



## Deliverable 2.1 OBSERVE Potential Hotspot Report

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# 1 Introduction

## 2.1 Background

The Future & Emerging Technologies (FET) programme invests in transformative frontier research and innovation with a high potential impact on technology, to benefit our economy and society. In particular the FET Proactive programme nurtures emerging themes, seeking to establish a critical mass of European researchers in a number of promising exploratory research topics. The aim of OBSERVE is to support the FET unit in identifying topics that fulfil the high aspirations of the FET Proactive funding programme.

For this purpose OBSERVE set up systematic screening of a diverse set of sources in 2015.<sup>1</sup> As a result of this process 171 emerging topics<sup>2</sup> were identified that are roughly assigned to the following five types (and combinations of two types):

- **Solution Idea (SI)**  
Emerging technological or social innovation or combination of both addressing a certain problem
- **Science (S) and Technology (T)**  
Emerging frontiers in science and technology development
- **Challenge/Need (N)**  
Challenge or need with long term relevance for society
- **Social Practice (SP)**  
Emerging change in social practices (new ways of doing) including policy practices
- **Collaboration (C)**  
New formats of collaboration in research and innovation and new constellations of actors collaborating across disciplines.

These 171 items were synthesised into 34 clusters which were then integrated with the 59 contributions to the FET Proactive consultation which ran from 10/02/-30/04/2016. The resulting 36 clusters form the “OBSERVE emerging hotspots” and are documented in this report.

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<sup>1</sup> Cf. OBSERVE Deliverable 1.3. Methodology Reprot

<sup>2</sup> Cf. Deliverable 1.2 OBSERVE Horizon Scanning Report

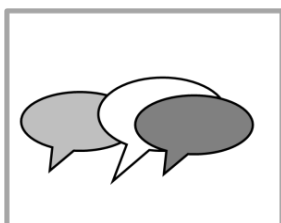
## 2.2 Structure of the Report

For each cluster we give a short summary and then present a tentative assessment of the emerging hotspot covering three different aspects which are explained below. Finally we list the individual topics belonging to this cluster stemming both from the OBSERVE screening and the consultation submissions. For better reference all OBSERVE emerging topics are presented along with their identification numbers from Deliverable 1.

## 2.3 The Assessment Criteria

The most important criteria for FET Proactive topics are a highly visionary perspective, transformative potential for the benefit of society as well as ability to mobilise diverse communities. In order to underpin assessment of these criteria we have collected information on three indicators: Discourse diversity, scientific publications (level and dynamics) and level of impact.

### Discourse Diversity



This assessment is build on the analysis of the diversity of sources in the OBSERVE screening phase. In addition the disciplinary backgrounds of FET consultation contributions were taken into account. A high diversity means that highly different types of discourses are pointing towards this issue. The diversity of two types of sources is of course a subjective assessment. Types of sources can differ in various ways such as print newspaper vs. social media blog but also a social science peer reviewed publication vs an engineering science one. In both cases we would assess the diversity with 2 meaning two types of sources. In the case of an item stemming from two news platforms such as eg the guardian and BBC we would rate the diversity as 1. We formed the following categories: 1-3 types of sources=low diversity, 4-6 types of sources=mid diversity, 7-10 types of sources=high diversity. As OBSERVE was not aiming for mainstream topics in many cases only few sources are behind one topic the diversity is often low for individual aspects. The whole cluster however often covers a high diversity of sources.

There are however examples of individual emerging topics with a high diversity of sources such as “Understanding and influencing human behavior” which is based on screening hits from the following sources: intelligencesquared, BBC Futures (4), Monocle, Sociological Review (2), Intelligent Life, The Verge, discover society, Catalysts for

Change (IFTSF), Nesta, The sociological imagination, FET Proposals (2), FET Projects (1) + Webmining.

## Impact level

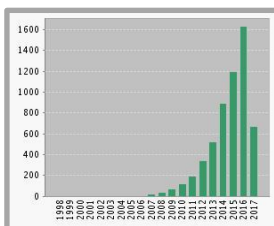


This is based on the assessment of the level of potential impact of the individual emerging topics identified in the screening phase. The “impact level” describes the type of impact expected from this development. In the OBSERVE screening phase we distinguish the following four levels:

- LO “Local”: impact in a specific domain (e.g. health)
- MR “Mid Range” impact across several domains e.g. a new materials with applications in health, ICT and energy
- WS “Widespread” impact across society e.g. fundamental changes in communication patterns
- FU “Fundamental” impact on the long-term future of the civilisation.

This classification is by no means an assessment of the relevance or even the relevance for FET. Developments with local impact (e.g. on a certain disease like heart attack) may well be of highest importance.

## Scientific Publications



The assessment of the scientific publications results from an analysis of the scientific publications from 1997-2017 in Thomson Reuters Web of Science Core Collection for all 171 findings from the OBSERVE screening phase using a rather simple keyword

based search strategy.<sup>3</sup> We captured the total number of publications<sup>4</sup> and the growth rate of publications. The total number is of course highly dependent on the broadness of the topic and the feasibility of a keyword search so a low number of publications does not necessarily indicate a lack of scientific attention. Still for most cases the analysis gives a first idea of the presence of the topic in the scientific discourse. As can be seen in the figure below most topics are not yet very much present in the scientific discourse but 19 topics are addressed by >10.000 publications between 1997 and 2017. This analysis could be used as a starting point for further analysis e.g. of disciplines, authors and journals prevalent to the topic.

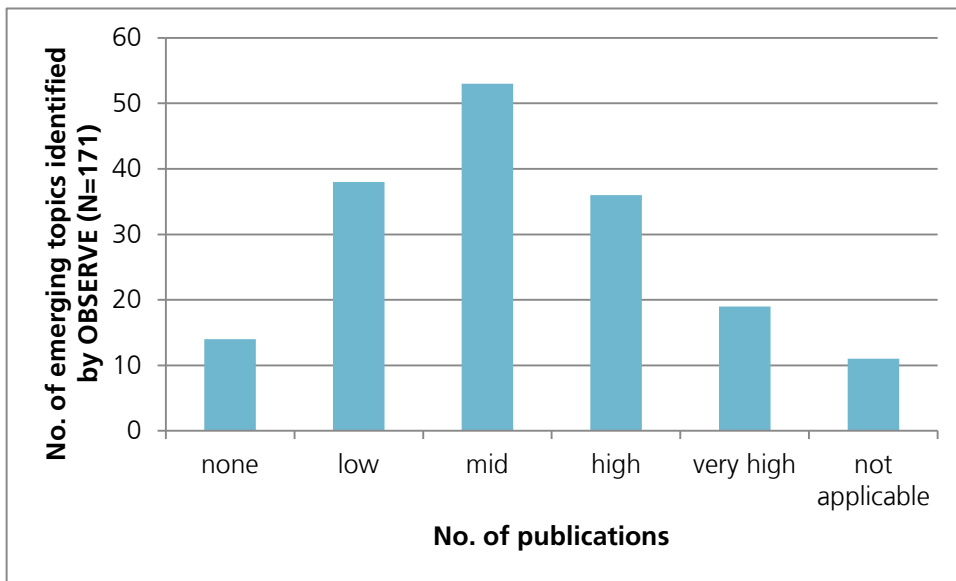


Figure 1: Analysis of Web of Science Publications for the 171 OBSERVE emerging topics

We also checked the dynamics of change in the rate of publications which enabled us to single out especially topics with a particularly dynamic development versus others with a more steady rise or even stagnation. The figures below give examples for typical dynamics in scientific publication activities among the OBSERVE topics.

<sup>3</sup> The keywords used for the search are provided in the Annex.

<sup>4</sup> The following labelling was used: LOW=<100 publications, MID=100- <1000 publications, HIGH=1000-<10.000 publications, VERY HIGH >10.000 publications. For 11 topics the analysis was not meaningful mainly because of their broadness (e.g. future of civilisation)

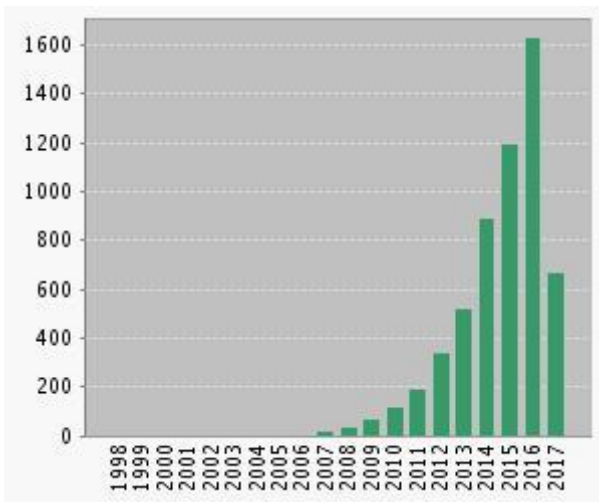


Figure 2: Example for steep rise of scientific publications (graphene quantum dots)

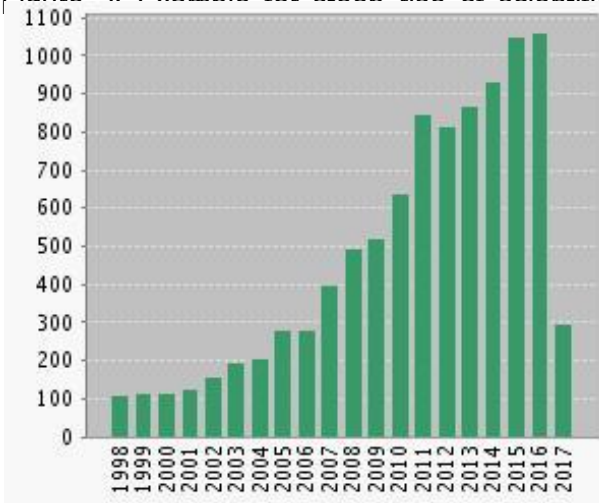


Figure 3: Example for steady rise of scientific publications (traditional medicine)

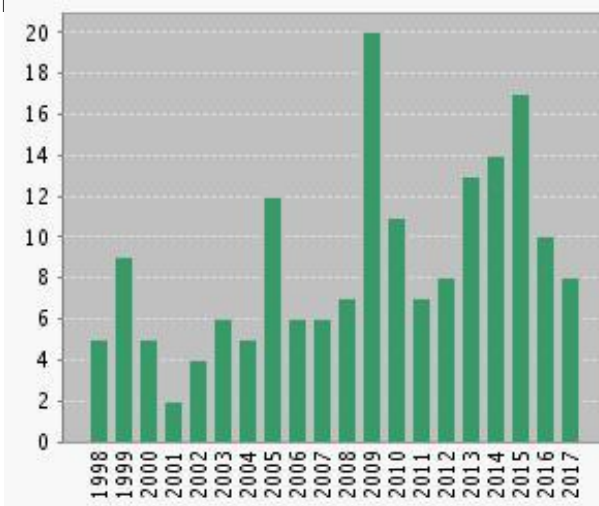


Figure 4: Example for up and down of scientific publications (brain interfaces and brain implants)


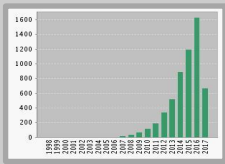



## 2 The Potential Hotspots

### 2.1 HPC<sup>5</sup> System Disruptions

#### Overview

Current patterns of high performance computing are challenged by a number of disruptive technologies such as Quantum Computing, Non-volatile Memory (NVM) technologies (including spintronics), Photonics, Resistive Computing, Neuromorphic Computing, Quantum Computing, Nanotubes, Graphene and Diamond Transistors<sup>6</sup> but also Biocomputing approaches. Also, computing *practices* may bring about changes. Research could explore radically novel HPC concepts in an integrated vertical approach.

Assessment	
Discourse Diversity 	Medium diversity. Voices stemming mainly from technology quarters with a focus on computer sciences. Nevertheless societal activists and social scientists are looking at societal aspects such as contributions from the DIY movement and novel collaboration patterns.
Scientific Publications 	Very high level of publications with partly very dynamic development
Impact Level 	Strong impacts can be expected in several heavily computing based sectors. Widespread changes could be the consequence especially when HPC system disruptions are combined with other research fields such as bio-manufacturing and societal aspects such as new forms of collaboration and privacy concerns.

<sup>5</sup> High Performance Computing

<sup>6</sup> Cf. <https://ec.europa.eu/futurium/en/content/impact-disruptive-technologies-high-performance-computing-next-decade>

## Underlying Aspects

<b>OBSERVE Emerging Topic</b>	<b>Discourse Diversity</b>	<b>Impact Level</b>	<b>Scientific Publications</b>	<b>No.<sup>7</sup></b>
Quantum computing challenges cryptography	Low	WS	Mid	N&T8
Spintronics: New principles for new, ultra-high capacity storage devices	Low	MR	High	T26
Photonic crystals for optical computers	Low	MR	High	T15
Neuromorphic computing	Low	LO	Mid, steep rise	T20
Plasmonics	Low	MR	High	T3
Biomanufacturing	Low	WS	Mid	C4
Distributed collaboration platforms	High	WS	Mid, steep rise	H9
DIY printing of circuits	Low	MR	Low	SP&T3
Universal software bug	Low	MR	Low	N8
Quantum Computing: Combining advances in quantum technology and photonics to realize a quantum computer	Low	LO	Mid	T33
Combination of scientific advances in nanotechnology, optics and spintronics with conventional electronics	Low	LO	Mid	T29

More detail on these topics:

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<sup>7</sup> The numbers refer to the OBSERVE Cards of emerging topics from Deliverable 1.2.

<https://ec.europa.eu/futurium/en/content/advanced-computing>

Related Topics from FET Proactive consultation:

- Impact of Disruptive Technologies on High-Performance Computing in Next Decade (Umbrella)
- SPIN COMPUTING: ultrafast, ultralow power, highly enduring and radiation hard
- Spin-orbitronics and topology for the development a new generation of low power reconfigurable spintronic devices
- Spin Orbit Effects for ultimately efficient spin dynamics of ultimately stable spin structures
- Magnon Computing
- Spintronics and Nanomagnetism for Brain-Inspired Computing
- Hybrid organic/inorganic spintronics
- Spin: Advancing the art of electronics
- Developing the synergy between magnetism and light
- Exploring magnonics and spin charge conversion

## 2.2 Game Change Enabling Materials

### Overview

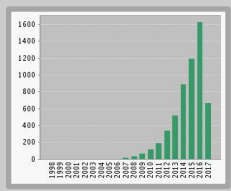

Several of the most dynamic research fronts with highly recognized scientific publications are located in material sciences. While some of these are basic research on synthesis and properties of new materials many focus on specific game changing applications especially in energy storage but also health, robotics, environmental technologies and ICT. In many cases sustainability considerations are an important aspect of the research. Within the cluster the following two areas can be distinguished: “Synthesis and analysis of new material types” and “Groundbreaking material application systems”.

#### Assessment

Discourse Diversity



Rather low diversity, mainly driven by material sciences.

<p>Scientific Publications</p> 	<p>High level of scientific activity,. in some fields very dynamic development</p>
<p>Impact Level</p> 	<p>High impact to be expected in specific domains such as health and energy.</p>

## Underlying Aspects

### Synthesis and analysis of new material types

<b>OBSERVE Emerging Topic</b>	<b>Discourse Diversity</b>	<b>Impact Level</b>	<b>Scientific Publications</b>	<b>No.</b>
Emerging research front: Synthesis of functional gold nanorods (applications: biomedical, spectroscopies, optoelectronics)	Low	MR	High	S13
Nanolattices	Low	MR	Low	S20
Emerging research front: Analysis of dynamic and static behaviour of functionally graded material	Low	MR	Mid	S1

Related Topics from FET Proactive consultation:

New materials for life

Supramolecular chemistry and mesotechnology

### Groundbreaking material application systems

<b>OBSERVE Emerging Topic</b>	<b>Discourse Diversity</b>	<b>Impact Level</b>	<b>Scientific Publications</b>	<b>No.</b>
Research front: Graphene and graphene oxide in biomedical application	Low	LO	High, steep rise	S11
Plasmonics (light-matter interac-	Low	MR	High	T3

tion) <sup>8</sup>				
Self-Propelled particles to treat severe bleeding	Low	LO	Mid	T12
Autonomous and soft materials for robot parts	Low	LO	Mid, steep rise	T22
Use recently discovered graphene characteristics in novel applications	Low	MR	Very high	T32
Smart materials for shape-changing mobile devices and other interfaces	Low	LO	High	T34

More information: <https://ec.europa.eu/futurium/en/content/advanced-materials>

Related Topics from FET Proactive consultation:

- [Molecular Materials in Spintronics and other Magnetic applications](#)
- [Magnetic Nanohybrids: Nanomagnets and nanomagnetic devices for energy conserving applications](#)
- [Functionalized Magnetic Nanoparticles for Bio- and Biomedical Technologies \(drug delivery\)](#)
- [next generation smart textiles](#)


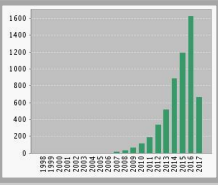

## 2.3 Bacteria Management Strategies

### Overview

Several of the OBSERVE findings relate to the way humanity deals with bacteria. One of the most prominent aspects is the rise of antibiotic resistance which poses a severe threat to many established practices of today's societies. All the more relevant seem other ways of dealing with bacteria such as antibacterial shields but also better understanding of the role of bacteria for human life (microbiome) and ways to influence bacteria e.g. through genome editing. At the same time bacteria are increasingly being used for processes.

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<sup>8</sup> <http://www.nature.com/nnano/journal/v11/n1/full/nnano.2015.333.html>

Assessment	
<p>Discourse Diversity</p> 	<p>Within each aspect the diversity of voices in the discourse is rather low. The aspects however stem from very different contexts.</p>
<p>Scientific Publications</p> 	<p>High and partly very high number of publications. Microbiome and CRISPR/CAS extremely dynamic.</p>
<p>Impact Level</p> 	<p>Very high transformative potential with the possibility of widespread impact.</p>

## Underlying Aspects

OBSERVE Emerging Topic	Discourse Diversity	Impact Level	Scientific Publications	No.
Post antibiotics	low	WS	Very high	N&S12
Water based nano bacteria shields	low	LO	None	N&S6
Antibacterial bio-microfilm	low	MR	Low	N&S3
Understanding the microbiome	low	WS	Very high, steep rise	S7, SP&S1
Emerging research front: CRISPR/CAS Genome-editing technology	low	MR	High, steep rise	S8
Biomanufacturing	low	WS	Mid	C4

More information: <https://ec.europa.eu/futurium/en/content/bacteria-management>

Related Topics from FET Proactive consultation:

- Infection-free medical devices would save lives!

## 2.4 Biomimicry New Frontiers<sup>9</sup>

A rapidly growing number of technologies are inspired by biological functions and solutions. One driver of the new momentum for biomimicry is the advance in simulation and freeform manufacturing (3D printing). Current examples of cutting edge biomimicry innovations include smell-guided-navigation, jellyfish inspired locomotion, insect-inspired robot design (vision and movement) and research into animal system behaviour (e.g. ants) that could help us develop the internet – or even understand how cancer spreads. Furthermore, biological principles and characteristics could be used for better computing. There are already many attempts to emulate biological systems in order to enhance computer chip performance or binary communication processes as well as bio-inspired parallel and neuromorphic computing. In the 2015 Lift China Conference there was a focus in biomimicry as the next generation sustainability concept.

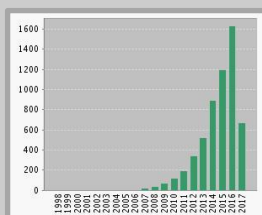
### Assessment

#### Discourse Diversity



The cluster rests on a high diversity of voices from a wide range of contexts, disciplines and application domains.

#### Scientific Publications



The topics attract a medium number of scientific publications

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<sup>9</sup> This is one of the few cases where a cluster was formed already in the screening phase. Therefore the individual findings are integrated in the description text.

Impact Level



Non-disruptive but partly substantial impact in a wide range of domains.

More detail on this topic (OBSERVE: H2)

<https://ec.europa.eu/futurium/en/content/biomimicry-new-frontiers>

## 2.5 Beyond, Within and Into the Brain

### Overview

The findings from the OBSERVE screening include several topics related to the brain. On the one hand research on understanding the human brain and brain related innovation are fast advancing. At the same time several societal questions such as the co-evolution of the brain and the digital society and the way to deal with mental illness and are emerging.

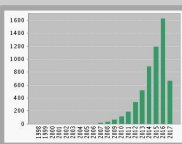
### Assessment

Discourse Diversity



Several isolated specialised discourses but growing interest in overarching meta-questions across disciplines including social sciences.

Scientific Publications



Very high level of scientific publication activity in the field

Impact Level



High potential for widespread transformative impact.



## Underlying Aspects

### Beyond the brain

<b>OBSERVE Emerging Topic</b>	<b>Discourse Diversity</b>	<b>Impact Level</b>	<b>Scientific Publications</b>	<b>No.</b>
Brain networking	mid	WS	Low	H28
Artificial brain	low	MR	Mid	S12
Brain cell transplantation	low	LO	Low	N&S4
Mental illness controversy	low	WS	Mid	N12
The human brain in the digital society	low	WS	None	C6
Global Challenge: Education and learning	low	WS	High	N4

### Within the Brain

<b>OBSERVE Emerging Topic</b>	<b>Discourse Diversity</b>	<b>Impact Level</b>	<b>Scientific Publications</b>	<b>No.</b>
Measuring Imagination	low	LO	Low	S10
Timekeeping mechanism of human-brain uncovered	low	LO	High	S6
Brain understanding	mid	WS	Very high	S19
Understanding and influencing human behaviour	high	WS	Very high	H23


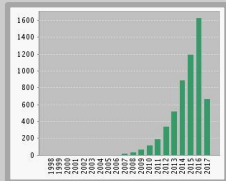

### Into the Brain

<b>OBSERVE Emerging Topic</b>	<b>Discourse Diversity</b>	<b>Impact Level</b>	<b>Scientific Publications</b>	<b>No.</b>
Non-invasive brain influencing	low	LO	Mid	T28
Treating phantom pain with a mirror	low	WS	Mid, steep rise	SP&S 2
Particle pollution may be the main cause for brain degenerative diseases	low	WS	Mid	N14
Brain interfaces and implants	high	LO	Mid	T18

## 2.6 Zero Waste Technologies

### Overview

Approaches towards a sustainable and circular cradle2cradle economy feature prominently in the debate among scientists, innovators, actors from civil society and policy makers. Establishing fully circular resource flows is however extremely demanding both for design and production. Circular solutions are bound to disrupt established patterns of science and engineering on the one hand and production and consumption on the other.

Assessment	
Discourse Diversity 	Highly diverse discourse across disciplines and contexts.
Scientific Publications 	High and steeply rising level of scientific publication activities.
Impact Level 	Widespread impact across a number of application domains


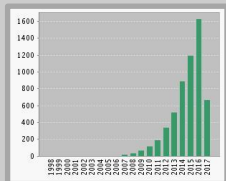

### Underlying Aspects

OBSERVE Emerging Topic	Discourse Diversity	Impact Level	Scientific Publications	No.
Circular material flows	high	WS	High, steep rise	H5

Wooden material on the rise	low	WS	high	SP&T 1
Carbon nanofibres made from CO2 in the air	low	MR	None	N&T7

## 2.7 Civilisational Transformation

Some of the OBSERVE screening results reflect on possibly upcoming fundamental transformations of human civilisation including both severe threats and opportunities

Assessment	
<p>Discourse Diversity</p> 	<p>High diversity of voices across domains such as art and science pointing towards essential tipping points for humanity. At the same time several specialised domains with rather homogenous discourse.</p>
<p>Scientific Publications</p> 	<p>Very high in some domains such as antimicrobial resistance but very few scientific papers reflecting on civilisational futures as such.</p>
<p>Impact Level</p> 	<p>Widespread fundamental transformation potential by definition.</p>

## Underlying Aspects

OBSERVE Emerging Topic	Discourse Diversity	Impact Level	Scientific Publications	No.
Future of civilization	high	FU	-	H12
Technological singularity	low	FU	Low	H16

Forest health	mid	MR	High	H27
Underwater operations	mid	MR	Very high	H24
Long term preservation of knowledge and timekeeping	low	FU	-	SI4/5
Post antibiotics	low	WS	Very high	N&S12
Extraordinary advances in facial recognition cause huge privacy issues	low	WS	Mid	N&T9
Space exploration	mid	LO	Mid	H21


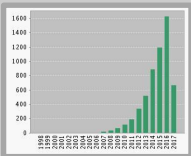
More detail on these topics:

<https://ec.europa.eu/futurium/en/content/long-term-transformations-civilisation>

## 2.8 Breathtaking Air Research

### Overview

Air pollution is a key topic in current futures debates. Monitoring air pollution as well as better understanding its evolution and effects poses substantial challenges to current research. For combating air pollution radical solutions are required.

Assessment	
Discourse Diversity 	Rather specific discourses in several fields
Scientific Publications 	Low to mid level of attention in scientific publications.

Impact Level



Mostly local impacts but potential for widespread disruptive development.

## Underlying Aspects

OBSERVE Emerging Topic	Discourse Diversity	Impact Level	Scientific Publications	No.
Research front: Atmospheric aerosol nucleation and growth	low	LO	Mid	N&S16
Carbon nanofibres made from CO2 in the air	low	MR	None	N&T7
Moss walls for air cleaning	low	LO	None	SI2
Particle pollution may be the main cause for brain degenerative diseases	Low	WS	Mid	N14
Bio-sensors: Using plants as environmental sensors and connecting them to sensor networks	Low	LO	-	T8

More detail on these topics: <https://ec.europa.eu/futurium/en/content/clean-air>

## 2.9 Infrastructures for Communicating in New Dimensions

### Overview

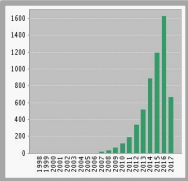

The OBSERVE screening revealed a diverse set of items related to the way we communicate ranging from highly technical aspects to cultural changes.

### Assessment

Discourse Diversity



Rather specialised discourses within the topics that are however highly different. Accordingly the total cluster draws together diverse voices.

<p>Scientific Publications</p> 	<p>Mostly low level of publications addressing these rather advanced communication aspects but high attention to the socio-technical shift towards active audience interaction.</p>
<p>Impact Level</p> 	<p>Mostly on local level but potentially disruptive aspects.</p>

## Underlying Aspects

OBSERVE Emerging Topic	Discourse Diversity	Impact Level	Scientific Publications	No.
Compressed conversations	Low	LO	Low	SP4
Terahertz communication enables a new range of wireless applications in the future	Mid	MR	Low	T14
Spectrum overcrowding	Low	MR	Low	N11
Active audiences	Mid	LO	High, steep rise	H3
Molecular communications	Low	LO	Mid	S4

More information: <https://ec.europa.eu/futurium/en/content/communication-futures>


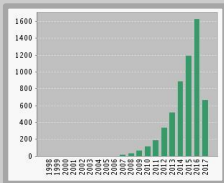

Two contributions to the FET Proactive consultation address the specific communication challenge of dealing with the spread of false and biased information. Another one is pointing to the potential of molecular communication, a topic that was also highlighted by OBSERVE.

- [Misinformation Spreading](#)
- [Automatic Fact Checking Technology for Improving our Society](#)
- [Molecular Communication](#)

## 2.10 Revolutionary Healthcare Diagnostics

### Overview

In the field of diagnostics disruptive advances maybe upcoming through a combination of several developments. On the one hand diagnostic technology is able to analyse ever more parameters with ever lighter and cheaper equipment and less time. At the same time more diseases can be detected through analysis of fluids especially blood due to advances in life sciences.

Assessment	
Discourse Diversity 	Rather homogenous discourse in specialist communities from similar contexts.
Scientific Publications 	Very high attention to the general field of lab on chip. Less but quickly rising activity in specific aspects.
Impact Level 	Substantial impact in several specific fields.

### Underlying Aspects

OBSERVE Emerging Topic	Discourse Diversity	Impact Level	Scientific Publications	No.
Microfluidics advancing Lab-on-a-Chip-technologies & other new applications	low	LO	Very high	T5

Enhanced bloodtest functionality	low	LO	Mid, extremely dynamic	N&T11
Fast HIV detection	low	LO	Low	N&T10
Micromotors in nano-scale micro-electro-mechanical systems	low	LO	Low	T36
Cancer-detection in real-time	low	LO	Mid	T31

More detail: <https://ec.europa.eu/futurium/en/content/diagnostics-revolution>

The following topics from the FET Proactive consultation fit into this domain:


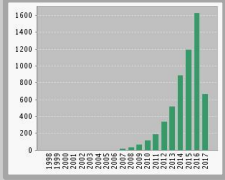

- IDAlert (self diagnosis device)
- Biosensors for Point-of-Care Applications
- Detecting risk factors for Alzheimer’s disease decades before disease onset to enable early therapeutic intervention

## 2.11 Global Enabling Infrastructures for New Economic Patterns

### Overview

A number of items captured in the OBSERVE radar reflect on emerging new economic models, the related modes of production and consumption and associated societal and technical transformations.



Assessment	
<p>Discourse Diversity</p> 	Highly diverse voices are arguing around this issue.
<p>Scientific Publications</p> 	The number of publications on the technological aspects such as blockchain and related technologies is rising steeply.
<p>Impact Level</p> 	As this refers to the very deep basics of societal interactions any changes can be expected to have widespread and even fundamental consequences.

## Underlying Aspects

OBSERVE Emerging Topic	Discourse Diversity	Impact Level	Scientific Publications	No.
Time as money	Low	FU	Low	SP2
Postcapitalist economy	High	WS	Low	H10
Global Challenge: Transnational organized crime	Low	WS	Mid	N3
Distributed collaboration platforms (eg. blockchain)	High	WS	Mid, steep rise	H9

- How much is a bitcoin worth, and why? (FET Proactive Consultation)

More detail on these topics: <https://ec.europa.eu/futurium/en/content/economy-futures>


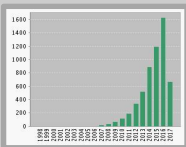

## 2.12 Dormant Effects of Climate Change<sup>10</sup>

The dynamics and effects of climate change are subject to intense research in many disciplines. Researchers from all-over the world point to the increasing likelihood of yet unknown catastrophic events as well as severe health risks and urge acting now. While some aspects are widely researched and discussed, the OBSERVE screening brought up also less explored aspects such as the rise of wildfires, possible emergence of superstorms and effects on soil bacteria. In addition the following current research fronts emerged in this context (N&S24):

- Regional climate models (required to investigate regional dynamics that may substantially differ from global patterns)
- Model analysis of non-CO2 greenhouse gases

More detail:

<https://ec.europa.eu/futurium/en/content/dynamics-and-effects-climate-change>


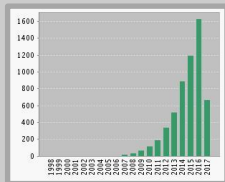

Assessment	
<p>Discourse Diversity</p> 	<p>A high diversity of sources is pointing in this direction.</p>
<p>Scientific Publications</p> 	<p>The cluster attracts a high number of publications that is still steeply rising.</p>
<p>Impact Level</p> 	<p>Most of the effects of climate change have the potential to substantially transform the framework conditions for human societies</p>

<sup>10</sup> This is one of the few cases where a cluster was formed already in the screening phase. Therefore the individual findings are integrated in the description text.

## 2.13 Emergency Preparedness

### Overview

Several of the findings of the OBSERVE screening point to possible disruptive events that may lead to emergency situations for human societies. At the same time the findings include strategies to deal with and prepare for specific threats and for disruptive change in general.

Assessment	
<p>Discourse Diversity</p> 	<p>The individual threats and possible reactions stem from rather homogeneous sets of sources. The topics and their supporting communities are however very different from each other. Accordingly the cluster combines highly diverse perspectives.</p>
<p>Scientific Publications</p> 	<p>Whereas some threats such as antimicrobial resistance and space weather receive high attention in scientific publications, other possible smaller threats such as software bugs are less addressed. Some measures of preparedness such as a pandemics strategy but also new types of collaboration platforms are covered by quite a few publications.</p>
<p>Impact Level</p> 	<p>Several of the threats have disruptive potential with widespread consequences or even in the case of solar decline fundamental transformation.</p>

### Underlying Aspects

OBSERVE Emerging Topic	Discourse Diversity	Impact Level	Scientific Publications	No.
Post antibiotics	Low	WS	Very high	N&S12
Threat of “space weather”	Low	WS	High	N9

Pandemics strategy	Low	WS	Mid	N13
Big data supported crisis management	Low	LO	Low	N&T17
Disaster management	Low	MR	High	H8
Decline in solar activity by 2030	Low	FU	Mid	N10
Universal software bug (integer overflow)	Low	MR	Low	N8
3D printed emergency shelter	Low	LO	Low	N&T5
Distributed collaboration platforms	High	WS	Mid	H9

More detail: <https://ec.europa.eu/futurium/en/content/emergency-preparedness>

The following topics from the FET Proactive consultation fit into this domain:


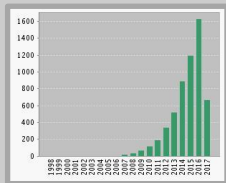

- FORMAL VERIFICATION OF SAFETY-CRITICAL DISTRIBUTED SYSTEMS
- Protection of the Sun against energy informational fields
- Development of the telescope for supervision in a range of vibrations of zero energy
- Detection of tunnels with hydrocarbons which will rescue a civilization from destruction

## 2.14 Groundbreaking Food Supply Systems

### Overview

Feeding the world without transgressing the earth's carrying capacity is one of the key challenges of the future that is also deeply related to other challenges such as water, energy, housing and health. In the near future we have to produce 70% more food than today without harming the environment. Meanwhile, the decrease in variety in plant and animal based food (eg rice/apples) is making food systems more susceptible to pests and diseases. Globally dependency on grain imports is on the rise. Production of meat and fish is rising steeply. At the same time ever more people advocate fundamental changes in human animal relationships. Technical approaches to food production such as smart floating farms, high-tech urban farming (e.g. vertical aquaponic growing system), fully automated and artificial food abound. Another angle is the reduction of food waste. Finally, there is a growing threat from foodborne diseases. Research addressing infection or intoxication caused by pathogenic factors entering into human bodies

through food is one of the most dynamic fields in agricultural, plant and animal sciences.

Assessment	
<p>Discourse Diversity</p> 	<p>In total the discourse on novel food solutions is covering diverse technologies and scientific disciplines including social and cultural sciences as well as citizens, artists and poets.</p>
<p>Scientific Publications</p> 	<p>Quite a few scientific publications cover synthetic food and changes in human animal relationship.</p>
<p>Impact Level</p> 	<p>Global food systems are highly interconnected so novel developments are likely to have widespread impact. At the same time there is a need for diverse and tailored local food solutions.</p>

## Underlying Aspects


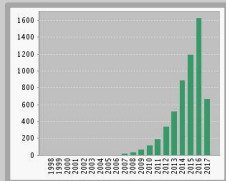

OBSERVE Emerging Topic	Discourse Diversity	Impact Level	Scientific Publications	No.
Food systems	High	WS	-	H11
Synthetic food	Low	LO	Mid	H22
Automated indoor farming	Low	LO	Low	T11
Human animal relationship	Mid	MR	Mid	H15

More detail on these topics: <https://ec.europa.eu/futurium/en/content/food-systems>

## 2.15 Low Footprint Chemical Processes

### Overview

Already in 1998 scientists developed 12 principles of “green chemistry” underpinning more environmentally benign chemical processes with e.g. less waste, higher efficiency and toxicity to human health and the environment. Several findings of the OBSERVE analysis relate to these principles indicating that this domain is still a highly active and future relevant domain for research and innovation with room for disruptive and foundational approaches with substantial sustainability benefit.<sup>11</sup>

Assessment	
<p>Discourse Diversity</p> 	<p>The debate on “green chemistry” remains among relatively few actors</p>
<p>Scientific Publications</p> 	<p>Many scientific publication address aspects of “green chemistry”. Some aspects are even current focus areas with steeply rising attention.</p>
<p>Impact Level</p> 	<p>The expected changes from these process innovations are often not disruptive but rather evolutionary. Nevertheless they carry substantial sustainability benefits such as reduction of energy demand and harmful substances. Therefore if widely applied in large scale processes the transformative potential in terms of ecological footprint is high.</p>

<sup>11</sup> Source: American Chemical Society <http://www.acs.org/content/acs/en/greenchemistry/what-is-green-chemistry/principles/12-principles-of-green-chemistry.html>

## Underlying Aspects

OBSERVE Emerging Topic	Discourse Diversity	Impact Level	Scientific Publications	No.
Emerging research front: Metal organic materials with optimal adsorption thermodynamics and kinetics for CO <sub>2</sub> separation	low	MR	Mid	S14
Emerging research front: Magnetically retrievable nanocatalysts	low	MR	Low	S16
Research front: Functional metal organic frameworks	low	MR	High, steep rise	N&S20
Emerging research front: Synthesis of copolymers by direct arylation polycondensation	low	MR	Low	S15
Emerging research front: Enhanced Visible Light photocatalysts	low	MR	Very high, steep rise	N&S23
Research front: Synthesis of pillar [5/6] arenes & their host guest chemistry	low	MR	Mid	S9
Emerging research front: Photoinitiated polymerization and Photoinitiators	low	MR	Mid	S17

More information: <https://ec.europa.eu/futurium/en/content/green-chemistry>

## 2.16 Understanding Beneficial Human Machine Symbiosis

### Overview

New forms of machine-human-symbiosis emerge on all levels and across types of activities. Aspects range from automation in all spheres of human activities to augmentation of intimate functions within the human body. In spite of frantic research in many of the aspects many argue that there is still little progress in understanding human machine interaction patterns that truly benefit our societies.

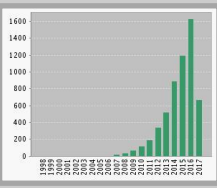
## Assessment

### Discourse Diversity



The debate on human machine relationship is led by all types of actors and disciplines.

### Scientific Publications



The field has some topics that are very highly addressed by scientific publications namely modelling the human and automation. But also several other aspects are highly covered. Some more long term concepts (singularity, autonomous production mechanism) but also societal implications are less covered.

### Impact Level



All-together the field has substantial potential to disrupt established socio-technical configurations across a wide range of domains and to initiate widespread and even fundamental transformations.

## Underlying Aspects

<b>OBSERVE Emerging Topic</b>	<b>Discourse Diversity</b>	<b>Impact Level</b>	<b>Scientific Publications</b>	<b>No.</b>
Machine society	High	WS	Low	H18
Modelling the human	Mid	LO	Very high	SP&T2
Automation	Low	WS	Very high	H14
Technological Singularity	Low	FU	Low	H16
Human enhancement	High	WS	Mid	H1
Robot reasoning	Low	MR	Mid	H26
Virtual Personal Assistant Bots	Low	WS	Low	T1



Fully autonomous production organism	Low	FU	None	T17
Rise of the drones	Low	WS	High, steep rise	T2
Cognitive overburden through perpetual evaluation	Low	WS	None	SP6
The human brain in the digital society	Low	WS	None	C6
Implants that store and transfer data	Low	LO	Mid	SP&T5
Optical implants	Low	MR	Low	N&T14
Automated indoor farming	Low	MR	Low	T11
Brain interfaces and implants	High	LO	Mid	T18
Robots will become more human-like as their vocabulary comes closer to that of real humans	Low	LO	Mid	T25
Insights from cognition research and biology may enable better Ambient Intelligence (Aml) systems	Low	WS	-	T27

More detail on these topics:

<https://ec.europa.eu/futurium/en/content/human-machine-symbiosis>

The following topics from the FET Proactive consultation relate to this domain:

- [home in a networked world; or rethinking architecture](#)
- [Adaptive bioelectronics](#)

## 2.17 Socio-Technical Internet Futures

### Overview

The internet will change in a technical and in a social way. Several debates are evolving around its long-term future (OBSERVE H17):


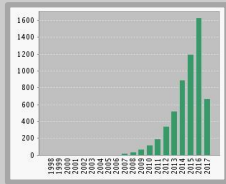

Some experts expect that “Intelligence moves to the networked edges”. Smaller and more specific networks may emerge where processing power and intelligence is distributed to “smart-hotspots” that facilitate seamless local interaction between diverse networked people and things (IFTF). Today’s infrastructure however limits many of these possibilities.

Others speculate about the way the digital and physical world may be interwoven in the future e.g. in a screenless “Internet in things” or a fully ambient user experience. At the same time some observers warn that even today’s expectations on the “Internet of Things” may be inflated and serious infrastructure bottlenecks are looming. Finally, huge efforts are under way to provide remote and mobile internet access points to the internet e.g. through drones or even satellites.

On the societal side the rise of non human traffic, trolls, viruses and abusive behaviour is raising concerns that trust in virtual communication is being undermined. Media and artists are increasingly pointing to the dark sides of the internet. Implementation of the “right to be forgotten” in the internet remains controversial. Attempts to create “offline spaces” are on the rise.

One FET consultation contribution makes a strong case for designing an Internet of People through putting “the human at the centre of the stage in the design and evaluation of Internet communication systems”.


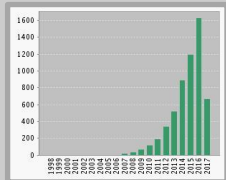

More detail on these topics: <https://ec.europa.eu/futurium/en/content/internet-futures>

Assessment	
<p>Discourse Diversity</p> 	<p>Internet futures are discussed by a diverse set of actors from different backgrounds and disciplines from electrical engineering to sociology. Also the topic is present in diverse discourses e.g. in politics, futures studies and the art world.</p>
<p>Scientific Publications</p> 	<p>A high number of publications addresses different aspects of the topic.</p>
<p>Impact Level</p> 	<p>As the internet has become a backbone for very many sectors of human activity, any innovation is highly likely to have widespread impacts on human societies and economies.</p>

## 2.18 New Ways of Exploiting Functions of Living Organisms

### Overview

Several of the findings from the OBSERVE screening pointed towards novel ways of using living organisms such as bacteria or plants for fulfilling useful functions.

Assessment	
<p>Discourse Diversity</p> 	<p>The discourse on the individual topics is still mainly among a narrow circle of actors. These communities (e.g. biologists and manufacturing engineers) are however very different from each other.</p>
<p>Scientific Publications</p> 	<p>In the field of the microbiome scientific publications are very high and still steeply rising. Applications of living organism in production processes also receive some attention.</p>
<p>Impact Level</p> 	<p>Both the microbiome and bio-manufacturing imply a potential for widespread impact in their respective domains. Both in health and manufacturing several established paradigms could be questioned by shifting perspectives on the use of living organisms. More specific applications could effect change on a local level.</p>

### Underlying Aspects

OBSERVE Emerging Topic	Discourse Diversity	Impact Level	Scientific Publications	No.
Biomanufacturing	Low	WS	Mid	C4
Bacteria-robot model systems	Low	LO	Low	T21
Yeast that makes opiate-like	Low	LO	Mid	N&S2

molecules out of sugar				
Bugs not drugs/the Microbiome	Low	WS	Very high, steep rise	S7, SP&S1
Moss walls for air cleaning	Low	LO	Low	SI2
Bio-sensors - Using plants as environmental sensors and connecting them to sensor networks	Low	LO	Na	T8

More detail on these topics: <https://ec.europa.eu/futurium/en/content/new-ways-exploiting-functions-living-organisms>

## 2.19 Mixed Realities for Extended Human Sensation<sup>12</sup>

### Overview


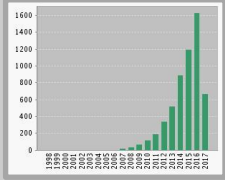

Several sources argue that we are entering the age of multiple realities (H25, SPT4). Technologies and practices which allow us to experience augmented or virtual reality are extremely prominent in the current discourse: 360 degree videos, advanced vr-gaming, vr-therapy, a real time painting 3D-model translator, vr development tools for animations, paint applications for oculus rift and space experiences. Virtualization and wearable computing devices are expected to combine to create a new wave of social technology. Oculus Rift already allows users to virtually explore real environments from the perspective of a child, and wearable recording devices are beginning to capture the details of everyday life. Developments like the personal headphones which can filter out unwanted noise point to a world where “reality will be in the eye (and ear) of the beholder”. VR and augmented reality topics are one of the most popular areas on Kick-starter. Science fiction novels envisage nano-cells on the skin that simulate an environment for the body that can be felt, heard and seen. Some observers argue that long term visions for “virtual reality societies” are lacking and several challenges remain.

More detail on these topics: <https://ec.europa.eu/futurium/en/content/mixed-realities>  
 One contribution from the FET Proactive consultation highlights the need to advance the understanding of sound in mixed reality systems:

- Introducing sound in depth within interactive digital systems.

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<sup>12</sup> This is one of the few cases where a cluster was formed already in the screening phase. Therefore the individual findings are integrated in the description text.

Assessment	
<p>Discourse Diversity</p> 	<p>The discourse is heavily driven by rather small circles of enthusiast (e.g. from gaming communities) on the one hand and futures thinkers including science fiction communities on the other.</p>
<p>Scientific Publications</p> 	<p>A high number of scientific publications is dealing with virtual, augmented and mixed realities.</p>
<p>Impact Level</p> 	<p>As this technology has implications across all sectors and domains of human life the impact of possible breakthroughs could be widespread.</p>

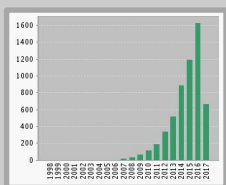
## 2.20 Next Generation Energy Storage (Beyond Lithium)

### Overview

Research and innovation in energy storage is highly dynamic driven by the rise of decentralised and renewable energy solutions. Important aspects are energy conversion efficiency, speed of storage, cost effectiveness; use of materials with low environmental and social impact. The field includes several potentially disruptive developments that go beyond today's lithium battery based solutions.

Assessment	
<p>Discourse Diversity</p> 	<p>The discourse is highly intense but each topic remains within its community.</p>

### Scientific Publications



New types of batteries are among the most debated topics in the scientific discourse. The number of publications is high and very steeply rising. Also other types of storage solutions receive researchers' attention. The decentralisation of the energy system is a highly dynamic area in terms of publications.

### Impact Level



Solutions to global energy demand are bound to generate widespread impact. Still, tailored local solutions are of paramount importance especially in a decentralised energy framework.

## Underlying Aspects

<b>OBSERVE Emerging Topic</b>	<b>Discourse Diversity</b>	<b>Impact Level</b>	<b>Scientific Publications</b>	<b>No.</b>
Organic flow batteries	low	MR	Mid, steep rise	N&S7
Emerging research front: Supercapacitors based on nanoporous carbon electrode	low	MR	Mid	N&S22
Research front: Electrode materials for sodium-ion batteries	low	MR	High	N&S19
Global Challenge: Energy demand	low	WS	Very high	N2
Reversible heat pump for energy storage	low	LO	Mid	N&T1
Decentralisation of energy supply	low	WS	Mid, steep rise	N&T2


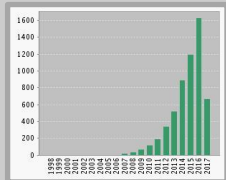

More detail on these topics:

<https://ec.europa.eu/futurium/en/content/next-generation-energy-storage>

## 2.21 Novel/unconventional Therapeutic Approaches

### Overview

Several of the OBSERVE findings refer to novel unconventional therapies for different diseases.

Assessment	
<p>Discourse Diversity</p> 	<p>As the approaches are quite specific the discourse remains in relatively homogeneous circle of actors for each topic.</p>
<p>Scientific Publications</p> 	<p>As is often the case in the medical field publication activity is high in most topics. Two less well known perspectives like mirror therapy and designer drugs are highly dynamic.</p>
<p>Impact Level</p> 	<p>From each novel therapy a substantial impact can be expected on the local level of the specific health domain. The perspective of spontaneous regression could span across several domains and impact on a mid range level.</p>

### Underlying Aspects

OBSERVE Emerging Topic	Discourse Diversity	Impact Level	Scientific Publications	No.
Prevent/repair heart attack	Low	LO	High	N&S1
Nano needles in regenerative medicine	Low	LO	Low	N&S5
New methods for drug deliv-	Low	LO	Low	N&S9

ery inside the body				
Spontaneous regression	Low	MR	Mid	N&S11
Treating phantom pain with a mirror	Low	LO	Mid, steep rise	SP&S2
Rising interest in traditional medicine	Low	LO	High	C5
Self-tracking pill	Low	LO	Low	N&T19
Self-Propelled particles for treating severe bleeding	Low	LO	Mid	T12
Emerging research front: Control and treatment of schistosomiasis in Africa using the drug praziquantel	Low	LO	High	N&S13
Research front: Newly emerging psychoactive substances (new designer drugs)	Low	MR	Mid, steep rise	N&S17

More detail on these topics: <https://ec.europa.eu/futurium/en/content/novel-therapies>

The following topics from the FET Proactive consultation relate to this domain:

- [Electromagnetic medicine \(EMF-MED\)](#)
- [Emergent personalized nanomedicine](#)
- [Functionalized Nanoparticles for Bio- and Biomedical Technologies](#)

## 2.22 Privacy Providing Systems

### Overview

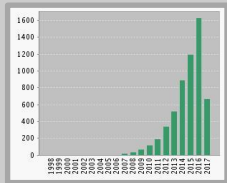
Privacy issues are an important element in current future oriented debates especially in the context of the rising use of big data analytics, face recognition and concepts like the internet of things or industry 4.0 on the one hand and concentration of user data in the hands of very few private companies on the other. Two OBSERVE emerging topics highlight the type of disruptive pathways that may be emerging both in terms of privacy threats and privacy solutions:

Assessment	
Discourse Diversity	The discourse on privacy concerns is highly intense and diverse. Nevertheless the notion of privacy preserving technologies or even systems was brought up only by few sources.





### Scientific Publications



The level of scientific publications is mid to high and rising fast.

### Impact Level



Privacy concerns are reaching across a number of domains. Both threats and solutions are bound to achieve widespread impact.

## Underlying Aspects


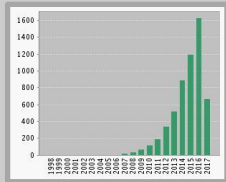

<b>OBSERVE Emerging Topic</b>	<b>Discourse Diversity</b>	<b>Impact Level</b>	<b>Scientific Publications</b>	<b>No.</b>
Extraordinary advances in facial recognition cause huge privacy issues	Low	WS	Mid	N&T9
Privacy preserving technologies	Low	WS	High, steep rise	N&T12

More detail on these topics: <https://ec.europa.eu/futurium/en/content/privacy-preserving>

## 2.23 Quantum Research

### Overview

A number of topics that emerged in the OBSERVE screening deal with quantum research. Aspects cover basic research needs, novel applications but also possible consequences for society.

Assessment	
<p>Discourse Diversity</p> 	<p>The individual aspects are each being discussed in specialists' circles from similar contexts.</p>
<p>Scientific Publications</p> 	<p>The number of scientific publications is on a medium level with graphene quantum dots considerably higher and dynamically growing.</p>
<p>Impact Level</p> 	<p>As soon as quantum technology moves into applications, widespread impacts such as the disruption of current cryptographic techniques are to be expected.</p>

### Underlying Aspects

OBSERVE Emerging Topic	Discourse Diversity	Impact Level	Scientific Publications	No.
Physicists set a new fiber-optic quantum teleportation record	Low	LO	Low	S5
Research front: Synthesis and application of graphene quan-	Low	MR	High, steep rise	S21

tum dots				
Quantum computing challenges cryptography	Low	WS	Mid	N&T8
Quantum squeezing	Low	LO	Low	S3
Quantum technology will move from basic research to applications	Low	WS	Mid	T30
Quantum computing: Combining advances in quantum technology and photonics to realize a quantum computer	Low	LO	Mid	T33

More detail on these topics: <https://ec.europa.eu/futurium/en/content/quantum-research>

Aspects of quantum research were also prominent in the FET Proactive consultation. The following contributions link up to this domain:

- [Quantum Nanophotonics](#)
- [NanoPhononics for Europe: Position, Strategic Agenda and Roadmap](#)

## 2.24 Unlocking Opportunities by Embracing Complexity

### Overview

Complexity is increasingly recognised both as a challenge and an opportunity in a wide range of science and practice domains. In the very rich and often controversial debate three aspects could be distinguished: Recognising and observing complex processes, decision making in the face of uncertainty, and approaches to embracing and even governing complexity. A central crosscutting aspect is the exploration of human thinking, decision making and behaviour as such.

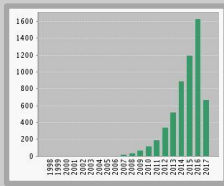
#### Assessment

##### Discourse Diversity



The diversity of sources dealing with complexity is extremely high. Voices include not only a wide range of disciplines from physics and informatics to philosophy, sociology and economy but also artists, policy makers and civil society activists.

### Scientific Publications



Complexity, simulation understanding the brain and human behaviour are among the very highest published topics in the whole OBSERVE spectrum. At the same time the field contains topics that are less addressed in scientific papers at the moment such as global decision making systems

### Impact Level



The field is dealing with the very core of human ability to deal with global challenges. Accordingly the impact of advances (or regress) in this is likely to be widespread or even fundamental.

## Underlying Aspects

OBSERVE Emerging Topic	Discourse Diversity	Impact Level	Scientific Publications	No.
Rise of complexity science	high	WS	Very high	H7
Multi-disciplinary simulation research	low	WS	Very high	C2
Data vs. Intuition?	low	WS	Mid	N7
Freakthinking	low	WS	Low	SP&S3
Making human impact visible	low	LO	None	N&T18
Global ethics	low	FU	Mid	N1
Global foresight/decision making	low	WS	Low	N5
New kinds of sensors and their smart connection will give us a new level of control over our surroundings	low	MR	na	T16
Hyperconnected sustainable planet	low	FU	None	N&T6
Intelligent combination of sensor-data replaces traditional technologies for authorization, monitoring and observation	low	WS	High	T10

Brain understanding	mid	WS	Very high	S19
Understanding and influencing human behaviour	high	WS	Very high	H23
Faster computers and newly available massive data hold the key for problems deemed too difficult to solve in the past	low	WS	na	T35

More detail on these topics:

<https://ec.europa.eu/futurium/en/content/dealing-complexity>

The challenge of dealing with complexity and uncertainty was also prevalent in the FET Proactive consultation with a particular focus on system science on the one hand and active construction of systems to deal with complexity. The following contributions fit into this domain:

- Foundations and Engineering of Collective Adaptive Systems (FoCAS)
- Summary of FoCAS Manifesto
- Beyond Digital
- Algorithms under Uncertainty
- Predictable components, systems and systems of systems
- Global Systems Science
- The Big Switch
- Theory of Evolving Systems
- Practice and the Dynamism of Form
- A “game changing” science of structures

## 2.25 Re-Engineering Life

### Overview

Several findings of the OBSERVE screening can be grouped under this heading as these approaches are actively attempting to push current boundaries of synthetically modifying or even creating life or else reflecting on the societal implications of such activities.

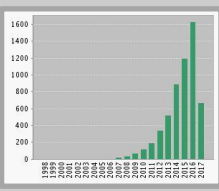
## Assessment

### Discourse Diversity



The discourse remains within rather specialised circles which however also include ethics and science fiction writers.

### Scientific Publications



CRISPR/CAS is addressed by a high and fast growing number of scientific papers. Approaches to artificial brains and robot reasoning as well as bioprinting also receive a good deal of attention. In bioprinting the development seems highly dynamic.

### Impact Level



The impact of reengineering life can be fundamental in the most extreme cases such as the technological singularity. But also ethnologies like CRISP/CAS and synthetic DNA may effects widespread changes on human lives including both huge opportunities and threats.

## Underlying Aspects

OBSERVE Emerging Topic	Discourse Diversity	Impact Level	Scientific Publications	No.
Emerging research front: CRISPR/CAS Genome-editing technology	low	WS	High, steep rise	S8
Synthetic DNA	low	WS	Mid	S2
Bio patent conflicts - who owns your body?	low	LO	Low	SP&T6
Artificial brain	low	MR	Mid	S12
Brain cell transplantation	low	LO	Low	N&S4
Technological Singularity	low	FU	Low	H16
Robot reasoning	low	MR	Mid	H26
Bioprinting	low	LO	Mid, steep rise	N&S7

More detail on these topics: <https://ec.europa.eu/futurium/en/content/re-engineering-life>


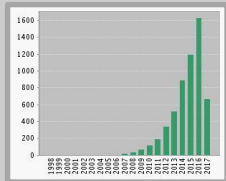

One contribution to the FET Proactive consultation highlights in particular the high potential of 3D Bioprinting, a topic that also emerged in OBSERVE:

- 3D BIOPRINTING EUROPE

## 2.26 Shifts in Research Practices

### Overview

The OBSERVE screening revealed debates around changes in research practices. Some are driven by societal demands such as gender equality, transparency, citizen participation and animal rights others stem from shifts in scientific approaches such as increasing use of computational methods.

Assessment	
<p>Discourse Diversity</p> 	<p>Several of the developments changing research practices remain within relatively confined circles. Some aspects however have been brought up by diverse communities: the need for gendering research practices, the emergence of new forms of human animal relationships and the need for distributed collaboration platforms.</p>
<p>Scientific Publications</p> 	<p>Scientists themselves are intensely reflecting on the new approaches especially on bioinformatics, genome wide association studies and simulation approaches. Also other aspects especially the gendering are addressed by quite a few papers with digital humanities steeply rising. The practical aspect of sharing fieldwork failures is less addressed.</p>
<p>Impact Level</p> 	<p>The rise of bioinformatics, genome wide association studies and simulation approaches has the potential for widespread impact on human health and nature of technologies. Changing human animal relationship may also impact across domains e.g. food, culture, medical experiments and agriculture.</p>

## Underlying Aspects

OBSERVE Emerging Topic	Discourse Diversity	Impact Level	Scientific Publications	No.
Distributed collaboration platforms	high	WS	Mid	H9
Scientists share their embarrassing #fieldworkfail stories	low	LO	Low	SP5
Gendering in research and innovation	mid	LO	High	H13
Human animal relationship	mid	MR	Mid	H15
Bioinformatics	low	WS	Very high	S18
Research front: Human disease analysis using Genome Wide Association studies	low	WS	Very high	N&S18
Digital humanities	low	LO	Mid, very dynamic	C1
Multi-disciplinary simulation research	low	WS	Very high	C2

More detail on these topics:

<https://ec.europa.eu/futurium/en/content/future-research-practices>

One contribution from the FET Proactive consultation emphasises the high potential of art contributing to knowledge generation:

- Fully integrating Arts in the S&T research and innovation agenda: the role of imagining and making in the creation of knowledge for innovation


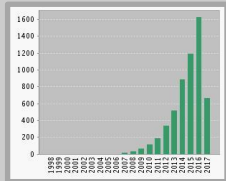

## 2.27 Robotic Frontiers

### Overview

Throughout the OBSERVE screening period robotics was an extremely dynamic field both in S&T sources and wider public debate. This was driven on the one hand by spectacular breakthroughs most notably in the field of deep learning and autonomous robotics. On the other hand social experiments and art projects such as the hitchhiking robot and the trust inspiring robot (Boxie) as well as popular fiction and movies featuring robots and AI fuelled the robotics discourse. Finally, in the ongoing debates around automation of ever more human activities and industry 4.0 robots form a core element.



Aspects related to new forms of interactions between humans and machines are captured under human machine symbiosis.

Assessment	
<p>Discourse Diversity</p> 	<p>These topics are based on a relatively homogenous set of sources from similar contexts.</p>
<p>Scientific Publications</p> 	<p>The number of scientific publications per topic is moderate but especially soft robotics is seeing a steep rise in publications.</p>
<p>Impact Level</p> 	<p>New types of robotics will impact on a mid range level within several diverse fields where robotics are applied ranging from production, disaster recovery to medical applications.</p>

## Underlying Aspects

OBSERVE Emerging Topic	Discourse Diversity	Impact Level	Scientific Publications	No.
Robot to robot collaborations	Low	MR	Low	T23
Robot learning	Low	MR	Mid	T24
Robot reasoning	Low	MR	Mid	H26
Bacteria-robot model systems	Low	LO	Low	T21
Autonomous and soft materials for robot parts	Low	LO	Mid, steep rise	T22
Interdisciplinary research to build context-aware robots	Low	MR	High	T7

More detail on these topics: <https://ec.europa.eu/futurium/en/content/robotics-frontiers>


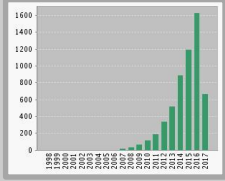

One contribution from the FET Proactive consultation points in particular to soft robotics as a key future field:

- Soft Robotics: the way for bringing science-based robotics to Society

## 2.28 Multi-Signal Sensing Systems

### Overview

Novel developments in sensing are mainly driven by the use of new materials and new concepts. This includes social innovations such as citizen driven measuring and monitoring initiatives. At the same time urgent requirements such as measurement of ocean acidification are calling for novel solutions.

Assessment	
<p>Discourse Diversity</p> 	<p>Each aspect within this cluster rests on a rather homogeneous set of sources.</p>
<p>Scientific Publications</p> 	<p>Publications on sensor combinations are high and papers on sensors to measure ocean acidification and distributed collaboration platforms are rising fast.</p>
<p>Impact Level</p> 	<p>Whereas each individual sensor development will impact on a rather confined level, widespread changes can be expected through novel combinations of sensors including citizens actively monitoring their environment.</p>

## Underlying Aspects

OBSERVE Emerging Topic	Discourse Diversity	Impact Level	Scientific Publications	No.
New sensors to measure ocean acidification	low	LO	Mid, steep rise	T13
Emerging research front: Synthesis of copolymers by direct arylation polycondensation	low	MR	Low	S15
Motion microscope	low	LO	None	N&T16
Distributed collaboration platforms	high	WS	Mid, steep rise	H9
Intelligent combination of sensor-data replaces traditional technologies for authorization, monitoring and observation	low	WS	High	T10
Bio-sensors - Using plants as environmental sensors and connecting them to sensor networks	low	LO	Na	T8

More detail on these topics: <https://ec.europa.eu/futurium/en/content/sensing-frontiers>

One contribution from the FET Proactive consultation stresses the use of drone technology for wildlife conservation.

- Drone technology for conservation

In the OBSERVE findings the rise of drones for a wide range of applications and its potentially disruptive impact was also highlighted (cf. Rise of the drones in “sustainable habitat”)

## 2.29 Shifting Understanding of Life and its Boundaries

### Overview

Our perception of what it means to be human and what characterises other species is shifting. Boundaries between humans and animals on the one hand and humans animals and machines on the other are blurring. Also plants are increasingly viewed in a new perspective e.g. as active communicators. New research methods transform the way we analyse species evolution.

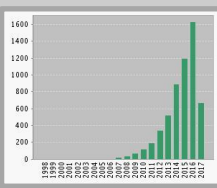
## Assessment

### Discourse Diversity



Except for human animal relationship which is being discussed in different realms of science and society, the aspects within this topic are suggested by a rather homogeneous set of sources.

### Scientific Publications



Scientific publications are on a mid level except for Models for predicting potential distributions of species which is subject of a high number of publications which is still growing fast.

### Impact Level



Radically novel interpretations of life's boundaries such as technological singularity may have fundamental impacts on humanity. But also less disruptive aspects such as a new recognition of plants as living beings or human rights for animals or the establishment of reasoning robots may affect changes that will spread widely or at least affect several domains

## Underlying Aspects


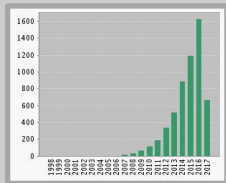

OBSERVE Emerging Topic	Discourse Diversity	Impact Level	Scientific Publications	No.
Plant communication	low	WS	Mid	H14
Human animal relationship	mid	MR	Mid	H15
Technological Singularity	low	FU	Low	H16
Robot reasoning	low	MR	Mid	H26
Research front: Models for predicting potential distributions of species	low	MR	High, steep rise	N&S15
Bacteria-robot model systems	low	LO	Low	T21

More detail on these topics: <https://ec.europa.eu/futurium/en/content/shifting-perceptions-life-and-its-boundaries>

## 2.30 Solar Age

### Overview

The reinforced search for renewable energy sources forwards the solar technology and solar installations in generally. New designs and materials for solar cells, solar powered devices and monitoring of favourable conditions for solar panel installation (e.g. in space) were key topics in the current debate. Several research aspects in chemistry, material science but also social sciences emerged.

Assessment	
Discourse Diversity 	The solar age is hotly debated in highly diverse communities such as physics, economics, cultural studies and engineering. Also novelists, journalists and policy makers are exploring the implications.
Scientific Publications 	The level of scientific publications is high in the overall field.
Impact Level 	Emergence of the solar age may have widespread impacts on all aspects of human lives including socio-cultural patterns. At the same time a sudden decline of solar activity would fundamentally challenge all life on earth. Breakthrough in solar technology including materials will affect several sectors.

### Underlying Aspects

OBSERVE Emerging Topic	Discourse Diversity	Impact Level	Scientific Publications	No.
Solar Age	High	WS	High	H20
Research front: Graphene-	Low	MR	High, steep rise	N&S21


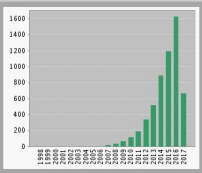

based photocatalysts				
Emerging research front: Synthesis of copolymers by direct arylation polyconden- sation	Low	MR	Low	S15
Decline in solar activity by 2030	Low	FU	Mid	N10

More detail on these topics: <https://ec.europa.eu/futurium/en/content/solar-age>

## 2.31 Future Living Spaces

### Overview

Several emerging topics relate to sustainable living spaces both in urban and rural areas. A particular focus could be on the question of how to dwell in a networked world. As highlighted by one contribution to the FET Proactive consultation there is an urgent need to rethink our approaches to the “built environment” and realise the high potential of cross-disciplinary research on adaptation of spaces to human needs:

Assessment	
Discourse Diversity 	Mobility, housing and urban systems are core functions in human societies and therefore discussed by a high diversity of sources. Naturally however, some of the findings stem from specialist communities.
Scientific Publications 	Apart from a few practice based topics, publication activities in this field are on a high level with especially the topic of drones rising fast in scientific attention.
Impact Level 	In this domain many local solutions may add up to mid level or even widespread changes in the way human living spaces are conceptualised and built.

## Underlying Aspects

OBSERVE Emerging Topic	Discourse Diversity	Impact Level	Scientific Publications	No.
Sustainable Housing	Mid	LO	Mid	H29
Urban catalysts	Low	LO	None	C3
Urban system design	High	WS	High	H6
Cycling Futures	Low	MR	Very high	SP1
Moss walls for air cleaning	Low	LO	None	SI2
Bee highway	Low	LO	na	SI6
Wooden material on the rise	Low	LO	High	SP&T1
Personal Heating	Low	LO	None	N&T13
Mobility futures	Mid	WS	Mid	H19
Rise of the drones	Low	WS	High, steep rise	T2

More detail on these topics:

<https://ec.europa.eu/futurium/en/content/sustainable-habitats>

Contribution FET Proactive Consultation:

- home in a networked world; or rethinking architecture

## 2.32 Diverse Unconventional Energy Supply Solutions

### Overview

Meeting global energy demand in a sustainable manner is one of the most discussed global challenges. In parallel to the mainstream lines of research for new energy technologies and concepts more unconventional approaches are followed by several research and innovation teams. In line with the diversification of energy technologies, innovations in grids and overall system designs are key topics of the debate on energy futures. A particular focus is on the decentralisation of energy supply.

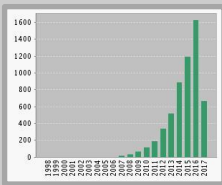
## Assessment

### Discourse Diversity



Energy solutions are of course subject to a wide and highly diverse societal discourse. OBSERVE sources for this topic include also artwork and science fiction.

### Scientific Publications



The cluster is covered by a very high number of scientific publications with two aspects (decentralised energy system and wireless transfer of electricity) strongly on the rise.

### Impact Level



As energy is underpinning all forms of human activities the implications of novel solutions and threats are widespread.

## Underlying Aspects

OBSERVE Emerging Topic	Discourse Diversity	Impact Level	Scientific Publications	No.
Global Challenge: Energy demand	low	WS	Very high	N2
Unconventional energy sources	high	WS	High	N&T15
Local energy production will power the smart grid	low	WS	Na	SI1
Decentralisation of energy supply	low	WS	Mid, steep rise	N&T2
Wireless transfer of electricity	low	WS	High, steep rise	T9
Energy Harvesting	low	MR	Very high	T4
Energy from oxidation in human bodies	low	LO	None	N&T4



More detail on these topics:

<https://ec.europa.eu/futurium/en/content/novel-energy-solutions>


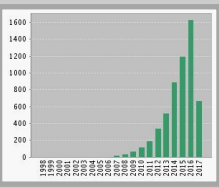

The following topics from the FET Proactive consultation fit into this domain:

- Energy sustainable ICT
- Powering the Internet of Things
- Demonstration Project of full scale floating prototype for Offshore Wind Market

## 2.33 Underwater Operations

Preparing for underwater operations emerges as a highly dynamic domain for research and innovation in a wide range of fields. Key issues are underwater: -gardening, -living, -(mini)robots, -cities, -streetview, -radio (graphene), -chemical plants, -charging, -flight, -volcanoes, -farms, -archaeology, - screening radar, -energy (wave/wind farms) and materials for underwater use. More detail on these topics:


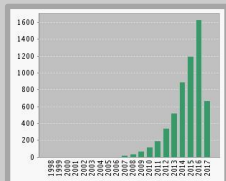

<https://ec.europa.eu/futurium/en/content/underwater-operations>

Assessment	
<p>Discourse Diversity</p> 	<p>Underwater solutions were surprisingly well covered within the sources investigated. Findings cover many diverse application fields suggested sources from different contexts.</p>
<p>Scientific Publications</p> 	<p>A very high number of scientific publications is addressing this topic.</p>
<p>Impact Level</p> 	<p>The impact of increasing underwater activity is likely to spread across several domains once the supporting technologies and competences are well developed.</p>

## 2.34 Water Challenge

### Overview

Water and especially clean water is becoming a scarce resource in ever more areas as climate change threatens water security. We need global strategies to prevent this or deal with. Implementation of existing strategies such as the European Water Framework Directive (WFD) requires suitable tools and methods. Water was one of the most addressed topics in 2015 science related tweets. Topics were water: -generation, -cleaning,-recycling,-pollution, -splitting, -based energy generation, - saving and -quality monitoring as well as measures dealing with droughts. Ways of measuring the quality of oceans, coastal and transitional waters is becoming an important research front in ecology. Another strand of debate is focussing on the future of oceans. Research on the impact of ocean acidification on marine ecosystems is growing fast. Artists such as Maarten Vanden Eynde (plastic reef) point towards the rise of plastic debris in the ocean - a topic that is also much discussed in science publications and media in general. In addition several more specific topics related to ocean futures were raised.

Assessment	
<p>Discourse Diversity</p> 	<p>The sources pointing towards the water challenge are highly diverse and include many sciences, technologies as well as civil society organisations and several artists who reflect on the human impact on oceans.</p>
<p>Scientific Publications</p> 	<p>The number of publications is high and rising fast especially in the field of ocean acidification. Some more specialised fields are also covered by quite a few papers.</p>
<p>Impact Level</p> 	<p>Due to the fundamental role of water for life on earth any developments in the domain can be expected to have widespread impact. Complementary local solutions e.g. for supporting coral reefs are also of key importance.</p>

## Underlying Aspects

OBSERVE Emerging Topic	Discourse Diversity	Impact Level	Scientific Publications	No.
Water Challenge	Mid	WS	High, steep rise	N&S14
Decline of microscopic plant-life in oceans	low	WS	Low	N&S10
Electric bio rocks save coral reefs	low	LO	Mid	N&T3
New sensors to measure ocean acidification	low	MR	Mid, steep rise	T13
Noise pollution in sea threatens whales	low	LO	Mid	N6
Research front: Effects of ocean acidification on marine ecosystems	high	WS	High	N&S24

More detail on these topics: <https://ec.europa.eu/futurium/en/content/water-challenge>

One contribution from the FET Proactive consultation, very much in line with the OBSERVE findings, highlights the need to “turn water challenges into new technological and societal opportunities”:

- FET in water and for water: Response to stakeholder consultation Horizon 2020 Future Emerging Technologies (FET) PROACTIVE

### 2.35 Microfluidics 2.0

Two topics submitted to the FET Proactive consultation deal with new frontiers in the field of microfluidics:

- Moleculonics
- Microfluidic organs on chip for pharmaceutical research, drug screening and regenerative medicine

This field strongly links to the OBSERVE cluster „Diagnostics revolution“ which also builds on developments in microfluidics.

## 2.36 System Science

Seven submissions from the FET Proactive consultation point towards a “system of systems” perspective. One particular element of this being the understanding and creation of collective adaptive systems:

- Foundations and Engineering of Collective Adaptive Systems
- Summary of FoCAS Manifesto
- Beyond Digital
- Predictable components, systems and systems of systems
- Global Systems Science
- The Big Switch
- Theory of Evolving Systems

This cluster is closely linked to the issue of “recognizing complexity” and could also be seen as a subset of this domain.

### 3 Annex: Background Data Publication Analysis

The table below gives the keywords and hits for the publication analysis for all emerging topics where the analysis was feasible and produced at least one hit. The search was carried out for the years 1997-2017 in the Core collection of Thomson Reuters Web of Science.

Name	Search Term	Hits	Class
N&S 10 Decline of microscopic plant-life in oceans	(Declin* micro* plant-life ocean*)	1	low
N&T 5 3D printed emergency shelter	(3D print* shelter)	1	low
SP 4 Compressed conversation	("digital communication" AND ("nature of language" OR "human language"))	1	low
T 23 Robot to robot collaborations	("Robot robot collaboration")	1	low
N&S 2 Yeast that makes opiate-like molecules out of sugar	(Yeast (opiate OR opioid) sugar)	2	low
N&S 3 Antibacterial bio-microfilm	(Antibacterial microfilm)	2	low
SP 5 Scientists share their embarrassing #fieldworkfail stories	("fieldwork fail*")	2	low
T 11 Automated indoor farming	("indoor farming" AND automat*)	2	low
N&S 4 Brain cell transplantation	("Brain cell transplantation")	4	low
SP&T6 Bio patent conflicts - who owns your body?	(Bio patent conflict)	4	low
SP 2 Time as money	Time as Money	6	low
T 21 Bacteria-robot model systems	(bio-hybrid robot* AND bacteri*)	6	low
T 36 Micromotors will be built into nano-scale micro-electro-mechanical systems (MEMS) and enable new lab-on-a-chip systems to biomedical implants.	("lab on chip" AND (micromotor OR nanomotors))	6	low
N&T 19 Self-tracking pill	("Self-tracking" AND (pill or drug))	7	low
SP&T3 DIY printing of circuits	(DIY print (circuits OR electronic*))	7	low
C 7 Astronomy and geology collaborate	(Astronomy and geology)	8	low
N&S 5 Nano needles in regenerative medicine	("Nano needle*" drug delivery)	8	low
N 11 Spectrum overcrowding	"Spectrum overcrowding"	9	low
S 5 Physicists set a new fiber-optic quantum teleportation record	(fiber-optic quantum teleportation)	11	low
H 18 Machine society	("machine societ*" OR "human-machine symbio*")	13	low
T 1 Virtual Personal Assistant Bots	Virtual Personal Assistant*	13	low
N&T 17 Big data supported crisis management	("Big data" AND "crisis management")	21	low

H 16 Technological Singularity	("technological singularity")	21	low
N&S 9 New methods for drug delivery inside the body	(deliver* drug* inside body AND ((microneedle) OR (hydrogel) OR (silicone)))	22	low
N 5 Global Challenge: Global foresight/decision making	(global tools AND ("collective intelligence" OR "collective decision making"))	24	low
SP&S 3 Freakthinking	Freakonomics	29	low
N&T 10 Fast HIV detection	("HIV detection" AND (fast OR rapid))	31	low
SI 3 Cleaner-fish keeps salmon healthy by eating lice	("Cleaner-fish" salmon lice)	33	low
H 10 Postcapitalist economy	(postcapitalist OR "post capitalism")	35	low
N 8 Universal software bug	("integer overflow")	43	low
S 20 Nanolattices	nanolattices	46	low
S 15 Emerging research front: Synthesis of copolymers by direct arylation polycondensation	Synthesis of copolymers by direct arylation polycondensation	46	low
S 10 Measuring Imagination	(measur* NEAR/5 imagination)	50	low
N&T 14 Optical implants	(optical NEAR/3 "implants")	51	low
H 28 Brain networking	("brain to brain")	63	low
S 3 Quantum squeezing	("Quantum squeezing")	79	low
T 14 Terahertz communication enables a new range of wireless applications in the future	("Terahertz communication")	86	low
S 16 Emerging research front: Magnetically retrievable nanocatalysts	(Magnetically (retrievable OR recover*) nanocatalysts)	91	low
N 10 Decline in solar activity by 2030	("solar activity" NEAR/3 Declin*)	112	mid
S 1 Emerging research front: Analysis of dynamic and static behaviour of functionally graded material	Analysis of dynamic and static behaviour of functionally graded material	116	mid
S 12 Artificial brain	("artificial brain")	133	mid
T 25 Robots will become more human-like as their vocabulary comes closer to that of real humans	(human NEAR/5 robot NEAR/5 language)	134	mid
N 3 Global Challenge: Transnational organized crime	(Transnational organized crime)	137	mid
N 14 Particle pollution may be the main cause for brain degenerative diseases	((("fine particle*" OR particle pollut*) AND(dement* OR Parkinson* OR neurodegenerative OR Alzhem* OR autism OR neurotox*))	148	mid
N&T 1 Reversible heat pump for energy storage	(Reversible "heat pump")	153	mid
H 14 Plant communication	"plant communication*"	160	mid
H 1 Human enhancement	neuroenhancement	163	mid
H 19 Mobility futures	("future* mobilit*")	172	mid

N&S 11 Spontaneous regression	(Spontaneous regression NEAR/5 tumor*)	181	mid
T 18 Brain interfaces and implants	("Brain interfaces" OR "brain implants")	182	mid
N&T 9 Extraordinary advances in facial recognition cause huge privacy issues	("fac* recognition" privacy)	184	mid
N&S 17 Research front: Newly emerging psychoactive substances (new designer drugs)	((("legal high*" OR "designer drugs") AND (herbal OR K2 OR spice OR "synthetic cathiones")))	199	mid
N 6 Noise pollution in sea threatens whales	(underwater noise whales)	202	mid
N 1 Global Challenge: Global ethics	"global ethic*"	202	mid
N&T 2 Decentralisation of energy supply	(Decentral* "energy supply")	219	mid
S 14 Emerging research front: Metal organic materials with optimal adsorption thermodynamics and kinetics for CO2 separation	("Metal organic" AND "CO2 separation")	230	mid
N&T 3 Electric bio rocks save coral reefs	("REEF RESTORATION")	230	mid
H 29 Sustainable Housing	("sustainable housing")	231	mid
T 30 Quantum technology will move from basic research to applications	("Quantum technology")	256	mid
N 13 Pandemics strategy urgently needed	(pandemics NEAR/3 strateg*)	278	mid
SP&S 2 Treating phantom pain with a mirror	("Mirror therapy")	289	mid
N 7 Data vs. Intuition?	(decision making data intuition)	311	mid
T 20 Neuromorphic computing	("Neuromorph* computing")	326	mid
T 22 Autonomous and soft materials for robot parts	(materials robot* AND ("Autonomous materials" OR "soft materials" OR "artificial skin" OR "artificial muscles"))	348	mid
C 4 Biomanufacturing	biomanufacturing	375	mid
S 9 Research front: Synthesis of pillar [5/6] arenes and their host guest chemistry	(Pillar[5]arene OR Pillar[6]arene)	385	mid
C 1 Digital humanities	digital humanities	438	mid
H 9 Distributed collaboration platforms	("collaboration platform*" OR "peer to peer collaboration" OR "co-creation platform") OR TOPIC: ("blockchain")	457	mid
T 12 Self-Propelled particles	("Self-Propelled particles")	458	mid
T 31 Cancer-detection in real-time	(Cancer-detection real-time)	481	mid
SP&T5 Implants that store and transfer data	(Implants NEAR/2 telemetr*)	487	mid
N&S 16 Research front: Atmospheric aerosol nucleation and growth	("atmospheric aerosol particles")	492	mid
T 24 Robot learning	("Robot learning")	497	mid

N 12 Mental illness controversy	mental health disorder	499	mid
S 17 Emerging research front: Photoinitiated polymerization and Photoinitiators	("Photoinitiated polymeri*ation")	503	mid
H 26 Robot reasoning	("cognitive robot**")	504	mid
N&S 22 Emerging research front: Supercapacitors based on nanoporous carbon electrodes	(Supercapacitors nanoporous carbon electro*de*)	511	mid
T 33 Quantum Computing: Combining advances in quantum technology and photonics to realize a quantum computer	quantum computing	517	mid
N&S 7 Organic flow batteries	(batteries AND (Organic flow OR quinone))	518	mid
N&S 8 Bioprinting	((("living tissue*" AND "3D print*") OR "organ print*" OR 3d bioprint*))	522	mid
N&T 8 Quantum computing challenges cryptography	("Quantum comput*" cryptography)	538	mid
S 4 Molecular communication	("Molecular communication")	572	mid
H 15 Human animal relationship	human* animal* relation*	574	mid
T 29 The combination of scientific advances in nanotechnology, optics and spintronics with conventional electronics will lead to new computing and switching devices with superior performance.	(nano* optic* spintronic*)	578	mid
H 2 Biomimicry new frontiers	biomimicry	663	mid
H 22 Synthetic food	("synthetic food" OR "artificial food")	696	mid
T 13 New sensors to measure ocean acidification	("Ocean acidification" AND sens*)	744	mid
T 28 non-invasive brain influencing	("non-invasive brain")	821	mid
N&T 11 Enhanced bloodtest functionality	("Liquid Biops**")	841	mid
H 21 Space exploration	"space exploration"	871	mid
S 2 Synthetic DANN	("Synthetic dna")	969	mid
N 4 Global Challenge: Education and learning	((neuroscience AND education) OR neuro-education)	1040	high
S 6 Timekeeping mechanism of human brain uncovered	((human brain "time keeping") OR ("internal clock"))	1282	high
T 34 Smart materials will be used to provide shape-changing mobile devices and other interfaces	("Smart material")	1287	high
N&S 1 Prevent/repair heart attack	(repair* NEAR/2 heart)	1323	high
H 25 Mixed Realities	mixed realit*	1356	high



N&S 13 Emerging research front: Control and treatment of schistosomiasis in Africa using the drug praziquantel	(schistosomiasis praziquantel)	1533	high
H 5 Circular material flows	("circular economy" OR "zero-waste")	1552	high
S 11 Research front: Graphene and graphene oxide in biomedical application	(graphene biomedical)	1564	high
N&S 19 Research front: Electrode materials for sodium-ion batteries	(Electrode material* sodium-ion batteries)	1586	high
H 6 Urban system design	"urban system"	1640	high
H 3 Active audiences	("audience interaction" OR "user generated content" OR "participatory media" OR "active audiences")	1778	high
S 8 Emerging research front: CRISPR/CAS Genome-editing technology	CRISPR/CAS	1849	high
T 15 Research in the field of photonic crystals may lead to a superior-performance optical computer.	("photonic crystals")	1849	high
N&S 20 Research front: Functional metal organic frameworks	Functional "metal organic frameworks")	1997	high
H 20 Solar age	"solar energy"	2475	high
T 2 Rise of the drones	drones	2604	high
N&S 21 Research front: Graphene-based photocatalysts	Graphene photocatalyst*	2611	high
T 9 Wireless transfer of electricity	("wireless charging" OR "wireless power transfer")	3100	high
H 8 Disaster management	"disaster management"	3382	high
H 13 Gendering in research innovation	("gender sensitiv*" OR "gender bias" OR "sex sensitiv*" OR "sex bias")	3521	high
N 9 Threat of ?space weather?	("space weather")	3537	high
N&S 14 Water challenge	(water NEAR/3 challenge)	3604	high
N&S 15 Research front: Models for predicting potential distributions of species	("Species distribution model*")	3704	high
SP&T1 Wooden material on the rise	((wood OR timber) material (construction OR housing OR building))	4317	high
N&S 24 Effects of climate change	"effects of climate change"	4415	high
T 7 Interdisciplinary research to build context-aware robots	("autonomous robot*")	4604	high
H 17 Internet futures	internet NEAR/10 future	4707	high
H 27 Forest health	fire threat	5229	high
N&T 12 Privacy preserving technologies	("preserv* privacy" OR "privacy preserv*")	5494	high

S 21 Research front: Synthesis and application of graphene quantum dots	(Graphene quantum dots)	5716	high
S 13 Emerging research front: Synthesis of functional gold nanorods	("gold nanorods")	5733	high
T 3 Plasmonics: From basic research to breakthroughs in high-performance computing and nano devices.	plasmonics	6487	high
T 10 Intelligent combination of sensor-data replaces traditional technologies for authorization, monitoring and observation	("multi sens*")	8213	high
N&T 15 Unconventional energy sources	(Energy AND (geothermal OR bio*mechanical OR ("blue energy") OR ("nuclear fusion")))	8504	high
T 26 Spintronics: New principles for new, ultra-high capacity storage devices.	spintronics	9497	high
C 5 Rising interest in traditional medicine	"traditional medicine"	9576	high
SP 1 Cycling Futures	bicycle	10706	very high
N&S 18 Research front: Human disease analysis using Genome Wide Association studies	("Genome Wide Association Studies")	11035	very high
S 7 Microbiomes	microbiome	11221	very high
SP&S 1 Bugs not drugs	microbiome	11221	very high
H 23 Understanding and influencing human behaviour	("human behaviour" OR "human behavior")	11361	very high
T 4 Energy Harvesting may be the solution for powering small and mobile devices in the future.	("energy harvesting")	13039	very high
N&S 23 Emerging research front: Enhanced Visible Light photocatalysts	Visible Light photocatalyst*	17962	very high
C 2 Multi-disciplinary simulation research	simulation (multidisciplinary sciences)	21418	very high
N 2 Global Challenge: Energy demand	sustainable energy	30124	very high
S 18 Bioinformatics	bioinformatics	33795	very high
H 24 Underwater	underwater	37271	very high

T 5 In the research field of Microfluidics, interdisciplinary work will yield advanced Lab-on-a-Chip-technologies and other new applications	("microfluidic*")	46859	very high
H 4 Automation	automation	52167	very high
N&S 12 Post antibiotics	("antimicrobial resistance" OR antibiotic* NEAR/3 resistan*)	55742	very high
SP&T2 Modelling the human	((modelling OR modeling) AND (human* AND (body OR beaviour OR behavior)))	85439	very high
T 6 CMOS technology will stay on the R&D agenda and will continue to boost chip performance and bring about new applications	CMOS	92965	very high
T 32 Use recently discovered graphene characteristics to produce better switches, lasers, chips, etc.	graphene	112122	very high
S 19 Brain understanding	(brain AND (memory OR "spatial mapping" OR "timing" OR "vision" OR "decision making" OR "emotional experience assignment" OR "social prediction" OR "hearing" OR "tinnitus" OR "pattern recognition" OR "aging"))	120673	very high
H 7 Dealing with complexity	complexity	405.531	very high