sewage>
<http://www.futurity.org/microbe-battery-gets-power/>

³⁶ Foss Hansen, S., Gee, D. 2014 Adequate and anticipatory research on the potential hazards of emerging technologies: a case of myopia and inertia? *Journal of epidemiology and community health* 06/2014; DOI: <http://dx.doi.org/10.1136/jech-2014-204019>

2.5 Public engagement and new business models

The late 20th and early 21st century has been characterised by an increasing public concern and engagement with science and technology and their ethical, social and policy implications. This includes environmental sustainability, as well as business innovation practices.

The public has become more engaged with science, partly as a result of ‘defensive’ policies that sprung out of the adverse public reactions to certain technologies, including clear technological failures amidst a background of technological hubris (e.g. nuclear accidents and mad-cow disease). The increasing interest of the public in science reflects the growing importance of science in everyday life, in the economy and in politics. Scientists were quick to realise that **the increasing involvement of the public with science could and should be an important resource**. This has been the case in health and the environment, where globally the demand for information on environmental changes and their effect on health is growing, and there are opportunities for citizens to contribute to the body of scientific data and evidence.

Modern data collection systems are increasingly organised in specific areas, in some cases involving the public in observation and data gathering, although there are still important barriers to data sharing and integration of different systems. Public involvement is an important development as solutions to health problems resulting from changes in the environment often depend on local conditions. Yet local needs are often overlooked due to the lack of tools to gather and analyse data at the local level. Citizen observatories can play an important role. Public engagement at the junction of health and environment, including food, can (i) support collection of relevant local data, (ii) contribute to ‘demand-driven’ research, with an early identification of the most apposite research questions, and (iii) help promote the uptake of research results. ***“User-led research is important to engage local populations or decision makers to identify the most pertinent research questions and ensure that research is targeted where there is demand”***.³⁷

Public engagement in issues related to the development of the bioeconomy is of key importance, considering the potential societal risks of new technologies, the involved interests, as well as the infancy of the market. Public engagement holds the potential for a better understanding of the bioeconomy and associated stakes and better decisions regarding the appropriateness of new technologies. For example, recent developments in **synthetic biology** have attracted attention of the public which is increasingly looking for information on the potential benefits and the associated risks. Engaging the public on societal choices concerning emerging and converging technologies will be crucial for the successful implementation of the bioeconomy. Transdisciplinary research platforms could create a new dynamic, not only in bringing science and society in a productive dialogue, but also in developing new research questions.

Of course, business has not remained indifferent towards increasing public engagement. The context in which companies operate today, is characterised by **growing societal demand for corporate social and environmental responsibility and accountability**, and a move towards more sustainable production and consumption patterns, not only in Europe and the US, but also in other important

³⁷ Wellcome Trust (2012). Impact of Global Environmental Challenge on Food/Nutrition and Water in Relation to Human Health, Workshop Report.

economies.³⁸ Businesses are embracing social responsibility and develop models that integrate the concerns of diverse stakeholders from employees and customers to local authorities and civil society organisations. There is also an increasing pressure of non-governmental organizations (NGOs) to move towards safer goods and greener production processes.³⁹

A related phenomenon in recent decades has been social innovation, and the development of an innovative social business sector. For example, Clinton and Whisnant (2014) argue that incremental innovation in the 21st century will become less effective and that businesses need to employ fundamentally different approaches to creating value.⁴⁰ **Whether “for profit” or “for purpose”, companies need to dare to be more innovative in their business models.** Challenging conventional thinking and finding complementary partners are of particular importance when implementing new business models and responsible research, where stakeholders replace shareholders and the business objective is to ‘serve society’.⁴¹ Examples can be found in the experience of **Grameen** (micro-finance to alleviate poverty, since 1976), which is channelled nowadays into building social businesses often combining the bioeconomy, health and environmental benefits, using local resources and providing jobs.⁴² Another example is Fairphone, a social enterprise that aims at building a movement for fairer electronics. They open up supply chains to understand how things are made and build stronger connections between people and their products. They focus on conflict-free minerals; longevity and repairability; employee wellbeing; social values; and addressing the full lifespan of mobile phones, including use, reuse and safe recycling. (www.fairphone.com)

The global dimensions of sustainable consumption

In September 2012 BBMG, GlobeScan and SustainAbility conducted an online survey “Re:thinking consumption. Consumers and the Future of Sustainability”. The survey mobilised 6,224 respondents from six countries: Brazil, China, Germany, India, UK and the US. 65% of all respondents feel they are responsible for purchasing ‘products that are good for environment and society’. An interesting finding is the readiness expressed by 60% of the respondents from Brazil, China and India to pay more for sustainable products, while at the same time 22% of the respondents from Germany, UK and US indicate such willingness. Globally, ~75% of the respondents consider that governments, businesses and consumers have shared responsibility for improving environment for the future generations.⁴³

³⁸ See for example resolution brought by activist shareholders requiring SHELL to test if its business model is compatible with global targets to limit global warming <http://www.theguardian.com/environment/2015/jan/29/shell-urges-shareholders-to-accept-climate-change-resolution>

³⁹ See for instance <http://www.greenpeace.org/international/en/campaigns/detox/>

⁴⁰ Clinton, L., Whisnant, R. (2014). Model Behavior. 20 Business Model Innovations for Sustainability. Sustainability Ltd.

⁴¹ Yunus, M., Moingeon, B. and Lehmann-Ortega, L. (2010). Building Social Business Models: Lessons from the Grameen Experience, *Long Range Planning*, vol. 43, issue 2-3, pp. 308-325

⁴² See for example <http://www.danonecommunities.com/en/project/grameen-danone-food>

⁴³ <http://www.globescan.com/component/edocman/?task=document.viewdoc&id=51&Itemid=0>

2.6 New production systems and intelligent decentralisation

While large institutions and vested interests can create ‘lock-ins’, coordination of small endeavours can have advantages in terms of the ability of the production and consumption systems to adapt to the challenges and opportunities of integration of health, environment and the bioeconomy concerns. **Intelligent decentralisation refers to a coordinated system of local endeavours of high diversity and high performance in terms of generating innovative technologies and innovative business models.** We expect intelligent decentralization to become a trend that feeds off the growing individualisation of consumer tastes, and to be a significant contributor to local economies in Europe by 2030. The following signals support this expectation:

- In **urban farming**, innovative technologies make local small-scale production economically viable, open new business opportunities and can contribute to mitigating climate change (see section 3.1.3).
- Local treatment (**recycling**) of various wastes to avoid transport cost (e.g. urban waste and by products of agriculture)
- A technological revolution has started through the introduction of **nanostructured micro reactors** in the field of high-purity chemicals. Intelligent parallel working micro-reactors producing chemicals of high purity could take the place of large centralised reactors in the chemical industry. Fine chemicals will no longer need to be produced at few sites in the world and then shipped to the user but can be produced in the quantities that are needed and where they are needed.
- **Increasing local production** can reduce logistics and commuting distances, which may decrease car use and allow increased commuting by foot and bicycle. Local production therefore reduces unhealthy air pollution emissions and exposures, while increasing physical activity, with both factors contributing to improved health.
- **Additive manufacturing (AM)**,⁴⁴ such as 3-D printing is widely used today in many areas; according to one report, 30% of parts production in 2012 was done using professional-grade 3D printing systems (defined as those which sell for more than US\$ 5,000). The additive manufacturing industry is also experiencing “staggering growth in low-cost ‘personal’ 3D printers”. These printers sell for less than US\$ 3,000, with many available in kit form or preassembled. Personal 3D printer unit sales grew by 289% in 2011, with an astonishing 23,265 units believed to have been sold (Figure 1). This technology could be useful to develop local activity, for example locally repairing devices to extend their life. However it must evolve in such a way it does not become another source of plastic wastes. Ethical and liabilities issues should also be addressed (e.g. 3D-printing of harmful substances or guns?).

⁴⁴ Additive production processes are ‘waste-free’, in comparison to traditional machining techniques.

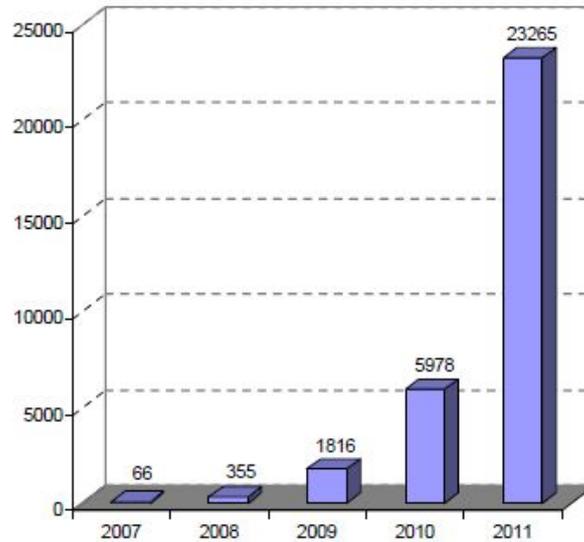


Figure 1: 3D printer sale trends (no. of unites across years)⁴⁵

- Innovative business models in **finance**, such as micro-credit and micro-insurance, have rapidly spread especially in South-East Asia and South America.
- **Crowd mapping**⁴⁶ was developed in the U.S. by students, who founded Ushahidi⁴⁷, a global organisation that empowers people to make a serious impact with open source technologies and cross-sector partnerships. It was first used after the Haiti earthquake in 2010.
- **Crowd sourcing** is used to finance local projects of cultural and commercial nature with a large number of small contributions from global investors.
- **Precision agriculture** can use global positioning systems (GPS) combining it with information from the satellites to provide sustainable agriculture according to local conditions, maximising yields with minimal chemical input.
- Photovoltaic solar and micro-hydro-energy production have opened opportunities for local and **municipal small-scale energy networks**. “Plus-energy” buildings (defined as producing more energy than it consumes) have gained increasing attention with policymakers for their contribution in developing resilient municipalities (e.g. increased public security and safety during blackouts with no people blocked in elevators and lesser insecurity in the streets).
- In the circular, bio- and blue economy, waste-to-resource innovations, also known as **industrial symbiosis**, have been developed to increase resource efficiency, lower carbon emissions and increase business competitiveness. Using waste from one company as a resource for another company, or developing local reuse and remarketing networks for second-hand goods, is usually a collaborative process involving social network development.⁴⁸
- In the circular economy of manufactured capital, regionalisation will grow through the **reindustrialisation of regions** linked to an economic reorientation towards the management of existing physical assets. From a systems perspective, activities such as reuse, repair and

⁴⁵ Figure originally published in Wohlers Report (2012). Currently available at:

<http://www.makepartsfast.com/2012/07/4018/terry-wohlers-on-why-most-adults-will-not-use-personal-3d-printers/>

⁴⁶ Crowd-mapping is the aggregation of crowd-generated inputs such as text messages and social media feeds with geographic data to provide real-time, interactive information on events such as wars, humanitarian crises, crime, elections, or natural disasters

⁴⁷ <http://www.ushahidi.com/product/crowdmap/>

⁴⁸ How to promote waste-to-resource innovations? Case studies from the Humber region. A research project supported by ERIE and EPSRC, by Anne Velenturf, Angela Druckman, Kate Burningham at the *Centre for Environmental Strategy*, University of Surrey, Guildford UK.

remanufacturing⁴⁹ are best done locally, where the clients and the goods are located, reducing the need for transport and big factories.

- The same is true for **business models of the performance economy**, such as renting and sharing goods rather than selling them; witness taxis, car sharing and laundromats. These examples could indicate that the trend of 'selling performance' already common among paint manufacturers and other sectors of the manufacturing industry, is spreading to consumer goods, creating local jobs and greatly reducing packaging and (emissions from) transport. In cities, this trend could contribute to the revitalisation of non-polluting economic activities. We expect that these trends will rapidly gain in importance by 2030 as they were first described in a structured way in 2006⁵⁰ and have since rapidly spread to new sectors and countries.

The macro-economic impacts of intelligent decentralisation are largely unknown. The potential health and environmental risks associated with the technologies and practices of intelligent decentralisation such as those mentioned above are also often unknown and significantly under-researched.

⁴⁹ Remanufacture means bring it back to its original condition ('as good as new') – Depending on sector, similar terms are: recondition, refurbish, restore and rebuild – See for example <http://www.product-life.org/en/archive/case-studies/caterpillar-remanufactured-products-group> or Stahel, W. R. (2010), page 225 in 'The Performance Economy', Palgrave MacMillan

⁵⁰ Stahel, W. (2006). *The Performance Economy*, Palgrave Macmillan.



3. Emerging important themes and opportunities

This section presents particularly important themes and trends in health, environment and the bioeconomy, which have potentially important impacts from the perspective of JHEB. They will be presented under **four clusters**: sustainable food; circular, bio & blue economy; integrated visions for cities; and holistic health.

3.1 Sustainable food

“A food system that supports food security, makes optimal use of natural and human resources, and respects biodiversity and ecosystems for present and future generations, and which is culturally acceptable and accessible, environmentally sound and economically fair and viable, and provides the consumer with nutritionally adequate, safe, healthy and affordable food”.

Definition of a sustainable food system according the ERANetwork SUSFOOD ⁵¹

Food production and consumption have a major impact on both health and environment, including regional planning and land use. The impact of changing diets over time on land requirements can be seen in Figure 2. If our food is to become more sustainable, action is needed in both food production (farming systems) and consumption (change in food choices), while also addressing food processing and food waste.⁵²

The need for environmental sustainability and food security both globally and locally combined with the patterns of global population growth generates particular sets of future challenges and opportunities for Europe and the world. We can no longer simply assume an increase in agricultural production by roughly 60% to feed 9 billion people on Earth by 2050. Most agricultural resources (land, water and nutrients) go to feed animals rather than humans and the current challenge is as much for ‘feed security’ as it is ‘food security’.

A rapidly developing narrative concerns the opportunity to optimize human diets, to provide appetising and nutritious food that not only meets calorific needs, but **minimizes the health and environmental risks** associated with overconsumption, waste and farming practices. Changing diets also affect the opportunity space for urban farming, with its own opportunities and risks.

Reducing excess intake of resource-intensive food types (such as meat and dairy products) also reduces the need to use arable land for the production of livestock feeds. This can potentially free

⁵¹ Susfood Strategic Research Agenda https://www.susfoodera.net/lw_resource/datapool/items/item_177/sra-final_website.pdf

⁵² Note that food sustainability and food security are also linked, through bioenergy, to energy security.

up land for carbon sequestration, supporting climate change mitigation, bio-based products replacing fossil inputs, as well as helping to meet bioenergy goals. However, all these options require systematic evaluation of their global and local impacts.

Similar challenges apply in fisheries and aquaculture, with rates of fish consumption increasing substantially. Meanwhile, land limitations push for improved methods to conduct agriculture in salt rich environments.

The call for ‘sustainable intensification’ of agriculture has offered a well-known and contentious narrative in recent years. For example, not all stakeholders agree with a priority for intensification, especially when considering the many associated pollution and health risks⁵³. At the same time, this framing can be considered as ‘policy prescriptive’, while the reality is that a mix of intensification and ‘sustainable extensification’ strategies may be appropriate according to local context. Others have sought to address concerns by emphasizing the intensification of non-market outcomes from agriculture, such as ecosystem services⁵⁴. Given the substantial opportunity in Europe to integrate dietary and agricultural strategies, we recommend exploration of more neutral ways of framing. Future research needs to consider all the possible options for what might simply be called *Food System Optimization*.

⁵³ Garnett, T. and Godfrey H.C.J (2012) Sustainable Intensification in agriculture. FRCN/Oxford Martin School. http://www.fcrn.org.uk/sites/default/files/SI_report_final.pdf

⁵⁴ Buckwell A. et al. (2014) Sustainable Intensification of European Agriculture. RISE Foundation, Brussels. http://www.risefoundation.eu/images/pdf/si%202014_%20full%20report.pdf

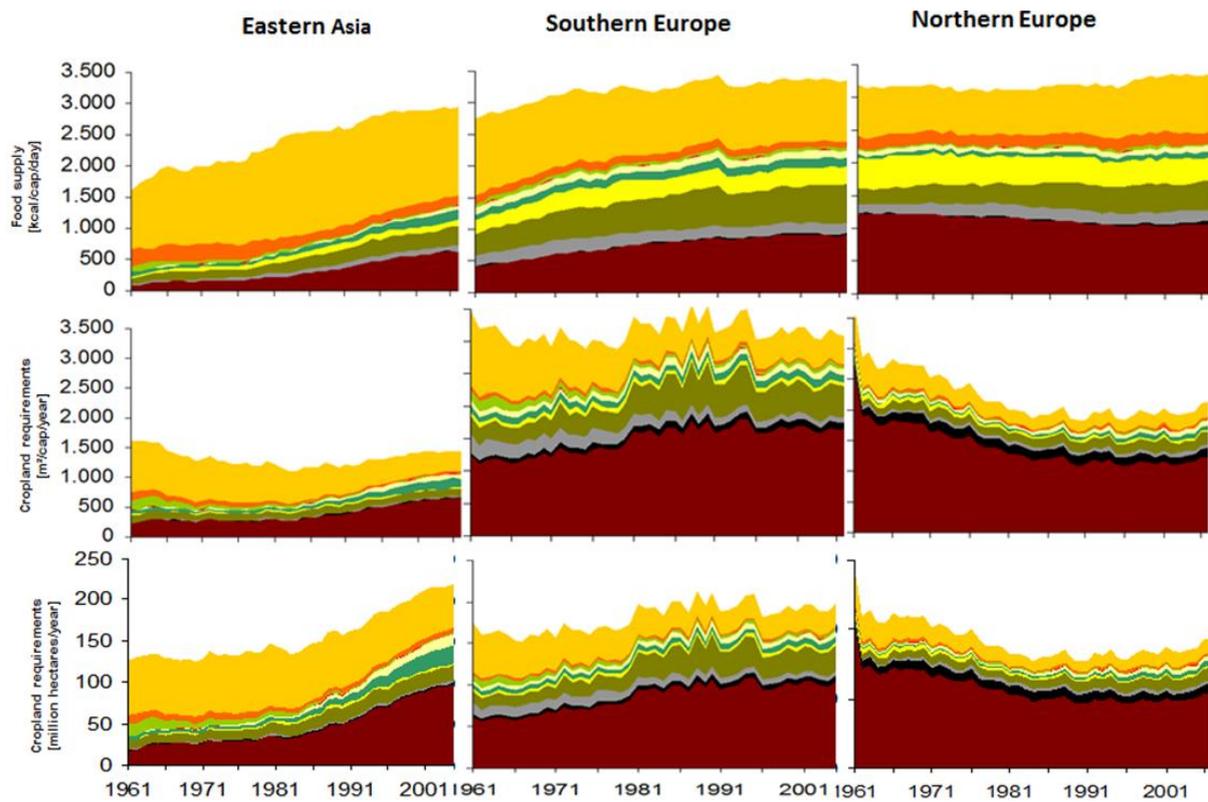


Figure 2: Implications of changes in per-capita food supply for cropland requirements, per capita and million hectares in three world regions: East Asia, South Europe and North Europe⁵⁵

- Cereals
- Starchy Roots
- Pulses
- Spices
- Fruits
- Vegetables
- Sugar & Sugar crops
- Oilcrops & Vegetable Oils
- Alcoholic Beverages
- Stimulants
- Animal Products

⁵⁵ Kastner, T., Ibarrola Rivas, M.J., Koch, W., Nonhebel, S. (2012). Global changes in diets and the consequences for land requirements for food. *Proc. Natl. Acad. Sci. USA* 109, 6868-6872.

3.1.1 Linking local and global sustainable food security

“Companies are recognising that the core elements of the food system – water, land, ecosystem services and oil – are becoming scarcer and will cost more. A sustainable food system will need responsible business.”

Duncan Williamson, WWF.⁵⁶

Agriculture faces global challenges linked to sustainable rural economies, global warming, plant and animal diseases, deforestation, erosion, soil depletion, eutrophication, diversity loss and desertification. Other factors threatening the sustainability of the food system are rising global demand for food, feed and biomass for bio-based products and energy, rapid urbanisation, dramatic decreases in rural habitation, and decreasing land available for food production, all pushing system resilience to its limits. There is a growing recognition of the need to optimize food production and consumption in relation to environmental challenges. Direct impacts of agriculture pose environmental threats affecting from water, air and soil quality, to climate, stratospheric ozone and biodiversity. These are caused by a wide range of material flows and their potential environmental load, such as greenhouse gases, nitrogen and phosphorus pollution, as well as heavy metal and pesticide residues.

There are great differences between countries in the world in food consumption patterns. In Western countries, the population is stable and its affluence is reflected in high levels of consumption. Future Western food consumption is not expected to increase substantially. At the same time, there is also a shift towards a higher share of processed foods and a lower share of fruits and vegetables resulting in increase of non-communicable diseases leading to increased morbidity and premature mortality.

There are weak signals that this pattern may change. Increasing vegetarianism and concerns with a healthy diet signal an opportunity to reduce Western consumption of resource-intensive foods (such as meat and dairy). Meanwhile, European food production and exports could increase to reflect growing consumption in other regions.⁵⁷ For example some European countries are aiming to increase milk production following the end of the milk quota system.

Around 10% of world's food production is exported. This figure might increase in the coming decades due to large differences in terms of food supply and demand in various countries. **Countries like China and India have not enough agricultural land of sufficient quality to satisfy their increasing demands for both feed and food. This will affect global food transport and might turn some regions into new feed and food exporters.** Transportation of food forms additional energy cost and additional environmental impacts from energy supply and use.

⁵⁶ *The Guardian*, 4 December 2013. <http://www.theguardian.com/sustainable-business/sustainable-food-chains-make-business-sense>

⁵⁷ Henk Weshoek et al., 2014, Food choices, health and environment: Effects of cutting Europe's meat and dairy intake. *Global Environmental Change* (<http://dx.doi.org/10.1016/j.gloenvcha.2014.02.004>); Sharada Keats and Steve Wiggins 2014 Future diets Implications for agriculture and food prices: <http://www.odi.org/sites/odi.org.uk/files/odi-assets/publications-opinion-files/8776.pdf>

Presently most countries are largely self-supporting with respect to food, but there are major challenges, where war, poor governance and extreme events lead to major humanitarian crises, especially in some African countries. In developing countries population growth is still the most important factor driving the need for food. Yet in many countries demand for food is driven more by affluence than by population growth. Increasing calorific intake and livestock consumption linked to an expanding global middle class is emerging as a future source of increasing demand.

Traditional economic drivers have led to spatial separation between different types of agricultural production, creating environmental challenges. For example, export of soya from Latin America to Europe for livestock feed exacerbates nutrient imbalances in Europe, where intensive livestock production generates excess manure, while large arable regions in Latin America depend on mineral fertilizer inputs. These **regional differences lead to** low recycling efficiency for manure and increased pollution threats (e.g. groundwater pollution, ammonia emissions, nitrous oxide emissions, phosphorus run off) and **strong environmental impact** such as deforestation for soya production in Latin America.

While there are possible trade-offs between food security and environmental quality strategies - for example, the over exploitation of agricultural land leads to 'soil mining', resulting in reduced yields, erosion and water pollution - it does not have to be so⁵⁸. **There are many opportunities for synergies** when considering global and local sustainable food security. Mixed farming systems **integrating livestock and crops and strategies for better spatial integration of resources and products** (e.g. food and feed crops and livestock manures) **and local food chains** (reducing transport and transaction costs) may offer potentially significant co-benefits. **Green economy mechanisms need to enable the benefits to be realised**, and achieve radical improvements in nutrient use efficiency in food systems, with recyclable nutrients minimizing virgin nutrient take-up and emissions. It is important to draw lessons from different food supply systems, and from their advantages and disadvantages when contrasting local and global scales, in order to provide sustainable food security for a healthy diet and environmental quality.

A key question in this context is whether there are viable alternatives to the prevailing industrialised agriculture. Is organic agriculture a viable alternative? How will different practices affect land fertility in the long-term? A transformation of the agricultural sector could have widespread benefits for food security, health and environment worldwide.

⁵⁸ World Agriculture: Towards 2010 (<http://www.fao.org/docrep/v4200e/v4200e00.htm>)

3.1.2 Optimizing diets: Dietary changes, health and environmental degradation

“The right course is to raise livestock with due regard for animal welfare and retain meat as part of a balanced diet. That means eating less of it. How much less? For Britons, 40 per cent less... If we all did, we would be healthier and might even enjoy it more.”

The Times, Leader article, 28 January 2015

The environmental and climate impact of our food depends on the composition of our menus. The production of meat and dairy, require large inputs of resources like energy, land, nutrients and water, and result in emissions both from animals (greenhouse gases) and manures (nitrogen, phosphorus). **Some 80% of global agricultural plant harvest (expressed as nitrogen) goes to feed livestock.**⁵⁹ Although smaller in their absolute impact, there are also significant environmental effects of vegetables, vegetable oils, coffee, tea and alcoholic beverages.

On a regional scale, rapidly increasing meat and dairy consumption in developing countries is increasing environmental degradation, especially as markets and citizens shift towards western diets. **Even small changes in diets can affect resource use and have important environmental and/or health impacts.**

All kinds of alternatives to meat emerge in supermarkets (croquettes, quorn, tahoe, etc.) or are currently under research. One example of laboratory grown meat is the so-called ‘stem cell burger’.^{60 61} The impact of such artificial foods on health and the environment remains to be ascertained.

By contrast, **there are emerging signals of reducing meat and dairy consumption in Europe, including rapidly developing narratives on vegan, vegetarian and demitarian (halving meat intake) lifestyles, including the possible health benefits.**

A major driver for change is the health risks from inappropriate diets, resulting, for example, from excess meat and dairy consumption.⁶² **Dietary risks represent the largest factor**, especially for cardio and circulatory diseases as well as by cancer (see Figure 3). **Reducing meat and dairy consumption offers the double benefit of improved health and improved environment**, as has

⁵⁹ Our Nutrient World’ (2013): <http://www.gpa.unep.org/index.php/global-partnership-on-nutrient-management/publications-and-resources/global-partnership-on-nutrient-management-gpnm/21-nutrient-management-key-messages-for-rio20-summit/file>

⁶⁰ <http://www.bbc.co.uk/news/science-environment-23576143>

⁶¹ <http://www.bbc.com/news/science-environment-23576143> or http://link.springer.com/chapter/10.1007/978-94-007-7454-4_4

⁶² <http://www.forbes.com/sites/alicegwalton/2014/03/04/the-protein-puzzle-meat-and-dairy-may-significantly-increase-cancer-risk/>

been recently highlighted by the UK Department of Energy and Climate Change.⁶³ Also, in the US, a government appointed panel recommended to reduce red meat and processed meat in diets.⁶⁴

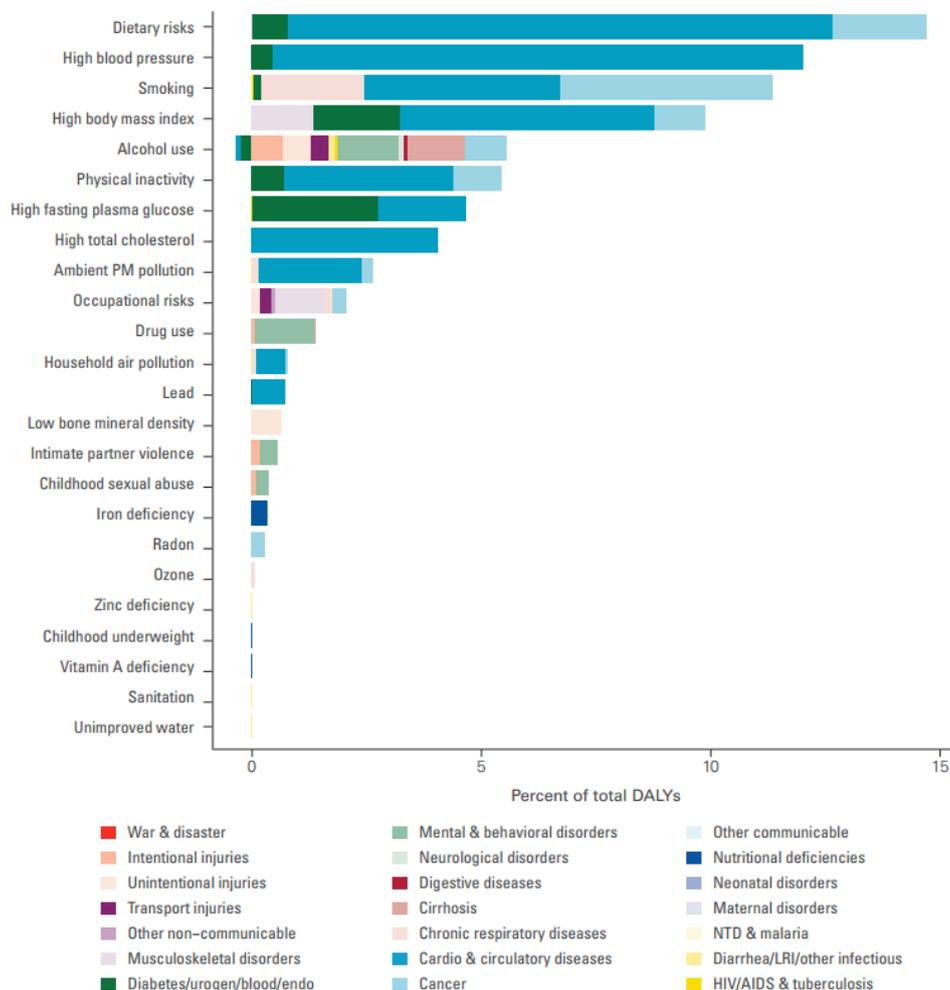


Figure 3: Disability-Adjusted Life Years (DALYs) attributable to leading risk factors, both sexes, all ages, EU and EFTA, 2010⁶⁵

Large scale dietary optimisation, including considerations of health and the environment, remains a challenge for Europe. However, the example of anti-smoking policies shows that it is feasible, although it requires a much better understanding of the relationship between different foods, health and the environment, to underpin both dietary advice and regulation (e.g. on food packaging and consumer protection).

⁶³ DECC (2015) report on global calculator:

https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/398596/Global_calc_report_WEB.pdf

⁶⁴ <http://health.gov/dietaryguidelines/2015-scientific-report/PDFs/Scientific-Report-of-the-2015-Dietary-Guidelines-Advisory-Committee.pdf>; <http://www.citizen-obs.eu/>

⁶⁵ http://www.healthdata.org/sites/default/files/files/policy_report/2013/The%20Global%20Burden%20of%20Disease_Generating%20Evidence,%20Guiding%20Policy%20-%20European%20Union%20and%20Free%20Trade%20Association.pdf

As Europe begins to reduce its meat consumption, **there is also an opportunity to reflect on the implications of global shifts towards more sustainable diets and relevant alternative strategies in our interactions with other parts of the world.**

3.1.3 Urban farming

“A new futuristic market garden, unveiled yesterday, lies a full 100 feet below ground. More than that, it sits under the streets of central London.”

Harry Wallop, The Telegraph, 30 January 2014

Urban farming is re-emerging as a means of providing local fresh food for own consumption or for sale, including both intensive production facilities and micro-production activities, including as a rewarding past-time with potential health and environmental benefits.

One of the main factors contributing to the spread of urban farming is **new technologies**, such as LED lighting for photosynthetically active radiation (PAR) that lowers the cost of energy and **makes new farming techniques efficient at small scale.**^{66 67} Vertical (multi-story) farming enables the use of urban space to grow food, especially in specialized niches, where high quality products could be offered at lower costs. Irrigation, fertilisers (e.g. from organic waste) and heating can be obtained from housing nearby, to contribute to the financial viability of urban farming ventures. In London, underused underground space is used for specialist salad production.⁶⁸ UpCycle,⁶⁹ a small French company active in the social and solidarity economy, combining recycling, circular economy and social concerns, launched a pilot project to help citizens to grow mushrooms in used coffee grindings. After testing the concepts and bringing the first mushroom growing kits to the market, the project is now scaled up through crowdfunding. An urban farm with the aim to produce zero waste is currently being built to cultivate oyster mushrooms. The major mushroom site lies underneath the Rungis International Market (the largest wholesale market in the world, located in the commune of Rungis, in the southern Paris suburbs). Prestigious restaurants buy the mushrooms for their delicate taste. The company hopes to produce and sell 30 tonnes a year. The success of mushrooms could well be followed by other food sources. One could imagine even an upscaling of insect farming in urban areas.⁷⁰

With limited amounts of land in urban areas, compared to the huge areas of agricultural land worldwide, **it is questionable whether urban farming (especially of plant based foods) could ever be more than a speciality activity. But the benefits of engaging in self-produced food in your “window box” might come just as much from their contribution to personal well-being as their calorific and nutrient value.** At larger scale, greening of cities is known to improve citizens’ welfare and supports climate change mitigation.

⁶⁶ http://ec.europa.eu/environment/ecoap/about-eco-innovation/policies-matters/eu/243_en.htm

⁶⁷ <http://www.theblueeconomy.org/blue/Principles.html>

⁶⁸ <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC4048258/>

⁶⁹ <http://fr.ulule.com/upcyclerungis/>

<http://www.20minutes.fr/societe/1306374-20140223-20140223-champignons-marc-cafe-futur-bonheur-chefs-etoiles>

⁷⁰ <http://www.bbc.co.uk/news/world-22508439>

In China, there is currently a rapid increase in sub-urban dairy farming, as livestock feeds are brought into farms with limited land area, to provide fresh milk near to consumers. One can imagine the trend spreading, propelled by the increase in urban consumption of livestock products.

So far little thought has been given to managing the manures from urban farms, while the ammonia emissions to the air from these farms are now recognized as contributing significantly to particulate matter (PM 2.5) in cities, thereby contributing to the human health risks of air pollution.⁷¹ Similar risks can be expected in relation to water pollution and disease transfer, especially for people in close contact with the animals.

The risks of urban and sub-urban farming need addressing, especially the public health risk, as megacities grow with increasing demand for meat and dairy products in the developing world. Actions to mitigate risks to air and water quality, and biosecurity threats are likely to be a rising concern accompanying the spread of urban farming.

3.1.4 The future of fish farming

“The world quietly reached a milestone in the evolution of the human diet in 2011. For the first time in modern history, world farmed fish production topped beef production.”

Janet Larson and Matthew Roney, Earth Policy Institute, June 2014⁷²

Fish plays an important role in the diets all over the world, and aquaculture has become more significant in fish production than the natural stocks (Figure 4)⁷³. Various fish farming systems exist. Ocean based, fresh water based to even indoor and recirculation systems, relieve some of the pressure on endangered natural fish populations. However, there are interactions between fish farming and natural stocks as, for example, wild catches are used as feed for some types of fish farming like salmon and shrimp.

Fish farming presents opportunities for nutrient recycling, including use of herbivorous fish for remediation of excess algae resulting from eutrophication. However, on a local scale, fish farming can also contribute to pollution. Poorly designed systems may exacerbate nutrient pollution and give rise to problems associated with the release of antibiotics and other chemicals in the environment. **There is a need to design systems that contribute effectively to environmental objectives.**

As fish farming increases rapidly in some parts of the world, such as South and East Asia, it needs to be better incorporated into global environmental assessments. There is potentially a wide range of side effects of aquaculture, including the impact of feed-crops, the increased human uptake of for example mercury and other chemicals, and the consequences of pollution on freshwaters and the

⁷¹ Gu, Baojing et al. (2014) Agricultural ammonia emissions contribute to China’s urban air pollution. *Frontiers in Ecology and Environment* 265-266 doi: <http://dx.doi.org/10.1890/14.WB.007> and <http://www.esajournals.org/doi/abs/10.1890/14.WB.007>

⁷² <http://permaculturenews.org/2013/06/14/farmed-fish-production-overtakes-beef/>

⁷³ The FAO data shows that aquaculture is already much more significant than fish capture <http://www.fao.org/docrep/016/i2727e/i2727e01.pdf>

coastal zone. By contrast, for other indicators like greenhouse gas emissions, the direct emissions from fish farming still appear to remain small compared with livestock and arable farming practices, providing an impetus for further growth of the industry.⁷⁴

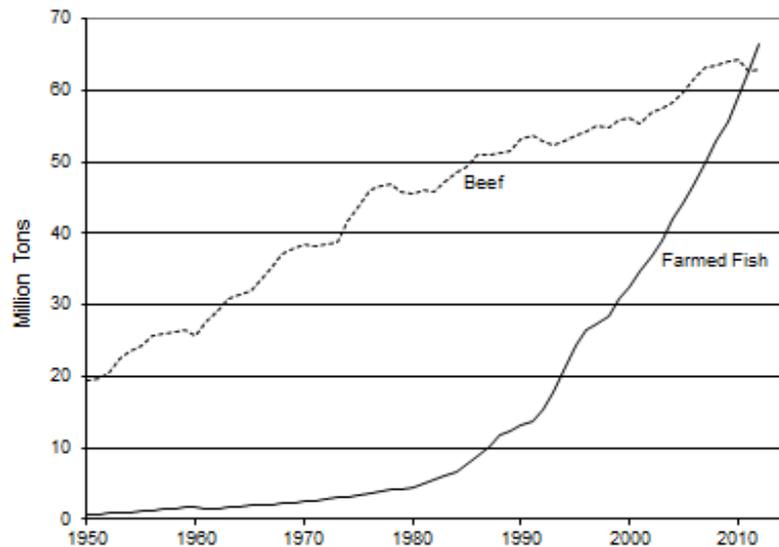


Figure 4: World farmed fish and beef production (1950-2012)⁷⁵

3.1.5 Saltwater and saline agriculture

“Salts are the bane of both irrigated agriculture and of civilizations that are based on irrigated agriculture... Thriving civilizations have declined or disappeared, in part due to poor irrigation.”

Michael Essington, in “Soil and Water Chemistry”

In the coming decades, the land suitable for agriculture is likely to become more limited as rising demand for agricultural products combines with encroaching urbanisation and sea level rise.

Some of the agricultural soils near the coasts suffer from influx of salt water; this makes them unsuitable so far for most prevailing agricultural crops. Soil salinity also results from irrigation in areas with high evaporation rates.

Studies on halophytes (plants that can grow in highly saline water or above saline aquifers) **are showing new potential opportunities for agriculture in the sea, coastal areas, salt marshes and deserts with subterranean saline aquifers**⁷⁶. Amongst the diverse range of over 10000 halophytes there are plants able to produce food, animal feed and biomass for industrial use and energy.⁷⁷

⁷⁴ <http://www.unep.org/pdf/UNEPN2Oreport.pdf>

⁷⁵ EPI based in FAO, USDA. Available at: http://www.earth-policy.org/plan_b_updates/2013/update114

⁷⁶ <http://www.i-sis.org.uk/SalineAgriculture.php>

⁷⁷ See for example www.plnatpower.eu

Some halophytes may even be employed to extract salt from the soil and thus restore it for cultivation with less salt tolerant plants. Research is being done on domesticating wild halophytes, on plant selection and breeding as well as on genetic modification.

The production of biomass for industrial use and energy from halophytes has so far not been economically feasible, but **there are promising signs⁷⁸ and enormous potential economic and environmental gains pursued by halophyte** pilot projects in Asia, North America, Australia and in the Arab states.

3.2 Circular, bio & blue economy

The circular economy, a concept that has a lot in common with green economy and industrial ecology models, is seen by many as a huge opportunity for innovation, job creation and economic development: estimates indicate a trillion dollar opportunity in this area,⁷⁹ encompassing a technosphere (reuse and service life extension of manufactured stock, material recycling) and a biosphere (organic materials including those in manure, mining waste).

A circular economy of manufactured stock (infrastructure, buildings, equipment and goods, materials), builds on local or regional reuse and on repair and remanufacturing strategies, including retrofitting existing structures. Compared with standard manufacturing, these activities have a **high potential for both local job creation and waste prevention, using small amounts of material, energy and water.**⁸⁰ Among the main impacts of a circular economy are improved health through reduced transport needs, massive annual GHG emission reductions (estimated for the UK to be 800 million tonnes of CO₂ annually - see Figure 5), and the creation of a diversity of local jobs. The gains from an environmental and societal perspective of reuse and service-life extension are a higher resource efficiency and resource security, combined with substantial reductions in waste and contamination.⁸¹ In addition, **keeping people in meaningful jobs or activities has health benefits, as unemployment is known to have repercussions for people's physical and mental health.**⁸²

Similar outlooks exist for the bio and blue economy. **Important opportunities for innovation, job creation and economic development, prevention of waste and pollution and reduction of overexploitation of soil and water are among the impacts of managing natural resources in cascades and cycles** (e.g. food waste).

Material recycling has physical and organisational limits. Particular attention should be paid to increases in recycling processes, which can produce harmful substances or release micro-organisms. For example **water, which is at the heart of a circular economy,** can be used more efficiently by closing loops in industrial applications as well as by sufficiency approaches (e.g. drip irrigation in

⁷⁸ <http://cleantechnica.com/2014/01/27/boeing-biofuel-breakthrough-big-deal/>

⁷⁹ From studies by the Ellen MacArthur Foundation and the consultant McKinsey

⁸⁰ The 2008 EU waste directive stipulates reuse and service-life extension of goods as priority.

⁸¹ Doubling the service-life of goods reduces resource consumption (energy, water, material) and waste volumes by half; remanufacturing, compared to manufacturing, prevents up to 90% emissions and is 40% more cost effective, even if it is much more labour intensive.

⁸² See Shigeaki Hinohara, a Japanese doctor and his research on lifelong learning;

<http://www.oecd.org/employment/mental-health-and-work-sweden-9789264188730-en.htm>

agriculture). But some water cycles have biophysical limits, e.g. through accumulation effects of toxic substances or salt. **Key challenges in the circular, bio and blue economy** include: reducing the accumulation of toxic substances and the release of pathogenic agents, promoting the high efficiency recovery of materials from alloys or mixtures (e.g. precious elements used in nanotechnology applications, recovery of components), and reducing the dissipative usage of materials. Particularly important are the operation and maintenance of infrastructure, including the remanufacturing / upgrading of ageing infrastructure; upgrading the European stock of existing buildings to high energy efficiency (retrofitting), recycling materials; and the low-emission deconstruction of tall buildings and infrastructure.

A circular economy builds on the intelligent management of stocks (capital) at an appropriate scale (local to global), based on functionality, with a strong focus on using existing resources. An example is the “selling of car sharing” as compared with the “selling of cars”.. Stewardship and an attitude of caring also apply to managing natural capital, cultural capital (both physical and intangible) and human capital (e.g. through education, health).

The shift to a circular economy in order to exploit its potential for jobs and dematerialised growth **demands a shift in the mind-set of policymakers**. Sustainable taxation, for instance, has cross-cutting implications, also for developing better materials and recycling processes. By taxing non-renewable resources (fuel, material) instead of labour, labour-intensive activities (including recycling) can become more competitive in comparison with resource intensive ones.⁸³

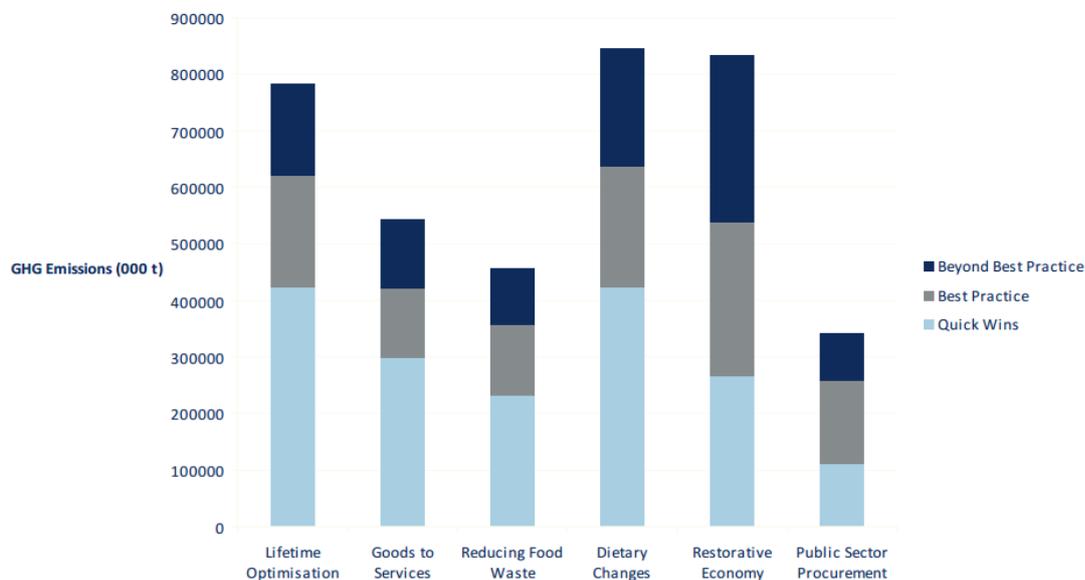


Figure 5: Cumulative GHG emission savings in the UK resulting from various options regarding demand strategies, 2009⁸⁴

⁸³ Stahel, W.R. (2013). Policy for material efficiency—sustainable taxation as a departure from the throwaway society; Published 28 January 2013 doi: <http://dx.doi.org/10.1098/rsta.2011.0567> Phil. Trans. R. Soc, 13 March 2013 vol. 371 no. 1986 20110567.

⁸⁴ http://www.wrap.org.uk/sites/files/wrap/Final%20Report%20EVA128_SEI%20%281%29%20JB%20SC%20JB3.pdf

3.2.1 From value added to value preservation

"If we did all the things we are capable of, we would literally astound ourselves."

Thomas A. Edison (1847-1931), one of the most prolific inventors of history

By 2030, it is expected that the circular economy of manufactured stock will expand considerably, driven by environmental regulations, the quest for higher resource security, and changes in corporate strategy, and facilitated by new university centres of expertise in remanufacture. **The circular economy has as its economic objective to preserve existing value.**

"The circular (or 'loop') economy of manufactured stock addresses a number of objectives at the same time, as it allows for manpower to be substituted for energy, takes into account resource security and waste prevention, and reduces greenhouse gas emissions. The circular economy departs from the take-make-waste model and builds on value preservation by exploiting the smallest loops (reuse before repair before remanufacturing of good; locally before regionally) instead of value added through global supply chains, and smart stock management instead of throughput management".⁸⁵

Important elements in the circular economy are:

- Remanufacturing: A few universities have begun to include re-manufacturing in their curricula and European level initiatives are under development to support the concept.
- Recycling end-of-life goods and waste: At the end of life of manufactured stock, one of the main challenges is to develop the separation techniques needed to recover resources in an economically viable way. Currently in Europe 2,500 million tonnes of waste originate every year from industry and households, 4% being considered as dangerous wastes.⁸⁶ Up to now, waste management has developed in two directions: energy recovery and the management of dangerous waste. Materials recovery and "closing the loop to the materials market" face a number of obstacles, physical, technological and regulatory.
- **The circular bioeconomy** is a subset of circular economy, which **creates value by better exploiting the natural capital** (microorganisms, animals and plants). The largest and oldest sectors are agriculture for food production, forestry and fisheries. More recently biotechnologies, agriculture producing methane, hydrogen and bio-plastics have been added to the mix. The bioeconomy, if operated in an environmentally sustainable way, can be considered as the circular economy of managing natural capital. The UK government has recommended that a Minister in the Department for Business, Innovation and Skills (BIS) is given responsibility for the development of a waste-based, high value bioeconomy.⁸⁷
- Approaches to facilitate the circular economy can be strong drivers of local job creation, reinforcing social links, reducing the need for transport and reducing waste. Examples include: "Local companies' ecosystems" (including **local integrated systems**, in which companies use other companies' waste as resource through industrial ecology and industrial symbiosis), direct marketing by farms and collaborative consumption by citizens. There is a new trend to produce food where it is consumed.⁸⁸ Smart (or precision) agriculture may become a significant contributor to local economies.

⁸⁵ <http://europesworld.org/2014/06/15/zero-waste-has-been-ineffective-in-the-west-even-if-its-had-limited-success-in-asia/#.U-ypnBCAuVo>

⁸⁶ http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Waste_statistics

⁸⁷ <http://www.waste-management-world.com/articles/2014/06/uk-government-action-to-build-waste-based-bioeconomy-following-lords-report.html>

⁸⁸ <http://www.newscientist.com/article/mg22129524.100-vertical-farms-sprouting-all-over-the-world.html>

3.2.2 Decreasing the environmental impact of human activities

If the earth must lose that great portion of its pleasantness which it owes to things that the unlimited increase of wealth and population would extirpate from it, for the mere purpose of enabling it to support a larger, but not a better or a happier population, I sincerely hope, for the sake of posterity, that they will be content to be stationary, long before necessity compels them to it.

John Stuart Mill, Principles of Political Economy (1848)

Even if by 2030 the share of the circular economy will have increased significantly, **material recycling will not totally prevent future situations of material scarcity and pollution.** Recycling means “ordering” wastes (sorting atoms or molecules), which needs energy at a rate increasing with the quality of separation, according to the second law of thermodynamics leading to overwhelming costs. Some materials (for instance mixtures of polymers and composite materials) are very difficult to recycle.

Even in an optimized circular economy, there will remain material leaks towards the environment. At present, such leaks encompass non-recycled waste such as plastic packaging, contaminants released by various activities, including wear and tear of goods and various chemical substances such as pesticides, housekeeping and personal care products, pharmaceuticals, heavy metals, radionuclides and more recently nanoparticles. There is no area on Earth where contaminants from human activities cannot be found.

Ecosystems (natural and artificial e.g. in water treatment plants) absorb and degrade substances. However some of them (or their transformation products) persist for a long time. **Sustainable human activity requires limiting releases of any substance at a level compatible with the assimilation capacity of ecosystem so that their concentration in environmental compartments is kept below toxicity levels.** Some contaminants are addressed in the 2001 Stockholm Convention on Persistent Organic Pollutants and in EU legislation, but a lot remains to be done.

The accumulation of plastic in the environment by littering cities, rivers, beaches, lakes and seas generates possible harmful impact on ecosystems,⁸⁹ forming large loads of drifting debris, with sizes from microns to more than one meter, often being swallowed by fish, mammals, birds and plankton-eaters and finally humans.⁹⁰ **The recognition of the problem is such that it can reasonably be expected that by 2030 the release into the environment of persistent chemicals and in particular of plastic waste will be strongly reduced.** The reasons for such optimism are a trend to strengthen regulations to control the release of chemicals combined with the development of more environmental friendly chemicals and materials for those products which have to be released (at least housekeeping products, body care products, packaging, pharmaceuticals, pesticides). Emerging innovations, including new business models, materials based on cellulose or other biomass are giving rise to non-persistent biodegradable and edible plastics and other bio-based materials that can be recycled by the environment,^{91 92 93} i.e. transformed into substances such as hydrocarbons and

⁸⁹ http://ec.europa.eu/environment/integration/research/newsalert/pdf/IR1_en.pdf

⁹⁰ <http://news.nationalgeographic.com/news/%202014/07/140715-ocean-plastic-debris-trash-pacific-garbage-patch/>

⁹¹ http://www.science20.com/news_articles/new_bioplastic_even_encourages_plant_growth_environment-130888

proteins, which can be “reused” by the biosphere. Such optimism, however, does not imply complacency. Research is needed on how different actions can be integrated towards achieving ambitious and achievable goals (for 2030 and beyond) in relation to clearly defined performance indicators, and to address the barriers that prevent progress on a global scale.

3.2.3 Water at the heart of the circular economy

Human health and well-being is intrinsically connected to, and impacted by, the seas and oceans which surround our continental landmass. To manage this relationship, we need an effective policy framework, linking maritime and public health policies”

Kostas Nittis (Chair, European Marine Board).

The Earth’s water is continually cycled between the reservoirs oceans, atmosphere and land, whereby oceans contain about 96% and **only about 3% is fresh water on land.**⁹⁴ **Water remains at the core of the food, environment, climate, health, energy and economy nexus.** Freshwater shortages hit agriculture and food production, human and animal health, most industrial sectors, change the environment and have important economic consequences.

Primary production is responsible for 70% of freshwater use. The development of the bioeconomy may pose additional strains on fresh water supplies, which are also challenged by climate change. **It is vital to develop a better understanding and monitoring capability of the global water cycle** covering precipitation, evaporation and evapotranspiration, soil moisture, river discharge, surface and groundwater storage. Drinking water distribution infrastructure should be improved to improve efficiency and reduce loss of water through leakage.

There is an important need to monitor water quality, including combined impacts of chemical pollutants leached to ground and surface waters. There is a real demand for rapid diagnostic tests of water and food quality including biological parameters such as the presence of EHEC, a strain of the E. coli bacterium. Emerging techniques for rapid sequencing of nucleic acids with sensors based on nanotechnology can fill a gap here. Also, chemical pollutants (such as pesticide residues), hormone and medicinal drug residues, and their combined impact, require further attention **in order to find efficient, proactive procedures to stop the impact of chemicalization.**

It is expected that water monitoring will improve under the impetus of concerns of the European Environment Agency (EEA) and the United Nations (UN) to measure progress towards the UN Sustainable Development Goals. The current debate in Europe on fracking also underlines the **need for sound hydrological knowledge to support decision making at the interface to water-energy-environment and health.**

⁹² http://www.rdmag.com/news/2014/05/nanocellulose-sponges-combat-oil-pollution?et_cid=3924681&et_rid=544710844&type=headline

⁹³ <http://www.dezeen.com/2014/04/01/edible-water-bottle-uses-algae-to-create-biodegradable-alternative-to-plastic-containers/>

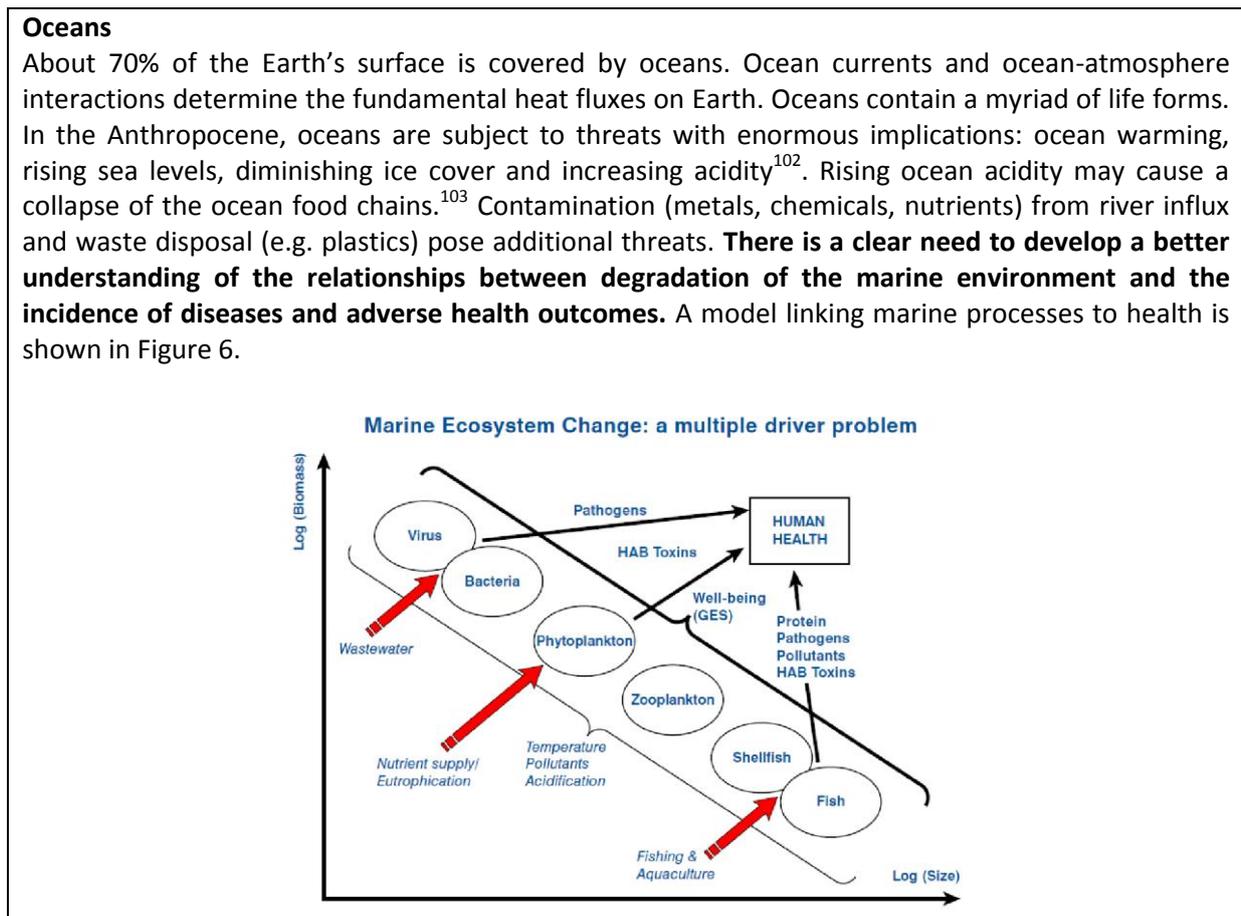
⁹⁴ <http://water.usgs.gov/edu/earthhowmuch.html>

Traditional approaches to solving specific local water issues (e.g. water distribution and wastewater treatment) are complemented by efforts to improve systemic understanding of the water-food-energy-climate and also health nexus.^{95 96 97 98} Economic and financial actors are also taking notice.⁹⁹ ¹⁰⁰. Novo Nordisk's efforts in Kalundborg to find a sustainable solution to the problem of scarce groundwater resources can also be mentioned here; the 2014 Horizon 2020 call – Water Innovation: boosting its value for Europe¹⁰¹ is already encouraging towards smarter water use.

In 2030, we can hope that the signals of planned large investments in some developing countries to radically improve the water supply and sanitation infrastructure will have come to fruition. **This will open up opportunities for a wide range of services provided by European companies.**

Oceans

About 70% of the Earth's surface is covered by oceans. Ocean currents and ocean-atmosphere interactions determine the fundamental heat fluxes on Earth. Oceans contain a myriad of life forms. In the Anthropocene, oceans are subject to threats with enormous implications: ocean warming, rising sea levels, diminishing ice cover and increasing acidity¹⁰². Rising ocean acidity may cause a collapse of the ocean food chains.¹⁰³ Contamination (metals, chemicals, nutrients) from river influx and waste disposal (e.g. plastics) pose additional threats. **There is a clear need to develop a better understanding of the relationships between degradation of the marine environment and the incidence of diseases and adverse health outcomes.** A model linking marine processes to health is shown in Figure 6.



⁹⁵ <http://www.earthobservations.org/area.php?id=he>

⁹⁶ http://www.who.int/water_sanitation_health/publications/9789241598422/en/

⁹⁷ ftp://193.194.138.98/meetings/201307_5th_geo_healthenv_washingtondc_usa/24%20Jul/EO2Heaven%20Cholera%20Case%20Study%20Washington%20SvB%20July%2023%202013.pdf

⁹⁸ <http://www.emwis.net/thematicdirs/news/2013/02/nearly-5000-litres-water-day-consumed-capita-eu>

⁹⁹ <http://www.weforum.org/issues/circular-economy>

¹⁰⁰ <http://www.businessweek.com/articles/2013-03-07/investors-seek-ways-to-profit-from-global-warming>

¹⁰¹ <http://water.usgs.gov/edu/earthhowmuch.html>

¹⁰² http://www.mitin-network.org/files/1148/4_symposium_Qingdao_2013/8_Slide_shows/197_WATSON_WRIGHT

¹⁰³ <http://www.pmel.noaa.gov/co2/story/What+is+Ocean+Acidification%3F>

Figure 6: Drivers of the processes contributing to the interactions between marine ecosystems and human health¹⁰⁴

Marine coastal regions are especially significant because about 70% of the world's population lives near the coast. Wetlands and tidal wetlands (salt marshes) are complex ecosystems continually threatened by factors such as hydrological changes in the water table, urbanization and industrial development, mining, agriculture and marine recreational activities. Exploitation of tar sands for mining is likely to have a serious negative effect on wetland ecosystems due to the destruction of the peat marshes covering the oil sands in wetlands. In addition, mining alters the flow of water in a wider area, thus changing the hydrological balance. Major persisting problems are loss and degradation (esp. of biodiversity and water quality) as well as intrusion of saltwater that impacts both the chemistry and microbiology of water supplies. Salt marshes, which play a large role in the aquatic food web, in the delivery of nutrients to coastal waters and in coastal protection are degrading. Such problems require integrated management approaches, for example, controlling water flow, vegetation and sediment accumulation jointly in salt marshes.

More research is required to better monitor and understand wetland processes in order to properly manage economic activities and eliminate health risks. Harmful Algal Blooms (HABs), waterborne and vector-borne diseases can develop under critical environmental conditions, especially in high levels of nitrogen and phosphorus pollution, and threaten human health. Diseases related to wetlands include diseases due to cyanobacterial toxins in the algal blooms,¹⁰⁵ diarrhoea, schistosomiasis,¹⁰⁶ Vibrio bacterial infections¹⁰⁷ and mosquito-borne diseases. Actions to reduce HABs have simultaneous environment and health benefits.

In the time span of 2015 to 2030, stress on the water cycle, including on water quality, is likely to increase markedly due to climate change and conflicts in the water-energy-food nexus. Advanced technologies to manage efficient water use for agricultural irrigation and inland aquaculture as part of integrated water management systems are important. A focus on resilience is needed to be able to deal with possibly abrupt changes in environmental, political and economic factors. This requires appropriate indicators of resilience, and improvement of monitoring of essential variables, exploiting all available data and information sources (EO, in-situ, surveys and citizen networks) and by developing the necessary IT standards to process large heterogeneous data sets.

¹⁰⁴ From Allen J.I. (2011). Marine Environment and Human health: an Overview. Hester R, Harrison R. (Eds.). Issues in Environmental Science & Technology 34:1-24. Royal Society of Chemistry, London.

¹⁰⁵ http://www.who.int/water_sanitation_health/diseases/cyanobacteria/en/

¹⁰⁶ <http://www.who.int/schistosomiasis/en/>

¹⁰⁷ <http://www.sfcddcp.org/vibrioinfections.html> & <http://www.who.int/schistosomiasis/en/>

3.2.4 Closing nutrient cycles

“Only once the world’s citizens begin to realize how nutrients represent a nexus that unites all our concerns, will many governments become sufficiently empowered to support society as a whole in taking the actions needed”

“Our Nutrient World” - Report for United Nations Environment Programme (UNEP, 2013)¹⁰⁸

The management of global nitrogen and nutrient cycles is a foundation for the circular bioeconomy, offering opportunities for water, air, greenhouse gas, ecosystem and soil management, while helping with food and energy security. Improving the efficiency of nitrogen and other nutrient use enables us to produce more food and energy with less pollution and less resource consumption. Better management of new nutrient sources such as fertilizers, combined with improved collection and reuse of nutrients would save on fertilizer costs, while reducing the environmental impacts and health concerns.

About 2% of global energy use goes to turning atmospheric **nitrogen** (N₂) into reactive nitrogen (N_r) compounds for fertilizers.¹⁰⁹ Losses of N affect all environmental compartments from the stratosphere, through particulate matter in the air we breathe, to terrestrial, freshwater and coastal ecosystems. Nitrous oxide (N₂O) - mainly from agriculture is a very powerful greenhouse gas and, now, the main cause of stratospheric ozone depletion⁶⁴, while nitrogen oxides (NO_x) are the major cause of tropospheric ozone pollution (threatening health and agricultural productivity). **Ammonia** (NH₃) is the largest source of atmospheric reactive nitrogen (N_r) deposition to terrestrial ecosystems in Europe. Nitrates (NO₃) threaten drinking water quality, and pose risks to human health and biodiversity through harmful algal blooms. Disturbances of the N cycle represent key systemic challenges for modern society. Terrestrial N_r input is now more than double natural levels, while only 20% finds its way to useful products, with 80% being waste contributing to pollution problems.¹¹⁰

In addition to nitrogen, there are key challenges for phosphorus (P), potassium (K) and micronutrient management, as these mined resources are non-replaceable. Key challenges for these nutrients include managing available reserves in more sustainable ways, especially given the dominance of global supply from a limited number of countries,¹¹¹ and finding ways to motivate better management practices that foster a better circular economy in these nutrients.

A key emerging theme is the idea of “full-chain” or “economy-wide” nutrient use efficiency (NUE) illustrated in Figure 7.

¹⁰⁸ Our Nutrient World’ (2013): <http://www.gpa.unep.org/index.php/global-partnership-on-nutrient-management/publications-and-resources/global-partnership-on-nutrient-management-gpnm/21-nutrient-management-key-messages-for-rio20-summit/file>

¹⁰⁹ Fowler D., Coyle M., Skiba U. and 15 others (2013). The global nitrogen cycle of the twenty-first century. *Philosophical Transactions of the Royal Society, B*. 368: 2130164. <http://dx.doi.org/10.1098/rstb.2013.0164>

¹¹⁰ M.A. Sutton et al. (eds.) (2011). The European Nitrogen Assessment. Cambridge University Press. <http://www.nine-esf.org/ENA-Book>

¹¹¹ U.S. Geological Survey (2012). Mineral Commodity Summaries 2012, Phosphate Rock, pp 118-119. See also Appendix B, pp 192-195 For definitions of reserve, resource and related terms. see http://minerals.usgs.gov/minerals/pubs/commodity/phosphate_rock/

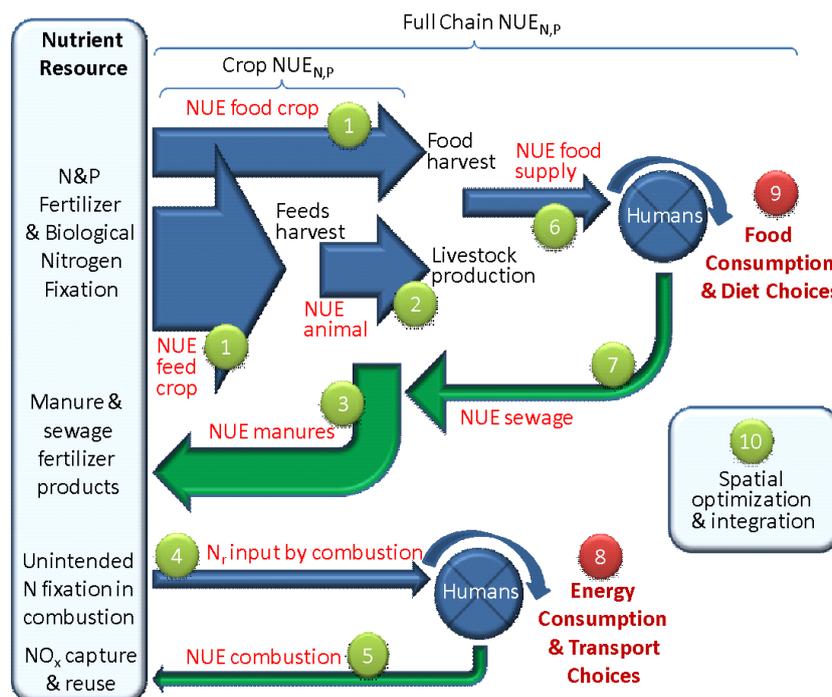


Figure 7: Major global nutrient flows highlighting the potential 10 key actions for the circular, green and bioeconomy to improve full-chain nutrient use efficiency (NUE) for nitrogen (N) and phosphorus (P)¹¹²

There are many ways to improve the nutrient use efficiency for crops (both food and feed crops), and these can be complemented by improved feed conversion efficiency in animals. However, **improving economy-wide nutrient use efficiency requires better management of food supply chains, maximizing recycling of manure and wastewater nutrient resources, as well as learning to recycle the huge amount of N_r produced globally (40M tonnes annually) in the form of NO_x emissions** (Key Action 5). Figure 7 shows that optimizing consumption patterns, both regarding food choices and energy consumption (Key Actions 8 and 9), will also improve economy-wide nutrient use efficiency.

The UN Global Environment Facility and UNEP are preparing the basis for an eventual ‘International Nitrogen Management System’¹¹³. European engagement could offer a science policy support process that couples the main nitrogen threats and benefits in engagement with key stakeholders. This would offer European Member States a mechanism to help meeting environment, climate, food and energy security goals simultaneously.

By 2030, wider development and implementation of digestion technologies could allow wastewater to be a valuable nutrient resource, while supplying significant amounts of bio-energy. This new thinking could change wastewater treatment plants of the future from generating costs

¹¹² “Our Nutrient World” (2013): <http://www.gpa.unep.org/index.php/global-partnership-on-nutrient-management/publications-and-resources/global-partnership-on-nutrient-management-gpnm/21-nutrient-management-key-messages-for-rio20-summit/file>

¹¹³ <http://www.inms.international/>

only to becoming profitable facilities.¹¹⁴ A pilot plant in Zurich has successfully implemented a process to develop a reusable nitrogen fertiliser, a clear liquid.¹¹⁵ A similar development to recycle P from waste-water was launched as EU research initiative.¹¹⁶ A new water-treatment plant pursuing a new concept is currently being built in Hamburg. Wastewater is first concentrated and then treated to create gases that will go to generate electricity and heat. Remnants of the process can then serve as fertilizers.¹¹⁷

The principle of recycling N_r rather than “denitrifying” it back to N₂ is also seen in the future potential to develop Nitrogen oxides Capture and Utilization technology (NCU)¹¹⁸ which **offers a multi-billion Euro opportunity to convert NO_x into fertilizers.** **Green Economy thinking could stimulate major benefits for health, environment and the bioeconomy.**

3.3 Integrated visions for cities

The urban population is increasing globally. As of 2014, 54% of the world’s population lives in the cities and this figure is expected to reach 70% by 2050¹²⁰. In Europe, more than two thirds of the population lives in cities. The increase of three billion people in the world will largely happen in urban areas in developing countries.

Cities have long been known to be society’s predominant place of innovation and wealth creation, yet they have also been main source of pollution and disease, especially in developing countries. To create sustainable and healthy cities, land resource availability, demographics, communication/transportation resources, energy, the bioeconomy, environmental services, health services and social/behavioural considerations need to be addressed and integrated with a shared vision.

By 2025 more than half of the world’s population will live in cities of more than 10 million inhabitants.¹²¹ These mega-cities are likely to cause substantial impacts, which will influence the health of their inhabitants, and affect global environment and ecosystems. But they are equally likely to generate new types of technology, creativity and lifestyles, shaping powerful markets and innovative ecosystems for the future. European cities are not expected to increase in size massively, but the proportion of single person households is likely to increase, and so is the segment of older generation inhabitants. Mobility and use patterns will change as a result. Some cities are shrinking, providing new opportunities for urban planners to improve health.

Improving health in cities has emerged as an important issue. In high-income countries, the burden of non-communicable diseases, including cardiovascular and respiratory diseases, cancer is

¹¹⁴ Magid, J. Eilersen, A. M. , Wrisberg , S. and Henze , M. (2006). Possibilities and barriers for recirculation of nutrients and organic matter from urban to rural areas: a technical theoretical framework applied to the medium-sized town Hillerod, Denmark. Ecological Engineering, 28, 44-54.

¹¹⁵ <http://www.bafu.admin.ch/dokumentation/umwelt/13233/13244/index.html?lang=de>

¹¹⁶ <http://p-rex.eu/>

¹¹⁷ <http://www.vdi-nachrichten.com/Technik-Wirtschaft/Wertschoepfung-Abwasser-gefordert>

¹¹⁸ Our Nutrient World’ (2013) <http://www.gpa.unep.org/index.php/global-partnership-on-nutrient-management/publications-and-resources/global-partnership-on-nutrient-management-gpnm/21-nutrient-management-key-messages-for-rio20-summit/file>

¹¹⁹ <http://initrogen.org/index.php/publications/our-nutrient-world/>

¹²⁰ <https://www.cbd.int/doc/publications/cbo-booklet-2012-en.pdf>

¹²¹ http://www.mckinsey.com/insights/urbanization/urban_world

projected to rise from some 86% in 2005 to 89% in 2030 in terms of DALYs.¹²² Air pollution, noise and temperature account for a considerable proportion of these non-communicable diseases. **Ambient particulate air pollution was ranked ninth as a determinant of disease in the ranking of the Global Burden of Disease estimates in 2010 and is estimated to reduce life expectancy by almost 9 months on average in Europe.**¹²³

In many cities, there is scope for improvement in environmental quality and health through targeted policies. There is considerable variation in levels of environmental exposures, such as air pollution, noise, temperature and lack of green space within cities, which are associated with a range of preventable adverse health effects. Emerging evidence suggests that multiple factors explain exposure variability. These include: urban and transport planning indicators, such as road network, distance to major roads, and traffic density, household density, industry and natural and green space, personal behaviours and lifestyles. The urban environment is a complex and interlinked system; for instance circular economy, urban farming, the need to reduce worker displacements, favour proximity production, address possible pollution sources in cities pose complex challenges. These challenges **require a holistic approach as social, economic, cultural and political issues are interwoven with urban planning, environmental, transport, energy, food and water issues.** For example, the European Commission white paper on transport envisages a substantially different transport use in 2050, but relies to a large extent on technological innovation to get there, without sufficient attention to other factors and related co-benefits on health. Also, making cities 'green and healthy' goes far beyond simply reducing CO₂ emissions. Environmental interventions at the community level, such as urban and transport planning have been shown to be more cost-effective than interventions at the individual level.¹²⁴

A sustainable and healthy city should have attractive open public spaces and promote sustainable, inclusive and healthy mobility. Some potential policies, such as a reduction of car use by increasing the attractiveness of public and active transportation, combined with more cycling lanes and green spaces may have joint effects in that they may not only reduce environmental exposures such as air pollution, noise, and temperature (i.e. heat islands), but also increase physical activity, UV exposure (Vitamin D), social contacts and thereby reduce stress, morbidity and premature mortality. Moreover, a green and active lifestyle may create co-benefits such as a reduction in CO₂ emissions and traffic congestion. Urban farming may increase biodiversity and quality of life. However, knowledge is still lacking despite a wide variety of experiments taking place in cities. Sharing about such experiments is also necessary as **decision-makers need better data to reduce the complexity of factors** in urban planning, transport, environmental exposures, social processes and behaviour affecting human health: they need **enhanced understanding of such issues to know at which level and where to target their actions in an efficient and cost effective way.**

Cities and new technologies

New information infrastructure enables new types of technologies and services to be deployed.

¹²² Busse R., *et al.* (2009). Managing Chronic Disease in Europe, Department of Health Care Management, Berlin University of Technology.

¹²³ Figure 3 and <http://www.aphekom.org/web/aphekom.org/home;jsessionid=F72B04D8770C600FD1311ABF499C250D>

¹²⁴ Chokshi DA, Farley TA. Cost-effectiveness of environmental approaches to disease prevention. *New Eng J Med* 2012; 367: 295-7

Barcelona, with a population of about 1.6 million people, embraced the “**Internet of Everything**” concept and is reaping the benefits. In practice, this means that the city has deployed free Wi-Fi and created a rich assortment of citizen and government apps. Barcelona is also using the “Internet of Everything” to improve the city’s water-management system (generating \$58 million in savings annually), and lighting, with smart street lighting (\$47 million). It has also embedded sensors in parking spaces to let drivers know where available spaces exist (\$67 million). Furthermore, research groups are tracking volunteer citizens for mobility, physical activity and air pollution exposure. In March 2014, *Fortune* also recognized the city’s mayor, Xavier Trias, as one of the world’s 50 ‘Greatest Leaders’, crediting him for ‘connecting citizens to government services through mobile technology’.¹²⁵

As for the “Cloud”, sharing infrastructure, which is what Cloud services permit, drastically reduce the costs involved in creating Smart City services and allows more stakeholders to participate to or benefit from the “Internet of Everything”.¹²⁶ Further opportunities exist to use **sensors** to measure energy use, car use and environmental pollution (e.g. air pollution, noise, temperature) in cities with a view to improve efficiency and thereby save resources, reduce pollution and disease.

The ubiquitous use of smartphones coupled with other **personal sensors** (i.e. sensors carried by people) may provide further opportunities to improve logistics and provide information of high resolution, enabling better informed decisions for authorities and individuals, but also raising ethical dilemmas that are yet to be fully explored and addressed.¹²⁷

New research tools, methods and paradigms are needed. Geographical information systems, smartphones, GPS devices, and remote sensors can be used to produce location-based data and measure environmental exposures and mobility.¹²⁸ The **Exposome** (i.e. totality of environmental exposures),¹²⁹ smart cities paradigm, citizen observatories and other related areas of science and technology can provide the information needed. **Further action needs to be taken for better visions and concerted research and action involving all stakeholders to provide more holistic solutions** (Figure 8). It requires further collaboration between both researchers and practitioners in the field, and more input from many sectors including, urban and transport planning, energy, the bioeconomy, environment, health and well-being and social and behavioural sciences.

¹²⁵ <https://fortune.com/2014/03/20/fortune-ranks-the-worlds-50-greatest-leaders/>

¹²⁶ See for example the EU funded project allowing now over 15.000 sensors in the city <http://www.smartsantander.eu/> (cited in MIT Technology Review, VOL.118, N° 1, January 2015)

¹²⁷ Nieuwenhuijsen, M.J., Donaire-Gonzalez D., Foraster M., Martinez D. and Cisneros A. (2014). Using Personal Sensors to Assess the Exposome and Acute Health Effect. *Int. J. Environ. Res. Public Health*, 11: 7805-7819.

¹²⁸ <http://www.mdpi.com/1660-4601/11/8/7805>

¹²⁹ <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC4048258/>

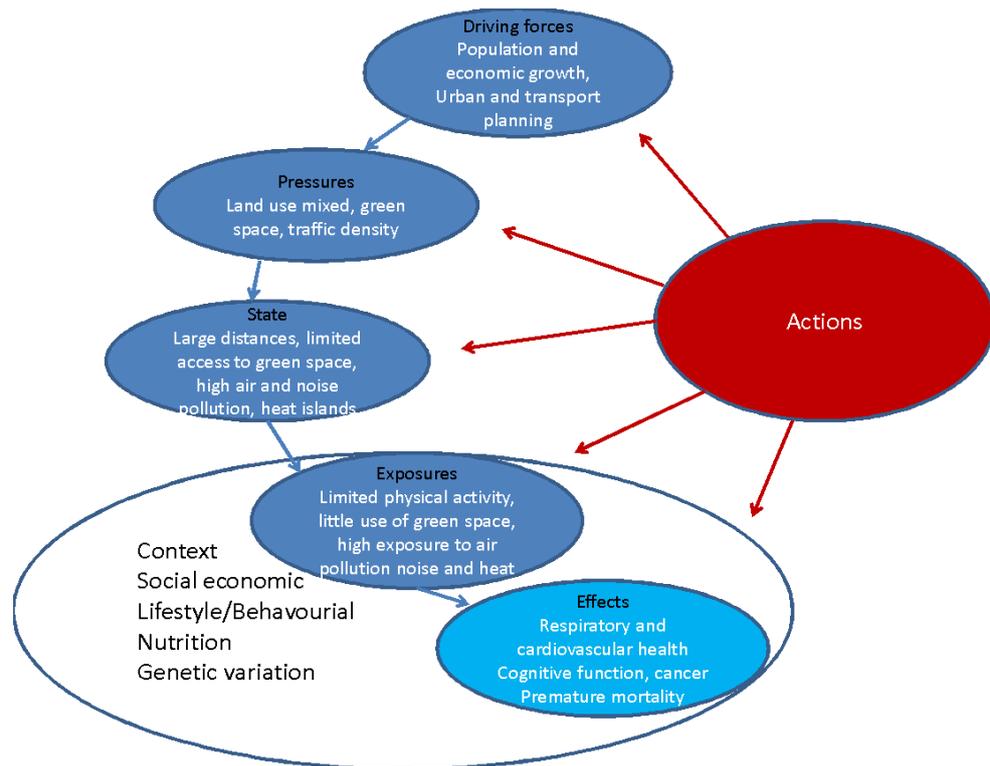


Figure 8: A DPSEEA model of environment-health interactions in cities¹³⁰
 - (DPSEEA is the abbreviation of different elements in the model)

3.3.1 Re-inventing cities for the circular economy

“Managing urban areas has become one of the most important development challenges of the 21st century. Our success or failure in building sustainable cities will be a major factor in the success of the post-2015 UN development agenda”

John Wilmoth, Director of UN DESA’s Population Division

At present, cities are the central components of the EU’s economy and thus hold the greatest potential for kicking-off a transition to a green and circular economy. In energy production, distribution and consumption, good practices already demonstrate this potential: orienting waste treatment towards energy production,¹³¹ waste-heat-to-power processes,¹³² and alternative power to buildings (the new Bio Intelligent Quotient (BIQ) building in Hamburg, Germany, which is powered by algae).

¹³⁰ Adapted from Morris G.P. (2010). Ecological public health and climate change policy, *Perspectives in Public Health*, 130; 34-40.

¹³¹ Westminster Food & Nutrition Forum keynote Seminar, 17 July 2014, London, Congress Centre Great Russel Street WC1, directed by Mark Pawsey, MB and Baroness Scott of Needham Market, chair, EU Sub Committee. D – Agriculture, Fisheries, Environment and Energy

¹³² <http://www.nytimes.com/2013/04/30/world/europe/oslo-copes-with-shortage-of-garbage-it-turns-into-energy.html>

The challenges that have to be addressed along the way are political, social, economic and environmental. Ageing population, ageing infrastructure, sustainable urban planning and management are just a few of the issues to be dealt with by the cities. The projection for 2050 is that more than a third of the European population will be aged over 60.¹³³ This will have strong implications for the long-term planning of urban development (use of technologies in health and social care, social infrastructure, social innovations and engagement of citizens). The responsibilities of local/municipal authorities for ensuring healthy ageing and the well-being of their elderly are likely to increase.

For Europe, in the perspective of 2030 the ageing infrastructure is a major challenge. Cities rely heavily on infrastructure, which requires maintenance and renewal, as population grows and its activities change, as demand shifts, as new technologies allow for new public goods and services to be delivered, and as new problematic issues emerge. One of the greatest barriers to the implementation of the circular economy is the *“lock-into resource-intensive infrastructure and development models”*.¹³⁴ **An infrastructure appropriate for the circular economy**, which is ‘user-friendly’ for citizens and convenient for collecting and sorting waste, sharing services, repair and re-use is needed, will require high up-front investment costs.

A recent initiative of the Association of Cities and Regions for Recycling and Sustainable Resource Management is to support authorities at the local and regional levels to develop and implement strategies on circular economy, **underpinned by a "multi-R approach"** (rethink, redesign, remanufacture, repair, redistribute, reduce, reuse, recycle, recover energy), a territorial hierarchy, innovative business models, multi-stakeholder partnerships and **an important role for local and regional authorities**.¹³⁵ **Citizens’ engagement is strongly emphasised**, focusing upon involving citizens in the design processes, so that future products and services can respond to the real needs of society. **A ‘circular city’ further calls for innovative business models employing entirely different approaches to resource use.** For example, the **'ownership concept'** is starting to lose ground in favour of the **'service model'**: the product is created to serve customers rather than being owned by them, meaning in particular take-back services and better re-use.

With regard to the built environment, a number of initiatives have been helped to green the cities by **converting existing infrastructure instead of demolishing it.** The most prominent example is the “high line” along the Hudson River in Manhattan, an elevated railway track converted into a park and leisure zone. London discusses building a “Garden Bridge” across the Thames River as artificial woodland to stride for the pleasure of tourists and local employee alike.¹³⁶

Austria’s biggest “plus-energy” office building (defined as producing more energy than it consumes) is planned to be built as part of the refurbishment of the University of Vienna. It will demonstrate the technical and economic feasibility of plus-energy office buildings, optimising power consumption and combining it with the installation of Austria’s largest façade-integrated photovoltaic plant.¹³⁷

¹³³ [Council of Europe Parliamentary Assembly](#), Doc. 12817 (9 January 2012), Demographic trends in Europe: turning challenges into opportunities.

¹³⁴ Preston, F. (2012), A Global Redesign? Shaping the Circular Economy (Energy, Environment and Resource Governance Briefing Paper, Chatham House).

¹³⁵ https://www.theparliamentmagazine.eu/articles/sponsored_article/regions-and-cities-are-invited-plan-circular-economy-acr

¹³⁶ <http://gizmodo.com/should-london-build-a-forest-bridge-across-the-thames-1462235473>

¹³⁷ https://www.theparliamentmagazine.eu/articles/sponsored_article/regions-and-cities-are-invited-plan-circular-economy-acr

The demolition of tall buildings in cities with minimal noise and dust emissions is an important challenge. The first such example is the 2014 deconstruction of the ANA hotel in Tokyo: not only did it use an innovative deconstruction technology, but as the crane was moving, the energy created by its move was captured and then reused elsewhere.¹³⁸

3.3.2 Cities towards healthy and sustainable environments

“It always seems impossible until it’s done”

Nelson Mandela (1918-2013)

Health is wealth and cities have the potential to be health promoting spaces by 2030 with the “health” focus shifting from the existence of hospital treatment to the preventive qualities of a health promoting and healthier environment. In Europe, population-dense cities contribute less greenhouse gas emissions per person than cities with extensive suburbs, but are still dominated by cars. In the United States, dominated by emissions from cars, trucks, and other forms of transport, suburbs account for about 50% of all household emissions - largely carbon dioxide.¹³⁹ Many cities (e.g. cities in the C40 network¹⁴⁰) now have policies in place to reduce CO₂ emissions and become more sustainable which will also produce co-benefits for health.

Alternative methods of active transport such as walking and cycling have shown social, health and environmental benefits through reducing environmental exposures such as air pollution, noise, and temperature (i.e. heat islands), and through increasing physical activity, and social contacts while reducing stress. Furthermore, they reinforce other lifestyle changes such a healthy diet or no smoking. They also create co-benefits such as reduction in CO₂ and congestion. **The simultaneous possible benefits of green spaces in cities** (e.g. better health, urban farming, less pollution) **is opening many opportunities to re-think urban development and to make cities much more liveable at a time when the world population is becoming increasingly urban.**^{141 142} Urban living can get healthier in the mid-term future, and help reduce healthcare costs. Reducing car use may result in smaller roads in cities and thereby providing the opportunity to create further public and green spaces. A major shift may be occurring in consumers' attitudes about use of personal vehicles (such as using car sharing instead of owning a car), with ramifications for manufacturers' and governments' investment in public transport and electro-mobility. **Planning the post automobile era for cities¹⁴³ is an important challenge of our time.**

Healthcare and other infrastructures mean that life expectancy in cities tends to be longer than life expectancy in the countryside. While migration to the EU may translate into a rejuvenation of cities, these are also attractive for older generations because of the increased access to medical services and greater opportunity for social contacts and activities, although concerns remain generally related to feelings of insecurity. The possibility of deploying new technologies including sensors in

¹³⁸ <http://www.copybook.com/construction/news/eco-friendly-building-deconstruction-in-japan>

¹³⁹ <http://www.futurity.org/half-household-emissions-come-suburbs/>

¹⁴⁰ <http://www.c40.org/>

¹⁴¹ http://w110.bcn.cat/portal/site/MediAmbient/menuitem.0d4d06202ea41e13e9c5e9c5a2ef8a0c/?vgnnextoid=49a980193fb3e310VgnVCM1000001947900aRCRD&vgnnextchannel=a1d8f314bdb3e310VgnVCM1000001947900aRCRD&vgnnextfmt=formatDetail&lang=ca_ES

¹⁴² <http://www.unfpa.org/pds/urbanization.htm>

¹⁴³ <http://www.businessweek.com/articles/2013-01-03/for-european-car-buyers-cheap-is-now-chic>

cities for environment and health management may further enhance the benefits by increasing information on and accessibility to health promoting areas and activities in the city. They can enable the testing of new concepts such as the exposome to integrate many health determinants,¹⁴⁴ to evaluate demographic changes and related environmental exposures¹⁴⁵ and to use intelligent environmental public health tracking.¹⁴⁶

New initiatives such as citizen observatories and citizen science may increase awareness of the environment, health and well-being in cities and thereby possibly change, and also increase social cohesion, but they are a fairly recent development that needs further work (e.g. with regard to privacy). **Cities enable us to address social cohesion as an issue of socio-ecological cohesion,¹⁴⁷ and to evaluate different systemic approaches to economic, social and policy problems.¹⁴⁸**

3.4 Holistic health

While population growth is usually seen as worsening the crises, inequalities and disturbances, the quest for longevity continues at pace, with a great deal of effort being put into finding the substances, interventions and habits that can keep people live longer and healthier lives, for example by revolutionising the treatment for a massive range of degenerative conditions.¹⁴⁹ For a meaningful long life, the elderly will need to have sufficient mental capital and retain better cognitive abilities and living standards. As people work to an older age, there is a chance that they will *de facto* be mentally stimulated for longer.¹⁵⁰

Europe is facing a rapidly ageing population in the short to medium term, and a population reduction in many countries in the longer term. In a few years, 20% of the European population will be over 65 years old¹⁵¹, **with an anticipated increase in non-communicable diseases (NCDs)** such as dementia, diabetes, arthritis and cancer. Recent estimates show that half the population is likely to get cancer. Furthermore the large increase in obesity has an enormous burden on the health care system and may result in shorter human life expectancy in future generations compared to the current generation. Health care costs have been increasing due to a combination of technology push and ageing population, particularly in the area of chronic diseases;¹⁵² a drastic **shift to more prevention effort is needed at each stage of life, in particular in adolescent health.**¹⁵³ Social inequality is increasing in education, occupation and household economy creating social and political tensions. International migration is also increasing as both incentives and the ability of people to move increase, which means that cultural issues make the challenge even more complex, with

¹⁴⁴ <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC4048258/>

¹⁴⁵ <http://www.unfpa.org/pds/urbanization.htm>

¹⁴⁶ <http://www.nrc.nl/nieuws/2013/03/05/chinezen-zorgen-voor-tekort-aan-babymelkpoeder/>

¹⁴⁷ <http://intl-usj.sagepub.com/content/49/9/1959.abstract>

¹⁴⁸ <http://www.eea.europa.eu/articles/environment-health-and-wellbeing-a>

¹⁴⁹ <http://www.gizmag.com/gdf11-protein-aging-mice-harvard/31929/>

¹⁵⁰ <http://www.pewinternet.org/2014/08/06/future-of-jobs/>

¹⁵¹ "Future of longevity in Switzerland: backgrounds and perspectives", *Institute of Social and Preventive Medicine Lausanne* (2008).

¹⁵² WHO report 2015: 'Preventing chronic diseases, a vital investment' http://www.who.int/chp/chronic_disease_report/full_report.pdf

¹⁵³ Worldwide application of prevention science in adolescent health <http://www.sciencedirect.com/science/article/pii/S0140673612602384>

increased impacts on education, affluence, birth rates and longevity, the latter being also pushed by advances in health and medical care.

The Eurobarometer survey of “Public perceptions of science, research and innovation” in 2014 indicated that 55% of EU citizens identified health and medical care as the top priority for science, technology and innovation over the next 15 years.¹⁵⁴ People live longer with risks of long periods of suffering from painful and costly diseases. However, quality of life is expected to increase with healthy food, meaningful work, safe workplaces, social security as well as recreational activities in local and global resorts. A shrinking active population has to bear the cost of a larger, older group.¹⁵⁵

The efficient shift from treatment to prevention, individual participation and responsibility, while ensuring the health of ageing societies and dealing with threats to treatment such as antimicrobial resistance, remain major challenges. The goal is that healthy life expectancy increases as genetic and environmental causes of disease and possible interactions between the two are better understood and as regulation prevent harmful exposure and promote healthy environments. The enhanced use of Information and Communication Technologies increases the amount of health-related information available and could thus continue improving our ability to turn knowledge into increasing life-expectancy and quality of life. **The market for diagnostic tools is likely to continue to flourish which could cause dramatic evolutions (positive or negative) in the field of health.**

A large part of the NCD burden is due to life style factors and environmental exposures,¹⁵⁶ which are largely preventable. Moreover, an accumulating body of evidence suggests that the prevention of NCDs, such as dementia, diabetes, arthritis and cancer, should start in the earliest phase of life. Pathways underlying observed associations may include developmental adaptations of cardiovascular, metabolic, respiratory and cerebral systems, in response to adverse exposures during critical foetal and childhood periods. These adaptations may shift developmental trajectories and lead to a higher susceptibility to development of NCDs in later life and to earlier ageing. Rising obesity levels largely due to unhealthy diets and sedentary lifestyles and possibly to chemical exposures, lead to a large disease burden at later ages.

Understanding these mechanisms is of key importance to reduce harmful exposure and to promote better physical environments, such as with higher walkability and bikeability, more biodiversity and green space or social environments with improved social cohesion all improve healthy life. Environmental exposures, e.g. to metals and endocrine disruptors, could explain some adverse effects in particular on neurobehavioral and reproductive health.¹⁵⁷

Better diets, lower air pollution and chemical exposure levels, healthier living environments and more active lifestyle will lead to a reduction in NCDs (outdoor air pollution is responsible for nearly 500,000 premature deaths in Europe alone¹⁵⁸). **More holistic approaches are needed.** Hazard identification and risk assessment require modern approaches taking individual and population

¹⁵⁴ European Commission, Using foresight to support the next strategic programming period of Horizon 2020 (2016-2018) – Internal document.

¹⁵⁵ “Future of longevity in Switzerland: backgrounds and perspectives”, *Institute of Social and Preventive Medicine Lausanne* (2008).

¹⁵⁶ http://www.ecdc.europa.eu/en/healthtopics/burden_of_communicable_diseases/project/Pages/project.aspx

¹⁵⁷ Decline in semen concentration and morphology in a sample of 26 609 men close to general population between 1989 and 2005 in France <http://humrep.oxfordjournals.org/content/early/2012/12/02/humrep.des415.short?rss=1>

¹⁵⁸ Air Quality in Europe – 2014 report <http://www.eea.europa.eu/publications/air-quality-in-europe-2014>

characteristics into account. The latter are currently developed in adverse outcome pathway focus in toxicology and creation of follow-up studies of suitable cohorts e.g. family and birth cohorts.

New approaches are needed for health and social care, building both on public engagement and technology, developing and supporting networks within different communities, and engaging people in disease prevention and the provision of healthcare and social services. New social paradigms are emerging, many of which are triggered by contradictions in the urbanisation process and new technologies. Social cohesion is an important determinant of health. Social and socio-ecological cohesion, including the urbanisation of nature and its socio-environmentally enabling and disabling conditions are key processes in healthy longevity.^{159 160 161}

Intervention and guidance towards healthy behaviour targeting communities as well as individuals are however needed. **New cross-cutting methods could help to take cross sectoral approaches including socio-economic and behavioural aspects**, the impact of climate change and increased urbanization into account. Human biomonitoring (HBM), sensing and health surveys can be used as tools for increasing health awareness and promotion, as well as assessing human exposure to environmental agents and their adverse and beneficial effects. Biomarkers are used to measure indicators of changes and events in biological systems with the analysis of specimens of human tissues such as blood, urine, hair, adipose tissue and teeth. Sensors can be used to measure lifestyle, mobility, behaviour and exposure patterns in order to suggest and promote healthier patterns.

Thanks in particular to green technologies which allow focusing on safe production and products, we could hope that by 2030, the burden on foetal and young generations will be less, resulting in reduction of neurobehavioral and reproductive problems along with improved immune resistance and mental health. The use of nature/green space to treat and relieve diseases such as obesity, COPD (please define), attention deficit hyperactivity disorder (ADHD), allergies, dementia and depression should be considered to ensure sustainable and resilient lifestyles through a balance between humans and nature.

3.4.1 Total health information, empowered people and prevention at JHEB

Cheap mapping of the genome has generated an important potential for early 'diagnosis' (or 'prognosis') for every individual. Mapping of the exposome (and all the other 'omes' like the 'virome') as well as other sensor based indicators and human biomonitoring promises to make health and disease, prevention, diagnosis and treatment amenable to analysis through vast amounts of computer power, offering potentially greatly improved health care and health. **Yet, considerations of privacy, as well as of cost, e.g. the cost of research, treatment and health insurance, dampen these possibilities and reduce the speed of developments.**

According to the Health and Environment Alliance (HEAL), conditions such as reproductive and fertility problems, abnormalities of sexual organs in baby boys, cancer of the breast, prostate, testes, children's behavioural disorders, such as autism and ADHD, obesity and diabetes costs the EU more

¹⁵⁹ http://www.sed.manchester.ac.uk/geography/staff/documents/Cities_social_cohesion_and_environment.pdf
<http://intl-usj.sagepub.com/content/49/9/1959.abstract>

¹⁶⁰ <http://www.citizen-obs.eu/>

¹⁶¹ <http://www.unfpa.org/pds/urbanization.htm>

than €600 billion per year.¹⁶² Attributing 5% of this cost to endocrine disruptor exposure (other major contributors include genetics and lifestyle factors, such as diet, smoking and insufficient physical activity) the exposure to endocrine disrupting chemicals (EDCs), is costing EU citizens about €30 billion per year.¹⁶³

Nutrigenomics and **nutrigenetics**, which are seeking to elucidate the interaction between diet and genes but with the ultimate goal to optimize health through the personalisation of diet, are taking off. In parallel, the field of metabolomics is building the tools to both diagnose individual variations in metabolism and identify the means to improve it. **Progress in understanding the basis of human disease and prevention will lead to the development of new technologies that could help manage health.** All aspects of intervention - lifestyle, diet, relevant screening - can be employed to lower disease risk and to balance individualisation and integration of prevention approaches.

Examples of pressing systemic changes include the way to deal with obesity, tobacco, alcohol and their consequences on health, with (re)emerging diseases, with health risks from exposure to new kind of substances (like nano products) or cocktails of pollutants, particularly influencing fertility and/or genes.

Sensor technology and information systems on the web allow access to a wealth of information on one's own behaviour, environment and health. This can lead to better prevention and health care in many cases but this type of information has ethical implications. Technologies for bio-monitoring, detection and diagnostics relevant for behaviour, environment and health are booming. They promise to usher a revolution both in how people deal with their own health and how patients are dealt with by health care systems. It could also strongly impact the field of clinical trials and epidemiology.

The benefits and interest in 'total' health information is huge, but so is the potential for misuse of information, and for confusion and damage by erroneous use of available information. Appropriate regulation and standards of practice are needed for different stakeholders (patient, health professionals, and insurers among the others) on how to deal with health information in a "total-information" environment. Anthropological and sociological research can be expected to have normative implications in this domain.

Prevention strategies at the level of citizens, communities and societies would start in early life, or even at the pre-conception stage, becoming a continued effort, with attention to environmental and occupational health at all educational levels (public schools, high schools and universities). Cultural differences between people will be an important part of these strategies.

¹⁶² http://www.env-health.org/IMG/pdf/18062014_final_health_costs_in_the_european_union_how_much_is_realted_to_edcs.pdf

¹⁶³ <http://www.foodqualitynews.com/Industry-news/Savings-of-31bn-possible-by-reducing-endocrine-disrupting-chemicals>

3.4.2 Balancing microbes

"We mostly don't get sick. Most often, bacteria are keeping us well"

Bonnie Bassler, Molecular biologist at Princetown University¹⁶⁴

Despite global efforts to prevent or delay the spread of antimicrobial resistance, bacteria are becoming ever less susceptible to antimicrobial drugs, while the pace of new discoveries in antibiotic research is declining. Multidrug-resistant bacteria have emerged as a severe threat to public health¹⁶⁵. Recent research allows identification and optimisation of novel naturally occurring chemical and biological compounds to fight infectious diseases.¹⁶⁶

Antibiotic (both human & veterinary) misuse drives rapid microbial evolution that is particularly threatening in countries with limited access to new medicines. This misuse entails large economic and human costs and diverts scarce financial resources in these countries. Resistance is a perennial challenge, but evolutionary tactics and genomics hold promises.¹⁶⁷ One of the pathways of antibiotics into humans is the food chain because of the high antibiotics use in food production. New strategies are emerging to reduce the use, such as dissolving films to kill bacteria in meat early.¹⁶⁸

As humans carry many microbes in and on them, a 'healthy' microbiome, defined as the right balance between microbes, is needed for a healthy living. 'Intestinal dysbiosis is a term used by researchers to describe a state where there is an overgrowth of the more troublesome microbe strains. Change may be seen in the makeup of the flora themselves, how they are distributed, and how they are functioning.¹⁶⁹ The **'hygiene hypothesis'** posited that early life exposure to certain microbes may direct the immune system into different directions and some studies in farmers seem to be support this by lower allergic rates in their offspring. Furthermore, a recent study on green space/biodiversity and allergy and asthma suggested that increased biodiversity improved the skin microbiome and therefore reduce asthma.¹⁷⁰ **In view of the potential for disease prevention, further work is needed on the relationship between environment and environmental exposures and the human microbiome.**

The use of antibiotics does not only kill 'bad' microbes, but also the 'good' ones and thereby increases the risk of disease. New concepts and paradigms are needed to obtain the optimum microbiome to prevent disease, while tackling the infectious disease burden, and reduce the use of antibiotics.^{171 172} For example, by studying an original model organism, aquatic worm dish called planar, researchers were able to identify a new defence strategy against bacteria (here the agent of *Mycobacterium tuberculosis*). This planar worm was best known for its extraordinary regenerative

¹⁶⁴ http://blog.ted.com/the_secret_soci/ Interview with Bonnie Bassler – 2009

¹⁶⁵ <http://copublications.greenfacts.org/en/biocides-antibiotic-resistance/l-3/5-biocide-contribution-resistance.htm>

¹⁶⁶ Fraunhofer magazine 2.14, p. 37ff, referring to the new 'Center of Excellence for Natural Products Research' of Sanofi and Fraunhofer Institute for Molecular Biology and Applied Ecology IME, established January 2014

¹⁶⁷ <http://www.scidev.net/global/genomics/news/evolution-research-crucial-to-development-goals.html>

¹⁶⁸ <http://www.gizmag.com/antimicrobial-pullulan-meat-film/31896/>

¹⁶⁹ <http://ibs.about.com/od/treatmentofibs/a/How-To-Have-Healthy-Gut-Flora.htm>

¹⁷⁰ <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3361383/pdf/pnas.201205624.pdf>

¹⁷¹ <http://www.mnn.com/green-tech/research-innovations/stories/giant-panda-holds-potential-as-powerful-antibiotic>

¹⁷² <https://globalhealth.duke.edu/media/news/genomic-test-accurately-sorts-viral-vs-bacterial-infections>

capacity: even when infected by the bacteria *Legionella pneumophila*, the worm does not die.¹⁷³ Latent in humans, the defence mechanism could be stimulated pharmacologically. Thus, **moving away from conventional models** (the fruit fly *Drosophila melanogaster*, the roundworm *Caenorhabditis elegans*) **is rewarding**.

Prevention and control strategies for (re)emerging diseases, based on the holistic health concept provide an innovative agenda for operational research and for veterinary and public health cooperation.¹⁷⁴

3.4.3 Pharmaceuticals: from today to the future?

The future of the health bioeconomy by 2030 will be determined by the interactions between the global science and industry innovation system, the increasingly global regulatory system, the increasingly divergent range of national and regional health care delivery systems and the stakeholder and advocacy groups that so far have not become systemically organised. Climate change and other factors are changing the distribution of health problems and the types of health problems people face. **It is therefore important to acknowledge the urgency of environment and health issues in pharmaceutical research**, and to integrate it in the development and testing strategies; **combining health and environmental research represent a major source of benefit for society.**¹⁷⁵ **New business models need to be researched, including emphasis on the prevention of disease as well as treatment of disease.**

A lot of potential new drugs are likely to come from the living world, thanks to progress in new technologies. The new OMICs technologies allow the identification of special molecules in plants or bacteria, many of which could be interesting as nutrients or pharmaceuticals. Technologies for monitoring, detection and diagnostics relevant for health are booming. They promise to usher a revolution both in how people deal with their own health and how patients are dealt with by health care systems, with **implications for ethics and with important potential impacts on clinical trials and epidemiology.** Signals pointing to a revolution in healthcare, including low-cost social innovation include:

- Evidence-based nutrition is a strong growth area for pharmaceuticals¹⁷⁶
- Adapting relatively low-cost equipment to accomplish high-tech tasks: researchers converted an iPhone to a microscope in Tanzania to identify parasites¹⁷⁷
- A new genetic 'barcode' for malaria parasites has been found which could be used to track and contain the spread of the disease¹⁷⁸
- Development of an adhesive patch that contains all the electronics and sensors to measure heartbeat irregularities, outperforming traditional tech¹⁷⁹

¹⁷³ [http://www.cell.com/cell-host-microbe/abstract/S1931-3128\(14\)00293-5](http://www.cell.com/cell-host-microbe/abstract/S1931-3128(14)00293-5)

¹⁷⁴ For example against Leptospirosis, see <http://planet-risk.org/index.php/pr/article/view/94/185>

¹⁷⁵ Endocrine Society-IPEN guide available on <http://www.endocrine.org/edcguide>

¹⁷⁶ http://www.pmlive.com/pharma_news/nutraceuticals_big_pharma_or_big_foods_next_big_growth_area

¹⁷⁷ <http://www.bbc.co.uk/news/technology-21769537>

¹⁷⁸ <http://www.sciencedaily.com/releases/2014/06/140613084504.htm>

¹⁷⁹ <http://www.gizmag.com/zio-patch-arrhythmia-monitor/30298/>

- Nanoparticles find potential applications in the quest for alleviating daily injections, for example for diabetic people¹⁸⁰

Recent developments in sensor technology have made it possible to better measure personal exposure to environmental pollutants and other factors, for a combined measurement of air pollution, noise, temperature, UV, physical activity, location, blood pressure, heart rate and lung function and to obtain information on green space and emotional status/mood that is the exposome.¹⁸¹ **Sensor technologies focusing on external and internal exposures** e.g. by human bio monitoring combined with citizen science/participation and crowd funding **could lead to leapfrog advances in understanding and solving health environmental challenges.**^{182 183}

Green chemistry principles outline a strategy to reduce hazard through molecular and process design. Green toxicology is the application of predictive toxicology to the production of chemicals with the specific intent of improving their design for hazard reduction.¹⁸⁴ **Reducing toxicity is at the core of green chemistry (i.e. operating chemical processes with less environmental impact) and sustainability.** Information derived from mechanistic and computational toxicology combined forms the nexus between toxicology and green chemistry.¹⁸⁵

Combined data mining of results, from surveillance studies with data on exposures, from clinical trials, from health surveys, from primary case systems, from publicly available genetic databases, from human bio monitoring and from larger research programs will enable more efficient planning of intervention and evaluation. Structures promoting data sharing across the private and governmental sector should be promoted in the field of health, environment and the bioeconomy.

“Breakthrough strategies rarely come from the typical strategic planning effort. Nor do they typically result from the common practice of generating and evaluating strategic options. And they certainly aren’t inspired in a traditional board offsite, executive retreat, or brainstorming session. Instead, they start with individuals working on big, specific challenges who find novel ideas in unexpected places, creatively combine them into innovative strategies, and personally take those strategies to fruition—against all odds”

Ken Favaro - PriceWaterhouseCoopers

¹⁸⁰ <http://www.gizmag.com/ultrasound-nanoparticle-insulin/29886/>

¹⁸¹ <http://www.mdpi.com/1660-4601/11/8/7805>

¹⁸² <http://www.citizen-obs.eu/>

¹⁸³ Perspectives for environment and health research in Horizon 2020: Dark ages or golden era, Roel Smolders, Patrick De Boever available at: <http://dx.doi.org/10.1016/j.ijheh.2014.05.003>

¹⁸⁴ Maertens and AL, http://altweb.jhsph.edu/altex/31_3/FFTMaertens.pdf

¹⁸⁵ http://altweb.jhsph.edu/news/2012/green_tox_Oct2014.html

Annex 1: JHEB Methodology

A.1 Scanning process

During the preparatory phase of the JHEB project a Scanning activity was undertaken. Led by the DG JRC, the scanning activity aimed at identifying the Weak Signals of potentially important emerging trends, which are not yet widely recognized, but may underpin new innovation challenges and opportunities linking the fields of health, environment and the bioeconomy in the longer term future (2030 and beyond). A set of abstracts were collected for the scanning activity both by the Expert Group members, by virtue of their expertise, experience, and access to studies (in particular on foresight); as well as by the European Commission (coming from the processes of preparing Horizon 2020, recent and on-going EU projects, as well as from horizon scanning activities in the JRC seeking to draw on recent collections of “weak signals” data).

Abstracts were selected from the past two years (2012-2014) to ensure the coverage of current trends and weak signals of emerging trends in science, economy, society and lifestyles, cutting across the domains of environment, health and the bioeconomy. A keyword cloud was developed by the JHEB Steering Group with the facilitation of the JRC to support the process of abstract identification and selection (Annex 3). The keyword cloud was used as a conceptual reference during the search and it helped focusing the attention on the intersection of the three domains. The connections between the domains were identified at two levels:

1. Triple-winners: The areas, which fall at the intersection of all three domains
2. Double-winners: The areas, which fall at the intersection of the any two domains of the three

These are illustrated with numbers 3 and 2 in Figure 1.

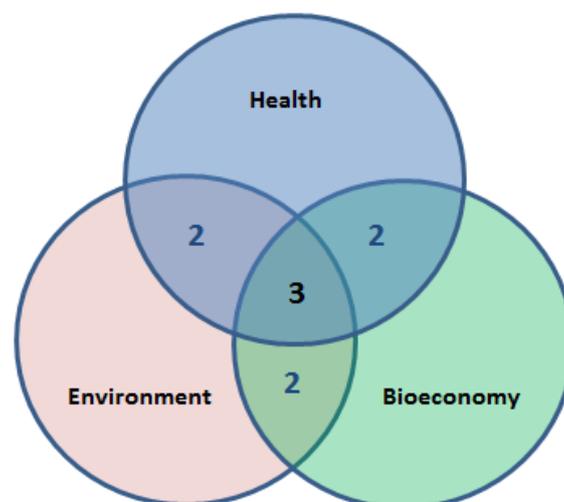


Figure A.1: Triple- and Double-winners at the intersection of Health, Environment and the Bioeconomy

The sources scanned for the extraction of abstracts included:

- A selection of global scientific news sources, and cultural news sources including: Bloomberg (Sustainability; Health and science sections), BBC News (science and environment; health sections), Quartz (the Sea section), Technology Review (biomedicine section), Asahi Shimbun, Wired, The Economist, New Scientist, Science, Nature, The Guardian Science, Nikkei, Gizmodo, NPR (health and science sections), Spiegel, and Reuters;
- Trade and industry-specific publications: C&I, European Pharmaceutical Review, and Nature Biotechnology.
- Social-media information, involving experts and sources followed by SBI Scan's Twitter account (see @SBI_Scan¹⁸⁶)
- SBI Scan database
- Academic and technical literature (using the Web of Science publication database)
- Patent information (WIPO, Espacenet)

In addition, the members of the Expert Group included any other additional sources, which they considered to be relevant for JHEB. A template was designed for the presentation of the abstracts, which included the title, source, date of publication, URL, summary, implications and relevance to the three domains of JHEB. The scanning process generated 186 abstracts in total, out of which 62 were described by the expert group, and the remaining 124 by the JRC.

Following the description of abstracts, the first step in the proposed horizon scanning process was clustering. Clusters were considered as groups of two or more abstracts that can be linked in some ways. A cluster indicates a potential evidence of a trend or weak signal of change. Each expert in the panel was asked to create their own clusters individually for discussion in the first workshop as a starting point and evidence for a structured discussion on the weak signals and emerging trends. Therefore, the experts were expected to read through the document with the compilation of the abstracts and create clusters by labelling each of them with an illustrative snappy title and write down briefly the rationale for creating each cluster. The outputs of the scanning and clustering process will be presented in the next sections of the report.

¹⁸⁶ SBI - Strategic Business Insight is a company specialized in Horizon Scanning.

A.2 Bibliometric analysis

A bibliometric analysis process was designed as a supplementary methodological approach for JHEB. Similar to the scanning exercise through the abstracts, the bibliometric analysis also aimed at identifying weak signals and emerging trends in the JHEB. With the analysis of Big Data, the bibliometric studies have become increasingly relevant for Foresight activities. Gathering intelligence on emerging technologies and socio-economic trends; identifying Weak Signals of future developments; and early warning of Wild Cards, shocks and surprises can be considered among the potential uses of bibliometric analysis. Within the scope of the current JHEB project, the bibliometric analysis provided “an opportunity to invent and investigate new methods and algorithms capable of detecting useful patterns or correlations present in big chunks of data” (ITU, 2013)¹⁸⁷. In this way it was possible to demonstrate the dynamic nature of scientific, industrial and policy domains through the analysis of structured and unstructured data. For the bibliometric analysis the VantagePoint software was used for data cleaning, clustering and generation of network matrices (Watts *et al.*, 1997)¹⁸⁸. The results of the analyses were visualised through the VosViewer software (van Eck and Waltman, 2009)¹⁸⁹.

The source of data for the bibliometric analysis was Web of Science (WoS). Scientific publications published in the Web of Science in the past 10 years (2003-2014). In order to identify the publications to be analysed a scoping exercise was undertaken. A survey conducted with the members of the steering group and the expert panel to identify the WoS categories based on their relevancy for Health, Environment and the Bioeconomy. Following, publications in 10 selected Web of Science categories were analysed. For each category the most highly cited 5000 publications were focused. Thus, total number of 50,000 publications were analysed in the past 10 years.

For each of the 10 Web of Science categories, automated clusters were generated after several rounds of data cleaning, natural language processing, and expert consultations. The outputs of analyses were presented in various formats:

1. Clusters with bubble diagrams. These were generated based on the frequency and adjacency of keywords/phrases. As an example, the diagram for the WoS Category “Biodiversity & Conservation” is given in Figure 2.

¹⁸⁷ ITU (2013). http://www.itu.int/dms_pub/itu-t/oth/23/01/T23010000220001PDFE.pdf (Last visited on: 24.01.2015).

¹⁸⁸ Watts, R.J., Porter, A.L., Cunningham, S.W., Zhu, D. (1997). Vantage point intelligence mining: analysis of natural language processing and computational linguistics, in: J. Komorowski, J. Zytkow (Eds.), Principles of Data Mining and Knowledge Discovery, First European Symposium, PKDD'97, Trondheim, Norway, Springer- Verlag, Tiergartenstr 17, D-69121 Heidelberg, Germany, 1997, 323–335.

¹⁸⁹ van Eck, N.J. and Waltman, L. (2009). Software survey: VOSviewer, a computer program for bibliometric mapping, *Scientometrics*, vol. 84, issue 2, pp. 523-538.

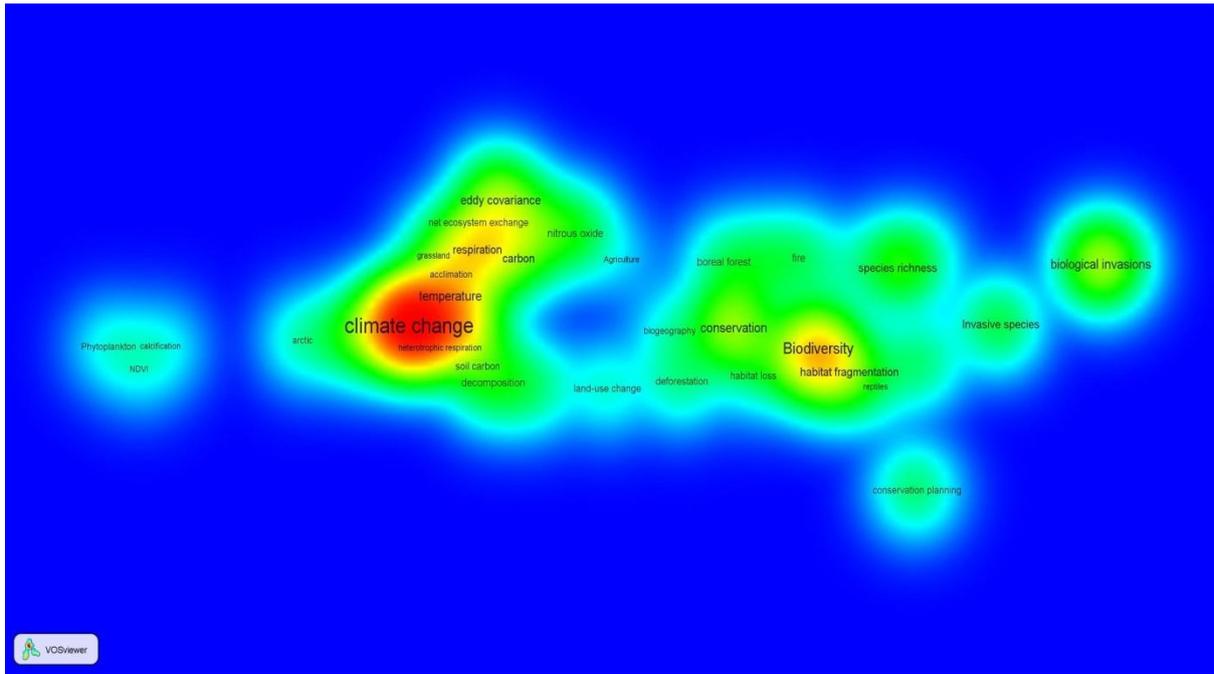


Figure A.3: Density view of keywords in top 5000 most cited articles with regard to the topic “climate change and ecosystems”

3. Citation figures for the sub-categories for each WoS categories. Experts were asked to look at the sub-categories and citation figures to tell which sub-categories would potentially represent the Weak Signals of emerging areas; and which sub-categories show unexpected/surprising trends, which could be considered as Wild Cards. As an example, Table 1 illustrates the figures for the sub-categories of the WoS category “Biodiversity & Conservation”.

Table A.1: Citation figures in Web of Science sub-categories under Biodiversity & Conservation

BIODIVERSITY & CONSERVATION	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Ecology (30335)	2060	2248	2436	2641	2670	2616	2815	2936	3110	2757	2731	1315
Environmental Sciences (16015)	945	1043	1098	1268	1277	1337	1356	1382	1825	1620	1808	1056
Genetics Heredity (2931)	98	84	118	95	156	224	450	396	330	398	392	190
Entomology (914)	22	31	0	36	43	95	97	107	113	133	185	52
Zoology (841)	108	61	96	46	87	110	48	61	95	62	52	15
Paleontology (534)	47	32	57	61	34	34	34	35	43	39	64	54
Evolutionary Biology (506)	67	32	75	36	48	34	34	35	43	39	34	29
Marine Freshwater Biology (423)	17	10	0	0	24	0	40	0	71	90	122	49
Biology (375)	0	0	16	47	28	32	35	49	48	51	57	12
Environmental Studies (304)	58	75	0	0	0	82	33	0	7	18	22	9

4. Aduna cluster maps. One of the key strengths of the bibliometric analysis with the Vantage Point software is the capability to generate automated clusters. In the scanning phase described earlier, the experts extracted the abstracts and generated the clusters themselves based on a low number of publications. However, in the bibliometric analysis, the clusters based on several thousands of publications were generated in an automated way in a much shorter time. Taking the advantage of both approaches, the manual clustering and automated clustering were used in a combined way to generate the final list of clusters in the JHEB study. The clusters in the bibliometric analysis were visualised with the use of Aduna cluster maps, which creates automated clusters of keywords and concepts based on based on Principal Components Decomposition¹⁹⁰. Experts can identify the Weak Signals and Wild Cards by looking at the cluster labels and the relationships between them

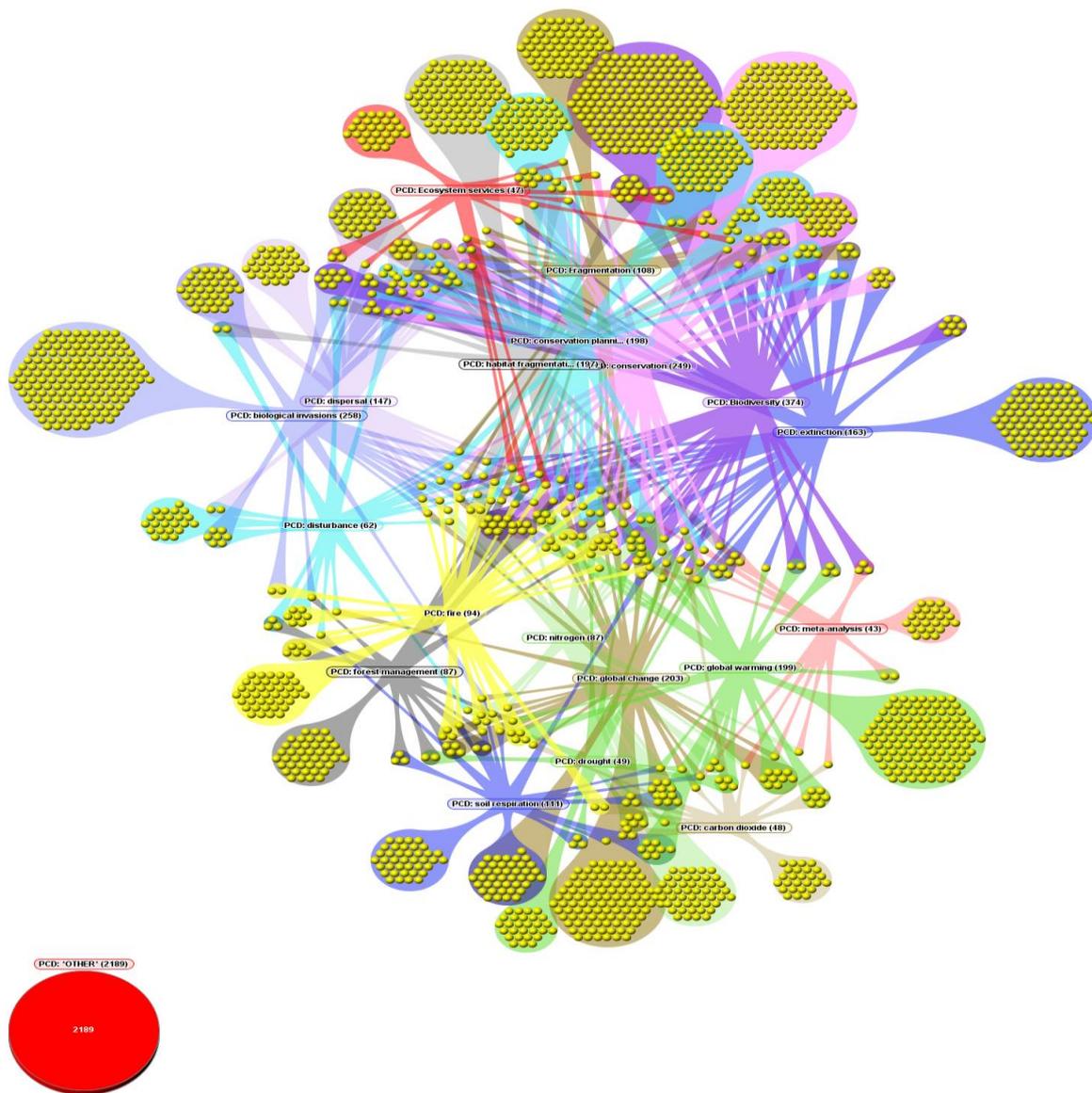


Figure A.4: Aduna cluster map for Biodiversity & Conservation category

¹⁹⁰ http://en.wikipedia.org/wiki/Principal_component_analysis (Last visited on: 21.01.2015).

Further time-based analyses were conducted to illustrate the evolution of the trends across time. These will be presented in the next sections of the report, where the results of the bibliometric analysis will be presented and elaborated further.

Annex 2: Clusters generated by scanning and bibliometric analysis

A2.1 Clusters generated by scanning

The initial clustering exercise undertaken before and during the first workshop generated 46 clusters out of 186 abstracts (Table A.2).

Table A.2: Clusters of abstracts

No.	Cluster label	Rationale
1	Solutions for plastic waste	Plastic waste in the environment has been recognised as an issue and policy action is being taken. Very diverse solutions are being developed and proposed. Bio-based plastics are also being developed.
2	Water in the blue and green economies	Water remains at the core of the food, environment, climate, health and economy nexus. Global initiatives are being taken. We seem to be moving away from the traditional approach to just solving specific local water issues (e.g. water distribution, wastewater treatment) and efforts are being made at improving systemic understanding. Economic and financial actors are also taking notice.
3	Supporting the bioeconomy opportunities	Supporting the bioeconomy requires that people understand what it is, and so far most don't. Getting this concept into popular culture would contribute to sustainable development. There are currently many developments that are relevant for the bioeconomy (food, health, environment, etc.).
4	Environmental governance and empowered green economy	This set of abstracts illustrates the global reach and the connectedness of many issues (e.g. food and energy production, climate change, shifting health threats, etc.) creating a need for integrated solutions applied at large geographical scales. This creates a context in which new business models can become successful.
5	Reinventing society and business models	Linked to the above, progress in many technologies coupled to changes in attitudes is already challenging traditional ways of doing things and traditional jobs. While creating opportunities for new business models, this is challenging well established socio-economic patterns.
6	Pollution from agriculture	In today's globalised world food demand somewhere can translate in environmental impacts from agriculture around the world. The last abstract strikes a note of optimism by focussing on the many benefits of sustainable food.
7	Digital revolution and industrial production	The fast development of information technologies is already having a large impact on the production of industrial products

		and food through better wellbeing for workers (153), process optimisation (161) and more. However, it is also threatening many jobs, both in industry and services.
8	Technology is impacting work patterns	Technology is having a radical impact on how people are employed (or not).
9	Techno-social foundation for the new society	A number of abstracts are pointing towards the emergence of new social paradigms, many of which are triggered by new technologies. This ranges from how people will deal with their own health (strong empowerment of the individual) to the emergence of new visions for the economy.
10	Clustering emerging risks	New (environmental and health) monitoring technologies as well as increasing understanding of complex issues such as the effect of environmental factors on health are allowing people to better assess exposures and risk factors.
11	Salt water agriculture	This is opening opportunities both to conquer land that is so far unsuitable for agriculture and to develop biofuels that are not in competition with edible crops.
12	From high-tech to green-tech	Numerous abstracts provide examples of how many new advanced technologies are being put to use to reduce our dependence on fossil fuels, to take advantage of renewable (biological) resources or to reduce the environmental impacts of economic activities.
13	New ways to detect fraud (on bio-products)	New techniques relying on invisible, non-toxic and edible materials seem to be cheap, reliable and simple enough to ensure the traceability and authenticity of a wide range of products subject to illegal imports and fraud. These examples focus on medicines.
14	Auto-diagnostics and self-management in health care	Technologies for monitoring, detection and diagnostics relevant for health are booming. They promise to usher a revolution both in how people deal with their own health and how patients are dealt with by health care systems. This is likely to have also implications in ethics. It could also impact strongly the field of clinical trials and epidemiology.
15	Green cities and urban farming	The understanding of the many simultaneous possible benefits of green spaces in cities (better health, urban farming, less pollution...) is opening many opportunities to re-think urban development and to make cities much more liveable at a time when the world population is becoming increasingly urban.
16	A multiplicity of sensors	Sensor technologies are fast progressing in many domains, especially in the health domain.
17	Nomadic technologies	Technologies developed in one domain can be applied to other

		domains and "migrate", as illustrated by 3-D printing now applied to food in space and organ "fabrication", microbial fuel cells.
18	Circular economy / Green economy	This set of abstracts illustrates the extent of waste produced currently, especially food waste, and provides examples of possible ways to evolve towards a sustainable economy, including aspects related to societal acceptance and to the need for systemic change.
19	Complex systems thinking	These abstracts illustrate various ways of how to start a change process and recognise the centrality of people and of planning. They connect to the previous set of abstracts on the need for systemic thinking that requires the development of shared visions of where to go.
20	Holistic approach to health	Many developments both at the level of individual health monitoring and at the level of public health and integrated understanding of exposures are taking place, opening the door to new approaches to public health.
21	Holistic approach to agriculture	These abstracts provide a broad outlook on the profound and large scale, direct and indirect impacts of the food and agriculture nexus, hinting at the need to look at these issues in a holistic way, covering health, the bioeconomy, environmental and nutritional aspects.
22	Nanotechnologies	These abstracts, through the example of graphene, nanocellulose and gold, show that nanomaterials are becoming ever cheaper to produce and that their risks are becoming better known, thereby enabling better ways to control the potential risks they represent.
23	Scarcity of natural resources	Several abstracts illustrate initiatives for resource/ energy efficiency.
24	Multidimensional / interconnected crises	All these abstracts point to the global scale and interconnectedness of the environmental, health, food, social and economic issues created by the current transition.
25	Nutrient cycles and access to nutrients for food production and environmental protection	More and more attention is devoted to recovering nutrients and this is leading to technological developments
26	Public health and social issues related to diagnostics: individual responsibility	Numerous technological developments can provide individuals with access to a wealth of information on their own health. This can lead to better healthcare in many cases but this information could also easily land in the hands of other people. The question is: is everyone equipped to deal appropriately with this information? What does that mean for the future of healthcare?

		Is this making "personalised medicine" a reality?
27	Lack of and imbalances of vitamins/nutrients in diets	Even in industrialised countries, nutrition has not been addressed properly.
28	The food production/consumption nexus is global	Food and dietary choices in various areas of the world have an impact on the environment, climate change and food security in other areas of the world, without the public realising.
29	Food security is also an issue for industrialised countries	As competition for food increases around the world while environmental concerns are putting limits on what can be done, care must be taken to let the diets of people in rich countries evolve to reach better nutritional outcomes with lower environmental impacts.
30	Biofuels: new developments and competition with food production	Technologies for biofuels are making steady progress and are increasingly diverse.
31	Future / high-tech foods	The high-tech efforts to make food more nutritious and less environmentally damaging are continuing.
32	The importance of human food consumption patterns	The abstracts show the world wide consequences of food choices, mostly in industrialised countries, but increasingly also in emerging economies.
33	Biotech for nutrition	The new OMICs technologies allow the identification of special molecules in plants, many of which could be interesting as nutrients or pharmaceuticals.
34	Sustainable food	Many abstracts point to how far we still are from sustainable food, with large amounts of food waste and far reaching environmental, health and social impacts. However, a way forward can be seen emerging, with nutrient cycling, changes in diets, etc.
35	From healthy diets to environmental degradation	Demand for specific nutrients or types of food in rich countries leads to environmental degradation elsewhere.
36	The centrality of cultural change for sustainable development	People's behaviour is central both to the environmental impact resulting from current lifestyles and to the shift to a more sustainable world.
37	From citizen science to public engagement and cultural change	Involving the public in scientific projects raises awareness about the interconnectedness of many issues and leads to lasting behaviour change (transdisciplinarity).
38	New developments in traceability for foods, pharmaceuticals & more	Smarter ways to fight illicit trade and counterfeit goods.
39	Antimicrobials resistance: new developments	While antimicrobial resistance is still spreading, novel efforts at finding new antibiotics are taking off

40	Global trade and emerging economies	In this set of abstracts, the focus is on food related issues and shows that it is now sometimes demand from emerging economies (China) that impacts the markets in industrialised countries.
41	Food security	Food security, health and environmental impacts of nutrients cycling, etc.
42	Cities and infrastructures	The increasing pressure on cities to absorb ever larger numbers of people requires a radical re-think of urban planning, with consequences for infrastructures, especially for water.
43	Pharmaceuticals: from today to the future?	These abstracts are witness to the fact that climate change and other factors are changing the distribution and types of health problems and that a lot of potential new drugs are likely to come from plants thanks to progress in omics.
44	Tools for managing fish stocks (and other bio resources)	Ocean models, remote sensing and new techniques to produce fish feed could usher an era of sustainable fish exploitation.
45	Using genomes as a resource	The increasing knowledge about genes and ability to read genomes is revolutionising how we use biological resources: the diversity of applications is staggering.
46	A new, integrated vision for urbanisation	Increasing knowledge about the many facets of quality of life in urban environments is making a new approach to urban planning possible, integrating health, quality of life, greening, food security, and pollution. This could be very useful in view of the increasing urbanisation of world population.

As the list above indicates, there were a number of topics, which could be merged together such as cities, food and health among the others. In order to reduce the number of clusters, a prioritisation exercise was conducted through a voting session in the second meeting on the October 13th. Each of the expert panel members rated the most important topics. This exercise generated 16 clusters out of the 46 clusters mentioned above. Table 3 indicates the clusters and scores they received from the experts.

Table A.3: Top ranked clusters with scores

Cluster No.	Cluster	Score
15	Green cities & urban farming	8
18	Circular economy	8
20	Holistic approach to health	8
24	Interconnected / multiple crises	7
46	A new integrated vision for urbanisation	7
34	Sustainable food	6
19	Complex systems thinking	5
21	Holistic approach to agriculture	5
2	Water in the blue and green economies	4
4	Environmental governance & empowered green economy	4
26	Public health & social issues related to individual diagnostics	4
37	From citizen science to public engagement & cultural change	4
7	Digital revolution & industrial production	3
29	Food security for industrialised countries	3
36	Centrality of cultural change for sustainable development	3
42	Cities and infrastructure	3

A2.2 Clusters generated by Bibliometric analysis

The scoping exercise at the beginning of the bibliometric study generated a set of Web of Science categories for the analysis. Figure A.5 illustrates the categories and their ranking.

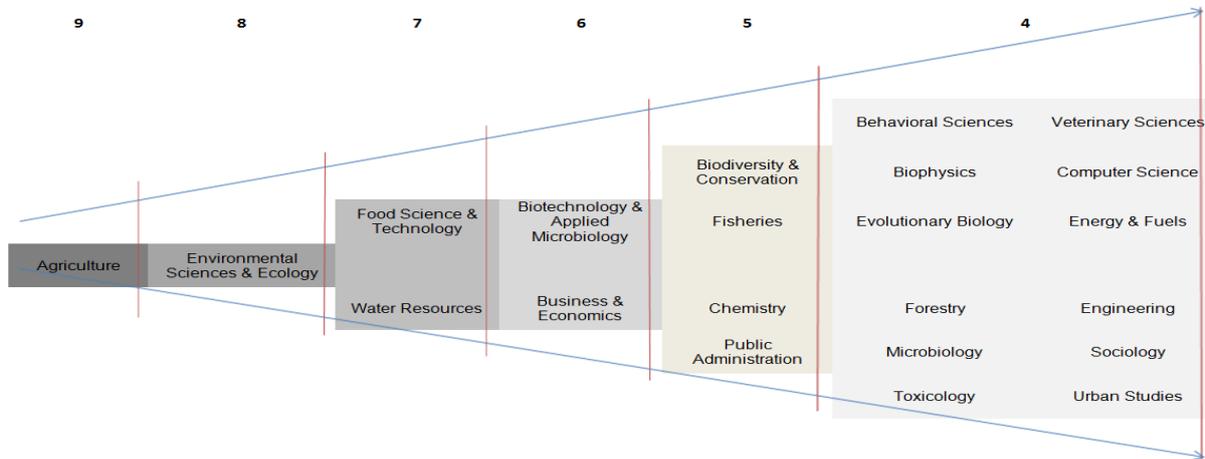


Figure A.5: Selected Web of Science (WoS) categories by the experts

In total 10 experts were involved in the scoping survey. As the figure illustrates, Agriculture is a common area for nine out of ten experts. Thus, it is considered to be among the top fields at the junction of Health, Environment and the Bioeconomy. Further consensus among eight experts was observed in the Environmental Science & Ecology domain. Other categories with high level of consensus are also given in the figure. For the purpose of this study the cut-off point was 5 (50% consensus), which resulted with 10 categories to focus for bibliometric analysis, including:

1. Agriculture
2. Environmental Services & Ecology
3. Food Science & Technology
4. Water Resources
5. Biotechnology & Applied Microbiology
6. Business & Economics
7. Biodiversity & Conservation
8. Fisheries
9. Chemistry
10. Public Administration

For each category, visualisations including bubble diagrams, heat diagrams, citation figures and aduna maps with automated clusters were presented. Principal Components Decomposition process created the clusters for each WoS category as illustrated in Table A.4 (with node density figures). At the bottom of the table, a legend is given to indicate possible clusters.

Table A.4: Clusters generated through the bibliometric analysis

Agriculture	Environmental Services & Ecology	Food Science & Technology
Anthocyanins (288)	Biodiversity (330)	Antioxidant (410)
Conjugated linoleic acid (192)	Nitrogen (302)	Anthocyanins (207)
HPLC (166)	Fragmentation (212)	Carotenoids (134)
Wine (122)	Global warming (195)	Wine (128)
Dairy cow (198)	Conservation (176)	Antioxidant capacity (113)
Antioxidant activity (166)	Invasive species (156)	Food (107)
Broiler (134)	Ecosystem services (151)	Antimicrobial activity (105)
Dairy cattle (119)	Soil respiration (144)	Polyphenols (103)
Milk (119)	Land use (142)	Chitosan (93)
Nutrition (118)	Eddy covariance (133)	Phenolic compounds (92)
Antioxidants (117)	Habitat fragmentation (129)	Dairy cow (50)
Pig (111)	Conservation planning (125)	Fatty acids (46)
Cattle (107)	Fire (108)	Phenolic acids (45)
Growth (95)	Disturbance (108)	Apoptosis (43)
Wheat (91)	Global change (107)	Mycotoxins (43)
Beef cattle (89)	Deforestation (99)	
Metabolism (76)	Nitrous oxide (98)	
Carotenoids (51)	Extinction (59)	
	Grassland (44)	

Water Resources	Biotechnology & Applied Microbiology	Business & Economics
Climate change (230)	Pretreatment (79)	Credit risk (150)
Wastewater (146)	Biomass (61)	Liquidity (124)
Drinking water (139)	Fermentation (57)	Monetary policy (118)
Fouling (138)	Biosensor (53)	Entrepreneurship (84)
Groundwater (137)	Adsorption (51)	Banks (82)
Water quality (133)	Cancer (47)	Executive compensation (75)
Wastewater treatment (130)	Tissue engineering (46)	Efficiency (67)
Heavy metals (119)	Gene therapy (43)	Capital structure (63)
Uncertainty (109)	Biosorption (42)	Banking (58)
Evotranspiration (102)	Transesterification (39)	Uncertainty (53)
Reverse osmosis (97)	Mesenchymal stem cells (39)	Investment (50)
Nitrification (70)	Nanoparticles (32)	Regulation (45)
Phosphorus (62)	Metabolic engineering (31)	Growth (29)
GIS (49)	Self-renewal (27)	Mergers and Acquisitions (27)
	Cellulose (27)	
	Biodegradation (16)	

Legend of clusters

Circular economy / Governance	Sustainable food / Agriculture	Holistic health	Cities / Land use
Ageing / Over-population	Water	Materials	Energy

Table A.4: Clusters generated through the bibliometric analysis (continued)

Biodiversity & Conservation	Fisheries	Chemistry
Biodiversity (374)	Atlantic salmon (182)	Nanoparticles (122)
Biological invasions (258)	Rainbow trout (179)	Nanotechnology (83)
Global change (203)	Fish (164)	Self-assembly (79)
Global warming (199)	Aquaculture (159)	Asymmetric catalysis (75)
Conservation planning (198)	Litopenaeus vannamei (127)	Homogenous catalysis (72)
Habitat fragmentation (197)	Temperature (145)	Adsorption (62)
Extinction (163)	Reproduction (109)	Catalysis (58)
Dispersal (147)	Survival (101)	Drug delivery (56)
Soil respiration (111)	Innate immunity (91)	Carbon nanotubes (52)
Fragmentation (108)	Cod (88)	Electrochemistry (47)
Fire (94)	Disease (82)	Sensors (44)
Nitrogen (87)	Stress (81)	Cross-coupling (42)
Forest management (87)	Larvae (80)	Photocatalysis (33)
Disturbance (62)	Diet (78)	Magnetic properties (22)
Drought (49)	Immune response (75)	Semiconductors (21)
Carbondioxide (48)	Atlantic cod (71)	
Ecosystem services (47)	Fatty acids (69)	
Meta-analysis (43)	Fisheries (66)	
	Mortality (65)	
	Crossostrea gigas (61)	
	Spawning (31)	

Public Administration
Governance (176)
Europeanisation (100)
Kyoto Protocol (81)
Accountability (70)
Welfare state (69)
Local government (68)
New public management (64)
Networks (57)
Implementation (55)
Democracy (54)
Public management (52)
Trust (49)
Globalisation (47)
Public policy (33)
China (26)
Poverty (25)
Germany (23)

Legend of clusters

Circular economy / Governance	Sustainable food / Agriculture	Holistic health	Cities / Land use
Ageing / Over- population	Water	Materials	Energy

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A rapidly increasing world population, unsustainable production and consumption patterns, and environmental change form complex and interdependent systemic challenges for our societies, threaten the biosphere and humanity as a whole. The key message from the exercise of identifying trends at the junction of health, environment and the bioeconomy is that a systemic approach to challenges is necessary, often going beyond the three areas, for example to encompass issues of energy and mobility. Searching for 'triple-winners', i.e. research delivering benefits across the three fields allowed to identify four areas offering the most potential: **sustainable food** improving human diets and minimizing risks to health and environment, **circular economy**, including the bioeconomy, **cities** as testing grounds and demonstrators of triple-winners, **holistic health** (i.e. integrating life-style, environment and well-being). Sensor technology development and user/citizen engagement are identified as two key enabling success factors throughout the three fields of Environment, Health and the Bioeconomy. **Observing the intersection between health, environment and the bioeconomy offers a unique occasion to contribute to a safer, more sustainable and healthy society.**

Studies and reports

