Deliverable 3.1 OBSERVE 360° Radar

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1 Introduction

1.1 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 but also to nurture the strategic development of the other FET programmes and underpinning the FET group's early awareness of emerging novel and potentially disruptive topics. For this purpose OBSERVE has gradually developed a "360° Radar" for screening and assessing diverse types of emerging topics.

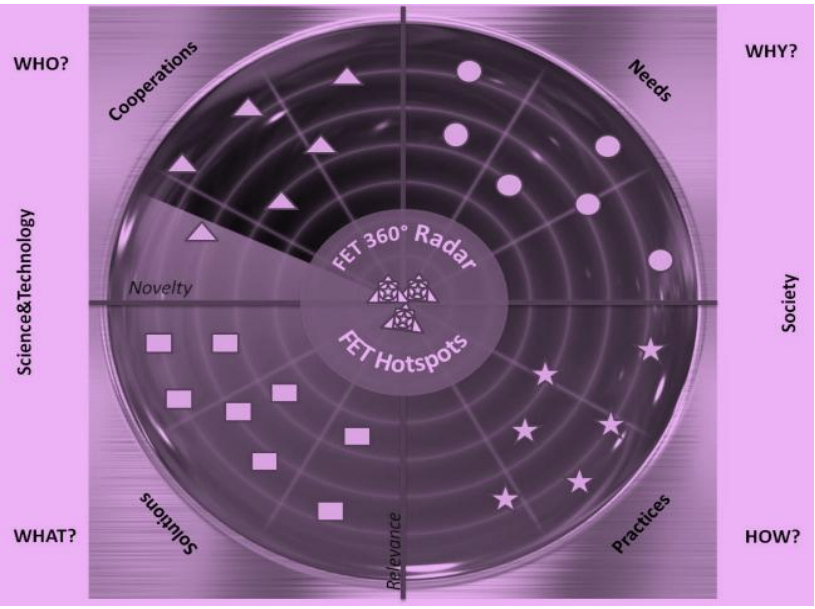


Figure 1: OBSERVE 360° Radar Scheme

1.2 Radar Building Approach

In its first phase, OBSERVE set up systematic screening of a diverse set of sources in 2015 using a combination of automated and manual scouting methods.[1] As a result of

[1] Cf. OBSERVE Deliverable 1.3. Methodology Report

this process 171 emerging topics[2] 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.

In order to enable the use of the findings in creative and strategic processes they were printed on a deck of cards with different colours indicating the different types as shown in Figure 2. A manual was provided with suggestions on how to use these cards in strategic processes.[3]

Figure 2: Radar Building Step 1 - Identifying emerging topics (Deliverable 1.2)

These 171"seeds of change hypotheses" were synthesised into 34 clusters which were then integrated with the 59 contributions to the FET Proactive consultation which ran

[2] Cf. Deliverable 1.2 OBSERVE Horizon Scanning Report

[3] Deliverable 4.3 Deck of Cards and Manual

from 10/02/-30/04/2016. The resulting 36 clusters form the “OBSERVE potential emerging hotspots” and are documented in Deliverable 2.1 OBSERVE Potential Hotspot Report. As visualised in

Figure 3, the “potential Hotspots” are clusters of emerging topics that combine aspects of different types so e.g. a societal challenge and a novel technology. They were formed by the OBSERVE team on the basis of a thorough analysis of the 171 individual emerging topics and their possible interlinkages.

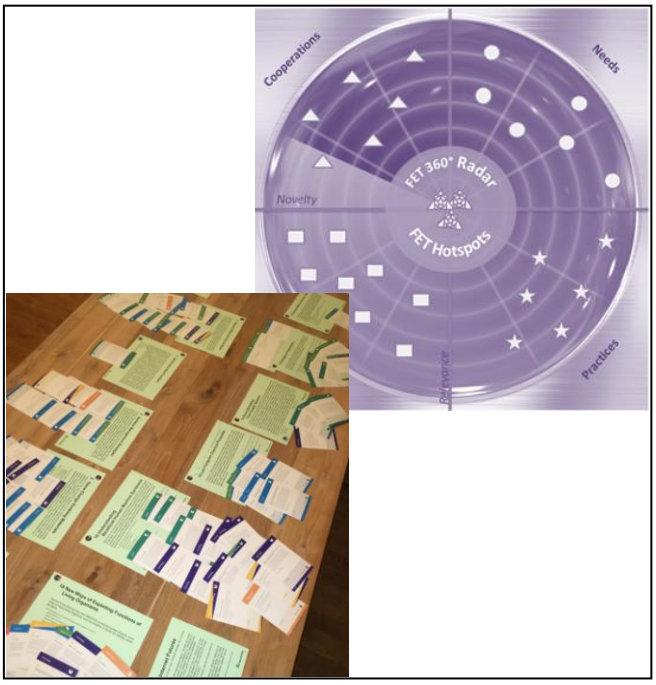


Figure 3: Radar Building Step 2 - Clustering the emerging topics into 36 potential hotspots (Deliverable 2.1)

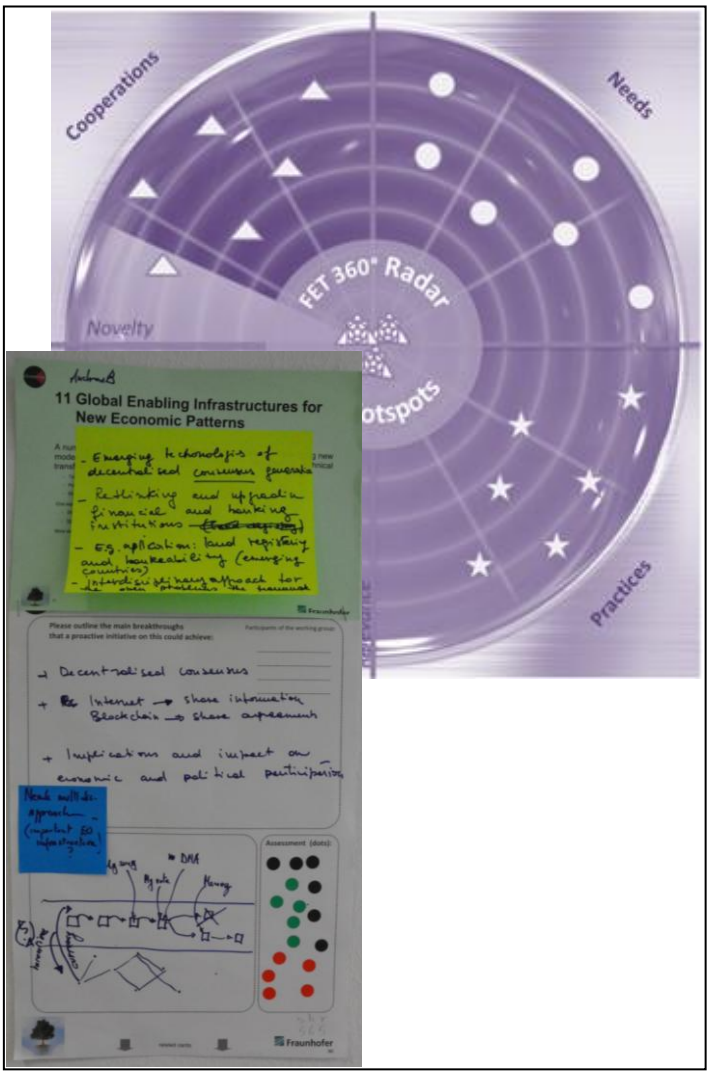


Figure 4: Radar Building Step 4 - Creating Hotspots (Deliverable 3.1 this Report)

Finally, the Hotspots that fill the very core of the 360° Radar cannot be a static result of a onetime scientific research effort. Rather, the material from the outer levels of the radar forms the basis for continuous sense making processes where actors with different perspectives come together and generate ever new combinations in a creative future oriented interactive processes. In the course of the FET topic definition a few such processes were carried out in different contexts e.g. with the FETAG advisory board. In the following section we document the process and outcomes of the “topic generation workshop” that was organised by the OBSERVE team on January 31st 2017 in Brussels. The workshop generated 17 Hotspots (c.f. Figure 4) that were fed into the FET Proactive topic generation process as one of several inputs. This workshop could be seen as a blueprint for many similar processes to be carried out in order to continuously populate the core of the Radar.

2 Radar Content

2.1 The 171 Emerging Topics

Title	Impact Level	Discourse Diversity	Publication Level
C 1 Digital humanities	Local	low	mid
C 2 Multi-disciplinary simulation research	Widespread	low	very high
C 3 Urban catalysts	Local	low	none
C 4 Biomanufacturing	Widespread	low	mid
C 5 Rising interest in traditional medicine	Local	low	high
C 6 The human brain in the digital society	Widespread	low	none
C 7 Astronomy and geology collaborate	Local	low	low
H 1 Human enhancement	Widespread	high	mid
H 2 Biomimicry new frontiers	Mid Range	high	mid
H 3 Active audiences	Local	mid	high
H 4 Automation	Widespread	mid	very high
H 5 Circular material flows	Widespread	high	high
H 6 Urban system design	Widespread	high	high
H 7 Dealing with complexity	Widespread	high	very high
H 8 Disaster management	Mid Range	low	high
H 9 Distributed collaboration platforms	Widespread	high	mid
H 10 Postcapitalist economy	Fundamental	low	low
H 11 Food systems	Widespread	high	na
H 12 Future of civilization	Fundamental	high	na
H 13 Gendering in research innovation	Local	mid	high
H 14 Plant communication	Widespread	low	mid
H 15 Human animal relationship	Mid Range	mid	mid
H 16 Technological Singularity	Fundamental	low	low
H 17 Internet futures	Widespread	high	high
H 18 Machine society	Widespread	high	low
H 19 Mobility futures	Widespread	mid	mid
H 20 Solar age	Widespread	high	high
H 21 Space exploration	Local	mid	mid
H 22 Synthetic food	Local	low	mid
H 23 Understanding and influencing human behaviour	Widespread	high	very high
H 24 Underwater	Mid Range	mid	very high
H 25 Mixed Realities	Widespread	mid	high
H 26 Robot reasoning	Mid Range	low	mid
H 27 Forest health	Mid Range	mid	high
H 28 Brain networking	Widespread	mid	low
H 29 Sustainable Housing	Local	mid	mid

N 1 Global Challenge: Global ethics	Fundamental	low	mid
N 2 Global Challenge: Energy demand	Widespread	low	very high
N 3 Global Challenge: Transnational organized crime	Widespread	low	mid
N 4 Global Challenge: Education and learning	Widespread	low	high
N 5 Global Challenge: Global foresight/decision making	Widespread	low	low
N 6 Noise pollution in sea threatens whales	Local	low	mid
N 7 Data vs. Intuition?	Widespread	low	mid
N 8 Universal software bug	Mid Range	low	low
N 9 Threat of ?space weather?	Widespread	low	high
N 10 Decline in solar activity by 2030	Fundamental	low	mid
N 11 Spectrum overcrowding	Mid Range	low	low
N 12 Mental illness controversy	Widespread	low	mid
N 13 Pandemics strategy urgently needed	Widespread	low	mid
N 14 Particle pollution may be the main cause for brain degenerative diseases	Widespread	low	mid
N&S 1 Prevent/repair heart attack	Local	low	high
N&S 2 Yeast that makes opiate-like molecules out of sugar	Local	low	low
N&S 3 Antibacterial bio-microfilm	Mid Range	low	low
N&S 4 Brain cell transplantation	Local	low	low
N&S 5 Nano needles in regenerative medicine	Local	low	low
N&S 6 Water based nano bacteria shields	Local	low	none
N&S 7 Organic flow batteries	Mid Range	low	mid
N&S 8 Bioprinting	Local	low	mid
N&S 9 New methods for drug delivery inside the body	Local	low	low
N&S 10 Decline of microscopic plant-life in oceans	Widespread	low	low
N&S 11 Spontaneous regression	Mid Range	low	mid
N&S 12 Post antibiotics	Widespread	low	very high
N&S 13 Emerging research front: Control and treatment of schistosomiasis in Africa using the drug praziquantel	Local	low	high

N&S 14 Water challenge	Widespread	mid	high
N&S 15 Research front: Models for predicting potential distributions of species	Mid Range	low	high
N&S 16 Research front: Atmospheric aerosol nucleation and growth	Local	low	mid
N&S 17 Research front: Newly emerging psychoactive substances (new designer drugs)	Mid Range	low	mid
N&S 18 Research front: Human disease analysis using Genome Wide Association studies	Widespread	low	very high
N&S 19 Research front: Electrode materials for sodium-ion batteries	Mid Range	low	high
N&S 20 Research front: Functional metal organic frameworks	Mid Range	low	high
N&S 21 Research front: Graphene-based photocatalysts	Mid Range	low	high
N&S 22 Emerging research front: Supercapacitors based on nanoporous carbon electrodes	Mid Range	low	mid
N&S 23 Emerging research front: Enhanced Visible Light photocatalysts	Mid Range	low	very high
N&S 24 Effects of climate change	Widespread	high	high
N&T 1 Reversible heat pump for energy storage	Local	low	mid
N&T 2 Decentralisation of energy supply	Widespread	low	mid
N&T 3 Electric bio rocks save coral reefs	Local	low	mid
N&T 4 Energy from oxidation in human bodies	Local	low	none
N&T 5 3D printed emergency shelter	Local	low	low
N&T 6 Hyperconnected Sustainable Planet (IoT)	Fundamental	low	none
N&T 7 Carbon nanofibres made from CO2 in the air	Mid Range	low	none
N&T 8 Quantum computing challenges cryptography	Widespread	low	mid

N&T 9 Extraordinary advances in facial recognition cause huge privacy issues	Widespread	low	mid
N&T 10 Fast HIV detection	Local	low	low
N&T 11 Enhanced bloodtest functionality	Local	low	mid
N&T 12 Privacy preserving technologies	Widespread	low	high
N&T 13 Personal Heating	Local	low	none
N&T 14 Optical implants	Mid Range	low	low
N&T 15 Unconventional energy sources	Widespread	high	high
N&T 16 Motion microscope	Local	low	none
N&T 17 Big data supported crisis management	Local	low	low
N&T 18 Invisible human impact	Local	low	none
N&T 19 Self-tracking pill	Local	low	low
S 1 Emerging research front: Analysis of dynamic and static behaviour of functionally graded material	Mid Range	low	mid
S 2 Synthetic DANN	Widespread	low	mid
S 3 Quantum squeezing	Local	low	low
S 4 Molecular communication	Local	low	mid
S 5 Physicists set a new fiber-optic quantum teleportation record	Local	low	low
S 6 Timekeeping mechanism of human brain uncovered	Local	low	high
S 7 Microbiomes	Widespread	low	very high
S 8 Emerging research front: CRISPR/CAS Genome-editing technology	Widespread	low	high
S 9 Research front: Synthesis of pillar [5/6] arenes and their host guest chemistry	Mid Range	low	mid
S 10 Measuring Imagination	Local	low	low
S 11 Research front: Graphene and graphene oxide in biomedical application	Local	low	high
S 12 Artificial brain	Mid Range	low	mid
S 13 Emerging research front: Synthesis of functional gold nanorods	Mid Range	low	high
S 14 Emerging research front: Metal organic materials with optimal adsorption thermodynamics and kinetics for CO2 separation	Mid Range	low	mid

S 15 Emerging research front: Synthesis of copolymers by direct arylation polycondensation	Mid Range	low	low
S 16 Emerging research front: Magnetically retrievable nanocatalysts	Mid Range	low	low
S 17 Emerging research front: Photoinitiated polymerization and Photoinitiators	Mid Range	low	mid
S 18 Bioinformatics	Widespread	low	very high
S 19 Brain understanding	Widespread	mid	very high
S 20 Nanolattices	Mid Range	low	low
S 21 Research front: Synthesis and application of graphene quantum dots	Mid Range	low	high
SI 1 Local energy production will power the smart grid	Widespread	low	na
SI 2 Moss walls for air cleaning	Local	low	none
SI 3 Cleaner-fish keeps salmon healthy by eating lice	Local	low	low
SI 4 Long term preservation of knowledge	Fundamental	low	na
SI 5 Long-term timekeeping	Fundamental	low	na
SI 6 Bee highway	Local	low	na
SP 1 Cycling Futures	Mid Range	low	very high
SP 2 Time as money	Fundamental	low	low
SP 3 From design inspired by nature towards nature inspired by design	Mid Range	low	none
SP 4 Compressed conversation	Local	low	low
SP 5 Scientists share their embarrassing #fieldworkfail stories	Local	low	low
SP 6 Cognitive overburden through perpetual evaluation	Widespread	low	none
SP&S 1 Bugs not drugs	Widespread	low	very high
SP&S 2 Treating phantom pain with a mirror	Local	low	mid
SP&S 3 Freakthinking	Widespread	low	low
SP&T1 Wooden material on the rise	Local	low	high
SP&T2 Modelling the human	Local	mid	very high
SP&T3 DIY printing of circuits	Mid Range	low	low
SP&T4 Smart dust	Local	low	none
SP&T5 Implants that store and transfer data	Local	low	mid
SP&T6 Bio patent conflicts - who owns your body?	Local	low	low
T 1 Virtual Personal Assistant Bots	Widespread	low	low

T 2 Rise of the drones	Widespread	low	high
T 3 Plasmonics: From basic research to breakthroughs in high-performance computing and nano devices.	Mid Range	low	high
T 4 Energy Harvesting may be the solution for powering small and mobile devices in the future.	Mid Range	low	very high
T 5 In the research field of Microfluidics, interdisciplinary work will yield advanced Lab-on-a-Chip-technologies and other new applications	Local	low	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	Mid Range	low	very high
T 7 Interdisciplinary research to build context-aware robots	Mid Range	low	high
T 8 Bio-sensors: Using plants as environmental sensors and connecting them to sensor networks	Local	low	na
T 9 Wireless transfer of electricity	Widespread	low	high
T 10 Intelligent combination of sensor-data replaces traditional technologies for authorization, monitoring and observation	Widespread	low	high
T 11 Automated indoor farming	Mid Range	low	low
T 12 Self-Propelled particles	Local	low	mid
T 13 New sensors to measure ocean acidification	Local	low	mid
T 14 Terahertz communication enables a new range of wireless applications in the future	Mid Range	mid	low
T 15 Research in the field of photonic crystals may lead to a superior-performance optical computer.	Mid Range	low	high
T 16 New kinds of sensors and their smart connection will give us a new level of control over our surroundings.	Mid Range	low	na

T 17 Fully autonomous production organism	Fundamental	low	none
T 18 Brain interfaces and implants	Local	high	mid
T 19 Advances in robotics will be achieved by combining biology, material science and computer technology	Mid Range	low	na
T 20 Neuromorphic computing	Local	low	mid
T 21 Bacteria-robot model systems	Local	low	low
T 22 New materials for robot parts	Local	low	mid
T 23 Robot to robot collaborations	Mid Range	low	low
T 24 Robot learning	Mid Range	low	mid
T 25 Robots will become more human-like as their vocabulary comes closer to that of real humans	Local	low	mid
T 26 Spintronics: New principles for new, ultra-high capacity storage devices.	Mid Range	low	high
T 27 Insights from cognition research and biology may enable better Ambient Intelligence (AmI) systems	Widespread	low	na
T 28 non-invasive brain influencing	Local	low	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.	Local	low	mid
T 30 Quantum technology will move from basic research to applications	Widespread	low	mid
T 31 Cancer-detection in real-time	Local	low	mid
T 32 Use recently discovered graphene characteristics to produce better switches, lasers, chips, etc.	Mid Range	low	very high
T 33 Quantum Computing: Combining advances in quantum technology and photonics to realize a quantum computer	Local	low	mid
T 34 Smart materials will be used to provide shape-changing mobile devices and other interfaces	Local	low	high

T 35 Faster computers and newly available massive data hold the key for problems deemed too difficult to solve in the past	Widespread	low	na
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.	Local	low	low

2.2 The 36 Potential Emerging Hotspots

No.	Cluster Title	Discourse Diversity	Publication Level	Impact Level	No. of associated emerging topics
1	HPC System Disruptions	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.	Very high level of publications with partly highly dynamic development	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.	11
2	Game Change Enabling Materials	Rather low diversity, mainly driven by material sciences.	High level of scientific activity,. in some fields very dynamic development	High impact to be expected in specific domains such as health and energy.	10
3	Bacteria Management Strategies	Within each aspect the diversity of voices in the discourse is rather low. The aspects however stem from very different contexts.	High and partly very high number of publications. Microbiome and CRISPR/CAS extremely dynamic.	Very high transformative potential with the possibility of widespread impact.	7
4	Biomimicry New Frontiers	The cluster rests on a high diversity of voices from a wide range of contexts, disciplines and application domains.	The topics attract a medium number of scientific publications	Non-disruptive but partly substantial impact in a wide range of domains.	1[4]

[4] Already a cluster of a number of items in the Horizon Scanning Phase

5	Beyond, Within and Into the Brain	Several isolated specialised discourses but growing interest in overarching meta-questions across disciplines including social sciences.	Very high level of scientific publication activity in the field	High potential for widespread transformative impact.	14
6	Zero Waste Technologies	Highly diverse discourse across disciplines and contexts.	High and steeply rising level of scientific publication activities.	Widespread impact across a number of application domains	3
7	Civilisational Transformation	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.	Very high in some domains such as antimicrobial resistance but very few scientific papers reflecting on civilisational futures as such.	Widespread fundamental transformation potential by definition.	9
8	Breathtaking Air Research	Rather specific discourses in several fields	Low to mid level of attention in scientific publications.	Mostly local impacts but potential for widespread disruptive development.	4
9	Infrastructures for Communicating in New Dimensions	Rather specialised discourses within the topics that are however highly different. Accordingly the total cluster draws together diverse voices.	Mostly low level of publications addressing these rather advanced communication aspects but high attention to the socio-technical shift towards active audience interaction.	Mostly on local level but potentially disruptive aspects.	5
10	Revolutionary Healthcare Diagnostics	Rather homogenous discourse in specialist communities from similar contexts.	Very high attention to the general field of lab on chip. Less but quickly rising activity in specific aspects.	Substantial impact in several specific fields.	5
11	Global Enabling Infrastructures for New Economic Patterns	Highly diverse voices are arguing around this issue	The number of publications on the technological aspects such as blockchain and related technologies is rising steeply.	As this refers to the very deep basics of societal interactions any changes can be expected to have widespread and even fundamental consequences.	4

12	Dormant Effects of Climate Change	A high diversity of sources is pointing in this direction.	The cluster attracts a high number of publications that is still steeply rising.	Most of the effects of climate change have the potential to substantially transform the framework conditions for human societies	1
13	Emergency Preparedness	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.	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.	Several of the threats have disruptive potential with widespread consequences or even in the case of solar decline fundamental transformation.	9
14	Groundbreaking Food Supply Systems	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.	Quite a few scientific publications cover synthetic food and changes in human animal relationship.	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.	4
15	Low Footprint Chemical Processes	The debate on “green chemistry” remains among relatively few actors	Many scientific publication address aspects of “green chemistry”. Some aspects are even current focus areas with steeply rising attention.	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.	7

16	Understanding Beneficial Human Machine Symbiosis	The debate on human machine relationship is led by all types of actors and disciplines.	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.	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.	17
17	Socio-Technical Internet Futures	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.	A high number of publications addresses different aspects of the topic.	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.	1

18	New Ways of Exploiting Functions of Living Organisms	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.	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.	Both the microbiome and biomanufacturng 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.	7
19	Mixed Realities for Extended Human Sensation	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.	A high number of scientific publications is dealing with virtual, augmented and mixed realities.	As this technology has implications across all sectors and domains of human life the impact of possible breakthroughs could be widespread.	2
20	Next Generation Energy Storage (Beyond Lithium)	The discourse is highly intense but each topic remains within its community.	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.	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.	6
21	Novel/unconventional Therapeutic Approaches	As the approaches are quite specific the discourse remains in relatively homogeneous circle of actors for each topic.	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.	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	10

				range level.	
22	Privacy Providing Systems	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.	The level of scientific publications is mid to high and rising fast.	Privacy concerns are reaching across a number of domains. Both threats and solutions are bound to achieve widespread impact.	2
23	Quantum Research	The individual aspects are each being discussed in specialists' circles from similar contexts.	The number of scientific publications is on a medum level with grapheme quantum dots considerably higher and dynamically growing.	As soon as quantum technology moves into applications, widespread impacts such as the disruption of current cryptographic techniques are to be expected.	6
24	Unlocking Opportunities by Embracing Complexity	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.	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	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.	13
25	Re-Engineering Life	The discourse remains within rather specialised circles which however also include ethics and science fiction writers.	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.	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.	8

26	Shifts in Research Practices	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.	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.	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.	8
27	Robotic Frontiers	These topics are based on a relatively homogenous set of sources from similar contexts.	The number of scientific publications per topic is moderate but especially soft robotics is seeing a steep rise in publications.	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.	6
28	Multi-Signal Sensing Systems	Each aspect within this cluster rests on a rather homogeneous set of sources.	Publications on sensor combinations are high and papers on sensors to measure ocean acidification and distributed collaboration platforms are rising fast.	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.	5

29	Shifting Understanding of Life and its Boundaries	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 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.	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	6
30	Solar Age	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.	The level of scientific publications is high in the overall field.	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.	4
31	Future Living Spaces	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.	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.	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.	10
32	Diverse Unconventional Energy Supply Solutions	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.	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.	As energy is underpinning all forms of human activities the implications of novel solutions and threats are widespread.	7

33	Underwater Operations	Underwater solutions were surprisingly well covered within the sources investigated. Findings cover many diverse application fields suggested sources from different contexts.	A very high number of scientific publications is addressing this topic.	The impact of increasing underwater activity is likely to spread across several domains once the supporting technologies and competences are well developed.	1
34	Water Challenge	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.	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.	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.	6
35	Microfluidics 2.0	FET Consultation	FET Consultation	FET Consultation	0
36	System Science	FET Consultation	FET Consultation	FET Consultation	0

2.3 The 17 Hotspot Topics

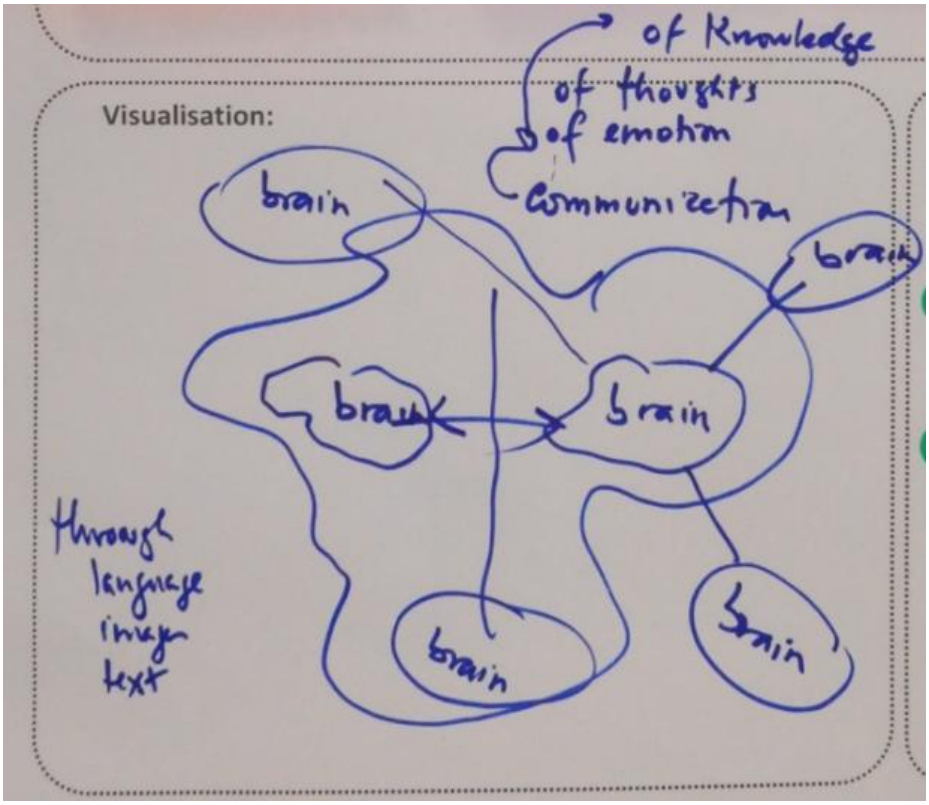
1 Beyond the Brain

Key idea

- Generate artificial consciousness
- Enable direct communication of thoughts, knowledge and emotions between human brains

Aspects

- Do we need a social brain/a social neuroscience?
- Is the main bottleneck safe human brain interfaces?
- Should we include hearts instead of only brains?



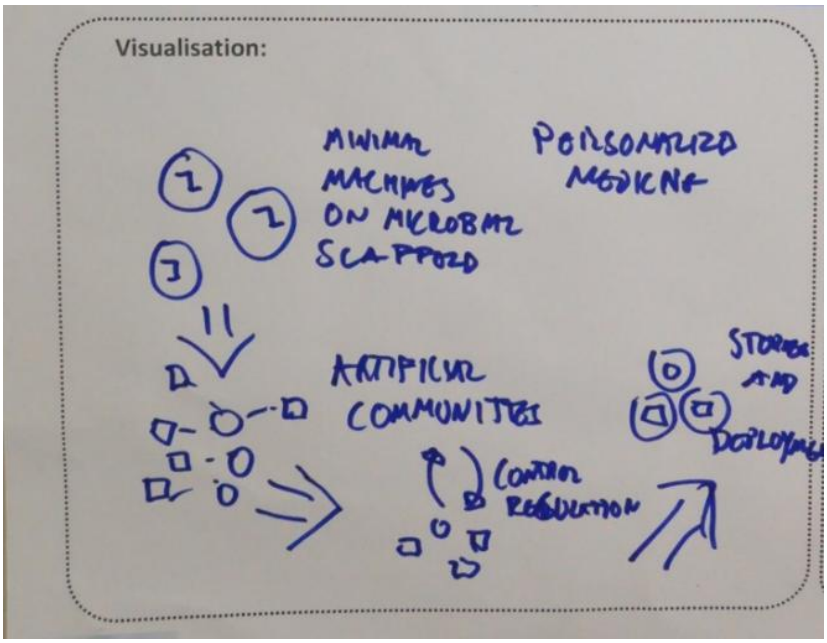
2 Molecular Microbial Machinery (Re-engineering Life)

Key Idea

- Designing artificial microbes such that they can reliably execute a function in context
- Designing artificial collectives of multiple types of such microbes to achieve more complex effects

Aspects

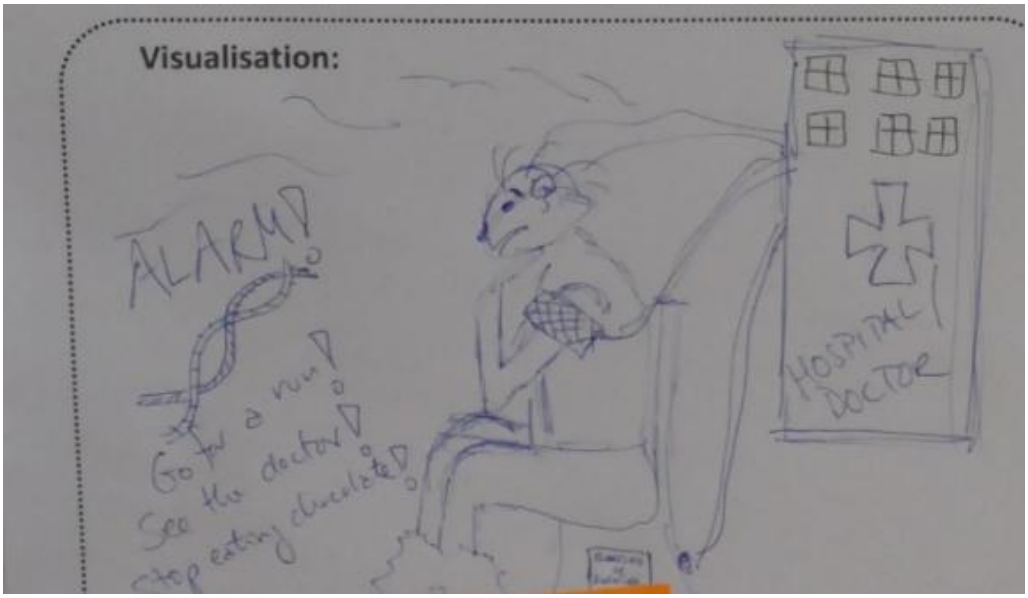
- Molecular Machinery delivered via a microbe-like designed scaffold
- Design of synthetic communities
- Designing ways to regulate and communicate with these communities in situ (e.g. light, magnetism, ultrasound) e.g. in medical technologies
- Resolving ethics aspects
- Storage and delivery for global access and usage



3 Revolutionary Healthcare

Key idea

Healthcare diagnostics will undergo major changes in the next decades. Research should be focused on the exploration of new disruptive technologies for diagnosis of personalised human wellbeing (e.g. cancer, HIV, psychological conditions, nutrition etc.). The costs for national healthcare systems need to be reduced. Therefore this topic aims for developing personalised diagnostic environments that enable fast and real time detection of diseases including rare ones and abnormalities. Environments to be considered are domestic applications, the medical doctor, and machine components.



Communities

Medicine, Engineering, computer science, Mathematics/statistics/data science, Life sciences, Architects (for integration into home), Nutrition, Psychology

4 Unlocking opportunities by embracing complexity

Key Idea

Complexity is a longstanding topic with huge potential but dominated by physics and still we understand very little. There is a need to integrate other perspectives e.g. mathematics and sociology.

Aspects

- Introducing self-organisation into real life networks (mathematical technology!)
- Understanding uncertainty, accepting uncertainty in prediction
- Phase-transitions to understand the dynamics of change in particular in the presence of uncertainty
- Online adaptation, self-organisation and intelligent control in networks
- Unifying models to incorporate different spatial and temporal scales
- Complexity perception as a socio-political and psychological phenomenon

Communities

Mathematics, computer scientists, statistics, probabilistic, data science, sociology, biology, psychology

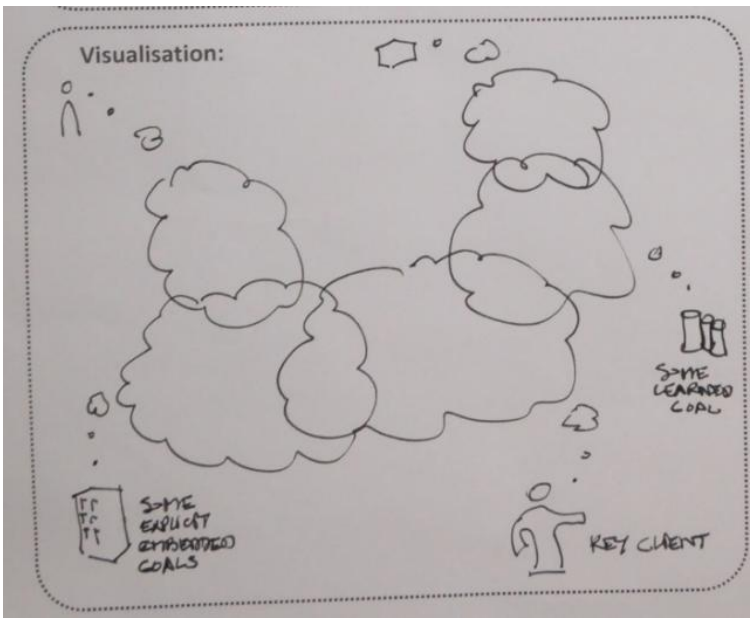
5 Human AI Negotiation Processes

Key Idea

Humans move within a cloud of potentially supportive AI artefacts (robotic resources). The artefacts follow different kinds of goals:

- some explicit goals preset by factory (e.g. safety, economy)
- some learned goals from the key client
- some explicitly set by the key client
- some level of autonomy improvisation

In order to get something done humans give only general rules (e.g. I want to see my kids more often) and the system improvises to realise the. Thus humans and machine enter into a continuous negotiation process on different levels. Value conflicts become apparent (e.g. between individuals values and actual actions, between individuals and environments (e.g. house, city). If the system provides a solution humans may question it. The breakthrough that is required to realise this vision is to develop the adequate language for the goal setting process. Systems cannot only be based on learning from history like in deep learning. We need an explicit process to interact. Such a language could be similar like for strategic games.



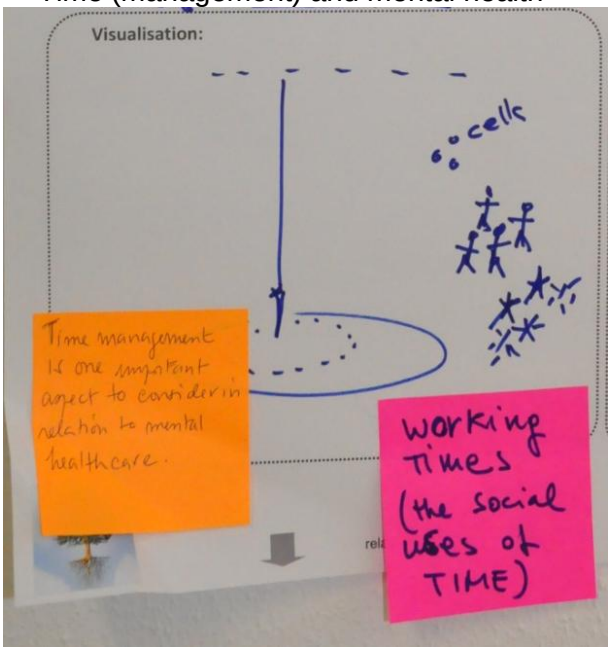
6 Tackling Time

Key idea

There is a need for interdisciplinary research across domains to better understand time not as a given and singular background against which things unfold, but rather as a resource that can be experienced, manipulated and used in different ways.

Key Aspects

- How can we manipulate the time something takes?
- Change the perception of time: More time for good experiences, more valuable spending of time
  - E.g. pain pattern: How to concentrate time on the nicer moments
- Synchronise different perceptions of time
- Different cultural readings of time (circular, static)
- Influx of information in condensed time
- Optimisation of speed of human development
- Time as a currency- value and uses (shifting time from one place to another)
- Learning applications (human organism)
- Changing use of time
- Working time (the social uses of time)
- Time (management) and mental health



7 Wearable and implantable intelligent devices

Key idea

Develop wearable and implantable devices that restore damaged functions (e.g. mobility, organs) but also in the long term enhance human capacities in several respects:

- Additional senses
- Cognitive augmentation e.g. memory
- Vastly increased bandwidth (I/O)
- Personalised medicine (diagnostics)

Key Aspects

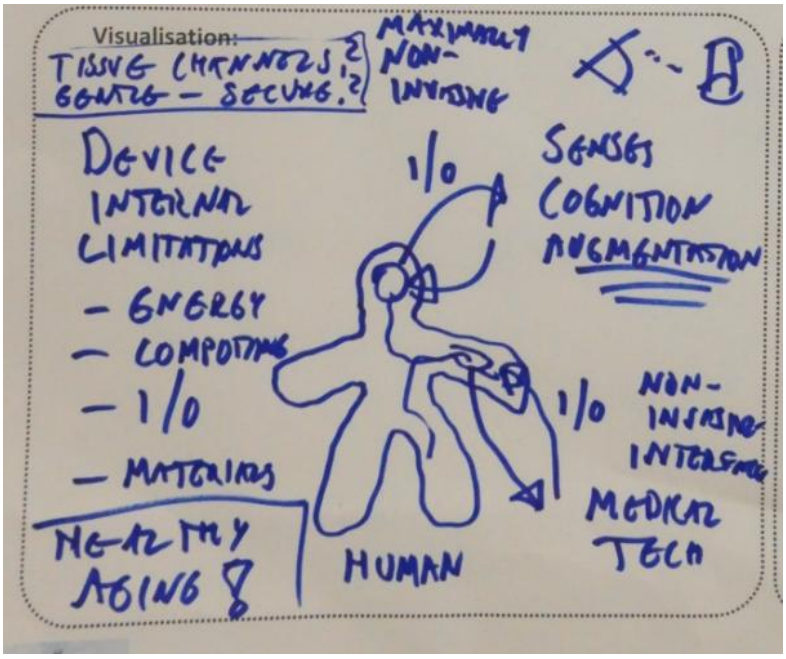
- Getting information across for controlling the devices in a minimally invasive way
- Solve energy provision
- Tackle ethical aspects.

Additional aspects

- Link with bacteria management, antibiotics
- Evolutionary devices, intergenerational devices

Communities

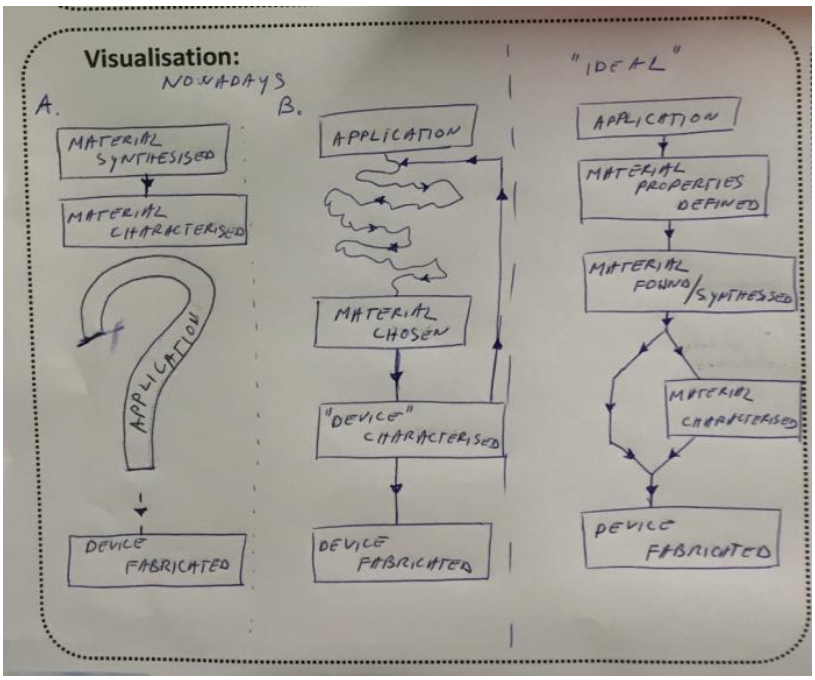
Medicine, engineers, computer science, cognitive psychology, material science, physiology



8 Bespoke material development

Key idea

Today novel materials are developed and applications devised afterwards. In the envisaged future materials would be developed to meet the properties specified by designers up front in order to meet the requirements of a specific application.



Communities

"Ab-initio" theoreticians, Material scientists, Domain of programmable materials, Engineers and companies from diverse application domains, Art and humanities (research on new materialities)

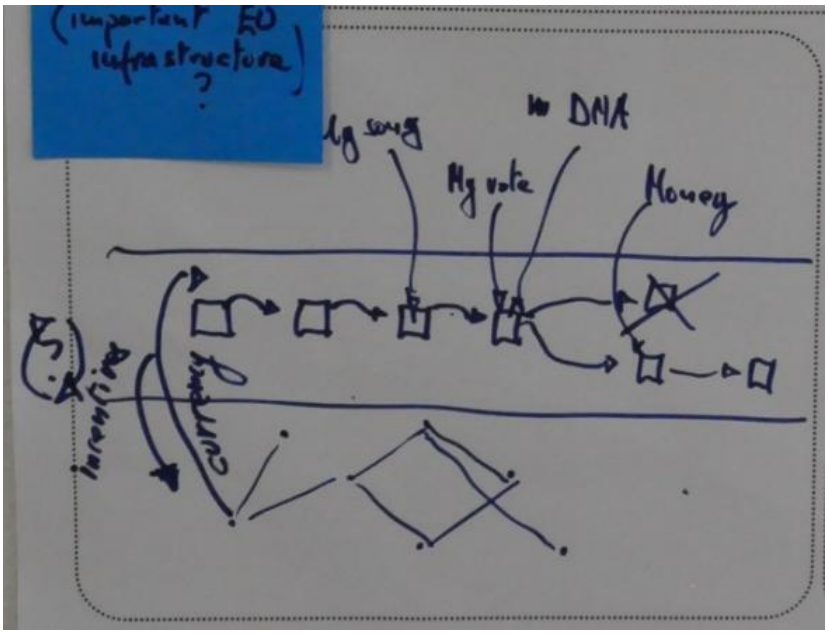
9 Technologies for decentralised consensus generation

Key idea

Through the internet we now share information – this may allow us to share consensus. Technologies like blockchain provide the possibility for people to jointly agree on the next chapter. This is now used for financial transactions (bitcoin) but it can be leveraged to carry out all sorts of interactions among individuals in a trusted, secure, privacy conserving way that keeps track of the full history of contributions. We suggest developing this into a decentralised consensus building mechanism. The system is very complex system, there are many open problems and no theory for this at the moment.

Applications/Implications

- Political and economic participation (including voting)
- Rethinking and upgrading financial and banking institutions
- Land registering and bankability (emerging countries)
- IPR system



Communities

Multi-disciplinary approach required, economy, democracy theory, mathematics

10 Understanding potentials and limits of human machine co-evolution interfaces

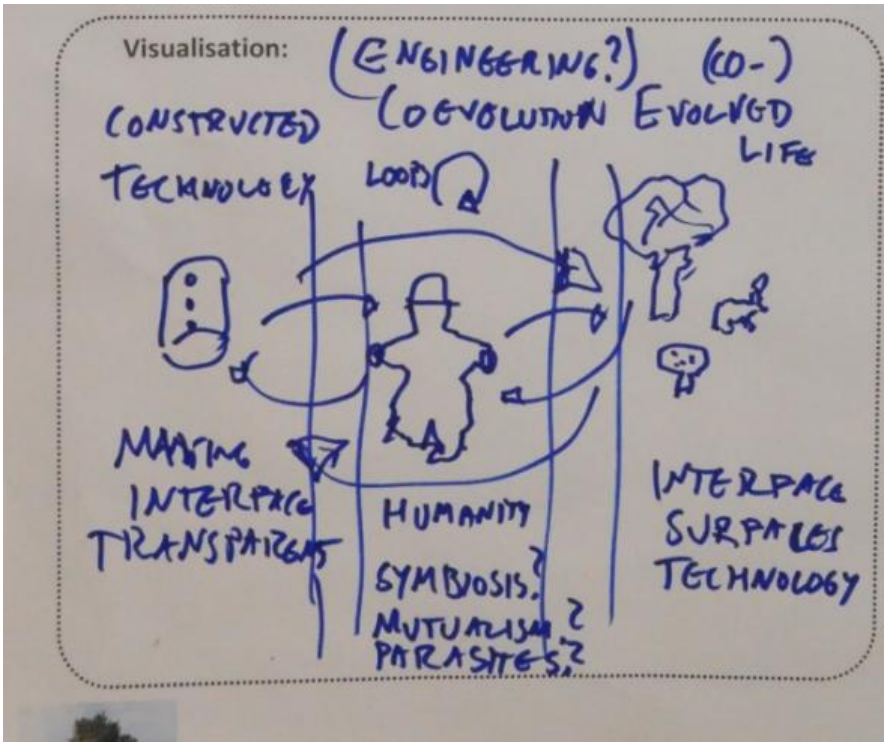
Key Idea

Develop a framework for assessing who benefits and who is impacted in co-evolving systems of humans, technology and nature of any scale. Thereby enabling ex-ante value-sensitive design paradigm on (non-)symbiotic interfaces. Make interfaces trans-parent so explicit decisions can be taken.

Develop technologies to enhance the beneficial feedback loops between societies of living systems.

Community

Sociologists, economists, ethnologists, anthropologists/ natural scientists, engineers. Applying the formers' tools to the latter's subject area?



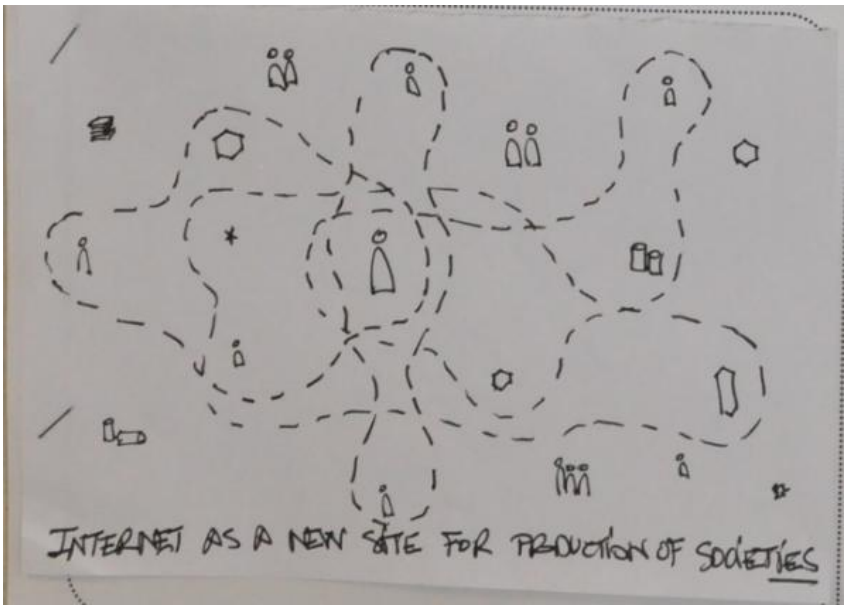
11 The Internet as a crucial site for production of society

Vision

The internet is a crucial additional site of production of society by transforming the social temporality of our interactions as well as challenging social structures as implemented today in social institutions (universities, hospitals, families ...)

Aspects:

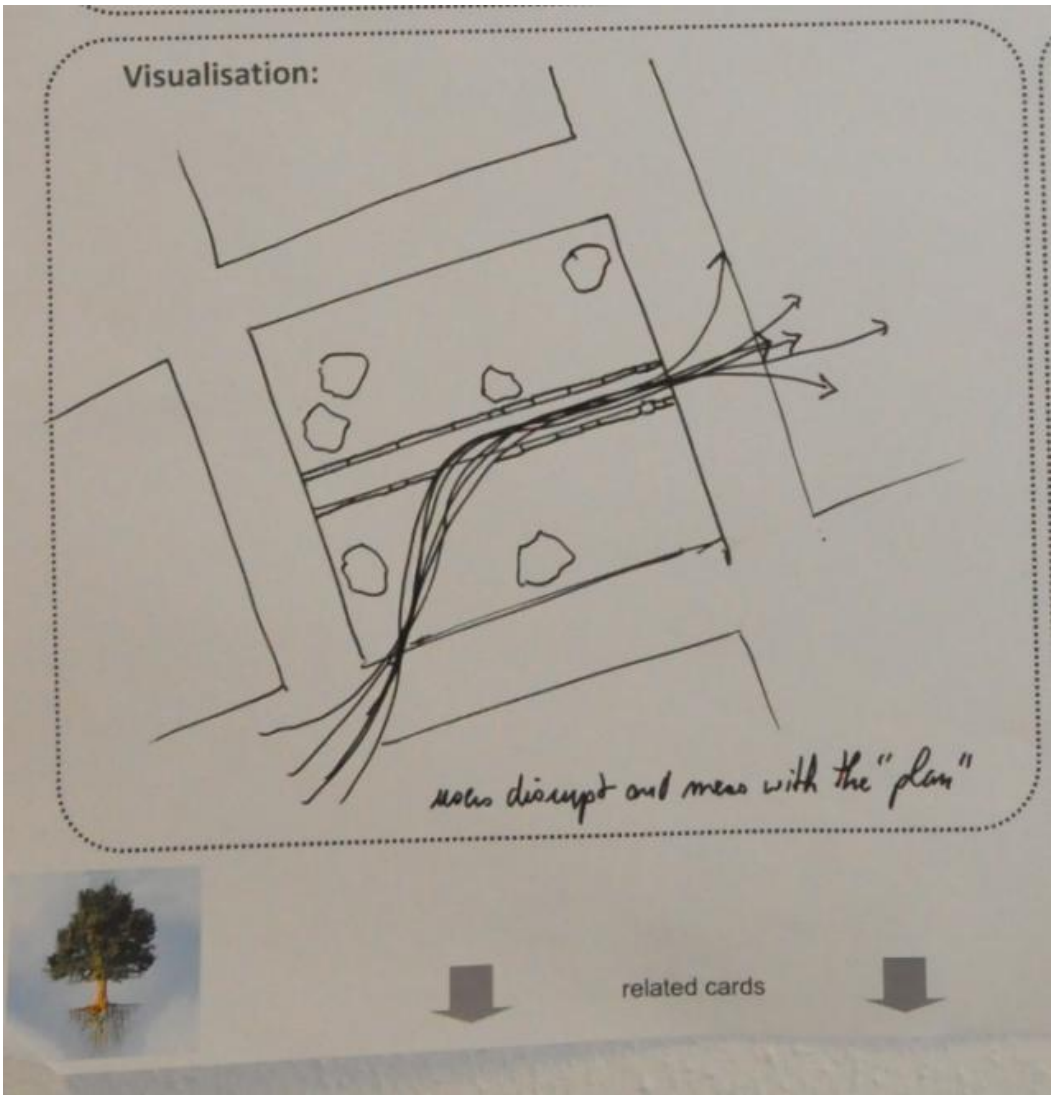
- Beyond the online/offline divide, new re-combinations
- Connected environments that allow freedom/liquid groups and multiple identities that challenge traditional authorities and enable new forms of trust
- Former physical institutions are replaced by new clouds of interactions
- Open innovation and participatory extended peer communities



12 From efficient cities to responsive cities

Key Idea

Facilitate all aspects of human life both on individual and collective level. Integrate citizens in the development of cities move beyond maximisation of efficiency. Understand human practices or even better generate technologies/infrastructures that can deal with unexpected behaviours and disruptions through improvisation in a responsive manner.



Planned vs. real routes taken by citizens

13 Minimising Energy Dissipation

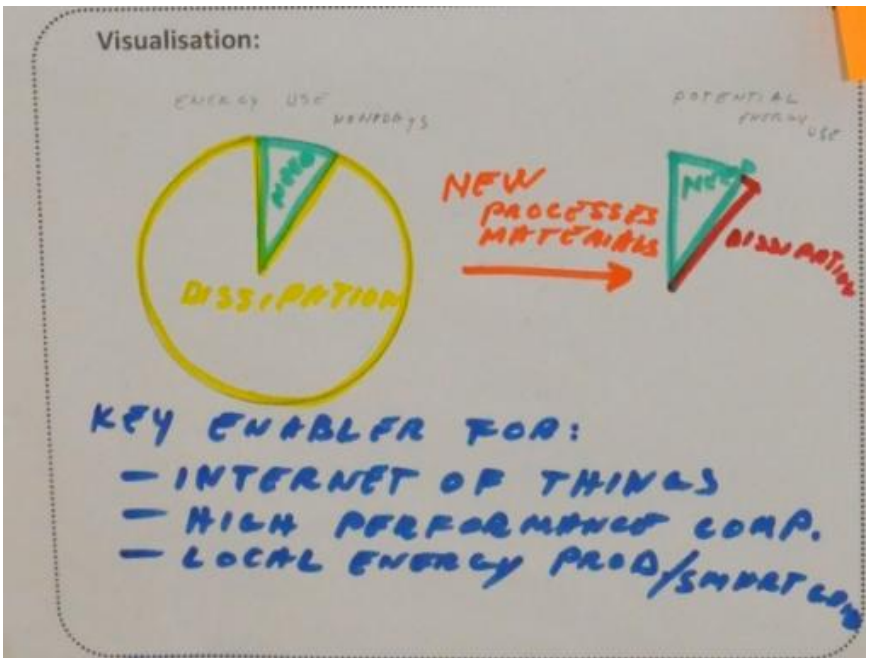
Key Idea

In today's energy system most energy is lost for human use through dissipation (transformed into heat). It is generally overlooked that dissipation loss is now a severe barrier for internet of things, local energy production, smart sensors, high performance computing etc.

The goal of this research is to generate new materials, processes and transformations that substantially minimise the loss in:

- Energy transformation processes
- Energy transport
- Energy conversion and use
- Energy storage

Communities
Electronic engineers, material scientists, transport companies, power plants, IT



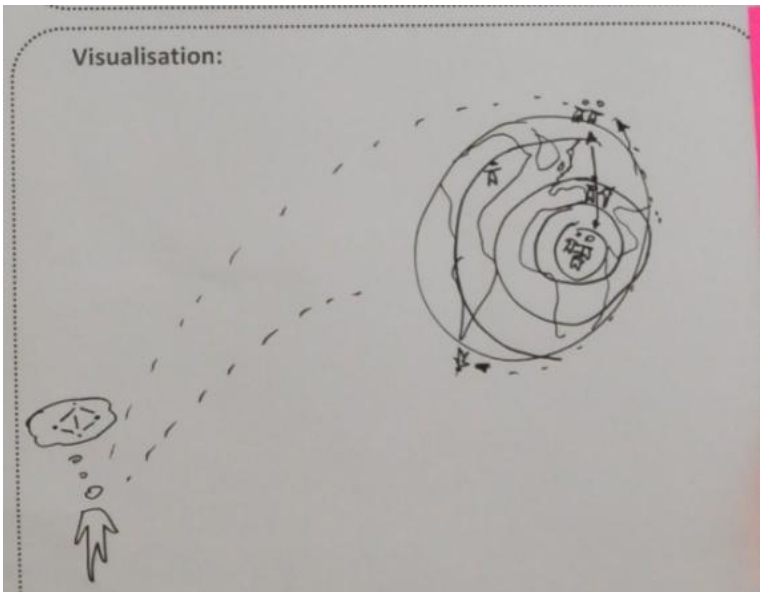
14 Massively parallel multi-scale polylogue on civilisational transformation pathways

Key idea

In order to unlock opportunities and avert threats to civilisations we need to experiment multiple, alternative transformation pathways across cultural contexts, value systems as well as temporal and spatial scales. Research could develop a supporting infrastructure for such a multi-scale polylogue (concepts, technologies e.g. fro decision making).

Aspects

- Transformation of value systems (by consequence and necessity)
- Technologies that allow us to address scales levels that are intertwined (local and global scale) when making decisions
- Concepts for bridging: time, space, cultural context, values bring that closer
- How can you make transformation mechanisms based on opportunities rather than only threat based?
- Beyond simplicistic solutions, Inspire and encourage parallel experimentation of alternatives e.g. through simulations, multiply diversity and pluralism, instead of



Communities:

Extended global peer communities, complexity research, artists&designers, biosociologists, cultural anthropologists, polylogue experts, ... chefs ..., storytellers

15 Introducing Art in Research and Innovation Frameworks - STEAM

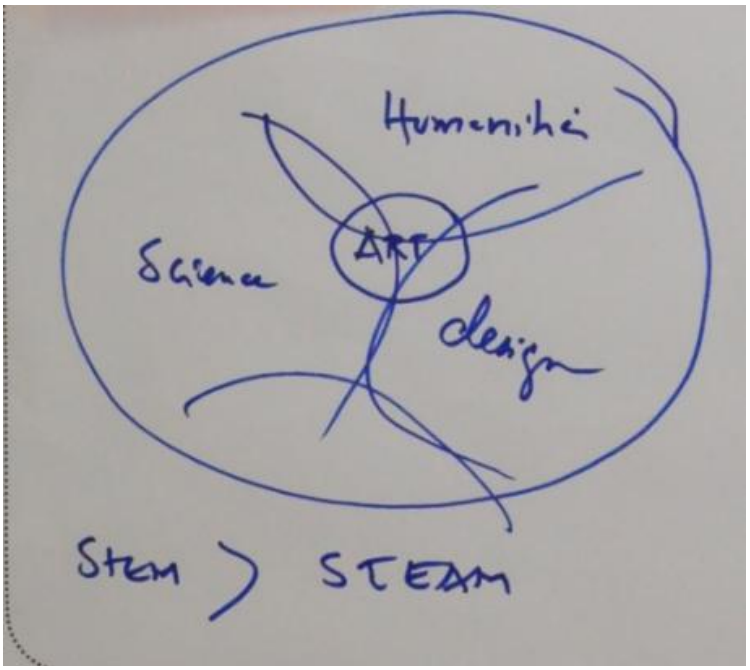
Key idea

Progress from STEM to STEAM (A=Arts) after H2020 and beyond. Integrate art with its own voice.

Aspects

Use approaches from arts in particular for:

- problematising the questions and problem definitions of science in the first place, introducing different perspectives
- boosting creativity in the researchers
- interpreting research results in new ways
- work across different disciplines
- as a distant early warning system DEW according to McLuhan. It is a kind of sensor able to detect very early trends in society
- challenge boundaries between subjectivity and objectivity both in art and science.



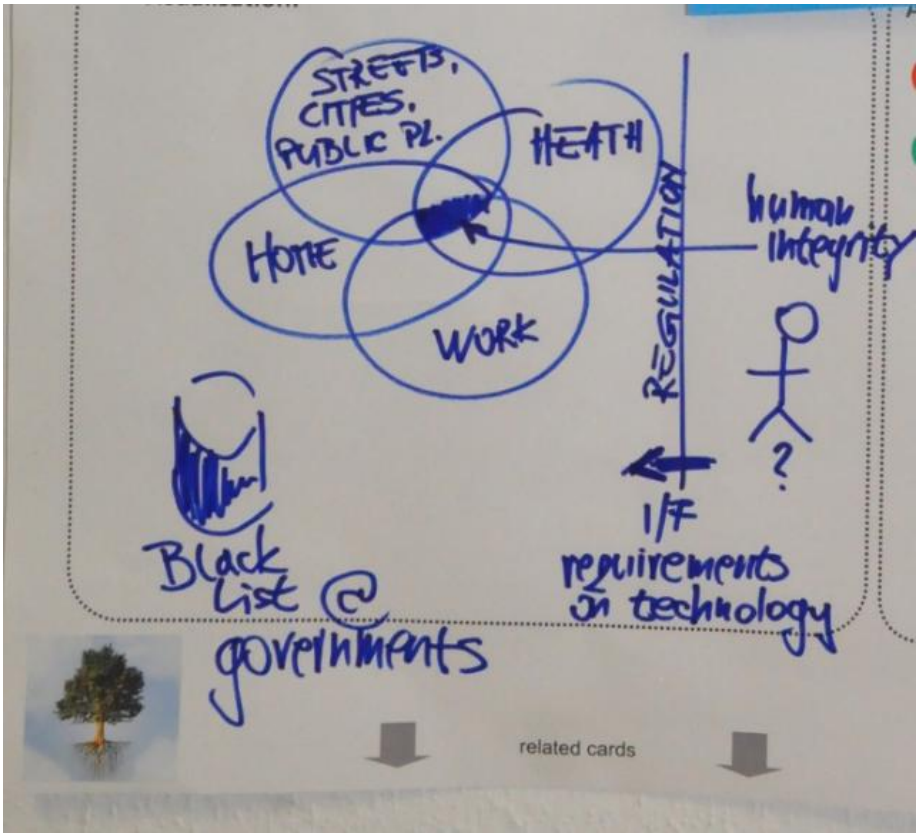
16 Privacy Providing Systems

Key idea

Create privacy protecting spaces that empower individuals based on a thorough understanding of privacy as a key pillar of human integrity.

Aspects

- Develop a refined definition of privacy based on human rights and integrity
- Establish regulation which generates protected spaces according to this definition reaching out across key societal domains (work, health, public space ...)
- Develop technologies supporting such privacy protecting spaces such as self data destroying technologies
- Concepts like “blacklists” as prisons of the future (people not on the blacklists are protected in the privacy spaces)



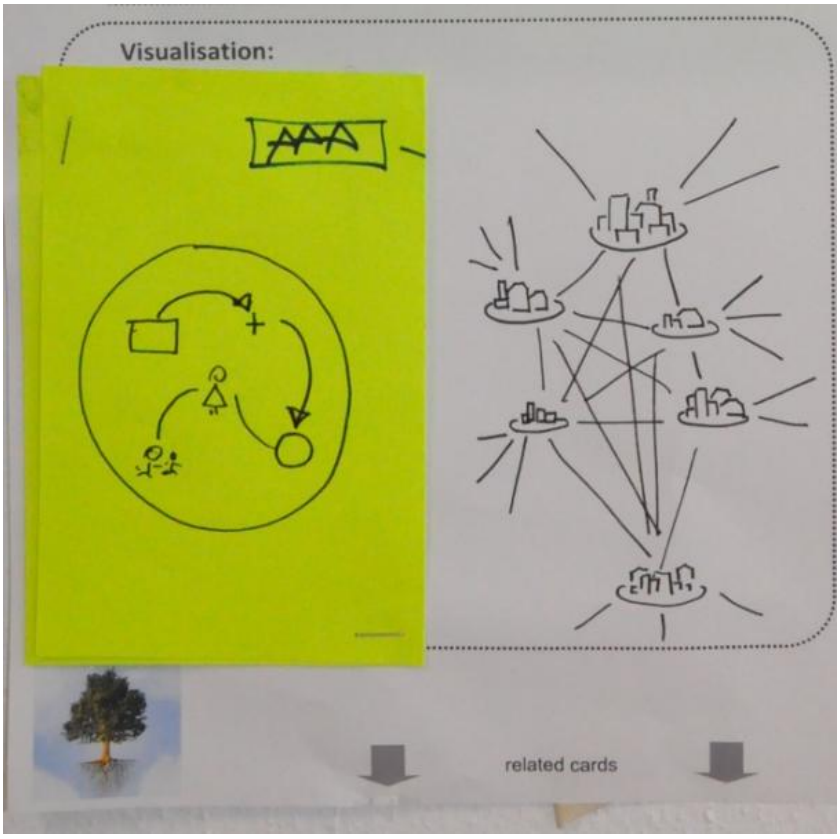
17 Future Living Spaces

Key idea

Rethink the connection of urban and rural spaces (not necessarily by road)

Aspects

- Distribution of services and infrastructure
- Optimal city size
- Scaling
- Freedom of choice for living space (basic income)



Topic Assessment

The table below documents the assessment of the topics with respect to the two main criteria important for FET Proactive topics; the long-term visionary transformative potential and the ability to mobilise diverse communities. Following advice from the OBSERVE advisory board we also asked experts to indicate their “gut feeling” about the topics. Finally we used the number of experts who selected the topic for elaboration as an indicator for its relevance within the group.

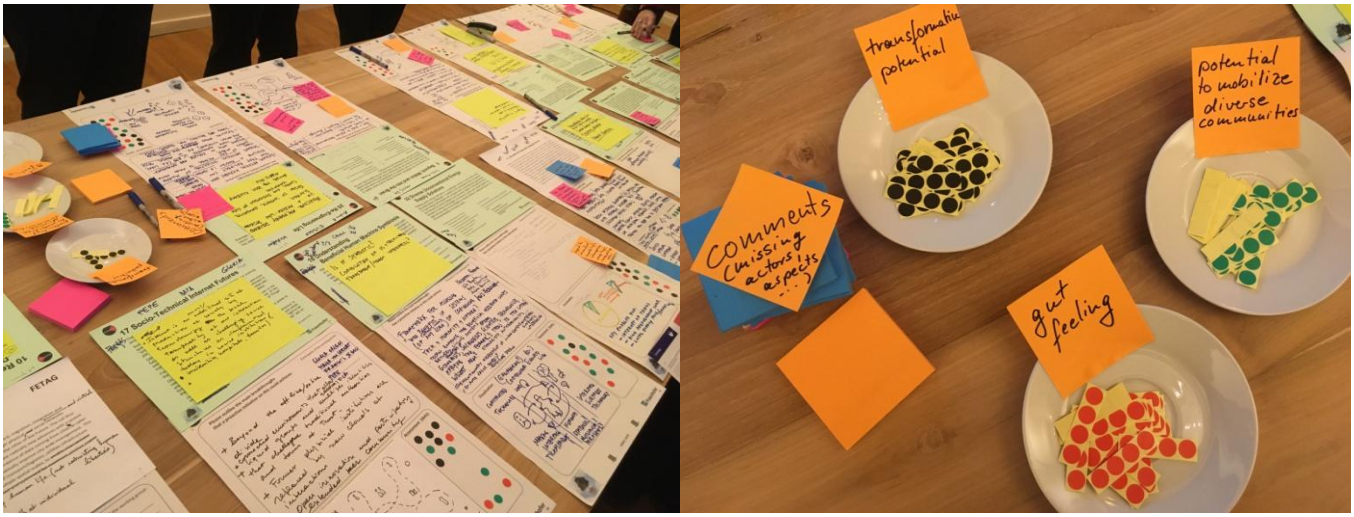


Figure 5: Assessment Process

Table 1: Assessment of the topics

Topic	Transformative potential	Mobilisation Potential	Gut feeling	Group size	Sum
1 Beyond the brain	5	8	6	5	24
2 Molecular Microbial Machinery	6	7	4	5	22
3 Revolutionary healthcare	5	8	5	4	22
4 Unlocking opportunities by embracing complexity	6	7	5	3	21
5 Human AI Negotiation Processes	8	7	3	2	20
6 Tackling Time	4	1	8	7	20

7 Wearable and implantable intelligent devices	5	4	4	5	18
8 Bespoke Material Development	7	4	5	1	17
9 Technologies for decentralised consensus generation	5	6	5	1	17
10 Understanding potentials and limits of human machine co-evolution interfaces	6	1	5	5	17
11 The Internet as a crucial site for production of society	4	5	3	5	17
12 From efficient to responsive cities	6	4	5	2	17
13 Minimising Energy Dissipation	3	8	3	2	16
14 Massively parallel multi-scale polylogue on civilisational transformation pathways	4	4	3	4	15
15 Introducing Art in Research and Innovation Frameworks – STEAM	3	1	5	3	12
16 Privacy Providing Systems	4	1	4	2	11
17 Future Living Spaces	2	1	4	3	10

3 Radar Assessment

In the following paragraphs we assess the radar content with respect to the ambitions formulated in the beginning of the OBSERVE project. Thereby we first assess the 171 emerging topics populating the “outer ring” of the radar and then turn to the 34 potential hotspot clusters. For both we discuss in how far they really cover different types of change and secondly we review and compare the indicators we formed for both groups i.e. discourse diversity, impact level and publication level. The aim of OBSERVE was not to increase all of these indicators for all radar items but rather to achieve a good balance of content with different characteristics.

3.1 Emerging Topics – Radar level 1

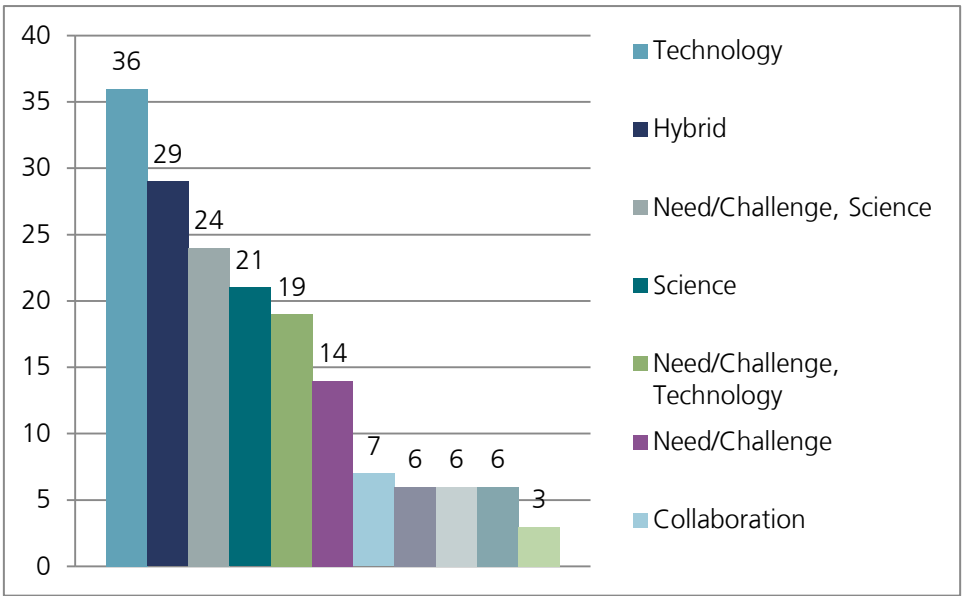


Figure 6 presents the distribution of the „emerging topics“ populating the outer ring of the radar according to the types of change. The following observations can be made:

- The outer level is dominated by topics from the realm of science and technology that together makeup 50 out of 171 topics. Social practices and solution ideas are the least well represented groups. This is partly due to the fact that these findings were often integrated into the “hybrids”. Also it is certainly partly due to the technology orientation of the FET programme which was one of the key sources of the radar. Nevertheless the lack of recognition of newly emerging social practices and solution ideas as potentially groundbreaking may be a bias in the topic assessment.
- There is a strong representation of more integrated topics that include all types of emerging changes. This is first of all indicated by the strong group of hybrids

(29/171 topics). Secondly, the topics that integrate two types (52/171 topics) form a substantial share. In particular the group topics combining needs and challenges with either science or technology topics is strong (43 topics) is well developed. This development has pros and cons. On the one hand the outer level is already moving towards the ultimate goal of the radar i.e. integrated hotspots that combine different aspects of socio-technical transformative breakthrough change. Nevertheless, as remarked also by the OBSERVE reviewers some thought provoking individual aspects may be lost in the process.

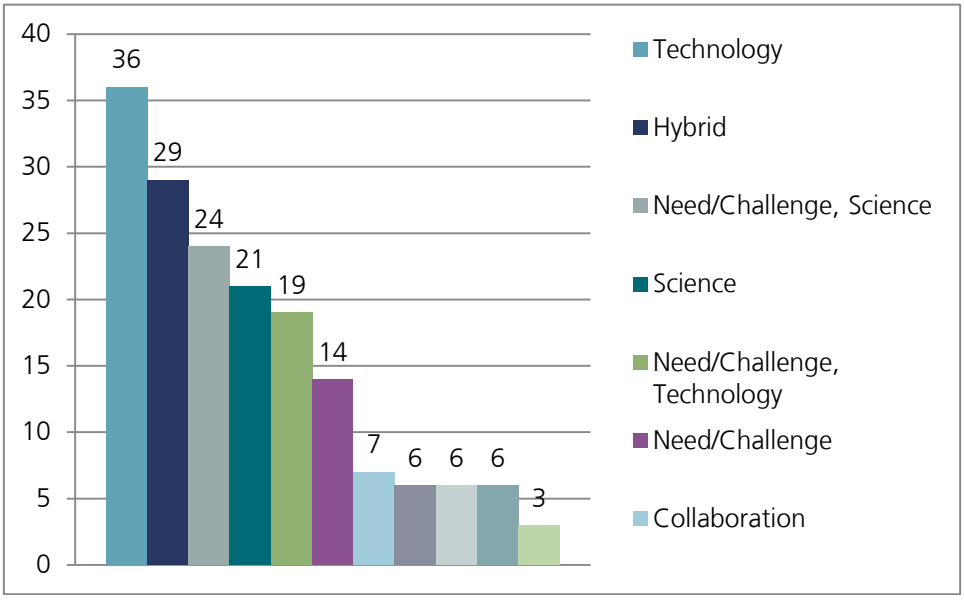


Figure 6: Emerging topics per type

Figure 7 displays the impact levels of the emerging topics as it was assessed by the project team following indications given by the sources. Here it is important to note that this assessment makes no claim on the relevance but only on the breadth of the potential impact. Local means impact within a narrow domain (e.g. one particular disease) whereas mid range means potential impact on a few different sectors and widespread possible implication across many different domains. Finally fundamental types of changes question challenge very basis of today's notion of socio-technical change. The distribution of impact level seems suitable for the outer level of the radar which should contain an equal share of items with more specific and more widespread potential impact. Especially for the FET programme also topics with hi breakthrough impact in a specific domain are also of high relevance.

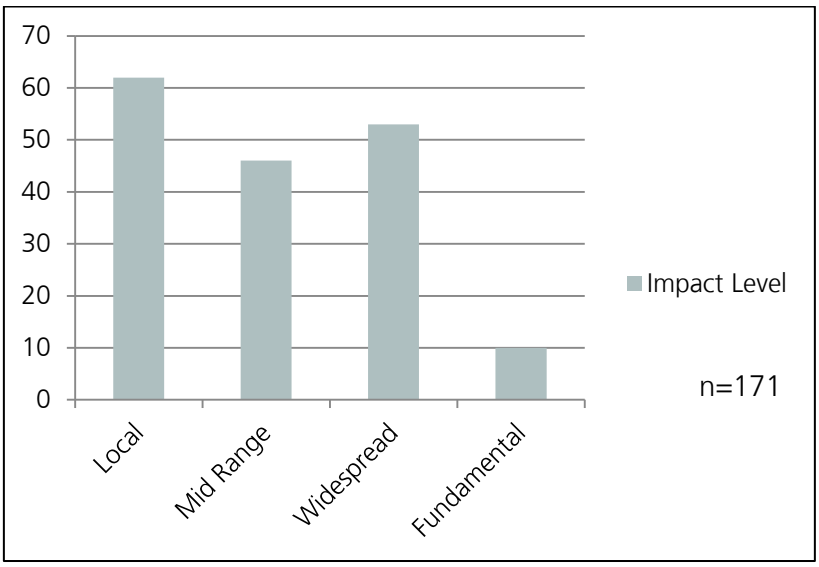


Figure 7: Emerging topics per impact level

The diversity of the sources pointing towards the emerging topics is presented in Figure 8. This indicator is not synonymous with the number of sources mentioning this topic which was presented in the Horizon Scanning report. Rather here we have used a very strict measure of diversity meaning completely different types of sources using 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 but in the contrary took care to take up topics that were only raised by fringe sources in many cases only few sources are behind one topic and consequently the diversity is often low. Nevertheless there are striking examples of high diversity where completely different actors e.g. from basic natural and social scientists to lifestyle bloggers, science fiction writers and artists take up a topic such as e.g. in the case of “Understanding and influencing human behaviour”, “machine society” and “solar age”.

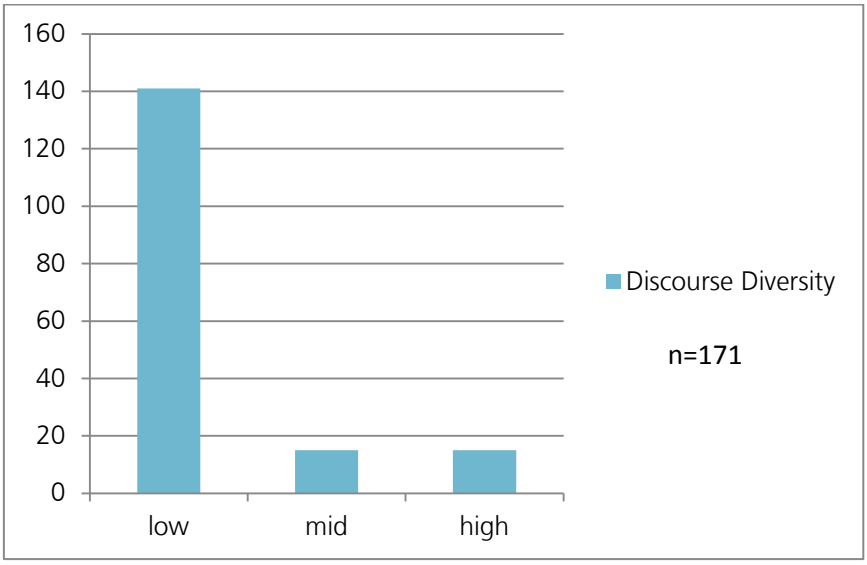


Figure 8: No. of emerging topics per category discourse diversity

Figure 9 displays the distribution of the emerging topics with respect to scientific publications, a rough assessment based on a rather simple keyword search that was made following the recommendation of one of the OBSERVE reviewers (c.f. Deliverable 2.1). As it was to be expected, several of the OBSERVE findings do not at all receive scientific publications as they are e.g. brought forward by artists, journalists or science fiction writers for others the analysis did not make sense mostly because the topics were too broad and could not be captured by keywords in a meaningful way (e.g. “Future of Civilisation”). At the same time several topics especially those that stemmed from the analysis of scientific sources receive very high attention in the discourse.

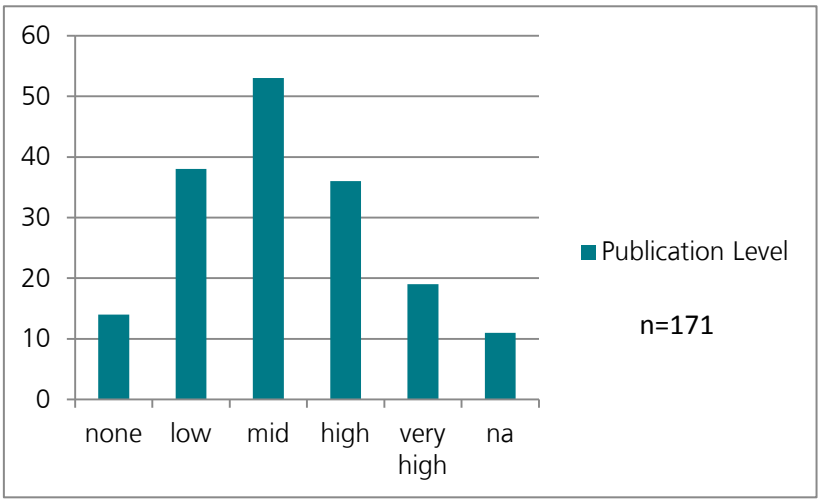


Figure 9: No. of emerging topics per publication level

3.2 Potential Hotspots - Radar Level 2

3.2.1 Type of change

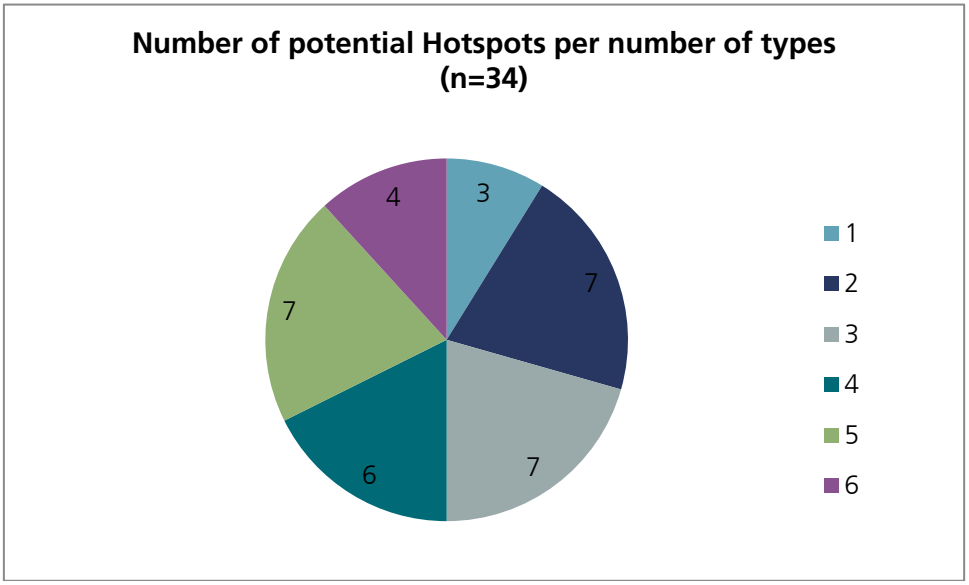


Figure 10: Distribution of Number of different types of change within the 34 potential hotspots

As shown in Figure 10, half of the potential hotspots are formed by 4, 5, or 6 different types of emerging topics.[5] The 3 topics with only one type are all „Hybrids“ meaning that these were already consisting of different aspects of change from the screening phase .In addition it is worth noting that seven Potential Hotspots are formed by 2 or more Hybrids. In total this implies that the second level of the radar indeed represents a more integrated perspective than the outer level. At the same time, there are also more narrow perspectives still present (14 topics consisting of only 2 or 3 types of emerging topics).

[5] For this analysis the combined types were taken apart meaning that e.g. a topic of the type „Technology&Need“ was counted as covering two types“. The two Hotspots stemming only from teh FET consultation were not included in the analysis.

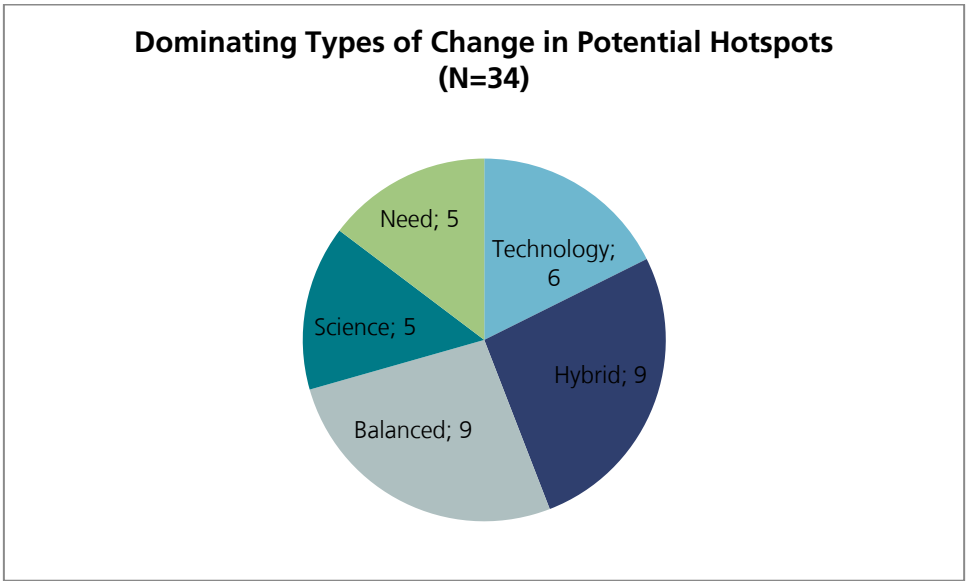


Figure 11: Distribution of dominating types of change across the potential hotspots

As illustrated in Figure 11 there is still a large share of potential hotpots (11/34) dominated by science or technology perspectives whereas only 5 are mainly needs driven. More than half of the hotspots however are either formed by a rather balanced share of different types or dominated by Hybrids. No hotspot is dominated by a social practice or a solution idea.

Figure 12 to

Figure 16 illustrate these assessments with a few typical examples of potential hotspots.

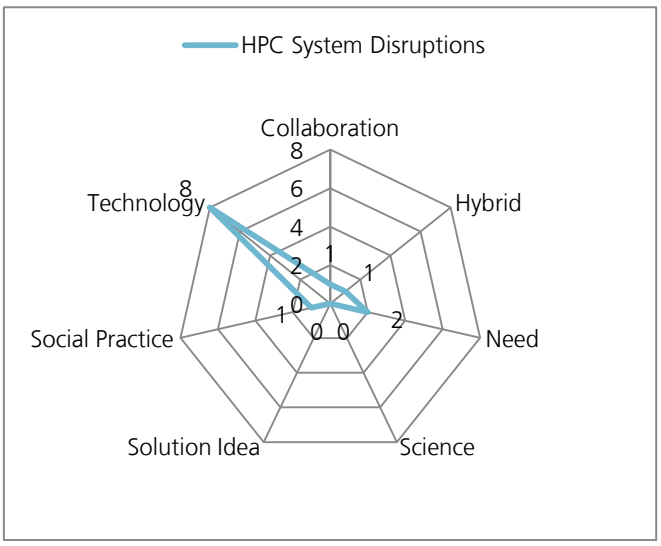


Figure 12: Example for potential hotspot formed of emerging topics from different types of change and dominated by emerging topics with the type technology

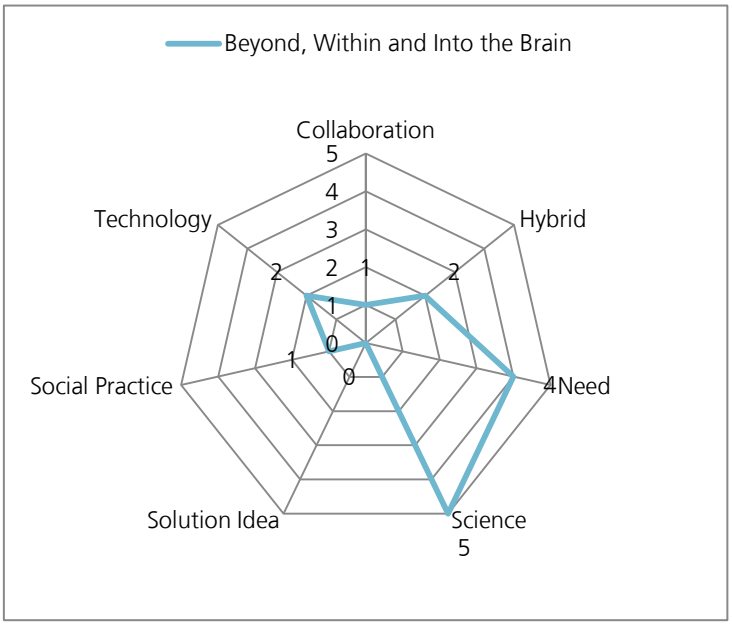


Figure 13: Example for potential hotspot formed of emerging topics from six different types of change and rather balanced representation of types of change

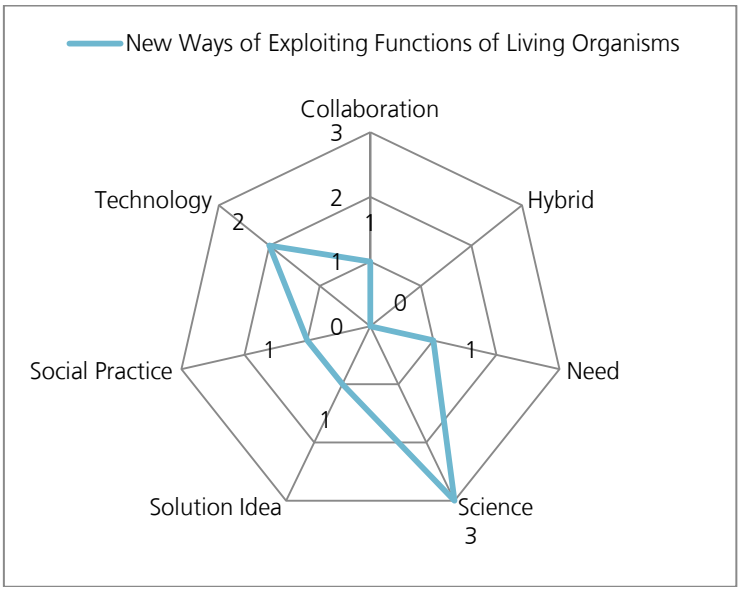


Figure 14: Example for potential hotspot formed of emerging topics of six different types of change and dominated by science type emerging topics

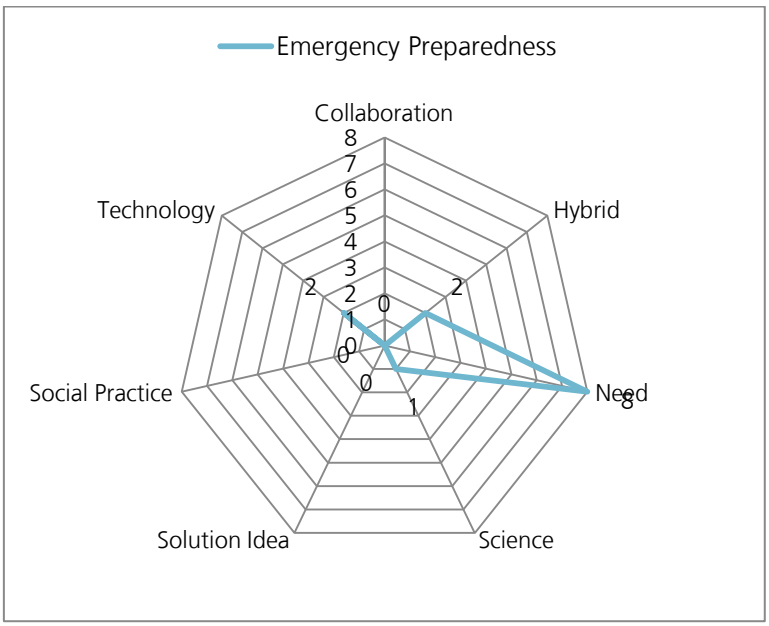


Figure 15: Example for potential hotspot formed of emerging topics of four different types and dominated by needs oriented emerging topics

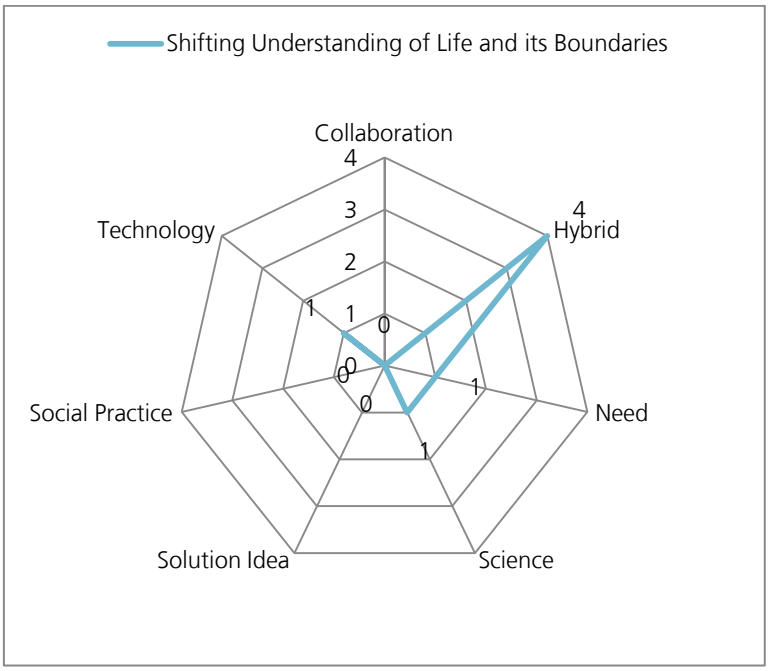


Figure 16: Example for potential hotspot formed of 4 different types and dominated by hybrid emerging topics

From the analysis above it can be concluded that the set of potential hotspot clusters has largely developed according to the targets of OBSERVE. The dominance of S&T in the initial set was softened through the clustering. A majority of the potential hotspots

integrates a diverse range of aspects of change. There is still a dominance of S&T driven hotspots but in the light of the strong technology orientation of the FET programme this can be seen as an adequate result.

3.2.2 Indicators

The figures below illustrate the distribution of OBSERVE topics with respect to the discourse diversity, publication level and impact level. The assessments were made by reviewing and integrating the assessment of the individual items belonging to the cluster.

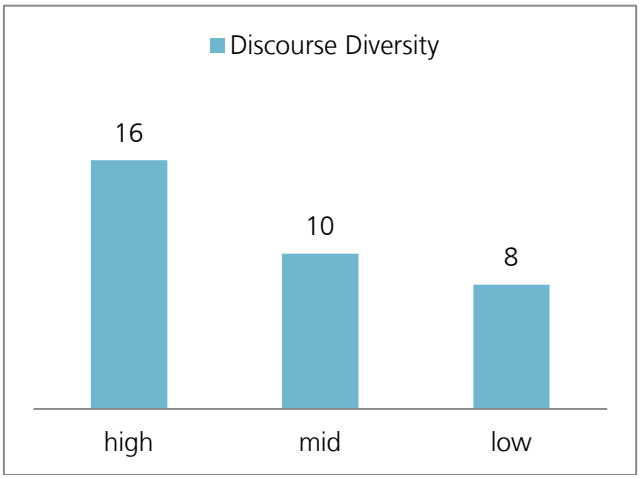


Figure 17: Distribution of discourse diversity across the 34 potential hotspots

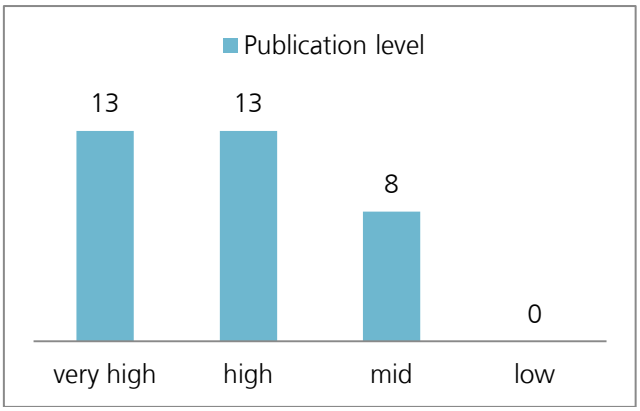


Figure 18:Distribution of publication level across the 34 potential hotspots

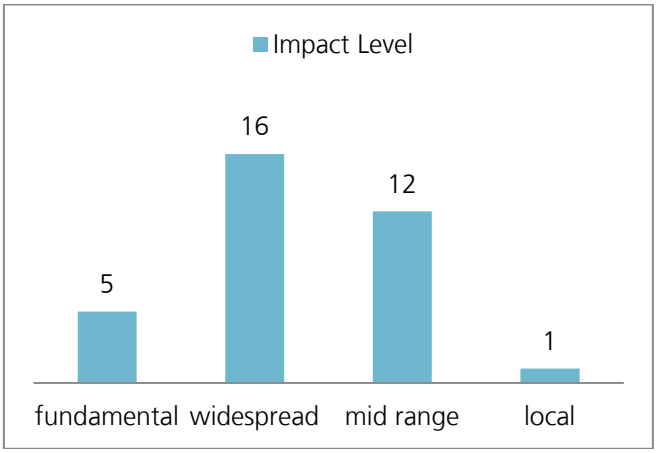


Figure 19: Distribution of impact level across the 34 potential hotspots

Table 2: Comparison of indicators for potential hotspots and emerging topics

		Hotspots	Topics
Discourse Diversity	high	47%	9%
	mid	29%	9%
	low	24%	82%
Publication level	very high	38%	11%
	high	38%	21%
	mid	24%	31%
	low	0%	22%
	none	0%	8%
	na	0%	6%
Impact Level	fundamental	15%	6%
	widespread	47%	31%
	mid range	35%	27%
	local	3%	36%

Table 2 gives a comparison of the indicators for the 171 emerging topics and the 34 potential hotspots. The following developments are interesting to note:

- The share of hotspots with high **discourse diversity** is substantially higher than in the emerging topics. This indicates that apparently the clustering succeeded in not only grouping the obvious but also really combining diverse aspects.
- The share of clusters with very high and high **publication level** much higher in the potential hotspots than in the emerging topics. This implies that the clustering also led to a combination of topics with high attention in the official world of science with insights from other sources such as art and science fiction.

- The share of items with widespread and fundamental **impact level** is much higher in the clusters than in the topics. This indicates that topics with local impact were often combined with others that impact on a more widespread level.

3.3 Conclusions

As targeted the OBSERVE Radar has managed to capture a set of “hypotheses of emerging seeds of change” that represented different types of change and introduced perspectives from very diverse sources. In the next step a clustering of the topics led to 34 potential hotspots. Most of these hotspots combined a number of diverse emerging topics resulting in a more integrated set of items with a higher diversity of perspectives, wider potential impact and deeper grounding in scientific communities. The set formed a fruitful basis for the sense making discourse and the further elaboration of a set of 17 topics that were useful as an input into the FET Proactive topic generation process.

At the same time the integration process – even more than the first screening process” partly led to a disappearance of some of the more “outlandish” findings from OBSERVE under much broader umbrella topics. Still, due to the transparent nature of the clustering process all potential hotspots can be traced back to the original emerging topics from where again through the database the original screening hits can be retraced.

4 Annex: FET specific Analysis

On request of the FET unit we extracted the list of clusters that contain emerging topics based on the analysis of FET project. Gives the resulting list of 11 potential hotspots where aspects are already addressed by FET activities.[6]

No.	Cluster Title
1	HPC System Disruptions
2	Game Change Enabling Materials
4	Biomimicry New Frontiers
5	Beyond, Within and Into the Brain
8	Breathtaking Air Research
10	Revolutionary Healthcare Diagnostics
16	Understanding Beneficial Human Machine Symbiosis
18	New Ways of Exploiting Functions of Living Organisms
24	Unlocking Opportunities by Embracing Complexity
27	Robotic Frontiers
28	Multi-Signal Sensing Systems

[6] It should be noted however that this is based on the identification of the emerging topics in 2015 so the current situation may be very different especially as FET increasingly opened up towards more disciplines such as the life sciences