Deliverable 4.4 OBSERVE User Brief 1

Project Name	Observing Emergence OBSERVE
Project No.	665136
Project Type	Coordination and Support Action
Project Duration	01/06/2015-30/05/2017 (24 Months)
Project Coordinator	Philine Warnke, Fraunhofer ISI
Funded under	Future and Emerging Technologies FET OPEN CSA
Work package	WP4 Dissemination
Deliverable	D4.4 User brief 1 Emerging Topics
Submission Date	01/07/2016
Version	1
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OBSERVE User Brief 1: Emerging Topics

1 Background

The Future & Emerging Technologies (FET) programme of the European Commission invests in transformative frontier research and innovation with a high potential impact on technology, to benefit our economy and society. FET provides a unique combination of high risk, long term, multidisciplinary and collaborative frontier research, which lays the foundations for radically new, next generation technologies. It converts proofs of concept into industrial applications and systems.[1] The OBSERVE project supports FET by screening emerging developments that could be relevant to be taken up in the FET funding activities. This User Brief presents selected findings of the OBSERVE screening phase that may be of relevance for several actors of the research and innovation landscape of different disciplines and sectors. The full results of the OBSERVE screening can be found in the Horizon Scanning Report (Deliverable 1.2) the methodology is explained in the Methodology Report (D1.2).

2 Overview OBSERVE Emerging Topics

The full report contains 171 emerging topics encountered in the OBSERVE screening phase. They are assigned to five basic categories: Science, Technology, Challenge/Need, Social Practice and Solution Idea, Collaboration, Hybrids (spanning all types). For each emerging topic the team assessed the expected impact level ranging from "local" (impact in a confined specific area) to fundamental (impact on the whole human civilization. In this user brief we will present a clustering of the 171 topics into 34 Clusters.[2] This clustering was done by the OBSERVE team and is naturally subjective. It serves to illustrate how users may work with the OBSERVE topics in order to underpin their own strategy building. Depending on the user perspective it could be carried out in many different ways.

Users wishing to obtain more detailed information on each of the items listed may consult the OBSERVE Horizon Scanning Report or else the FET Proactive Consultation. For the latter specific links are provided for each cluster. Reference to the Chapters of the OBSERVE Horizon Scanning Report/The OBSERVE Deck of Cards is as follows:

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[1] https://ec.europa.eu/digital-agenda/future-emerging-technologies-fet, last access 27/04/2016

[2] These Clusters were also submitted to the FET Consultation on future topics for the Proactive funding programme https://ec.europa.eu/futurium/en/digital4science/discussions/FET%20Proactive%20consultation, last access: 27/04/2016

H=Hybrid, T=Technology, S=Science, C=Collaboration, N=Needs and challenges, N&S=Needs and challenge & science, N&T=Needs and challenge & technology, SP=Social Practice, SP&S=Social practice and science, SP&T = Social practice and technology, SI=Solution idea.

2.1   Advanced Computing[3]

Many teams of scientists and innovators around the world are exploring technologies and concepts to enable faster and more efficient computing with the FET community among the frontrunners. At the same time the way computing technologies are embedded into economy and society may also be changing with peer2peer approaches to hardware development and software programming fast emerging, and some developments such as quantum computing challenging established organisational patterns.

Related OBSERVE emerging topics:

- Quantum Computing: Combining advances in quantum technology and photonics to realize a quantum computer T33

- Quantum computing challenges cryptography N&T8

- Advancing CMOS technology T6

- Spintronics: New principles for new, ultra-high capacity storage devices T26

- Combination of scientific advances in nanotechnology, optics and spintronics with conventional electronics T29

- Photonic crystals for optical computers T15

- Neuromorph computing T20

- Plasmonics T3

- Biomanufacturing C4

- Distributed collaboration platforms H9

- DIY printing of circuits SP&T3

- Universal software bug N8

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[3] https://ec.europa.eu/futurium/en/content/advanced-computing

2.2   Advanced Materials[4]

Several of the most dynamic research fronts with highly recognized scientific publications are located in the material sciences. While some of these are basic research on synthesis and properties of new materials many focus on specific 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.

Related OBSERVE emerging topics:

− Emerging research front: Analysis of dynamic and static behaviour of functionally graded material S1

− New materials for robot parts T22

− Use recently discovered graphene characteristics in novel applications T32

− Smart materials for shape-changing mobile devices and other interfaces T34

− Research front: Graphene and graphene oxide in biomedical application S11

− Emerging research front: Synthesis of functional gold nanorods S13

− Emerging research front: Metal organic materials with optimal adsorption thermo-dynamics and kinetics for CO_2 separation S14

− Emerging research front: Magnetically retrievable nanocatalysts S16

− Nanolattices S20

− Research front: Synthesis of pillar [5/6] arenes and their host guest chemistry S9

− Self-Propelled particles T12

− Plasmonics T3

2.3   Bacteria management[5]

Several of the 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.

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4 https://ec.europa.eu/futurium/en/content/advanced-materials

5 https://ec.europa.eu/futurium/en/content/bacteria-management

through genome editing. At the same time, bacteria are increasingly being used for processes.

Related OBSERVE emerging topics:

- Post antibiotics N&S12

- Water based nano bacteria shields N&S6

- Antibacterial bio-microfilm N&S3

- Bugs not drugs SP&S1

- Emerging research front: CRISPR/CAS Genome-editing technology S8

- Biomanufacturing C4

2.4   Biomimicry[6]

An increasing 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 bioinspired parallel and neuromorph computing. In the 2015 Lift China Conference there was a focus in biomimicry as the next generation sustainability concept.

Related OBSERVE emerging topic: H2

2.5   Brain Impacts[7]

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.

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

7 https://ec.europa.eu/futurium/en/content/brain-impacts

The following individual aspects were emerging in the OBSERVE analysis:

– Brain networking H28

– Brain interfaces and implants T18

– Non-invasive brain influencing T28

– Timekeeping mechanism of human brain uncovered S6

– Artificial brain S12

– Brain understanding S19

– The human brain in the digital society C6

– Global Challenge: Education and learning N4

– Particle pollution may be the main cause for brain degenerative diseases N14

– Brain cell transplantation N&S4

– Treating phantom pain with a mirror SP&S2

– Understanding and influencing human behaviour H23

– Robots will become more human-like as their vocabulary comes closer to that of real humans-HM Symbiosis-Brain Futures T25

– Measuring Imagination S10

– Mental illness controversy N12

– Cognitive overburden through perpetual evaluation SP 6

2.6   Circular Resource Flows[8]

Approaches towards a sustainable circular economy feature prominently in the debate among scientists, innovators and actors from civil society and policy. The following topics emerged in the analysis of recent discourses:

– Circular material flows H5

– Wooden material on the rise SP&T1

– Carbon nanofibres made from CO_2 in the air N&T7

2.7 Civilisational Transformation[9]

Some of the OBSERVE screening results reflect on possibly upcoming fundamental transformations of human civilisation.

Related OBSERVE emerging topics:

- Future of civilization H12
- Technological Singularity H16
- Forest health H27
- Underwater H24
- Long term preservation of knowledge and timekeeping SI4/5
- Post antibiotics N&S12
- Extraordinary advances in facial recognition cause huge privacy issues N&T9
- Space exploration H21

2.8 Clean Air[10]

Air pollution is a key topic in current futures debates. Aspects are monitoring and combating air pollution as well as better understanding its evolution and effects.

The following OBSERVE findings relate to clean air:

- Research front: Atmospheric aerosol nucleation and growth N&S16
- Carbon nanofibres made from CO_2 in the air N&T7
- Moss walls for air cleaning SI2
- Bio-sensors: Using plants as environmental sensors and connecting them to sensor networks T8
- Particle pollution may be the main cause for brain degenerative diseases N14

2.9 Communication Futures[11]

The OBSERVE screening revealed a diverse set of items related to the way we communicate:

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

10 https://ec.europa.eu/futurium/en/content/clean-air

11 https://ec.europa.eu/futurium/en/content/communication-futures

- Compressed conversations SP4

- Terahertz communication enables a new range of wireless applications in the future T14

- Spectrum overcrowding N11

- Active audiences H3

- Molecular communications S4

2.10   Diagnostics Revolution[12]

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.

The following individual elements relate to this domain:

- Microfluidics advancing Lab-on-a-Chip-technologies and other new applications T5

- Micromotors in nano-scale micro-electro-mechanical systems T36

- Enhanced bloodtest functionality N&T11

- Cancer-detection in real-time T31

- Fast HIV detection N&T10

2.11   Economy Futures[13]

A few developments captured in the OBSERVE radar reflect on emerging new modes of production and consumption and the related societal and technical transformations:

- Time as money SP2

- Postcapitalist economy H10

- Global Challenge: Transnational organized crime N3

- Distributed collaboration platforms H9

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[12] https://ec.europa.eu/futurium/en/content/diagnostics-revolution

[13] https://ec.europa.eu/futurium/en/content/economy-futures

2.12   Effects Climate Change[14]

The dynamics and effects of climate change are subject to intense research in many disciplines. Researchers worldwide 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 super-storms and effects on soil bacteria.

In addition, the following current research fronts emerged in this context:

- Effects of ocean acidification on marine ecosystems
- Greenland ice sheet dynamics
- Global sea level change
- Regional climate models
- Model analysis of non-CO_2 greenhouse gases

Related OBSERVE emerging topic: N&S24

2.13   Emergency Preparedness[15]

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.

The following elements of the findings relate to this umbrella topic:

- Post antibiotics N&S12
- Threat of "space weather" N9
- Pandemics strategy urgently needed N13
- Big data supported crisis management N&T17
- Disaster management H8
- Decline in solar activity by 2030 N10
- Universal software bug N8

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

15 https://ec.europa.eu/futurium/en/content/emergency-preparedness

- 3D printed emergency shelter-sustainable habitats N&T5
- Distributed collaboration platforms H9

2.14 Food System Solutions[16]

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.

OBSERVE findings highlight different aspects:

- Food systems H11
- Synthetic food H22
- Automated indoor farming T11
- Human animal relationship H15

2.15 Green Chemistry[17]

Already in 1998, scientists developed 12 principles of "green chemistry"[18] underpinning more environmentally benign chemical processes, e.g. with 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.

The following aspects of OBSERVE findings relate to this domain:

- Emerging research front: Metal organic materials with optimal adsorption thermodynamics and kinetics for CO_2 separation S14
- Emerging research front: Magnetically retrievable nanocatalysts S16
- Research front: Functional metal organic frameworks N&S20
- Emerging research front: Synthesis of copolymers by direct arylation polycondensation S15
- Emerging research front: Enhanced Visible Light photocatalysts N&S23

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16 https://ec.europa.eu/futurium/en/content/food-systems

17 https://ec.europa.eu/futurium/en/content/green-chemistry

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

– Research front: Synthesis of pillar [5/6] arenes & their host guest chemistry S9

– Emerging research front: Photoinitiated polymerization and Photoinitiators S17

2.16   Human Machine Symbiosis[19]

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.

The OBSERVE Screening brought up the following elements:

– Machine society H18

– Modelling the human SP&T2

– Automation H4

– Technological Singularity H16

– Human enhancement H1

– Brain interfaces and implants T18

– Robot reasoning H26

– Virtual Personal Assistant Bots T1

– Fully autonomous production organism T17

– Rise of the drones T2

– Robots will become more human-like as their vocabulary comes closer to that of real humans T25

– Cognitive overburden through perpetual evaluation SP6

– The human brain in the digital society C6

– Insights from cognition research and biology may enable better Ambient Intelligence (AmI) systems T27

– Implants that store and transfer data SP&T5

– Optical implants N&T14

– Automated indoor farming T11

2.17   Internet Futures[20]

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

Related OBSERVE emerging topics: H17

2.18   New ways of exploiting functions of living organism [21]

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.

The following aspects of such "organism based solutioning" appeared in the debate:

– Biomanufacturing C4

– Bacteria-robot model systems T21

– Yeast that makes opiate-like molecules out of sugar N&S2

– Bugs not drugs/the Microbiome SP&S1/S7

– Moss walls for air cleaning SI2

20 https://ec.europa.eu/futurium/en/content/internet-futures

21 https://ec.europa.eu/futurium/en/content/new-ways-exploiting-functions-living-organisms

– Bio-sensors - Using plants as environmental sensors and connecting them to sensor networks T8

2.19 Mixed realities[22]

Several sources argue that we are entering the age of multiple realities. 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. The 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 Kickstarter. 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.

Related OBSERVE emerging topic: H24, SPT4

2.20 Next Generation Energy Storage[23]

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.

In the OBSERVE screening, the following individual elements came up:

– Organic flow batteries N&S7

– Emerging research front Supercapacitors based on nanoporous carbon electrode N&S22

– Research front: Electrode materials for sodium-ion batteries N&S19

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22 https://ec.europa.eu/futurium/en/content/mixed-realities

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

- Global Challenge: Energy demand N2

- Reversible heat pump for energy storage N&T1

- Decentralisation of energy supply N&T2

2.21 Novel Therapies[24]

The following items of the OBSERVE findings refer to novel or unconventional therapies:

- Prevent/repair heart attack N&S1
- Nano needles in regenerative medicine N&S5
- New methods for drug delivery inside the body N&S9
- Spontaneous regression N&S11
- Treating phantom pain with a mirror SP&S2
- Rising interest in traditional medicine C5
- Self-tracking pill N&T19
- Self-Propelled particles T12
- Emerging research front: Control and treatment of schistosomiasis in Africa using the drug praziquantel N&S13
- Research front: Newly emerging psychoactive substances (new designer drugs) N&S17

2.22 Privacy Preserving[25]

Privacy issues are an important element in current future oriented debates, especially in the context of the rising use of big data analytics 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 elements from the OBSERVE screening highlight the type of disruptive pathways that may be emerging both in terms of privacy threats and privacy solutions:

- Extraordinary advances in facial recognition cause huge privacy issues N&T9
- Privacy preserving technologies N&T12

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[24] https://ec.europa.eu/futurium/en/content/novel-therapies

[25] https://ec.europa.eu/futurium/en/content/privacy-preserving

2.23   Quantum Research[26]

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.

Related OBSERVE emerging topics:

– Physicists set a new fiber-optic quantum teleportation record S5

– Research front: Synthesis and application of graphene quantum dots S21

– Quantum computing challenges cryptography N&T8

– Quantum technology will move from basic research to applications T30

– Quantum Computing: Combining advances in quantum technology and photonics to realize a quantum computer T33

– Quantum squeezing S3

2.24   Recognising complexity[27]

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.

The following individual elements that emerged in the OBSERVE screening gave rise to the suggestion of this topic:

– Rise of complexity science H7

– Multi-disciplinary simulation research C2

– Intelligent combination of sensor-data replaces traditional technologies for authorization, monitoring and observation T10

– Data vs. Intuition? N7

– Freakthinking SP&S3

26 https://ec.europa.eu/futurium/en/content/quantum-research

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

- Invisible human impact N&T18

- Brain understanding S19

- Understanding and influencing human behaviour H23

- Faster computers and newly available massive data hold the key for problems deemed too difficult to solve in the past T35

- Global ethics N1

- Global foresight/decision making N5

- New kinds of sensors and their smart connection will give us a new level of control over our surroundings T16

- Hyperconnected sustainable planet N&T6

- Distributed collaboration platforms H9

2.25   Re-Engineering Life[28]

The following 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:

- Emerging research front: CRISPR/CAS Genome-editing technology S8

- Synthetic DNA S2

- Bio patent conflicts - who owns your body? SP&T6

- Artificial brain S12

- Brain cell transplantation N&S4

- Technological Singularity H16

- Robot reasoning H26

2.26   Research Practices[29]

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.

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[28] https://ec.europa.eu/futurium/en/content/re-engineering-life

[29] https://ec.europa.eu/futurium/en/content/future-research-practices

Related OBSERVE emerging topics:

- Distributed collaboration platforms H9
- Scientists share their embarrassing #fieldworkfail stories SP5
- Gendering in research innovation H13
- Human animal relationship H15
- Bioinformatics S18
- Research front: Human disease analysis using Genome Wide Association studies N&S18
- Digital humanities C1
- Multi-disciplinary simulation research C2

2.27 Robotic Frontiers[30]

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.

Specifically with respect to advances in robotics, the following elements emerged:

- Robot to robot collaborations T23
- Interdisciplinary research to build context-aware robots T7
- Robot learning T24
- Robot reasoning H26
- Bacteria-robot model systems T21
- New materials for robot parts T22

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[30] https://ec.europa.eu/futurium/en/content/robotics-frontiers

2.28   Sensing Frontiers[31]

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.

The following elements emerged:

- New sensors to measure ocean acidification T13
- Intelligent combination of sensor-data replaces traditional technologies for authorization, monitoring and observation T10
- Bio-sensors - Using plants as environmental sensors and connecting them to sensor networks T8
- Emerging research front: Synthesis of copolymers by direct arylation polycondensation S15
- Motion microscope N&T16
- Distributed collaboration platforms H9

2.29   Shifting interpretations of life and its boundaries [32]

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. New research methods transform the way we analyse species evolution.

Related OBSERVE emerging topics:

- Plant communication H14
- Human animal relationship H15
- Technological Singularity H16
- Robot reasoning H26
- Research front: Models for predicting potential distributions of species N&S15
- Bacteria-robot model systems T21

[31] https://ec.europa.eu/futurium/en/content/sensing-frontiers

[32] https://ec.europa.eu/futurium/en/content/shifting-perceptions-life-and-its-boundaries

2.30   Solar Age[33]

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:

- Solar Age H20

- Research front: Graphene-based photocatalysts N&S21

- Emerging research front: Synthesis of copolymers by direct arylation polycondensation S15

- Decline in solar activity by 2030 N10

2.31   Sustainable Habitats[34]

Several emerging topics relate to sustainable living spaces both in urban and rural areas:

- Sustainable Housing H29

- Urban catalysts C3

- Urban system design H6

- Cycling Futures SP1

- Moss walls for air cleaning SI2

- Bee highway SI6

- Wooden material on the rise SP&T1

- Personal Heating N&T13

- Mobility futures H19

- Rise of the drones T2

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[33] https://ec.europa.eu/futurium/en/content/solar-age

[34] https://ec.europa.eu/futurium/en/content/sustainable-habitats

2.32   Unconventional energy[35]

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.

The following specific aspects were emerging:

– Global Challenge: Energy demand N2

– Unconventional energy sources N&T15

– Local energy production will power the smart grid SI1

– Decentralisation of energy supply N&T2

– Wireless transfer of electricity T9

– Energy Harvesting T4

– Energy from oxidation in human bodies N&T4

2.33   Underwater[36]

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.

Related OBSERVE emerging topic: H24

2.34   Water Challenge[37]

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 Frame-

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[35] https://ec.europa.eu/futurium/en/content/novel-energy-solutions

[36] https://ec.europa.eu/futurium/en/content/underwater-operations

[37] https://ec.europa.eu/futurium/en/content/water-challenge

work 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.

Related topics from OBSERVE Horizon Scanning:

– Decline of microscopic plant-life in oceans N&S10

– Electric bio rocks save coral reefs N&T3

– New sensors to measure ocean acidification T13

– Noise pollution in sea threatens whales N6

– Water challenge N&S14

3   Implications for different actor groups

Each cluster has specific implications including both risks and opportunities for different actor groups and sectors. As an example the cluster of "recognizing complexity" is certainly an issue for **policy** on all levels ranging from local level (e.g. use of predictive analytics for city governments) to global governance mechanisms tackling, e.g. implementation of global strategies for coping with disasters or pandemics. At the same time the topic raises a number of interdisciplinary **research** questions involved ranging from highly technical aspects, e.g. modelling and simulation, to social science approaches such as resilience and human cognition. Finally, **companies** from different sectors will encounter a number of business opportunities but also challenges related to the complexities of their own strategy building. We suggest for user groups to use these clusters to reflect on risks and opportunities emerging from it for their specific field of activity. In addition it makes sense to review the full set of emerging topics and extract different clusters preferably with people from different positions within an organisation. The OBSERVE Deck of Cards[38] can be a useful tool for such an exercise. Together with the cards OBSERVE provides a manual indicating possible workshop formats to work with the cards in a strategic manner.

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[38] For download on the OBSERVE Website