Smart4Europe2

Catalysing Digitisation throughout Europe

Deliverable 4.1

Technology and Innovation Radar

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[1] R=Report, DEC= Websites, patents filling, Ethics, ORDP: Open Research Data Pilot, etc., O=Other

[2] PU = Public, CO = Confidential, only for members of the consortium (including the Commission Services)

Acronyms Listed in Document	
AENEAS	Industry Association for Electronic Components and Systems
AI	Artificial Intelligence
ATI	DG Grow Advanced Technologies Initiative
CGI	Computer Generated Imagery
CPAP	Continuous Positive Airway Pressure
CPS	Cyber-Physical Systems
DIH	Digital Innovation Hub
EC	European Commission
ECSEL	Joint Undertaking in Electronic Components and Systems for European Leadership
EDIH	European Digital Innovation Hub
EFECS	European Forum for Electronic Components and Systems
EPoSS	Industry Driven Policy Platform for R&D in Smart Systems Integration
ETP	European Technology Platform
HMI	Human Machine Interface
HPC	High Performance Computing
HTML	HyperText Markup Language
H2020	Horizon 2020 Programme
IA	Innovation Action
ICT	Information and Communication Technologies
IoT	Internet of Things
KDT	Key Digital Technologies
OLAE	Organic and Large Area Electronics
RTO	Research and Training Organisation
SAE	Smart Anything Everywhere
SSI	Smart Systems Integration
SRIA	Strategic Research and Innovation Agenda
TRL	Technology Readiness Level
UAV	Unmanned Aerial Vehicle
VR	Virtual Reality
WP	Work Package

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3D	3 Dimensional
5G	5th Generation Telecommunications

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Short description of the content of the deliverable

In this document, we present the Smart4Europe Technology and Innovation Radar. The Technology and Innovation Radar is part of a work package (WP4) which is dedicated to the investigation and rating of the relevant technological offerings and related applications for SAE. The essential objectives of the WP are to identify new innovative ICT technologies that can contribute to the SAE vision and create a Technology and Innovation Radar that can be used to assess the status of these technologies.

The radar was initiated as a paper-based version in Smart4Europe1 and in Smart4Europe2 it has evolved into an online web service. The radar has been populated and maintained via desk work, input from experts, questionnaire input, and from a number of workshops held both by Smart4Europe, but also in conjunction with other major events such as EFECs.

The original radar was developed around the SAE core topics of Cyber-Physical Systems (CPS), embedded systems, Smart System Integration (SSI), Organic and Large Area Electronics (OLAE) and, advanced computing for the Internet of Things (IoT), however, under Smart4Europe2 it has been significantly extended as more Innovation Actions have been funded under SAE. There has also been a change in emphasis towards Green Technologies which has been a driver for the radar under Smart4Europe2. The radar covers a wide range of technologies providing a description of the technology along with the technical challenges, the commercial barriers and green opportunities for each. An assessment of maturity is also given to answer the question, “should my company be looking at this now?”.

Of interest to SMEs and Mid-caps are examples of applications where the technologies can be used. This helps companies identify potential commercial markets for the technologies both in terms of new innovative uses which could be replicated and also in providing ideas where new uses may be possible. Examples of applications are given in Smart Agriculture, Home Automation, Wearables, Sustainable Manufacturing of Electronic Goods, Intelligent Energy and Low Carbon Technologies, Ocean Monitoring, Food and Beverage, Art, Entertainment, Music and Literature. Additionally, a section on Technologies to Combat COVID-19 was included in response to the world events. This helps companies quickly see the technologies that could provide business opportunities over the next 10-20 years. The topics have been chosen to align with EC priorities under Horizon Europe and Digital Europe and in particular address ambitions put forward under the Green Deal.
made of the information it contains.

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1 Executive Summary

SMEs and Mid-caps struggle to keep track of new technologies that may be important to their business in the short, medium and long term. The aim of the Smart4Europe Technology and Innovation Radar is to provide a useful reference for the SAE community highlighting up and coming technologies that SMEs, Mid-caps, as well as Large Industry, can exploit as well as the current maturity of these technologies.

Originally in Smart4Euorpe1, a paper-based radar was created which covered 107 technologies. From feedback it was clear that the radar was seen as a useful resource, but in order to make it more easily accessible and promote it more widely, there was a need to create an online clickable version of the radar. This has been done in Smart4Euope2 by creating a Web Service that is rendered using SVG (Scalable Vector Graphics). This has made the radar a "live" resource which is easy for companies to access and navigate. The radar can be accessed at:

https://www.thhinkbv.com/docs/New1Radar/index.html

In addition, the online version has opened up a raft of opportunities for easily collecting analytics on the use of the radar, feedback on the usefulness of the radar, ideas for additional technologies that can be added, as well as comments on the positioning of technologies with respect to maturity. This feedback has proved invaluable leading to many enhancements. Notable this improved "online presence" has also led to discussions with organisations, e.g., Sensing Innovation Leadership Council, with an interest in contributing to and sponsoring the radar in the future.

A major continuing effort has been put into identifying new technologies and innovative areas to add to the radar to make it even more useful for the SAE community. Notably, the radar now covers around 200 technologies. However, more significantly under Smart4Europe2 additional information has been added for the technologies on Technical Challenges, Commercial Barriers and Green Opportunities. This provides useful technical and commercial background information for the technologies enabling a greater depth of understanding. This information has been gathered via desk research, questionnaires, feedback and workshops with experts. Due to interest in the radar, a Technology Radar Working Group has also been set up. The radar is divided into the following 8 key groupings:

- Robotics and Autonomous Systems
- Artificial Intelligence (AI)
- Green Technologies
- Technology Enablers
- Human Machine Interfaces (HMIs)
- Data Analytics
- Smart Systems Integration (SSI)
- Organic and Large Area Electronics (OLAE)

These categories have evolved from the categories defined in the original paper-based radar. Notably, the areas of AI and Green Technologies have become prominent over the last 2 years and this is reflected in separate categories being created for these. Within these categories, the technologies have been banded into short-term up to 2025, medium-term 2025-2035 and long-term 2035 onwards and the maturities of technologies are coloured with a traffic light sequence of red (very immature), amber (may wish to monitor and consider for future opportunities) and green (mature and usable) which SMEs and Mid-caps can easily understand.

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It was also highlighted from discussions with SMEs and Mid-caps that they struggle in particular to understand how the new technologies could be used. Large companies tend to have a research department that investigates new technologies and potential applications, small companies do not have this luxury and so there is a need to provide more information than just on the technologies themselves. Thus, it was decided to undertake a major activity of creating an Applications Accordion giving an overview of application domains covering opportunities, examples, and barriers to commercialisation. This has been developed during Smart4Euope2, resulting in sections on Smart Agriculture, Home Automation, Wearables, Sustainable Manufacturing of Electronic Goods, Intelligent Energy and Low Carbon Technologies, Ocean Monitoring, Food and Beverage, Art, Entertainment, Music and Literature and Technologies to Combat COVID-19. The domains covered have been driven by the priorities of the new Horizon Europe and Digital Europe programmes with a new green emphasis, via workshop feedback highlighting sectors of interest, and via enhanced interest in certain sectors due to the pandemic, e.g., Food and Beverage, Art, Entertainment, Music and Literature and specific technologies to combat COVID-19. Notably, analytics show that the Applications Accordion section of the radar is the most visited area which highlights that most users identify with the application sectors first and foremost. This has become a Unique Selling Point and differentiator for the radar, which makes it more interesting for users.

The radar has been extensively promoted at technical and domain-specific events and there has been good engagement with 703 views of the radar to date. The stakeholder engagement has been wide going beyond SMEs and Mid-caps, to large well-known companies and also other stakeholders, such as national government and EC policy makers. Different communication channels have been adopted for promoting the radar and notably Linked-In which has many sectoral groups has been a useful tool. The more direct approach of promoting the radar at events held for different communities has also been employed (e.g., Smart Agriculture, Ocean Monitoring, Entertainment), technologies (e.g., AI) or with SME and Mid-Cap targets (e.g., DIH events). This has proved to produce the best conversion rate in terms of getting people to look at the radar and in generating interest in the radar. The radar has also been instrumented with easy to provide feedback buttons on every open window which enables THHINK to gather technology/application-specific feedback leading to improvements in the radar.

Looking to the future, the radar is “live” and thus continually improves with more content. To help in this process maintenance tools have been developed. This includes an App that automatically parses through the radar to check for broken links and for formatting that does not work well with html. This has been actively used and has proved very valuable. A Radar Editor Windows application is also under development that allows the user to edit the content of the radar and perform various validations of the content against rules. The aim is that the editor will allow a non-html expert user to edit existing content, add new content, remove old content, and preview the radar before the content is published. These tools help THHINK sustain the radar as part of future commitments to build on and maintain the radar.

Finally, a key outcome of WP4 is to provide a clearer picture of future opportunities and to make strategic recommendations for the SAE Initiative within the new Digital Europe Program. As part of this, the gathering of the radar data and creation of the applications accordion provide a strategic resource and insights into where future opportunities lie (particularly with the emphasis on green opportunities) within the twin green and digital transformation.

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2 Introduction

Smart4Europe2 directly supports the Smart Anything Everywhere (SAE) Initiative which addresses the "next wave of products that integrate digital technologies" with the aims of transferring knowledge and fostering collaboration and hence the uptake of digital technologies by European industry. The overall ambition is to contribute to Europe's need to accelerate the design, development, and uptake of advanced digital technologies by bringing Innovation Actions (IAs) together. In order to boost digital transformation of European Industry, Smart4Europe2 supports European small and medium-sized enterprises (SMEs) and Mid-caps to produce competitive products based on innovative electronic components, software, and systems. In addition, Smart4Europe2 supports companies to achieve competitive advantage by promoting early technology adoption and it assists technology suppliers to seek finance for their product development as well as enabling access to early customers.

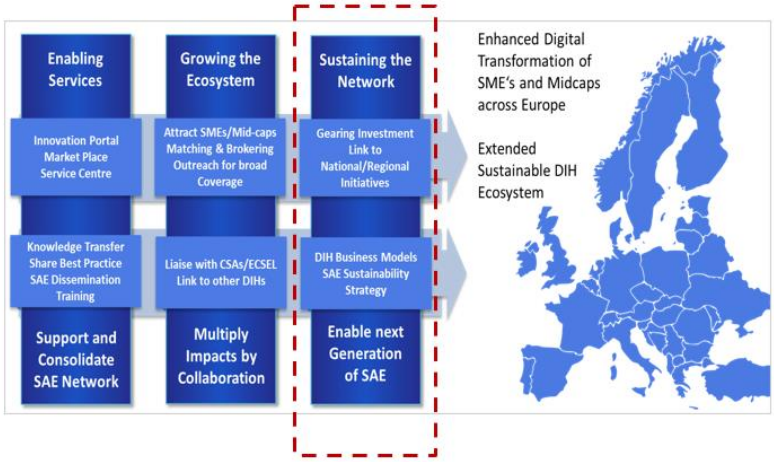

Figure 1 Overall Objectives of Smart4Europe2

As shown in Figure 1, Smart4Europe2 has three strategic objectives which are:

- Providing enabling services and consolidating the SAE network
- Growing the ecosystem and multiplying the impacts of collaboration
- Sustaining the network and enabling the next generation of SAE

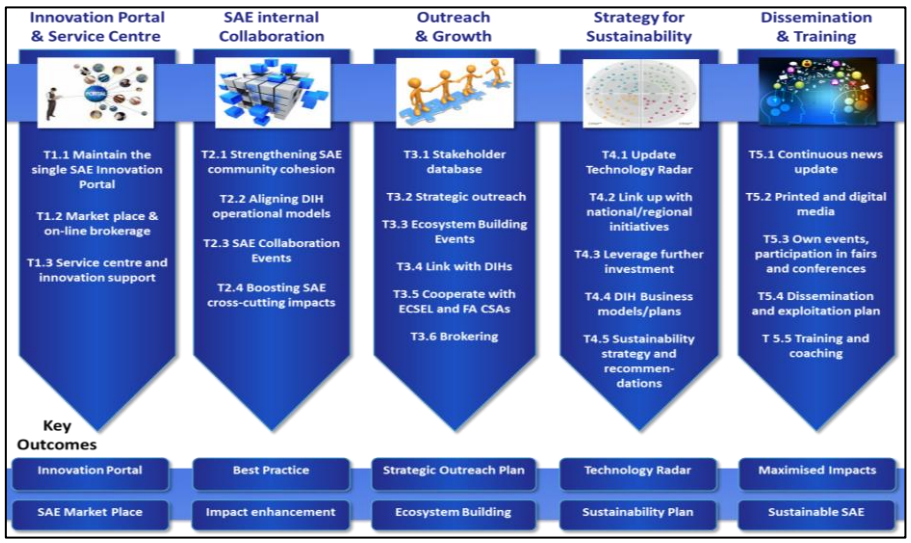

Figure 2 Overall Project

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The work within WP4 as shown in Figure 2 is particularly addressing "sustaining the network and enabling the next generation of SAE" by identifying promising new technologies and application fields to expand the SAE Initiative and via supporting strategic development within the new Framework Programme, Horizon Europe and Digital Europe. The motivation is that Digital Technologies have already entered our daily life, with many interactions. Digital transformation and innovation are now considered a necessity for all industrial sectors, especially if they want to stay ahead in the global race. Thus, action at a European level is required to achieve digitisation successfully in order to create benefits for both society in general and also in a European economic sense.

A challenge is that it is difficult for companies to keep track of new technologies and know whether these will be of importance for future products. For large companies, it is possible to expend some effort internally on monitoring new advances and also in exploring the potential of new technologies. Even for these companies, it is challenging to keep up to date in many diverse technology fields. For SMEs and Mid-caps with limited resources, however, it is almost impossible to track developments and understand all the new technologies that are coming to fruition. Therefore, the uptake of new technologies and digitisation in general by SMEs and Mid-caps is poor. The Technology and Innovation Radar thus has the goal of bringing together key information on new technologies that are expected to be important in the future to provide a single reference, which can be used by companies both large and small as a source of information.

A paper-based Radar was first developed under Smart4Europe1, which concentrated on 4 SAE ecosystem disciplines and sectors. At the applications level this covered **Internet of Things** and **CPS** through enabling software, algorithms and connectivity that are used to create "Smart Systems". These are used to provide the "Things" in the **Internet of Things** and provide embedded system components that become part of a **CPS** which interacts closely with physical systems. Two underlying areas that feed into these were also covered. These were **Smart Systems Integration** (SSI) which addresses microsystems considering the ability to combine sensors, actuators, data processors and communication interfaces in one single compact system to perform a desired functionality for a (human) user or for another (connected) system. The other was **Organic and Large Area Electronics** (OLAE). This area is driving the uptake of affordable and easily integrable electronics for numerous applications (e.g., flexible electronics, lower-cost touch pads and display panels). In this respect materials science is providing solutions with suitable properties and supporting low-cost processes for producing them (i.e., design, synthesis, production techniques and characterisation of materials).

Each of the fields, SSI, IoT, OLAE and, CPS already have their own European Technology Platforms (ETP) [1] as industry-led stakeholder initiatives to drive innovation, technology transfer and European competitiveness. Each ETP organises events for its own ecosystem, develops its own roadmaps and strategic research agendas, and mobilises public and private funding on a regional, national and EU level to achieve its goals. Smart4Europe1 aimed to try and bring these communities together to address the Smart Anything Everywhere Vision and Digitisation of European Industry initiative by interdisciplinary cooperation to exchange and learn from previous experience, combine funding and coordinate activities on emerging and future technologies.

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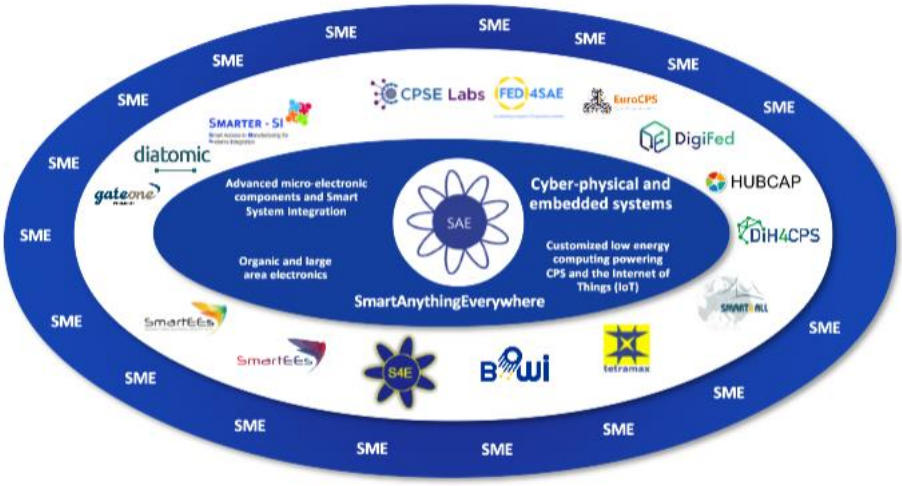

Figure 3 Identifying New Technologies and New Applications

These 4 core areas have been significantly expanded in Smart4Europe 2, as shown in Figure 3. A number of new initiatives were launched at the same time as Smart4Europe2 and these add to the technological areas being covered, resulting in new technologies being added to the radar. It is also important to note that the primary stakeholders within the SAE community are the SMEs and Mid-caps and it is these that the Technology and Innovation Radar serves. These companies are not only interested in the technologies but also in the potential use of these technologies in applications. This has led to the development of the "Applications Accordion" in Smart4Europe2 to provide information on applications sectors, examples of technology use and commercial barriers in the domains. The domains covered have been driven by the Horizon Europe and Digital Europe priorities, as well as the Green Deal. Other sectors were included as a result of interest identified in Technology Radar workshops and due to them being highlighted as being societally important by the COVID-19 pandemic. As there is a drive towards digitisation in new non-traditional areas, there is an emphasis on this in the application sectors chosen, such as Smart Agriculture, Home Automation, Wearables, Ocean Monitoring, Food and Beverage, Art, Entertainment, Music and Literature.

The radar also has a strategic role in developing a strategy for sustainability, as shown in Figure 4. This brings together a number of activities looking at technologies and applications of importance for SMEs, linking up national and regional initiatives, leveraging investment and identifying business models and plans.

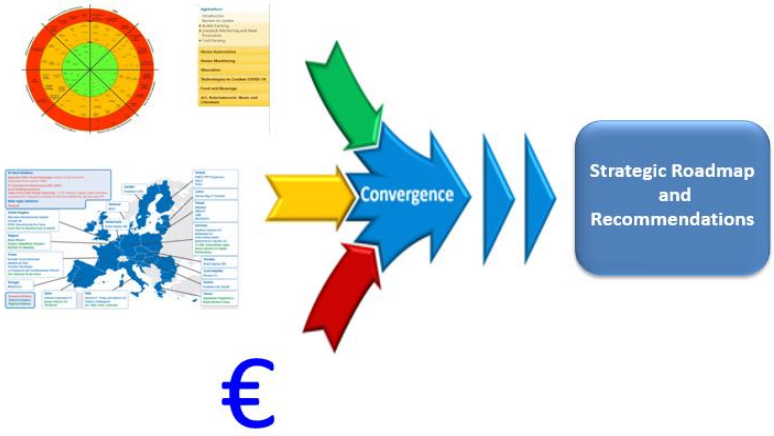

Figure 4 Strategic Role of Radar

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This all contributes to providing a strategic roadmap for the future of the SAE initiative, considering important technologies and funding available to support their development, as well as recommendations for the Horizon Europe and Digital Europe programmes.

3 Evolution of the Radar

A Technology and Innovation Radar (See ThoughtWorks [2]) is used to classify new technologies and innovations into sectors according to some categorisation. Technology and Innovation Radars are used by companies to try and identify where research and innovation investments should be made internally. It is a useful tool for identifying whether it is worth investing time and resources into a given technology, dependent on its potential and maturity. It also gives information on when is the most appropriate time is to do this. By following the progress of technology over time it is possible to track the maturity as it develops or identify that the technology should not be pursued further.

There are different types of Technology and Innovation Radars. Typically, a radar is developed by a company for internal use and is specific to that company's activities. This makes the use of the radar in a more general sense difficult unless used by a Tier 1 company, e.g., aerospace or automotive, as a means of guiding its supply chain. There are, however, other forms of technology radar that can be used with different objectives. Technology and Innovation Radars can also be used to monitor the progress of innovation. For instance, in other work for the European Commission THHINK proposed a standardised Technology and Innovation Radar for monitoring the innovations being produced by the Public Private Partnerships based on the maturity and impact of different innovation outcomes. The overall concept of the radar can be tailored to present information in the most appropriate way. In this case, the objective is to provide a radar for SMEs and Mid-caps who may already develop technologies for a number of different application sectors or may have an interest in addressing other traditional and non-traditional sectors. This presents a challenge as there is a wide variety of technologies across SAE and many potential applications.

3.1 Initial Data Gathering for the Original Smart4Europe1 Paper-Based Radar

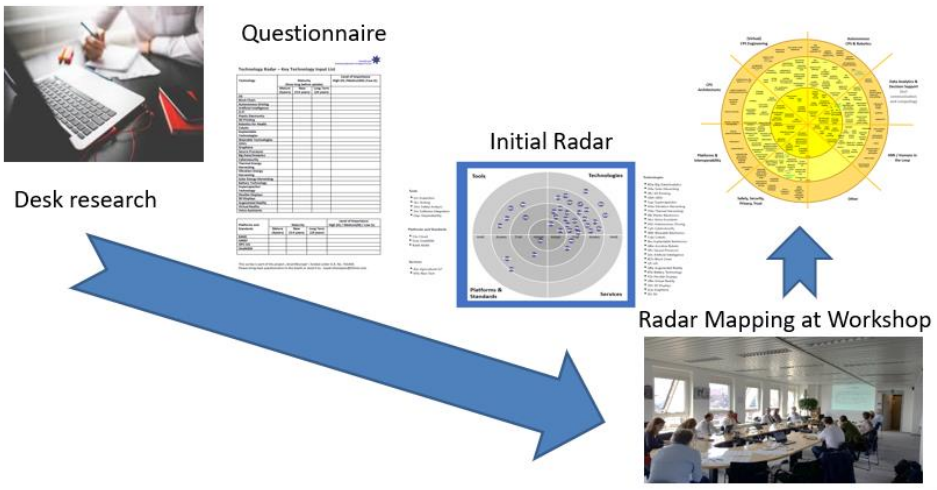

Figure 5 Approach to producing Initial Technology and Innovation Radar

The approach shown in Figure 5 was used to develop the Initial Paper-Based Technology and Innovation Radar. In the first instance, desk research was performed to identify an initial set of technologies of interest focused on technologies and scenarios that are based on the SAE vision

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covering the core topics of CPS, embedded systems, SSI, OLAE and advanced computing for IoT. Up and coming technologies and innovations being explored in existing projects were also explored (this identified technologies and innovative areas where active research and development was underway within European projects), and also from advances announced for the future on the Internet. This wider look at technologies and innovations was in order to look not only in Europe but around the world, for technologies and innovations which may have high significance in the future.

In parallel with this, a questionnaire was developed covering 36 technologies which was sent to key experts for feedback. This was also made available on the Smart4Europe1 website and was taken to exhibitions and events to gather face-to-face feedback. The aim of the questionnaire was to obtain feedback on the maturity of given technologies from experts as well as the potential for the technologies. In addition, respondents were also asked to highlight any new or unusual applications that they had come across or would like to see. The results from the questionnaires indicated some differences in response (and indeed conflicting opinions in terms of technologies and innovation areas, e.g., 5G, AI, etc. with respect to maturity and potential) dependent on the respondents understanding and engagement in the technology area. In general, respondents were able to provide information on areas of their expertise, however, not in a generalist sense. This is to be expected as there was a wide range of technologies on the list, some of which are very specific.

The feedback from the initial questionnaire was very important in the design of the Technology Radar.

Challenge 1 Providing a SAE Domain Radar - In the case of Smart4Europe the intention is to provide a Technology and Innovation Radar that can be used by many companies working in the SAE domain. This is challenging in that it is not derived for a single company and it is also not designed for monitoring innovations (metrics on TRL changes obtained through prototyping and demonstrator work are not easily accessible). Although a single company can consider priorities for a given technology based on its own business interests, the aim of the Smart4Europe Technology and Innovation Radar is much wider than this addressing the SAE community as a whole. There will thus be different opinions about the “interest” of particular technologies. It was clear from feedback from the questionnaire that a more well-defined scope was needed to categorise areas. For instance, initially AI was considered to be a technology area, however, in reality AI has application in many domains, including machine learning, natural language processing, chatbots, virtual assistants, image recognition, gesture control, augmented reality, emotional recognition, robotic process automation, personalised recommendation, context-aware community and business analysis. This eventually led to a subdivision of these areas into AI and HMIs on the radar.

Challenge 2 Defining the Maturity of Technologies - A second challenge is that the maturity of a technology has to be considered for a specific application domain. For instance, a technology or innovation developed for the automotive domain with a high TRL would have a low TRL in the aerospace domain. Thus an experts’ opinion of TRL depends on the application sector they are working in. As an example, “UAVs” are a mature technology in the military domain but less mature in the civil domain. The responses also depend on the size of the UAV. For Smart Agriculture small UAVs are just beginning to be used for monitoring, but there is also potential to use larger UAVs for spraying, etc. In general, larger UAVs open up many opportunities for inspection of wide areas, e.g., farms, electrical grid inspection, etc., however, these larger UAVs would require certification and thus rigorous and costly development processes. Regulation also needs to be introduced to allow their use which is a non-technical barrier.

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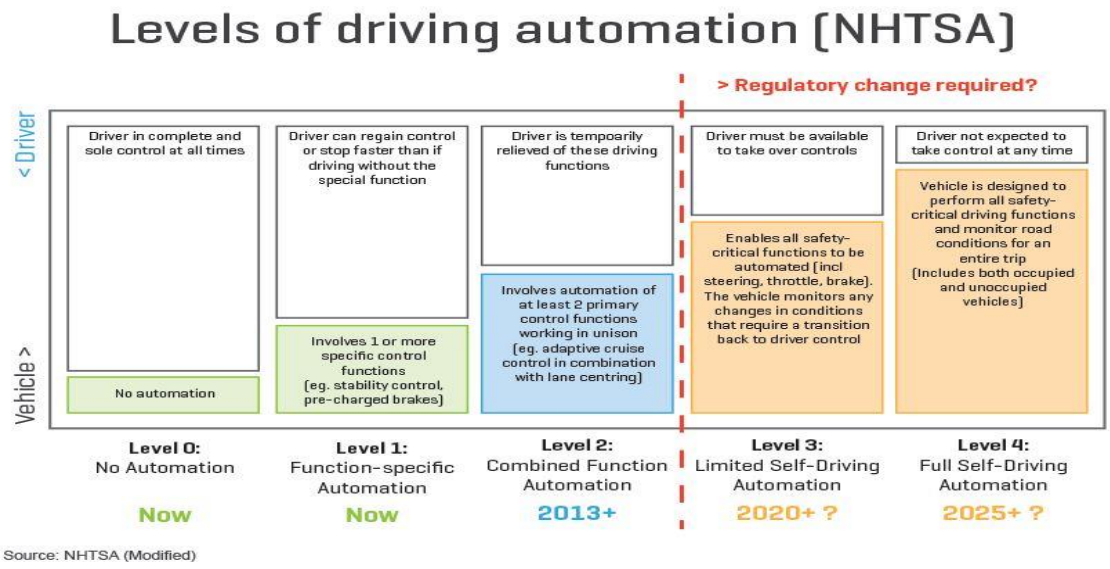

Figure 6 Autonomy Classifications for Cars

There are similar non-technical barriers in terms of autonomous cars with again different views with respect to the level of autonomy that can be used (see Figure 6). Already autonomous cars with level 3 autonomy are being sold, e.g., Tesla, but fully autonomous cars are not expected to be on the road until 2035. In terms of technology, many barriers have been solved, but there are also the legal, liability and trust barriers that need to be overcome to enable uptake.

Additionally, it was noted that existing technologies and innovations identified may be integrated together to create new technologies in systems integration. This is not just a simple matter of combining TRLs. In general, the overall TRL will be that of the lowest TRL component, but it can also be lower than this based on risks introduced by interactions between the component technologies. Smart Systems Integration is thus a concern at both a low level and also at higher applications levels such as a CPS, e.g., an autonomous car.

To avoid collecting subjective information on TRLs the data on maturity was gathered in terms of three easier to define classes of maturity:

- *Mature* (TRL 6-7 demonstrator)
- *Lower Maturity* (prototype TRL4-5)
- *Very Low Maturity* (TRL 1-3 experimental)

according to the TRL levels defined below:

- TRL 1 – basic principles observed
- TRL 2 – technology concept formulated
- TRL 3 – experimental proof of concept
- TRL 4 – technology validated in lab
- TRL 5 – technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies)
- TRL 6 – technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies)
- TRL 7 – system prototype demonstration in operational environment
- TRL 8 – system complete and qualified

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- TRL 9 – actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space)

Based on this 3-level categorisation and the technology being considered (which may also be subject legislative barriers, etc.), a judgement was made based on when it was believed a technology or innovation will be mature enough for commercial use. This provides an indication of maturity that is easier to assess by the community:

- Short Term (S) – available by 2025
- Medium Term (M) – available between 2025 and 2035 and,
- Long Term (L) – available after 2035

In creating the radar the perceived "maturity" of a technology or innovation has thus been considered rather than specific TRLs. A key advantage of providing a 3-level classification is that a red (immature), amber (lower maturity), green (mature) traffic light sequence can be applied to the technologies, which is much easier for SMEs to assess at a glance. This can be interpreted as *green* the technology is mature and available for use, *amber* it is a technology that may be of interest in the near future, *red* the technology is long term and should be just watched for now.

Challenge 3 Technology Enablers – Originally called "tools and techniques", *Technology Enablers* on the radar covers topics such as testing, modelling, simulation, certification and also standards. A challenge here is to define the maturity of these tools, techniques and standards. Many tools already exist and allow certain aspects of systems to be modelled, tested or certified. However, there are new areas such as autonomous cars where unforeseen conditions may be experienced. These cannot be covered by existing testing and certification strategies which are used within predictable environments. There are also other areas such as AI and adaptive algorithms which present challenges for certification. Obviously, mature tools are available to test and certify aircraft, etc., so it is politically difficult not to give a tool or technique a "green" maturity status (this would imply that our current systems may not be safe). However, it is clear that some new challenging aspects being driven by new technologies and increasing complexity of systems cannot be coped with by present tools. There is a need for more research into developing new modelling, testing and certification tools and in integrating these together so it is also difficult to classify them as being "mature" at the same time. A continuum of tools is thus represented on the radar with an amber classification for maturity in the knowledge that tool development is an ongoing activity. Within the described areas, technical and commercial barriers are identified which provides more detailed information on where more work is needed. The standards identified on the radar exist and have been classified as green, however, the challenge for these is the uptake of the standards across the industry. Again, these challenges are highlighted in the individual descriptions for the standards.

3.2 Development of Categories for Technology Radar

Several different categorisations were tried to organise the technologies in the radar. In the initial version of the radar 36 technologies were divided into 4 categories *Technologies, Services*, *Platforms & Standards* and *Tools*. Even with relatively few technologies this was unsatisfactory due to the diversity of technologies and so other categorisations were considered. These included adding sections on CPS and IoT and also restructuring around Robotics and Autonomous Systems, Smart Pervasive Monitoring (IoT), Mastering Data and Human Machine Interaction. However, these were all found to be too limiting.

To resolve this, a renewed emphasis was placed on gathering new technologies to better define categorisation. In particular, a search for more immature technologies (an area that was unpopulated) and applications that may be important in the future was made. Emphasis was also placed on

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identifying technologies specific to the Smart Systems Integration and Organic and Large Area Electronics areas which were also under-represented compared to the CPS and IoT application domains. The result of this wider search resulted in around 90 technologies being identified. This allowed a new categorisation to be identified around 8 categories:

- Robotics
- Artificial Intelligence
- Energy Harvesting
- HMIs
- Tools, Platforms and Standards
- Data Analytics
- Smart Systems Integration
- Organic and Large Area Electronics (OLAE)

This particular classification scheme was found to allow a better distinction of technologies. Within each of these categories technologies were considered with respect to their maturity.

Robotics
3D printing S
Adaptive Manufacturing M
Assistive Robots M
Cobots M
Self-Reconfiguring Robotic Systems M
Industry X.0 M
UAVs M
Autonomous Driving L
Mobility as a Service L

Artificial Intelligence
Image Recognition S
Machine Learning M
Deep Data Mining M
Reinforcement Learning M
Precision Medicine M
Self-Diagnostic Medicine M
Ambient Intelligence (AmI) M
Natural Language Processing M
Neuromorphic Computing L

Energy Harvesting
Solar Harvesting S
Solar Roof Tiles S
Supercapacitor S
Thermal Harvesting S
Energy-Harvesting Floors S
Vibration Harvesting M
Flywheel Energy Storage M
Hot Solar Cells M
Fabrics that Generate Electricity M
Wireless Energy Transfer M
Cold Fusion L

HMIs
Voice Assistants S
Augmented Reality S
Wireless Display Technology S
Chatbots S
Virtual Assistants S
Emotional Recognition S
Personalised Recommendation S
Virtual Reality S
Paying with Your Face M
2D to 3D Converting Device M
3D Gaming M
Eye Tracking M
Gesture Control M
Social Television M
Brain Print as a Password L
Neural Interfaces L

Tools, Platforms and Standards
OneM2M S
RAMI S
SAREF S
OPC-UA S
Design, Modelling and Simulation M-L
Inspection M-L
Testing M-L
Safety Analysis M-L
Software Integration M-L
Dependability M-L
Certification M-L

Data Analytics
Big Data Analytics S
Bitcoin S
Blockchain S
Cybersecurity S
Remote Maintenance S
Smart Surveillance S
Smart Tracking S
Activity Monitoring S
FinTech S
Cloud S
Elderly Monitoring M
Li-Fi M
5G M
Remote Health Service M
Wellness Monitoring M
Secure Processor M
Internet for Everyone M
Smart Agriculture M
Smart Contracts using NLP and Blockchain M
Exascale Computing M
Faster Wireless Connectivity – MIMO Connectivity M
DNA Digital Data Storage L
Practical Quantum Computers L

Smart Systems Integration (SSI)
Combinational Sensing S
Micro-actuators S
Nanotechnology S
Micro-Electro-Mechanical Systems (MEMS) S
Microfluidics S
Microsensors S
Micro-Nano-Bio Systems (MNBS) M
Micro-Opto-Electro-Mechanical Systems (MOEMS) M
Moulded Interconnect Devices (MID) M
More-than-Moore Technologies M
Nanoelectromechanical Systems (NEMS) M
Molecular Electronics L

Organic and Large Area Electronics (OLAE)
Plastic Electronics S
Integrated Smart Systems S
OLED Lightening S
MicroLED Displays S
OLED Displays S
Reel-to-Reel Processing S
Flexible and OLED Displays M
Organic Photovoltaic (OPV) M
Aerogels for Insulation M
Solid-State Battery Cells M
Wearable Electronics M
Implantable Electronics M
Organic Electronics and Components L
Disposable Paper-Based Transistor L
Graphene L
Atomtronics L

Figure 7 Key Technologies and Innovations

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4 Technology and Innovation Radar 2019

At the end of Smart4Euope1, the paper-based radar shown in Figure 8 was created. This was presented at Workshops and feedback on new technologies and maturity levels was gathered. In total 107 technologies were identified.

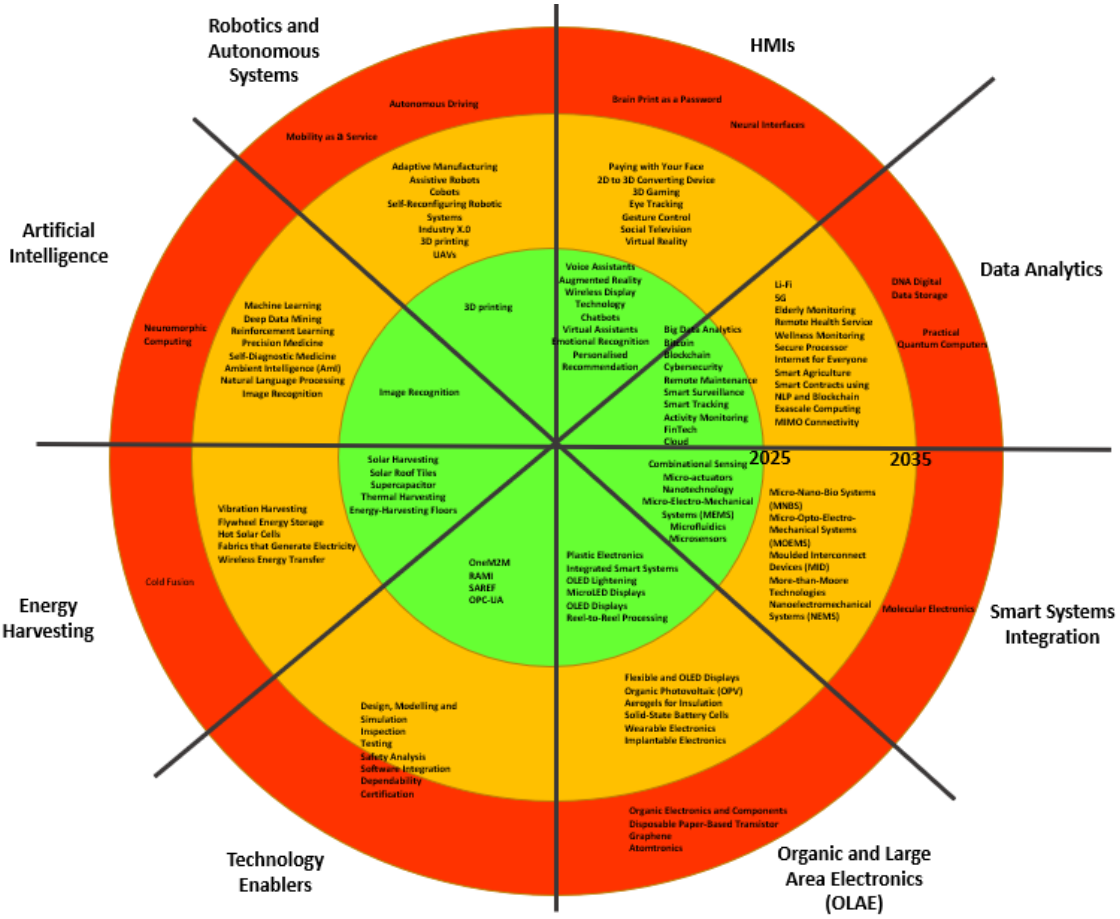

Figure 8 Smart4Europe Technology and Innovation Radar 2019

The resulting Technology and Innovation Radar present the technologies in three sectors:

- Green – technologies that SMEs and Mid-caps can consider to be mature in the short term,
- Amber - technologies that are coming in the 2025-2035 timescale that SMEs/Mid-caps should be aware of for the future and may have an interest in that they may wish to monitor and,
- Red – technologies that are still very immature and should not be considered at this time.

The radar was updated as new technologies were identified and the status of technologies was reviewed periodically to identify if the maturity level had changed. In some cases there was a need for a continuum of innovations, particularly in the areas of technology enablers reflected in them being assigned an amber and red classification to highlight the fact that there are some aspects of systems that cannot be covered at present.

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5 Technology and Innovation Radar 2021

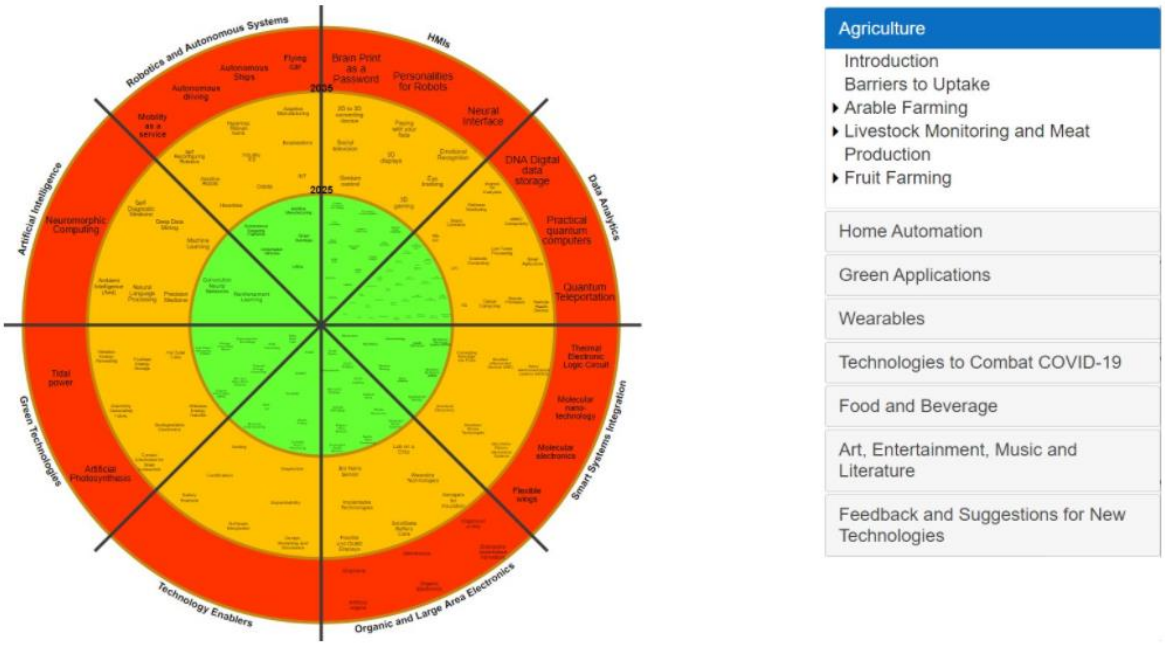

Figure 9 Smart4Europe Technology and Innovation Radar 2021

It was clear that although at the end of Smart4Europe1 the radar was perceived as being very useful by the community, a paper-based radar was not ideal. In order to make it more easily accessible and promote it more widely, there was a need to create an online clickable version of the radar. This has been done in Smart4Europe2 by creating a Web-based radar rendered using SVG (Scalable Vector Graphics). This has turned the radar into a "live" resource which is easy for companies to access and navigate. It is possible to zoom in and scroll around the radar on PCs, tablets, etc., allowing users to delve into areas and zoom in on technologies. This zooming feature has allowed management of the radar content as it has become more populated with technologies. This was already becoming an issue with the paper-based radar with around 100 technologies and now with around 200 technologies the paper-based version would not be possible. The technology titles are automatically scaled to the section they are in, driven by the number of entries there are in the section. Thus, sections with more technologies in have smaller titles and these are automatically spaced by an algorithm that tries to optimise the space available. This provides a scalable and sustainable solution that allows the addition of more content. This difference is very clear when comparing Figure 8 with Figure 9. The look and feel of the online radar has also been improved over a number of iterations following feedback from users. This has led to improvements in how the titles are presented, optimisations of the scaling algorithms and changes in the shape and colours utilised for the technology windows to be more "modern". Here, advice was taken on how to appeal to a younger engineering audience.

The online version has also opened up a raft of opportunities for easily collecting analytics on the use of the radar allowing THHINK to better understand where interest is. It has also made it much easier to collect feedback on the usefulness of the radar, ideas for additional technologies that can be added to the radar, as well as comments on the positioning of technologies with respect to maturity. This feedback has proved invaluable leading to many enhancements. Notable the improved "online presence" has led to much better dissemination of the radar, helping THHINK in its activities to raise awareness. Coupling the radar with the presentation of the Applications Accordion has also provided a differentiator, a Unique Selling Point, with respect to other sector-specific radars that is attractive to

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industry and has led to discussions with organisations, e.g., Sensing Innovation Leadership Council, with an interest in contributing to and sponsoring the radar in the future.

The categories on the radar have also evolved from the categories defined in the original paper-based radar. Notably, interest in Green Technologies has become prominent over the last 2 years. Although many of the technologies on the radar have potential to be used for green aims (optimising use of energy and resources, reducing wastage, reducing emissions, etc.), those that are clearly "green" have been reflected in a separate category being created encompassing technologies such as energy harvesting technologies, biodegradable electronics and low power technologies such as FDSOI. This reflects the emphasis on the Green Deal within Europe. The main categories are now thus:

- Robotics and Autonomous Systems
- Artificial Intelligence (AI)
- Green Technologies
- Technology Enablers
- Human Machine Interfaces (HMIs)
- Data Analytics
- Smart Systems Integration (SSI)
- Organic and Large Area Electronics (OLAE)

As highlighted, a major continuing effort has also been put into identifying new technologies and innovative areas to add to the radar to make it even more useful for the SAE community. This has been done via desk research, feedback from workshops and events, and via THHINK participating in a large number of diverse events in order to cover the interests of a wide range of application sectors, both traditional and non-traditional. Notably, the radar now covers around 200 technologies.

5.1 Current Radar Upgrade

The radar is not static and is being continually upgraded with new content and updates as a result of feedback and identification of new technologies and innovations.

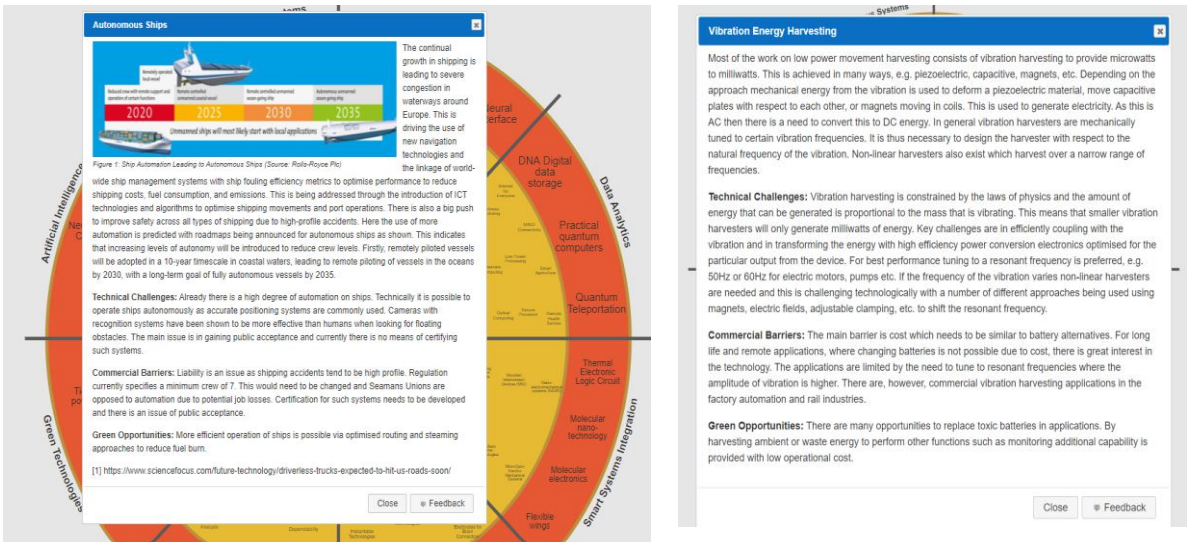

Figure 10. Addition of Technical Challenges, Commercial Barriers and Green Opportunities

However, more significantly, the whole radar is currently undergoing a major upgrade. In this, additional information is being added for each of the 200 technologies on the radar to highlight Technical Challenges, Commercial Barriers and Green Opportunities, as shown in Figure 10. The addition of more detail on technical challenges was highlighted in the mid-term review of Smart4Euorpe2 as being something that should be provided on the radar. Discussion with SMEs on the

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level of detail required, highlighted information on technical challenges is welcomed, but care needs to be taken not to provide "overly scientific" information on the technologies as they will, if interested, go and look this up anyway. What was more of a concern was if there are commercial barriers to exploitation for a given technology. Thus, it was decided to provide relevant background information for each of the technologies that enabled a greater depth of understanding. The technical challenges section provides insight into what are the key technological challenges that need to be overcome for a technology to be deployed. Here, naturally the technical challenges tend to be more significant for red and amber technologies. The commercial barriers section provides a market-oriented perspective considering issues such as standards, regulation, high investment costs and other issues, e.g., customer acceptance, that an SME or Mid-cap needs to consider. In many cases these commercial barriers are more of an issue than the technical aspects and are quite often not fully understood by SMEs and Mid-caps.

Green Opportunities has also been added as the author is active in meetings with the Commission with respect to the Green Deal and it has been noted that SMEs and Mid-caps are struggling to identify how the technologies that they are working on fit with the proposed funding calls. Here ideas are presented based on examples of how technologies can be used to achieve green aims. This is more a guide to the community on how twin digital and green objectives may be fulfilled.

At the time of writing of this report the upgrade has been done for the technologies on the Left Hand Side of the radar and in coming months, those on the Right Hand Side will also be updated.

5.2 Applications Accordion

Presenting an overview of technologies to SMEs and Mid-caps is useful as a reference but in reality companies are more interested in examples of applications where the technologies can be used. This helps companies identify potential commercial markets for the technologies, both in terms of new innovative uses which could be replicated and also in providing an overview of activities/trends within a given domain where new uses may be possible. This helps companies quickly see the technologies that could provide business opportunities over the next 5-10 years. In order to do this, an Applications Accordion has been created located on the right-hand side of the radar which is proving to be a key differentiator. The application domains that have been chosen for the accordion align strongly with EC twin green and digital priorities under Horizon Europe [3] and Digital Europe [4] and in particular address ambitions put forward under the Green Deal.

Figure 11 Horizon Europe Pillar 2 Priority Clusters

The emphasis on Green technologies is notable in the new Horizon Europe Research Programme. Under Pillar 2 of this five Research and Innovation Missions have been defined. These are led by key figures and address "moonshot" missions which have been defined as strategic for Europe:

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- **Ms Connie Hedegaard**, former European Commissioner for Climate Action, for the mission on 'Adaptation to Climate Change including Societal Transformation'
- **Professor Harald zur Hausen**, Nobel Prize Laureate in Physiology or Medicine, for the mission on 'Cancer'
- **Mr Pascal Lamy**, former Trade Commissioner and Director-General of the World Trade Organisation, for the mission on 'Healthy Oceans, Seas, Coastal and Inland Waters'
- **Professor Hanna Gronkiewicz-Waltz**, former Mayor of Warsaw, for the mission on 'Climate-Neutral and Smart Cities'
- **Mr Cees Veerman**, former Dutch Agriculture Minister, for the mission on 'Soil Health and Food'.

This places an emphasis on green and sustainable research activities. Likewise, these green objectives also run through Digital Europe.

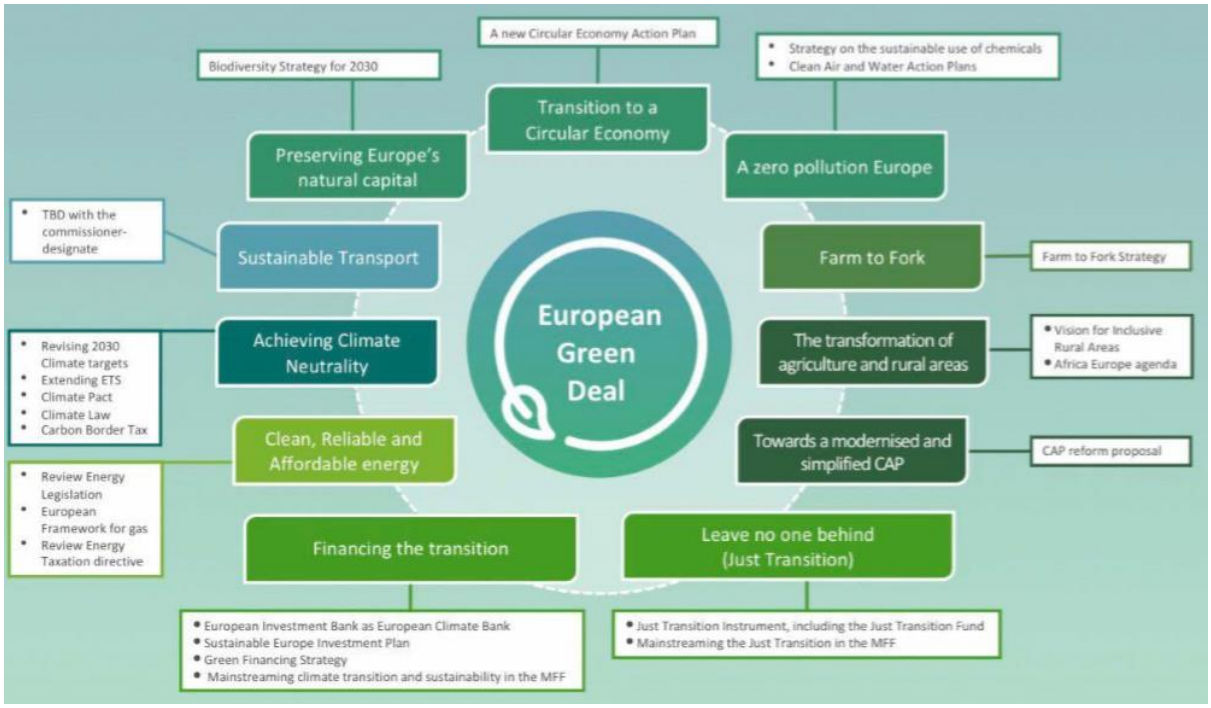

Figure 12 European Green Deal

The key driver behind this is the European Green Deal which is an action plan [5] put forward by the European Commission to:

- boost the efficient use of resources by moving to a clean, circular economy
- restore biodiversity and cut pollution

This covers many areas, including energy, carbon tariffs, sustainable transport, biodiversity, circular economy, zero pollution and smart agriculture, as shown in Figure 12. The European Union aims to be climate neutral by 2050 and this is being backed by a proposed European Climate Law [6]. Notably, this affects all sectors of the economy, including:

- investing in environmentally-friendly technologies
- supporting industry to innovate
- rolling out cleaner, cheaper and healthier forms of private and public transport

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- decarbonising the energy sector
- ensuring buildings are more energy efficient
- working with international partners to improve global environmental standards

Figure 13 Financing for Green Deal (Source: European Commission)

To support this "green conversion", a plan bringing together a variety of investments and financing tools available has been put together with the aim of mobilising €1 trillion Euros. The EU will also provide financial support and technical assistance to help those that are most affected by the transition towards the green economy by mobilising €100 billion over the period 2021-2027 via the Just Transition Mechanism. This huge mobilisation of resources and launching of funding calls to support these priority activities has led to the Applications Accordion providing coverage of applications within digital industry, civil security, health, agriculture and food, climate, energy, mobility and culture and creativity. The following areas being covered by the Applications Accordion

- Smart Agriculture – Sustainable farming
- Food and Beverage – Food manufacturing, distribution, tracking, refrigeration, advertising, future restaurants (as a result of COVID-19)
- Home Automation – Energy management, security, entertainment
- Wearables – Health and well-being
- Sustainable Manufacturing of Electronic Goods – Reducing use of energy and materials, adoption of environmentally friendly materials and recycling
- Intelligent Energy and Low Carbon Technologies – Reducing energy consumption and carbon emissions
- Ocean Monitoring – Impact on climate, pollution and impact on aquatic life
- Art, Entertainment, Music and Literature – Culture and creativity
- Technologies to Combat COVID-19 – In response to world events

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5.3 Domains Represented in Accordion

Agriculture

Figure 14 Examples of Agricultural Applications

Agriculture is an area which is currently undergoing a Digital Transformation leading to Precision Agriculture and Smart Agriculture. The farming and agricultural industry relies on innovative ideas and technological advancements to help increase yields and better allocate resources. The number of farm workers required to manage a European farm has gone down significantly with the average number of workers on a farm in Europe being 6 people. The latest revolution in the sector is being driven by IoT to increase agricultural production and reduce costs, e.g., in terms of fertiliser and water use. The domain represents a strong opportunity for companies who sell connected sensor solutions as wide deployments are required. IoT applications in agriculture include farm vehicle tracking, crop monitoring, livestock monitoring, storage monitoring, and many more across the logistics chain. The smart agriculture market is expected to grow from $5.18 billion in 2016 to $11.23 billion by 2022. The topics covered on the radar are shown below. For detailed information, please go to radar.

- Introduction
- Barriers to Uptake
- Arable Farming
    - Introduction
    - Plant and Soil Monitoring for Precision Farming
    - Automated Weather Monitoring
    - Precision Crop Management Services
    - Growth Monitoring
    - Pest Control
    - Beehive Monitoring
    - Soya Protein Management and Traceability
    - Internet of Vegetables
    - Weeding Data and Weed Stamping
    - Farm Machinery Interoperability
    - Autonomous tractors

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- Livestock Monitoring and Meat Production
  - Introduction
  - Moocall calving monitor
  - CattleWatch
  - Grazing Cow Monitor
  - Happy Cow
  - Automatic Herdsman
  - Milk Quality Monitoring
  - Pig Farm Management
  - Sheep Farm Management
  - Poultry Farming
  - Meat Transparency
- Fruit Farming
  - Introduction
  - Hyperspectral Imaging for Fruit Quality
  - Table Grapes
  - Wine Production
  - Olive Production
  - Smart Orchard
  - Fruit Logistics
  - Greenhouse Production
  - City Farming

Home Automation

Figure 15 Examples of Home Automation Applications

Home automation is concerned with building automation for a home and includes control and automation of lighting, heating (such as smart thermostats), ventilation, air conditioning (HVAC), and security, as well as home appliances such as washer/dryers, ovens, refrigerators/freezers etc. Wi-Fi is often used for interconnectivity and home devices, remotely monitored and controlled via the Internet, are becoming an important constituent of the Internet of Things. Modern systems generally

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consist of switches and sensors connected to a central hub called a “gateway” from which the system is controlled with a user interface for interaction that is either a wall-mounted terminal, a mobile phone software, a tablet computer or a web interface. This is often, but not always, connected via Internet cloud services. The markets for smart kettles, fridges, washing machines, lighting, heating, energy management, security and home entertainment, e.g., Alexa, are all growing rapidly. It is estimated that the market will be $137.91 Billion by 2023. The topics covered on the radar are shown below. For detailed information, please go to radar.

- Introduction
  - Home Automation
  - Potential Markets
- Barriers and Limitations for Home Automation
  - Introduction
  - Connectivity and Security
  - Privacy
  - Cost
- Current Applications
  - Introduction
  - Connectivity Requirements for a Smart Home
  - Standards KNX
  - IoT Inspired Home Applications
  - Interacting with Home Automation
- Evolution and Homebots
  - Introduction
  - Designing bots
  - Success Factors in Marketing Homebots and New Business Models
- Home Automation for the Elderly and Sick
  - Introduction
  - Emergency Assistance Systems and Tools
  - Reminder Systems
  - Medication Dispensing
  - Challenges

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Sustainable Manufacturing of Electronics Goods

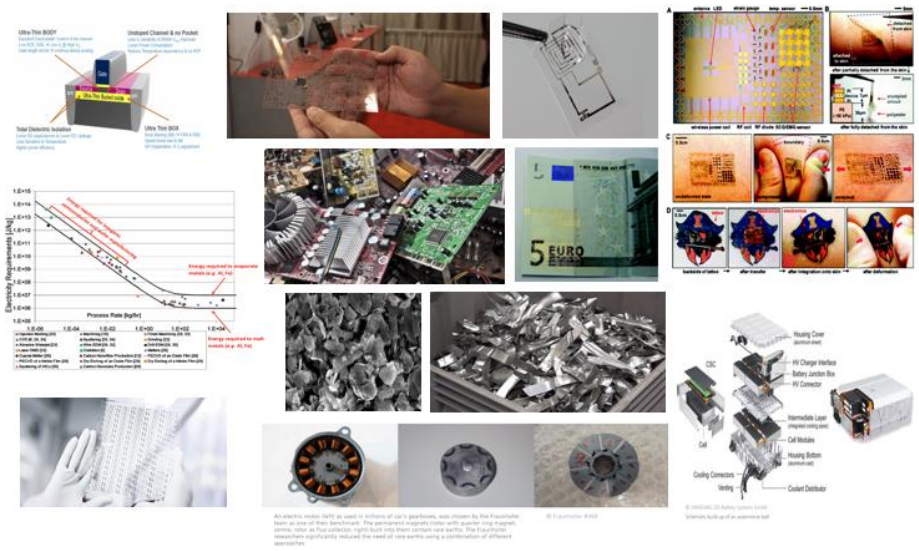

Figure 16 Examples of Sustainable Electronics and Recycling

There is great interest in sustainability in the manufacture of electronic goods, driven by desires to reduce energy and materials costs and via regulation on recycling. Important topics in this domain are resource efficiency in design, which automatically results in benefits for the environment, and use of eco-friendly or substitute materials for critical/scarce materials. Considering manufacturing efficiency, there are interests in reducing the use of raw materials, minimising waste and looking at ways to capture value from waste in "circular models". There is also a move to sustainable business models, e.g., such as more efficient use of energy within a factory and in installing a wind turbine to supply energy to a factory. This may extend all the way to moving from supplying products to services, for instance, leasing cars rather than selling them. There is also now much more interest in recycling products at end of life due to regulations. Products can be recycled to recover high-quality metals such as gold, copper, tantalum and rare earth elements. High-quality plastics can also be recovered and there is increasing interest in plastics overmoulding to recycle plastics. Gold and copper are relatively easy to recover efficiently, but still around half of the low-concentration metals contained in e-waste are lost. In the sector there is interest in using new materials to provide green electronics and in electronics that biodegrade. The topics covered on the radar are shown below. For detailed information, please go to radar.

- Introduction to European Green Deal
- Sustainable Manufacturing of Electronics Goods
  - Introduction
  - Reduction of Energy in Manufacturing
  - Electronic Waste (e-waste)
  - Plastic Electronics

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- Materials Used in Green Electronics
  - Introduction
  - Aluminium
  - Iron Alloys
  - Borosilicate Glass
  - Graphene
  - Biomaterials
    - Biodegradable Electronics
    - Biomedical Devices
    - Natural Substrates
    - Paper as a Substrate
    - Synthetic Polymers
    - Silk
    - Shellac
- Lighthouse Project “Criticality of Rare Earths”
- Recycling of Waste Electric Vehicle Batteries

Smart Energy and Low Carbon Technologies

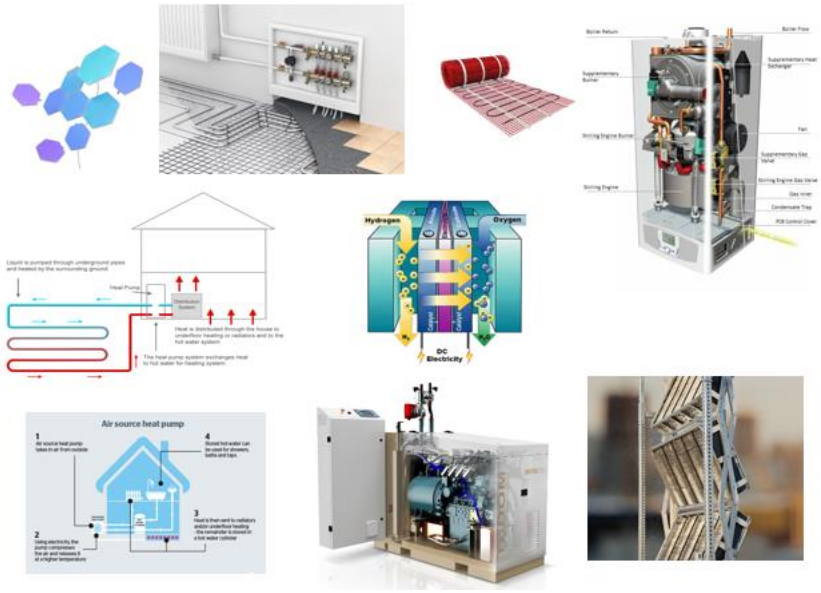

Figure 17 Examples of Smart Energy and Low Carbon Applications

New regulation is driving a change to more carbon-efficient technologies. This includes new forms of heating and lighting in buildings. For heating, incentives are being offered to install ground and air source heat pumps as well as new more efficient boiler technologies using Stirling engines and fuel cell technology. For large buildings, local distributed power generation systems are being developed. Carbon capture technologies are also being installed to capture carbon emissions at source and store them underground. Novel ideas such as “smart tree” technology to create mechanical trees is also being developed that are more efficient at removing carbon dioxide from the atmosphere. The topics covered on the radar are shown below. For detailed information, please go to radar.

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- Intelligent Energy Efficient Lighting
- Underfloor Heating
- Ground Source Heat Pumps
- Air Source Heat Pumps
- Micro Combined Heat and Power (Micro-CHP)
- Internal Combustion Engine CHP
- Fuel Cell CHP Technology
- Stirling Engine
- Off Grid Renewables
- Carbon Capture and Storage (CCS)
- Artificial Trees

Ocean Monitoring

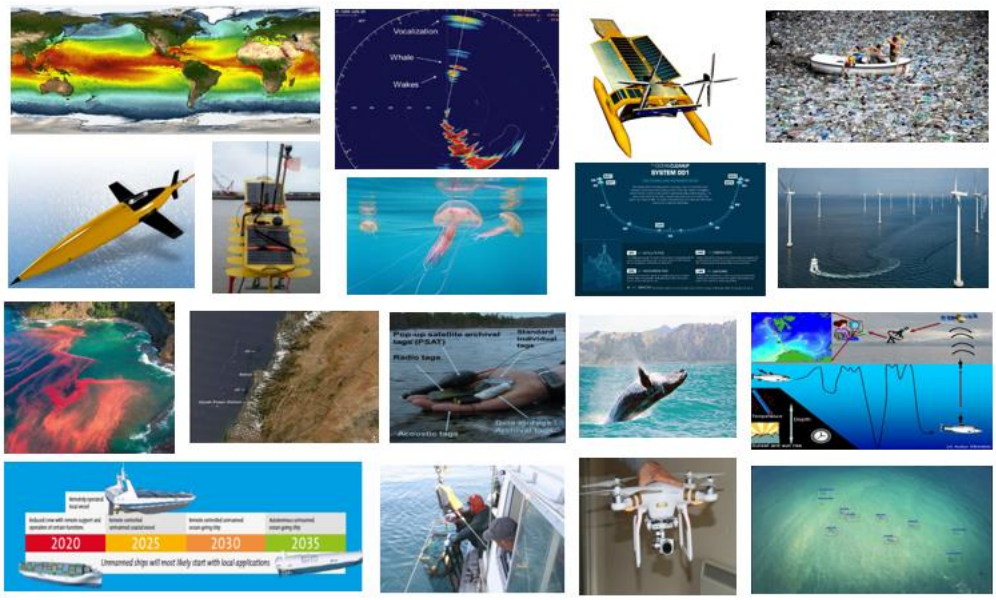

Figure 18 Examples of Ocean Monitoring Applications

The world's oceans cover 71% of the Earth's surface and they are an important resource for the planet influencing our weather while also being a major source of food. However, little is known about the oceans and they are vulnerable to man's activities. There is an increasing awareness with concerns about the impact of accidents at sea, pollution spills, ocean acidification, loss of wildlife, and also the relationship between the oceans and climate change. Thus, there has been a major effort to introduce more monitoring particularly of sea temperatures, which influence weather, and pollution which has major negative impacts on sea life. Although oil spills have been a major and growing concern for the past 50 years more recently man has realised that there is a major problem with plastics in the oceans. According to research, about eight million tons of plastic enters the ocean every year. There is great interest in mammal and fish monitoring to protect the integrity and health of species, their habitats, and ecosystems. It is, however, difficult and expensive to monitor animals in their natural habitats leading to the use of autonomous vehicles for monitoring. Another area that has been growing in recent years is the use of electronic tagging, giving detailed information on animals below the seas and their migration paths. Newer tags are now being built with miniature transmitters that can be used to wirelessly transfer data either via radio or satellite communication. The topics covered on the radar are shown below. For detailed information, please go to radar.

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- Introduction to Ocean Monitoring
  - Ocean Monitoring
  - Barriers
- Weather
  - Isocline Monitoring
- Autonomous Craft
  - Autonomous Vehicles for Ocean Monitoring
  - Autonomous Ships
  - Wind Turbine Inspection Using Drones
  - Underwater Gliders
- Pollution Monitoring
  - Oil Spill Monitoring
  - Plastic pollution
  - Ocean Cleanup
  - SeaVax
- Mammal and Shark Monitoring
  - Mammal Monitoring
  - Whale Monitoring
  - Harbour Porpoises
  - Dolphins
  - Shark Detection
- Fish, Crustaceans, Jellyfish, and Plankton Monitoring
  - Electronic Tagging
  - Lobster Monitoring
  - Jellyfish Monitoring
  - Plankton Monitoring

Wearables

Figure 19 Examples of Wearable Applications

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The Internet of Things (IoT) has started to impact many aspects of our lives, but arguably the most personal area is that of wearable devices. By wearing a device, the human becomes a "Thing" on the Internet which is a significant step. Wearable smart watches, glasses, t-shirts, sensors, etc., are being used for access control, location monitoring, activity and sports monitoring, emotion monitoring and sharing. In the health sector wearable sensors and smart adhesive monitoring patches are being used for identifying falls, respiratory monitoring and direct drug infusion. There is also work on wearable power systems, e.g., micro generators from movement and thermal generators as well as blood sugar driven fuel cells. There are many different types of device that already exist, but new ideas are being invented all of the time, e.g., self-tying shoes, so an ever-increasing range of devices is becoming available. The topics covered on the radar are shown below. For detailed information, please go to radar.

- Wearable IoT and Existing Products
    - Wearable IoT
    - Existing Wearable Devices
    - Hearables
    - Clothing and Fashion
    - Smart Materials
    - Identity
    - Virtual and Mixed reality
- Health and Fitness
    - Health
    - Fitness
- Interacting with the World
    - Deskless Workers
    - Nearables
    - Haptics
- Extension of the Individual
    - Personal Identity
    - Wearables as an Extension of the Individual
- Technical Challenges
    - Communication
    - Displays
    - Durability
    - Maintainability
    - Powering Devices
    - Privacy
    - Security

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Technologies to Combat COVID-19

Figure 20 Examples of Applications to Combat COVID-19

A major event in 2020 was the advent of the COVID-19 pandemic. In response to this, a section was added to the radar in 2020 on technologies that could be important. At the time, there was a shortage of ventilators across Europe and in response the radar highlighted a license-free design for a CPAP breathing device. Other technologies which were highlighted were 3D printing which was extensively used to manufacture various components for ventilators and personal protection equipment. This was also used to fill shortages within the manufacturing supply chain in several areas. The section also includes information on contact monitoring sensors which helped workers to socially distance as they went back to work. A key issue with the lockdown was loneliness for the elderly which has a big impact on mental health. Here easy to use technologies targeted at staying in touch with the elderly were highlighted. The topics covered on the radar are shown below. For detailed information, please go to radar.

- Continuous Positive Airway Pressure (CPAP) Breathing Device
- 3D-Printing of Medical Equipment
- Ventilators
- Staying in Touch with the Elderly
- Contact Tracing

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Food and Beverage

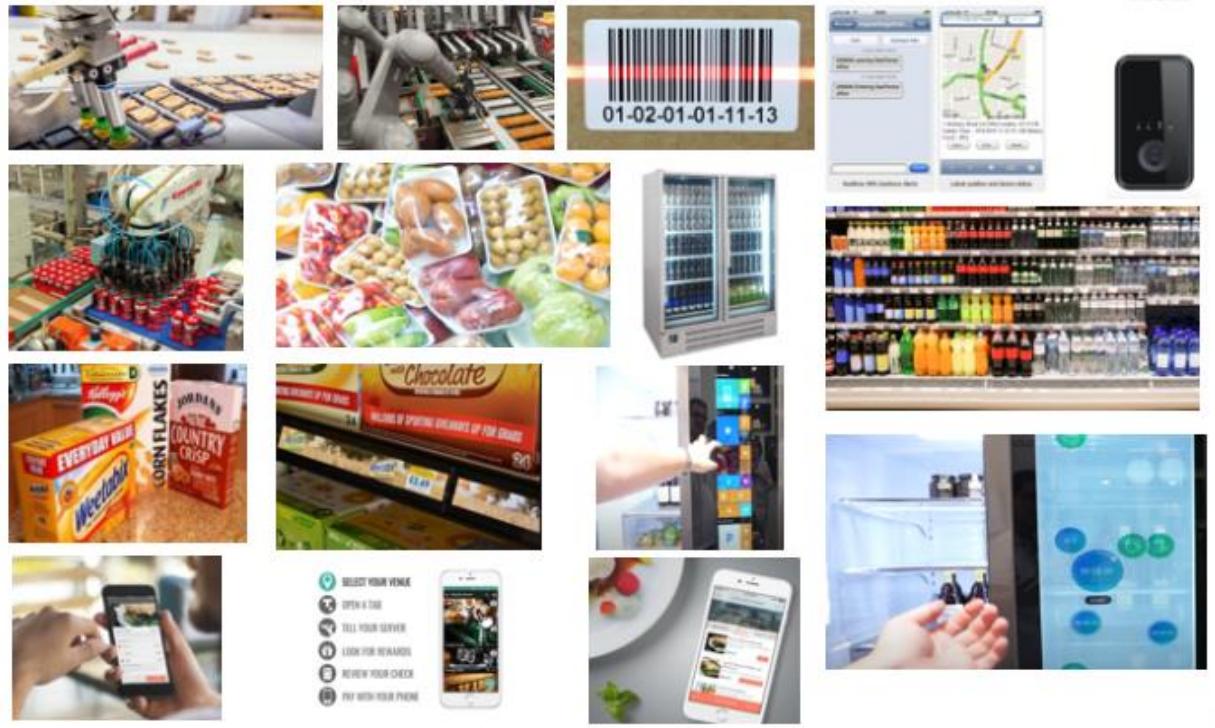

Figure 21 Examples of Applications in Food and Beverage Sector

The food industry grows year on year and there is a constant drive to reduce costs and increase production which must be done while maintaining the quality of the product. Automation has thus become a key factor in the processing and packaging of food. This includes automated ovens, cutting and forming machines, sortation equipment, mixers and blending machines, filling equipment and wrapping equipment. Traditional jobs, e.g., workers sitting alongside a conveyor picking, sorting and packaging food items, or operators monitoring processes are disappearing in many production lines being replaced by robots which can work in cold and hot environments without suffering from repetitive strain. Also, importantly robots do not make mistakes or contaminate products leading to more consistent quality. This reduces costly product recalls which are a major concern in the industry.

There is a revolution going on in food packaging to become more sustainable, reducing the use of plastic and cardboard, and with better tracking of freshness and hence quality. In shops there are also new more efficient refrigeration technologies saving significant energy and novel advertising approaches using flexible display technologies on shelving and refrigeration cabinets.

With the advent of COVID-19, the so-called “shut-in” economy has forced many traditional bricks and mortar businesses, to move to online systems. This requires businesses to create digital storefronts to attract consumers, connect with delivery services and provide a means to purchase and receive their products with minimal human contact. This is a market that has expanded greatly over the past year. During the pandemic there has been an explosion in online ordering and delivery services from restaurants via service companies such as Deliveroo and Just-Eat. This is requiring restaurants and other food providers to use online tools to deal with ordering and paying for goods. These need to be secure and integrate with delivery services. Restaurants are using Apps to extend their business to sell breakfasts, lunches and dinners in advance with pre-paid orders and tips. This is convenient for customers as they have access to the menus in advance and can order online. For restaurants it means

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that they can make sales before their guests enter the door. Most importantly, due to reduced capacity within restaurants due to social distancing rules, they can increase table turnover as guests spend less time ordering and paying. Restaurant employees can accept and confirm orders quickly with tablets or phones just by checking incoming messages. The topics covered on the radar are shown below. For detailed information, please go to radar.

- Food Production
  - Automation
  - Lot Tracking in Production
  - Traceability Through to the Customer
- Food Packaging
  - Bottling
  - Plastic Packaging
  - Cardboard Packaging
  - Tracking in Packaging
- Food Shops
  - Refrigeration
  - Logistics
  - Advertising on Shelving
  - Advertising on Refrigeration Cabinets
- Restaurants
  - Pre-Order Menu
  - Point of Sale Payment
- Food Delivery
  - Online

Art, Entertainment, Music and Literature

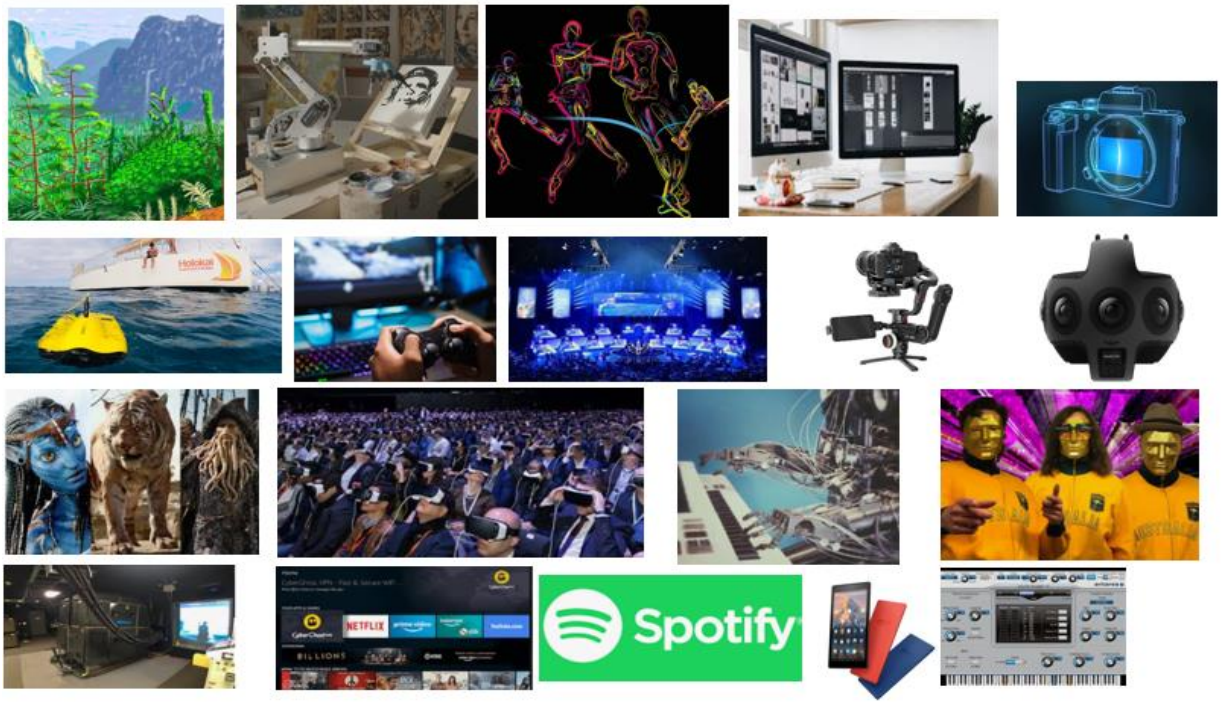

Figure 22 Examples of Applications in Art, Entertainment, Music and Literature

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The Creative and Cultural Industries covers a vast area, including art, entertainment, literature and music. This is an area that has seen rapid online expansion and importance with the advent of COVID-19 and national lockdowns. The area is also being revolutionised by new technologies. There have been a number of disruptive changes in terms of products, online and mobile channels of distribution, experimental business models, social media, data analytics, etc., which present challenges to existing market players. New players are offering solutions for aggregating and distributing content (free subscriptions, micro-payments, premium services, etc.). There are also a number of technological intermediaries such as Google, Amazon, Apple, etc. who dominate distribution. The industry covers a number of different areas.

Graphic Design and Art - In graphic design the use of digital tools has increased workflow for many designers replacing many hours with pencils arranging compositions. The development of high-performance multi-core computing platforms has revolutionised graphic design and a GPU (graphics processor unit) is essential when working with high-quality images Increasingly for advertising designers need to have an online presence, on Facebook, Twitter, a blog or a portfolio site. The improved processing power and memory in smaller devices like tablets is leading to them also being used by painters, e.g., David Hockney, and Artificial Intelligence is changing the nature of creative processes. The computer is already being used to assist an artist or automatically create in the new area of "Computational Creativity". This is also being linked with robotic painting systems.

Photography - Digital photography has rapidly taken over from traditional film photography as the photos can be seen straight away and the cost/delays of developing film are removed. The size of cameras has also reduced, making it possible for many more people to capture events easily on their phones. Photos can be captured anywhere and anytime, be sent to another person with text messages, shared online in emails and saved onto USBs and memory cards. Capturing images digitally also allows them to be edited to improve them. One key area that has changed through digital technology is journalism. It is possible to post things immediately which allows a journalist to be first to break a story and release photos and articles immediately as a story unfolds. This has also led to the need for more rules and laws in order to keep photojournalism accurate and impartial to deal with "fake news". The advent of social media means that stories can be shared internationally instantly giving them a global presence. Most innovations are being made in cameras for mobile phones in terms of higher resolution, anti-shake, and the use of AI for identifying faces and correcting optical issues. However, there are also advances being made in 360^0 cameras, stabilisation, illumination, lenses and camera drones.

Film Industry - In the film industry a number of high-tech companies have emerged. This includes production companies, service providers and visual effects companies. This has been driven by rapid developments in camera and recording equipment as well as digital video and editing tools, e.g., trimming and splicing tools, image manipulation, layering, blending, filtering, adding sound, titles, credits and introducing transitions. Computer Generated Imagery or CGI is now extensively used in the film industry particularly in action movies and Sci-Fi movies. There is also an increased use of motion capture to record the movement of people for insertion into CGI characters. Although 3D cinema has not taken off, there is active work on Glasses-Free-3D and the first-ever VR-only cinema opened in Amsterdam in 2016. Users are also demanding new interactions and cinema-goers can also be provided with offers, trivia and information via their mobile phones. The industry is being transformed by new intermediaries (e.g., Ymagis, Akamai, UFO Movies, Netflix, etc.) who provide digital content to theatres and to online distributors. Some of these have also become content producers, e.g., Netflix and Amazon.

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Video Games - The video games industry is a "born-digital creative industry" and is distinguished by its interactive dimension. It is a significant global industry driven by technology which is expected to reach $180.1 Bn in 2021 and 59% of this will be mobile gaming. There are a range of different business models and many disruptive new entrants. There are strong links with the digital technology industries (equipment, operating systems) and developments are linked with the Internet, mobile technology and social media applications. To make games more realistic, there has been a growth in the use of 3D modelling software to create interactive worlds with controllable elements and lighting. The video games industry is also exploring interaction with its customers through various means via communities, data mining for compiling viewers' recommendations and expanding into other media.

Music Industry - In the music industry there has been a move to streaming via the Internet via virtual stores such as iTunes and Spotify. This has created a revolution in business models and has disrupted the whole economy of the industry. This is not only for the distribution of music but also in the production of new music (artists are now posting their material directly online). Artists earn their money from performances and related rights rather than from royalties. To deal with this trend, record companies offer a portfolio of services, from recordings to live performances, merchandising and the rights for online services, radio plays, use of the music in films, games and TV series, the so-called "360 degrees deals" with artists. Consumers' habits are also changing and people prefer to create their own playlists rather than buying albums. Another change has been to the style of music itself. If a song does not catch the consumer within a few seconds it is unlikely to be played. Thus, songwriters are writing their songs for this new generation of consumer. New tools are making it easier to produce music, e.g., autotuning and rule-based AI can be used to generate melody and harmony. It is now also being used to generate music completely, e.g., the AI Song Contest.

Newspaper Industry - The newspaper industry is adapting to the digital revolution and competition from new forms of information production that disrupt the flow of revenues they were getting from readership, directly or indirectly (advertising). ICT has introduced layout tools and electronic correction, offset and typesetting. There has been increasing decentralisation with outsourcing of writing, printing and distribution, and the sale of advertising space. There are also different monetisation approaches, such as providing the paper for free and relying on advertising. Online editions are also replacing newsprint copy removing the cost of distribution and storage to almost zero. However, with online editions the update of information is continuous with the need for procedures, proofreading and verification by content editors. The use of blogs has also grown in importance with many papers providing liveblogging, video and data journalism.

Book Publishing - The book publishing sector has seen the creation of digital libraries, publishing-related community blogs, social media and social networking sites are emerging as key tools for attracting new clients and fostering the diffusion of e-books. Specialised technological companies (that provide e-readers, tablets, etc.) are emerging and supporting publishers in the production of content. Collaborative e-book distribution platforms created by consortia of major publishers have also appeared.

The topics covered on the radar are shown below. For detailed information, please go to radar.

- Introduction
- Graphic Design and Painting
    - Graphic Design
    - Painting
    - AI for Painting
    - Robotic Painting

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- Photography
    - Introduction
    - 360° Cameras
    - Illumination
    - Camera Stabilisation
    - Curved Image Sensors
    - Camera Drones
    - Underwater Drone Photography
- Cinema and Moving Pictures
    - Introduction
    - Animation
    - 3D Graphics and CGI
    - Glasses-Free-3D
    - 4D cinema
    - VR Cinema
    - Laser Projection
    - Changing the Cinema Experience
    - Film Distribution
- Video Games
- Music Industry
    - Introduction
    - AI in Music
        - Introduction
        - Autotuning
        - Composing Music
        - Automatic Harmonisation
        - Composition
        - AI Song Contest
        - Synthesising Expressive Music
        - Improvising Music
    - Music Distribution - iTunes and Spotify
- Literature
    - Newspapers
    - Books
    - Kindle
    - AI for Literature
- Barriers and Issues
    - Ownership and Exclusivity
    - Sharing Art
    - Piracy
    - Investment

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Publicising the Radar and Gathering Feedback

It would not have been possible to create the radar without feedback from the community. Inputs have been sought from many stakeholders, including SMEs, Mid-caps, large industry, research organisations and the EC. This has led to many enhancements to the radar both in terms of content and also presentation. Gathering feedback is only possible if the radar is publicised, so there has been a strong effort placed on “getting the radar seen” by key stakeholders. At the same time easy to use feedback mechanisms have also been developed to encourage stakeholders to contribute to the radar.

5.4 Built-In Feedback

Before engaging on a strong promotional campaign for the radar, it was decided to build in a range of easy-to-use feedback mechanisms into the radar itself.

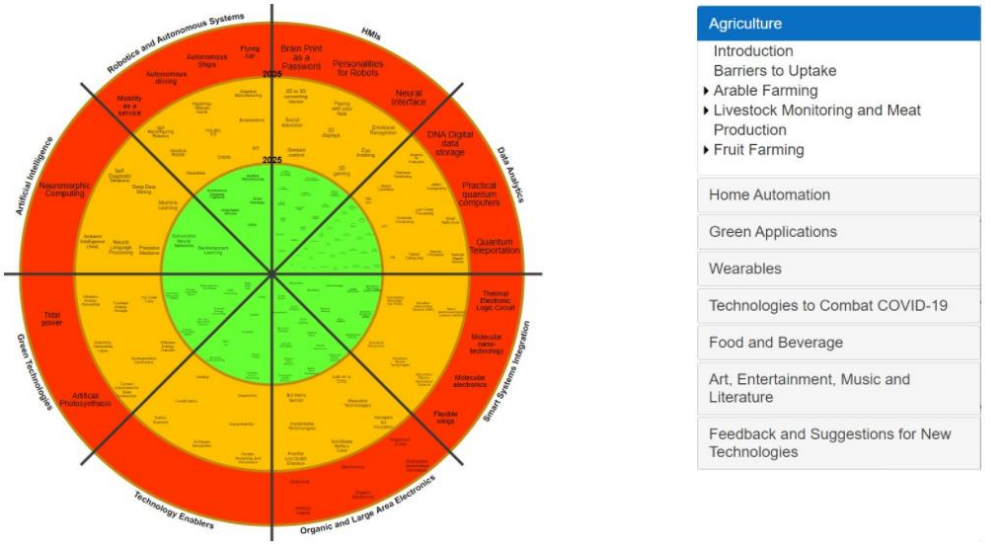

Figure 23 Smart4Europe Technology and Innovation Radar Top Level

At the top level as the radar is displayed the user is presented with a tab on the Applications Accordion to provide Feedback and Suggestions for New Technologies.

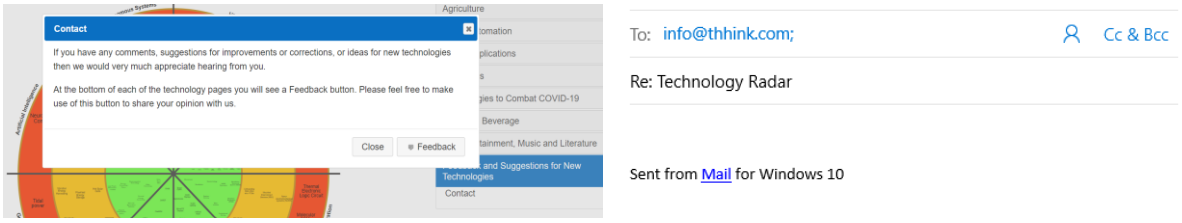

Figure 24 Feedback Tab on Accordion and Auto-generated Email

Clicking on the feedback tab automatically opens up an email with the general heading Technology Radar to be sent to THHINK. However, going beyond this, it was realised that it would be beneficial to provide the opportunity to provide feedback on every technology accessed as a user is most likely to be inspired to provide feedback while looking at a given page.

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Figure 25 Feedback Tab on Individual Technology Window

A key advantage of doing this is that it is possible to capture a user's thoughts immediately on a given technology. If the feedback button is clicked on a technology window an email is automatically set up with the technology being commented on as the title of the email's header. This makes it easier for the user but also provides a clear categorisation of the feedback for THHINK.

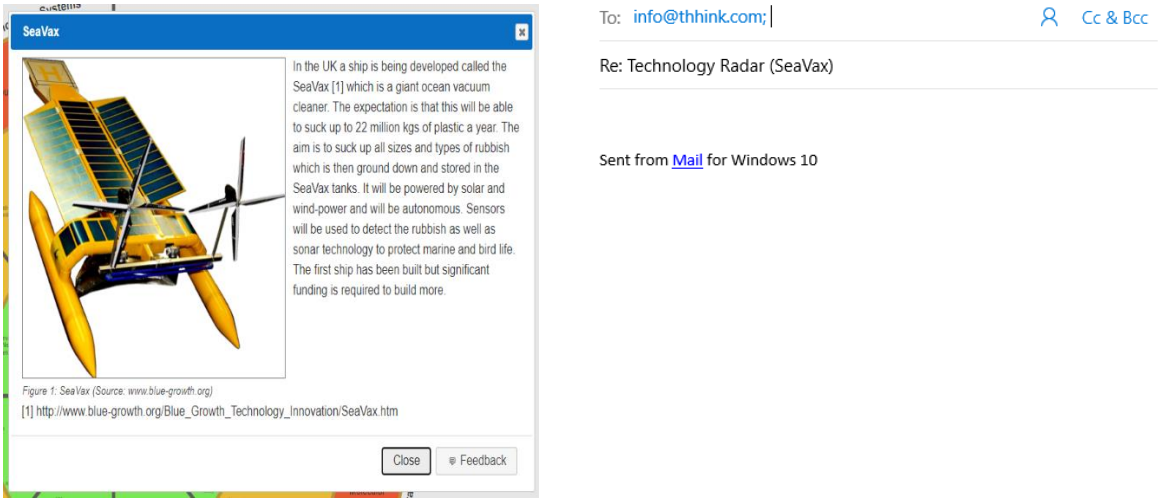

Figure 26 Feedback within Applications

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Likewise on all the applications highlighted in the accordion feedback buttons have been provided that automatically generate an email with the heading of the application being commented upon being included.

5.5 Technology Radar Working Group

In order to support the promotion of the radar and to gather new input for the radar, a Technology Radar Working Group was set up in September 2020. This was promoted amongst the Innovation Actions as well as externally to other interested parties.

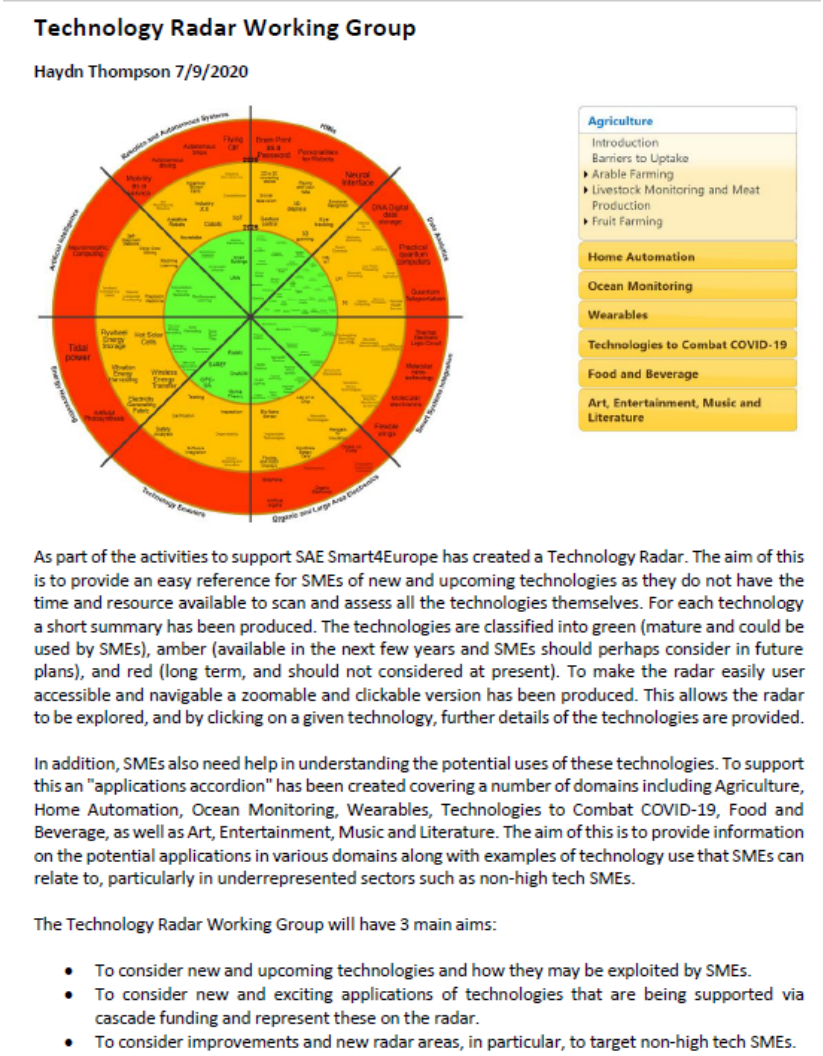

Figure 27 Feedback within Applications

People were invited to contribute to the Working Group via meetings held in conjunction with Collaboration Meetings and at other events. This was also promoted outside of the Innovation Action and DIH communities to other actors from industry as well as people/organisations with roles in promoting technologies such as sensing at a national level. The group has attracted input from representatives of the IAs, VDI/VDE, AVL-LIST, Sensor Associations and Academics.

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5.6 Workshops

SAE Cluster Collaboration Meeting (October 2020)

Smart4Europe organises regular Collaboration Meetings between the various Innovation Actions that are funded under SAE. As part of its Autumn Collaboration Meeting, the Smart4Europe CSA held a Working Group Workshop on the Technology Radar. In particular, this considered new and upcoming technologies and how they may be exploited by SMEs as well as new and exciting applications of technologies. An overview of the aims and objectives of the radar and its current status was first presented. Improvements and new radar areas were then solicited, in particular, to target non-high-tech SMEs. At this workshop the online MURAL tool was used to provide two-way communication with participants to gather input on technologies and potential applications. Mentimeter was also used to gather feedback on the demographics of the audience, on new non-technical applications of technologies, and further inputs to extend the technology radar. Feedback on how useful the workshop had been for participants was also solicited.

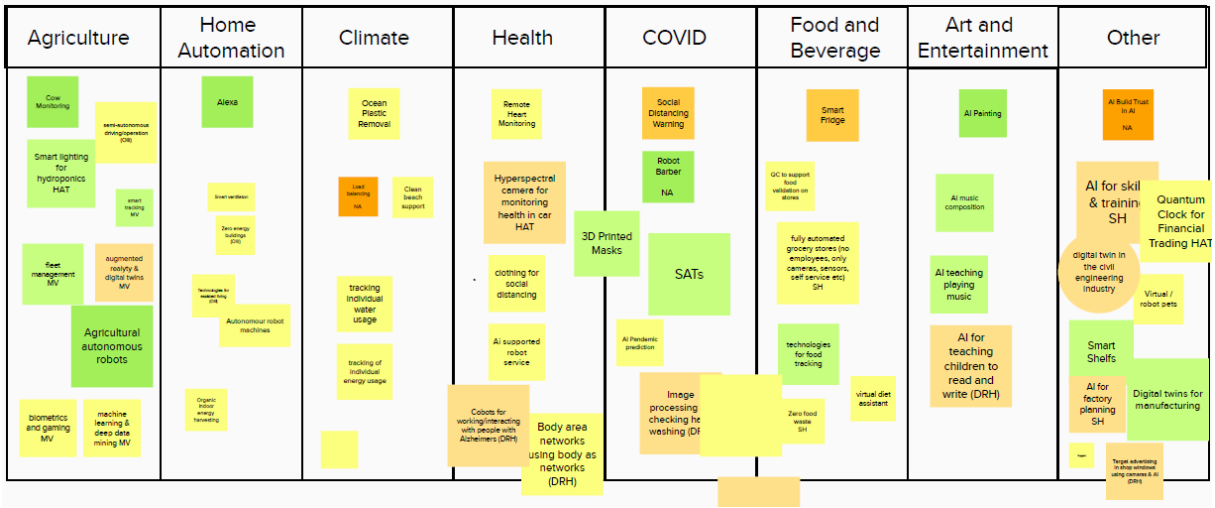

Figure 28 Technologies and Applications Highlighted

In total, the MURAL interactive session identified 52 technologies and applications. Some of these already existed on the radar, but there were some new and interesting ideas that lead to additions. The 16 workshop participants included a mix of RTOs, academia, SMEs and also policy actors. A poll was held of the technologies of most importance. AI and Virtual Reality featured strongly, with sensors, low energy manufacturing, recycling, HPC and security via blockchain being identified as important. New important topics relevant to SAE were thought to be gamification, wearables, humans in the loop, sovereignty and resilience.

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Figure 29 Non-Tech Applications Highlighted

Mentimeter was used to collect interesting examples of non-tech technologies. Notably, the use of AI in art and entertainment was highlighted by the audience which supports the inclusion of the section on Art, Entertainment, Music and Literature in the accordion. Tourism and construction were also highlighted as interesting topics leading to these also being considered for future inclusion. Here THHINK has initiated some work looking into the areas. In the construction industry, there are activities in robotics for construction, deployment of sensors for pile driving, etc., and also 3D printed buildings. This also links to building energy management with extensive modelling of buildings before construction to efficiently heat and ventilate buildings. Tourism is a major industry across Europe and has been badly affected by the current COVID-19 pandemic. There are opportunities here to link with European efforts under Recovery Funds and THHINK has been exploring how technologies can help the industry via connection with DIHBAI-TUR which is the Digital Innovation Hub for the Balearic Islands.

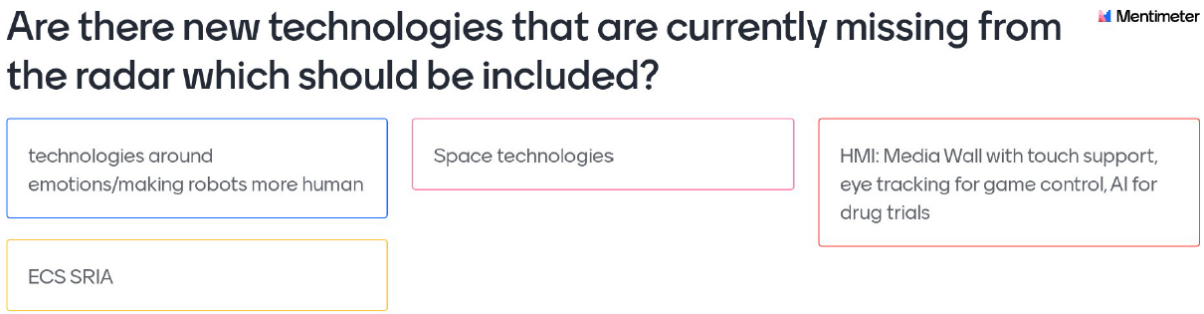

Figure 30 Technologies and Applications Highlighted

Other technologies that were highlighted included emotions for robots, new HMIs as well as coverage of space technologies. THHINK has been actively attending events in the Digital HMI field, e.g. Integrated Systems Europe in the Netherlands, which has led to content being added to the radar. THHINK has also attended meetings on research into emotions for robots and the topic of emotional recognition has been added to the radar. The area of space technologies is an area that is more challenging for SMEs and Mid-caps to engage in. THHINK as a company, is working on nascent Swarm Satellite technology which opens up the opportunity for IoT connectivity anywhere on Earth and has attended several meetings on Space Weather monitoring. Information is thus being gathered and this may lead to a new section on the Applications Accordion covering Space in future. The ECS SRIA was also highlighted as a source of ideas for technologies. Notably, the author is closely linked with ECSEL and has been actively involved in the formation of the KDT. At the same time he also contributes as an

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Expert to writing the ECSEL SRIA. The radar has been highlighted to Bert de Colvenaer, the Executive Director of ECSEL, and there are synergies with many topics covered by ARTEMIS-IA, AENEAS and EPoSS actors within ECSEL.

Figure 31 Technologies and Applications Highlighted

Participants in the workshop were asked if there are other sources of information that could be used as input for the radar. THHINK had already looked at other sources such as the IEC Radar and reports from the 5E project. The IEC Radar is notable as it is non-domain specific and was highlighted by a member of the Technology Radar Working Group who worked on it. It was created by VDI/VDE Innovation and Technik GmbH in 2012/2013 for IEC covering a number of emerging technologies at the time but provided no descriptions of the individual technologies or maturity assessment for them. It thus provided a collection of interesting titles for technologies but lacked detail. Unfortunately, this radar was also paper-based and was never maintained, leading to it disappearing from IECs website around 2015. This highlights the importance of creating an online radar that can be easily maintained and in providing something that goes beyond a technology title. The PlatformsCPS and Road2CPS projects were also highlighted as sources of information by the workshop participants and interestingly the author was involved in generation of both of these roadmaps.

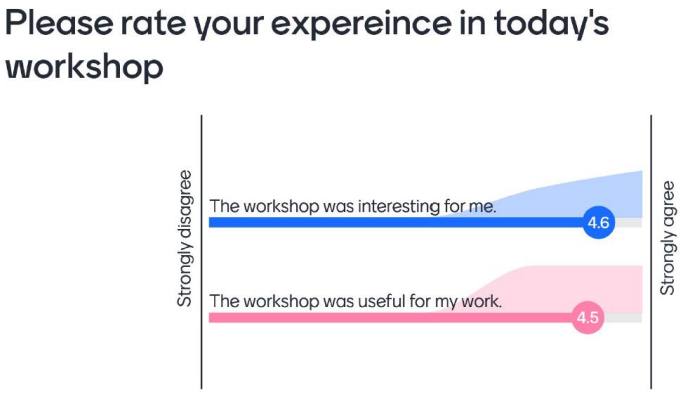

Figure 32 Technologies and Applications Highlighted

A matter of key importance for running the workshop was that the participants found the event stimulating and got an opportunity to engage with the radar. It was also important that participants found the radar and outcomes from the discussions on the radar useful for their work. In both respects, high approval ratings were obtained. This gave confirmation that the format and content of the workshop was appropriate and should be maintained in future workshops.

EFECS 2020 (November 2020)

A second workshop was organised for EFECS 2020. The format of the workshop was kept similar to the previous workshop that had received good feedback, however, due to time restrictions, less time was

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allocated to the workshop compressing some activities. Taking into account the recommendations of the reviewers following the interim review, a specific theme of this interactive workshop was the twinning of "green and digital" technologies which is being promoted through Horizon Europe and the Green Deal.

The MURAL tool was used once again to interact with the participants in order to collect feedback on technologies and applications, while Mentimeter was used to collect feedback on the origin of the audience (type of organisation), and further inputs to extend the technology radar. Participants were also asked for feedback on the workshop itself.

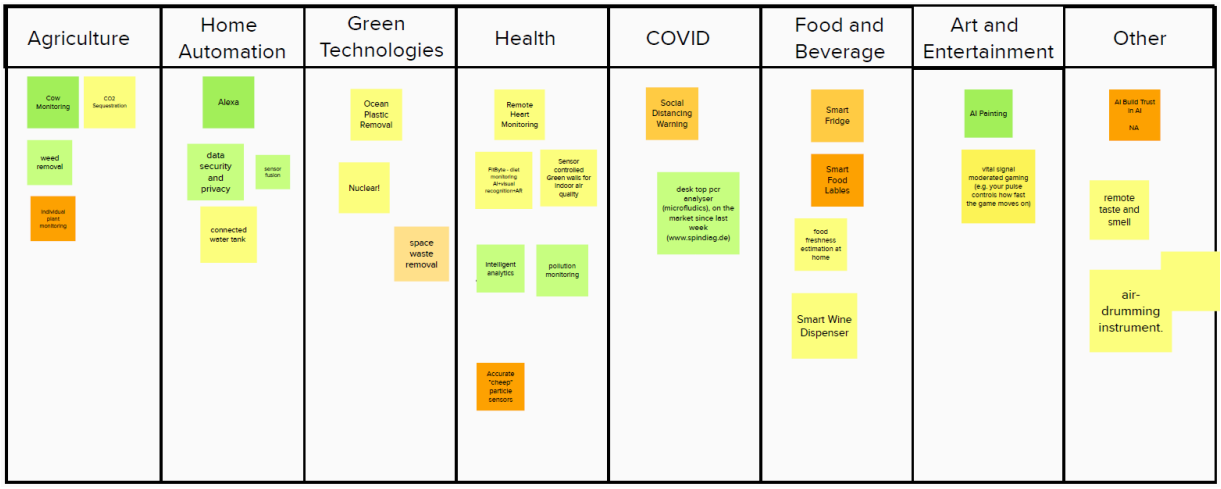

Figure 33 Collecting input via MURAL

Many green opportunities were identified, such as sensor fusion for home energy automation, indoor green walls, monitoring smart freshness of food and beverages, sensors for plant monitoring, weed stamping approaches for smart agriculture as well as CO_2 sequestration. Technologies for health and well-being also featured with novel already available technologies for diet monitoring and Covid-19 desktop analysers being highlighted. Notably, many of the technologies/ideas identified are already on the radar or are covered in the accordion sections on Home Automation, Wearables, Agriculture and Food and Beverages. This was pleasing to see as it highlights that the radar has good coverage of technologies that the ECSEL community considers to be green opportunities. The workshop also led to some additions to the radar, for instance, the area of CO_2 sequestration was added to the material on Smart Energy and Low Carbon Technologies and some additions are still being considered, e.g., space waste removal for a future Space section.

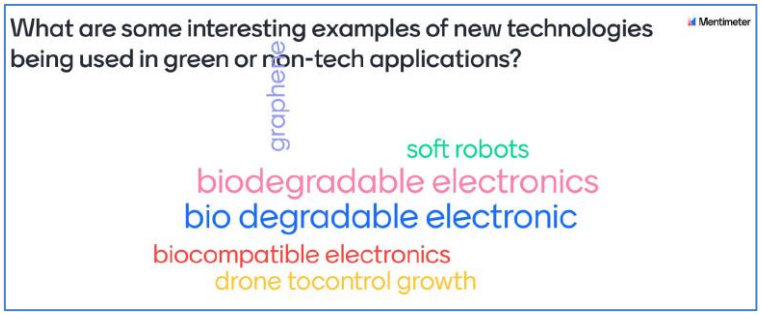

Figure 34 Green Technologies

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Mentimeter was also used to collect information on new green technologies and this led to an update of the radar to include a new section in the *Sustainable Manufacturing of Electronics Goods* accordion section on biodegradable and biocompatible electronics. Although graphene was already covered as a technology on the radar, more information on the potential applications of graphene was also added to the accordion as clearly, this will be important for the future.

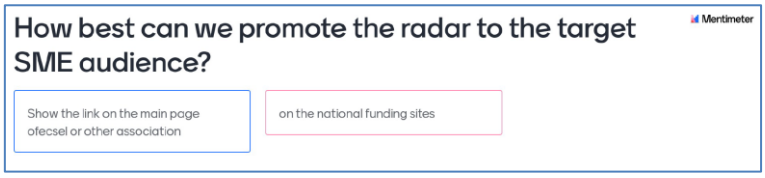
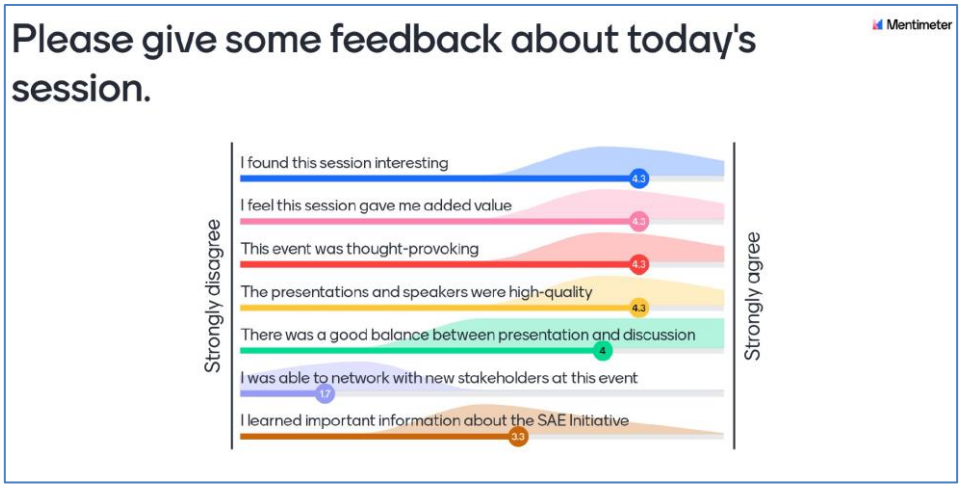


Figure 35 Green Technologies

Feedback on the best way to promote the radar highlighted that providing a link to the radar from the ECSEL website and from national funding websites would be a good idea. This is being explored with the Dutch national site for SMEs KVM, as well as SME organisations in France, Spain and Germany. The idea of linking to the ECSEL website has also been raised.



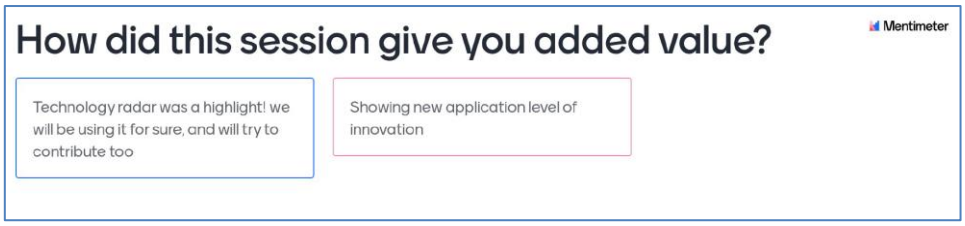


Figure 36 Feedback collected on the EFECS workshop

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Following the feedback collected from the 1st Workshop, it was decided to collect more detailed feedback from this event. Notably, the feedback on the format and usefulness of the workshop to participants was again highly ranked with good feedback but with finer granularity highlighting that the event was *thought-provoking* and *added value*. This indicates that it had some impact on the participants. There was also agreement that the format of the event was balanced in terms of presentation and discussion. Networking and presenting the SAE initiative was not the objective of the workshop and indeed they were not specifically presented. This is unsurprisingly reflected in the lower scores for these criteria. Specific feedback on the added value highlighted the usefulness of the radar, "Technology radar was a highlight! We will be using it for sure." Interestingly, when considering how to improve the workshop there was some feedback that more time was needed (this was a known constraint when organising the event) and was not a surprise. It also indicated that there was sufficient interest from the participants for a longer meeting highlighting that they were engaged and wished for more.

A Vimeo recording of the EFECS workshop is available on the Innovation Portal https://smartanythingeverywhere.eu/events/efecs-2020/

5.7 Analytics

A key advantage of placing the radar online is that it can be instrumented using Google Analytics to collect data on its usage. The radar is hosted by THHINK and all accesses to the radar and where they are from are logged by the company.

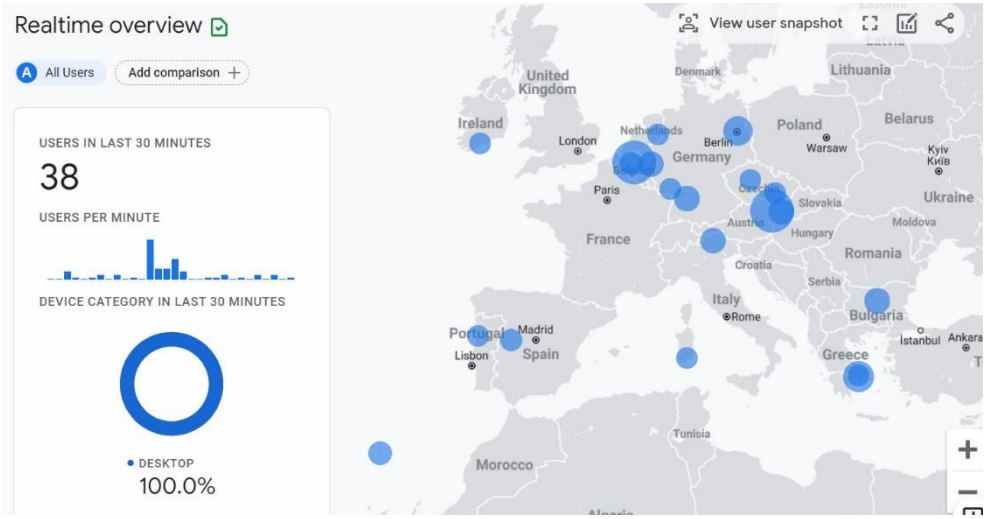

Figure 37 Real-time Snapshot of Radar Accesses During Conference

The monitoring provides a daily update of accesses, long term trends, as well as real-time feedback on the immediate access profile. This real-time feedback was found to be useful to see the immediate impact of publicising a link to the radar along with where these radar accesses were coming from. Something interesting observed was that after an initial burst of activity lasting between 30 minutes to an hour following an event, there were still additional accesses to the radar in the evening with new users accessing the radar. This would suggest that participants forward the radar link to other people they know who then access the radar, so-called network effects. This indicates that the radar is seen as useful and something worth highlighting to the community.

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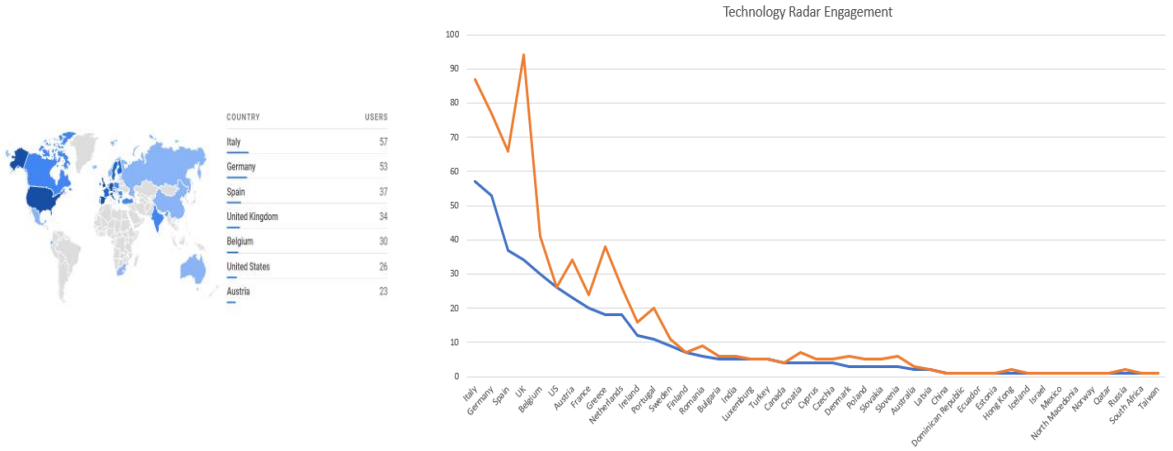

Figure 38 Demographics of Radar Access

Analysis of the demographics of engagement indicates that there is most engagement with Italy, Germany, Spain, United Kingdom, Belgium, USA, Austria, France, Greece and the Netherlands. Notably, in Figure 38, the blue line shows the engagement in terms of users accessing the radar while the orange line shows the number of technologies/applications viewed. This shows that some users are looking at multiple pages. It is also notable that the spread of engagement is wide, including the Eastern European countries as well as views from China, Dominican Republic, Ecuador, Estonia, Hong Kong, Iceland, Israel, Mexico, North Macedonia, Norway, Qatar, Russia, South Africa and Taiwan. At the time of writing, there have been 703 views of the radar.

5.8 LinkedIn

There are a number of online platforms that could be used to promote the radar such as Facebook, Twitter and LinkedIn. Experience shows that Facebook is perhaps not the most appropriate platform to promote technology-oriented developments such as the radar. Although there are specific groups on aspects of machine learning and Big Data, these tend to act as a forum for discussion between software developers. Twitter has been found to be most effective when linked to an event. The radar has been highlighted via Twitter by Smart4Europe in conjunction with events, but it is clear that in the promotional activities it is necessary to engage with a much wider and diverse set of actors.

In the first instance, a post was put out via THHINK to direct LinkedIn contacts. This covers a lot of links covering SMEs, large industry, government and the European Commission. This advertised the radar across a wide spectrum of actors.

Figure 39 LinkedIn Feedback

This resulted in 938 reads of the post and 18 likes, including from the European Commission. It is also possible to retrieve some information on the demographics of who looked at the post. A snapshot of this is shown in Figure 40.

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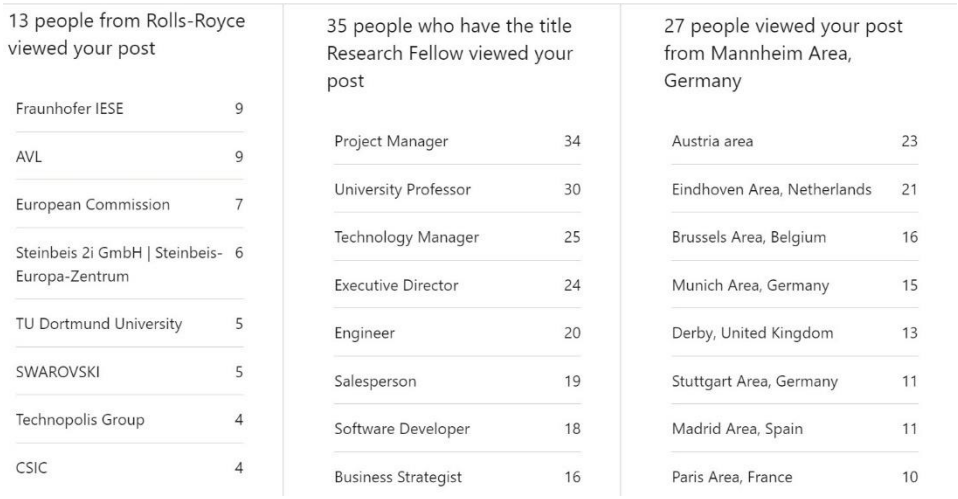

Figure 40 Snapshot of LinkedIn Reads

This highlighted interest from both large companies, e.g., Rolls-Royce and AVL, but also from research organisations and technology organisations. As SMEs and Mid-caps tend to have fewer people one would expect only one or two views from an organisation. Something that gives an indication of SME and Mid-cap engagement is the number of Directors and Technology Managers that read the post. There also was quite a lot of interest from Professors and Research Fellows covering the academic sector as well as Salespeople and Business Strategists. The interest from the Netherlands was expected, but it was surprising to see interest from Austria which is partly attributable to AVL and also Derby which is the HQ of Rolls-Royce.

The post led to many people going on to look at the radar with nearly 100 accesses.

As a result of this it was decided to investigate placing posts on a number of specific LinkedIn groups which were thought to be relevant. These were:

- **Future Technology: Artificial Intelligence, Robotics, IoT, Blockchain, Bitcoin | Startups (BIG)** 158,615 members
- **Agriculture** 157,873 members
- **FOOD & BEVERAGE NETWORK** 68,639 members
- **Semiconductor Professional's Group** 102,965 members
- **Artificial Intelligence and Business Analytics (AIBA) Group** 255,631 members
- **Horizon 2020, Framework Programme for Research and Innovation Group** 139,509 members
  "H2020 SME / COSME" Competitiveness of SMEs, Small Business, Growth & Innovation 10,072 members
- **Medical Device Guru** 57,878 members

The response however was much lower with far fewer reads of the posts (an issue here is that when there are many members the posts are very transitory and thus disappear very quickly from the feed in a mass of other posts). The result in terms of reads was thus that there were very few reads of the posts. However, the posts did result in some people looking at the radar and providing feedback. Of interest here was gathering feedback from different communities.

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Andrey Osykin Engineer

"Great tool! I found it useful for getting a quick look of technologies that are outside my competence. I think, to look from the outside at technologies in different areas is especially useful for specialists in narrow fields for searching new ideas or adapting ideas of other disciplines for their own. It is an impressive work!"

Figure 41 LinkedIn Feedback from Semiconductor Professionals Group

An example of this feedback from a member of the Semiconductor Professionals Group is shown in Figure 41.

5.9 Promotion at Events

A more direct approach to promote the radar across different communities was also employed. This targeted participation in events, either specific to domains (e.g., Smart Agriculture), technologies (e.g., AI) or with SME/Mid-cap targets (e.g., DIH events).

Examples of this are:

- ATI Workshop Smart Agriculture, 4th December 2020 (40 attendees 12 looked at radar – 30%)
- ICT AGRI Workshop, 10th December 2020 (80 attendees 36 looked at radar – 45%)
- ATI Workshop on Monitoring Digital Transformation – The Role of AI in Industrial Modernisation, 15th January 2021 (161 attendees 37 looked at radar – 23%)
- 1st Annual EDIH Conference 26-27th January 2021 (1495 attendees 153 looked at the radar - 10%)

As can be seen, the effectiveness of this approach was monitored using Google Analytics. It should be noted that typical conversion rates published by the marketing industry from dissemination activities are shown below:

- Direct Mail 2-5%
- Website Pop-Ups 3-5%
- Direct Email 5-10%

Thus, a conversion rate of 23-45% is very good and highlights the effectiveness of this approach. This, however, needs to be traded off against the time and effort engaged in participating in the events. Notably, THHINK has taken the opportunity, where it can, to promote the radar in events that it is attending as a matter of course.

Something that can be seen is that sector-specific dissemination resulted in better conversion to radar accesses, i.e., interest primarily generated by the applications accordion. Promotion at larger events, although giving greater visibility to a wider potential audience, resulted in a lower percentage uptake as the relevance of the radar across all actors varies and the "noise" of competing initiatives diluted the impact of the dissemination. The messages from this are that higher effectiveness is achieved disseminating to targeted communities in larger meetings.

6 Maintaining the Radar and Sustainability

THHINK is committed to maintaining the radar and to make this more streamlined, effort has been put into developing maintenance tools. The first of these tools is an App that parses through the radar to check for broken links and usage of formatting that does not work well with html. This has been used successfully to update the radar from February 2021.

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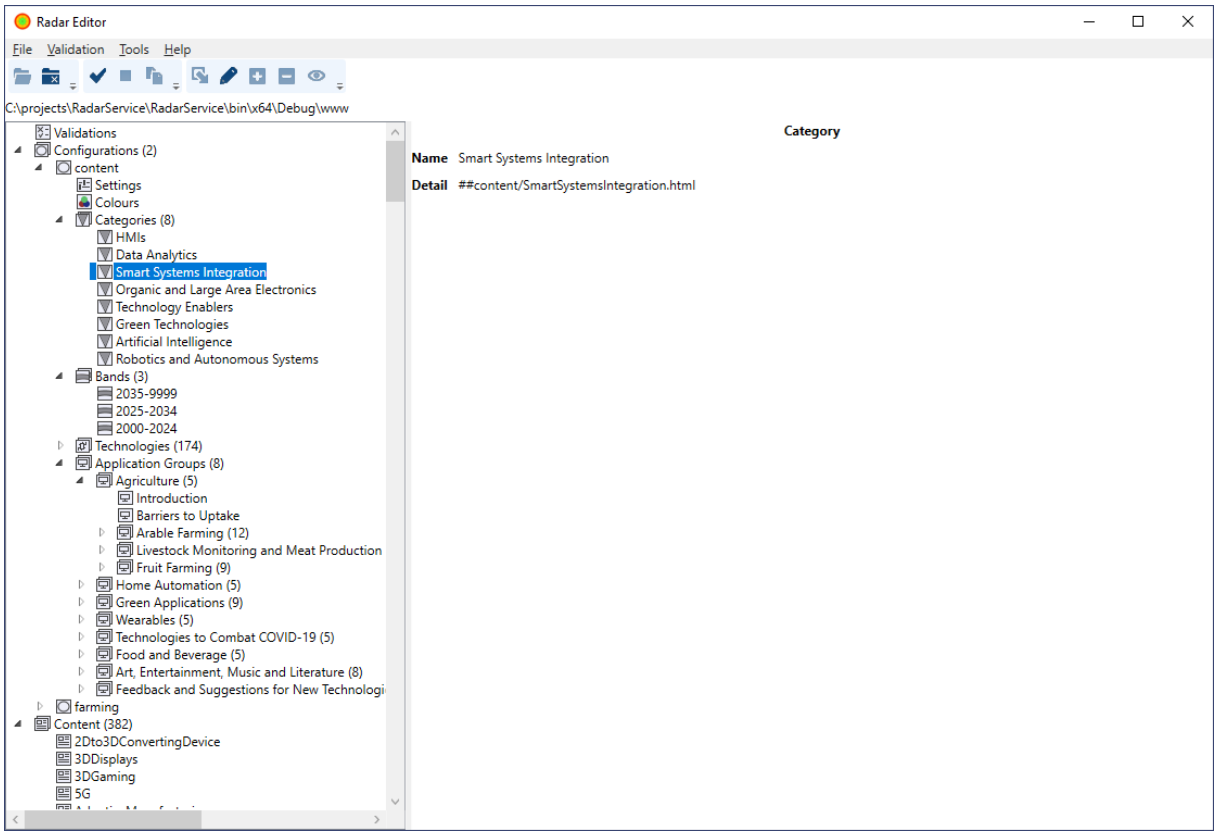

Figure 42 Radar Editor Tool

An initial Radar Editor Windows application has also been created that allows a user, who is not an HTML expert, to edit the content of the radar and perform various validations of the content. It also offers the ability to preview the radar before publishing the content. The editor allows the user to edit existing content, add new content or remove old content. The current functionality of the Beta version of the editor allows:

- Opening the folder of the radar from the application, visualising the content in a tree-like hierarchy and then selecting content to see more detail.
- Validation of some aspects of the content against rules (in code) that allows checking of content (have titles been added to images, do the images have sizes, do the images and content files mentioned exist, etc.).
- Adding a new configuration. To ask the site to display a completely different set of content. The editor allows you to add the new configuration for this or delete an old one.
- Preview the radar within the app. This allows the user to see if the edits are what they wanted before publishing the changed content to the web.
- Editing the Settings and Colours used. This allows some customisation of aspects of the radars “look and feel”.
- Editing the title and detail popup of the categories (wedges).
- Editing the bands of the wedge (e.g., the year ranges and the colour).
- Editing the content for the popups (categories and technologies in the radar and accordion). This shows the result of editing the HTML directly so the user can immediately see the change.
- A partial system of help is built in to provide some guidance as to how to use the system.

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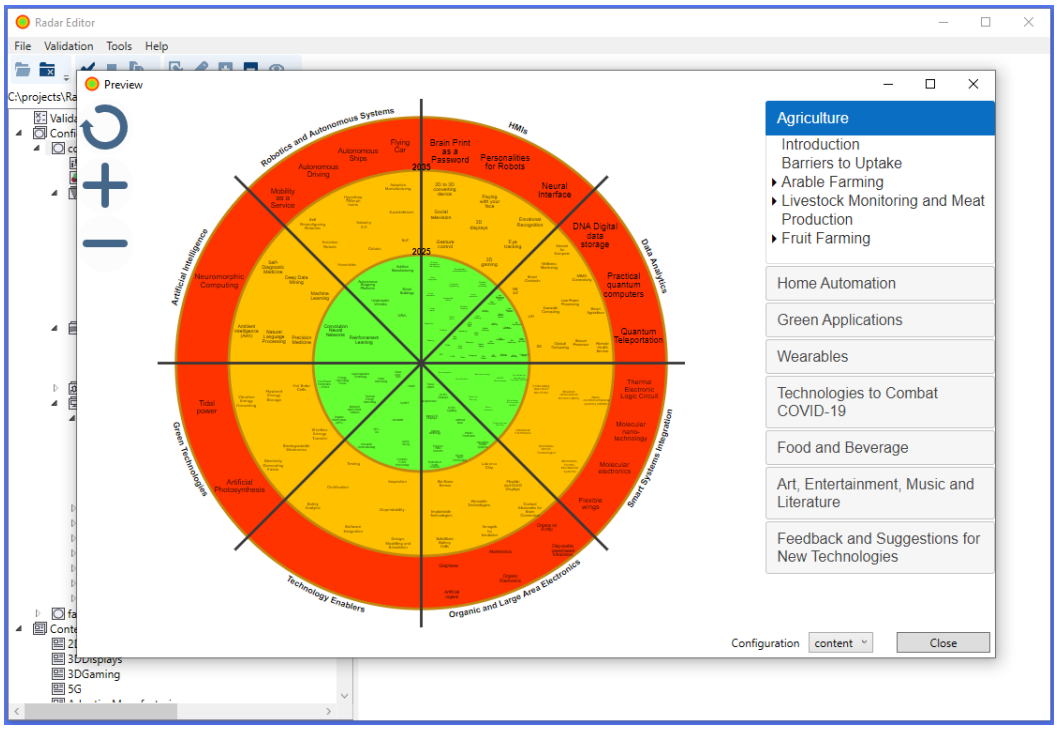

Figure 43 Radar Editor Tool

As highlighted the editor is still being created and a number of additions are under development. These include

- Editing the technologies in the radar.
- Editing the accordion content to add the different steps and contents.
- Tools for managing images, e.g., adding to content, re-scaling of images to avoid large images being used in order to avoid dynamic scaling which slows down the Internet connection and the browser.
- The ability to add new content based on a template.
- Add more information to the help system and add this to each of the forms that are used for editing so that the user can get contextual help.

7 Conclusions

The aim of the Smart4Europe Technology and Innovation Radar is to provide a useful reference for SMEs, Mid-caps and Large Industrials in the SAE community to highlight new up and coming technologies that may be of interest. The radar has evolved with input from desk research, questionnaires, interactive workshops and feedback from the community. The new online "live" radar is easy for stakeholders to access and navigate. This has also opened up opportunities to more easily collect analytics on the use of the radar, feedback on the usefulness of the radar, and ideas for additional technologies and improvements. To enable this, the radar has been instrumented with feedback buttons on every open window which enables THHINK to gather technology/application-specific feedback. This has proved invaluable leading to many enhancements.

There is a continuing effort on identifying new technologies and innovative areas to add to the radar to make it even more useful for the SAE community and this has grown to around 200 technologies whose maturities have been banded into red, amber and green so that they can be easily understood by SMEs, Mid-caps and large industry. Additional information is also being added for each of these technologies on Technical Challenges, Commercial Barriers and Green Opportunities, and currently

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half of the radar has been updated. There have also been changes to the categories on the radar and notably, there has been a "greening" of the radar over the last 2 years.

Discussions with SMEs and Mid-caps identified that they struggled to understand how the new technologies could be used and so there is a need to provide more information than just on the technologies themselves. To address this, an Applications Accordion has been created giving an overview of application domains covering examples, opportunities and barriers to commercialisation. This covers topics that are priorities of the new Horizon Europe and Digital Europe programs, the Green Deal, areas that have come to prominence during the COVID-19 pandemic, as well as sectors and applications highlighted via workshop feedback. This includes Smart Agriculture, Home Automation, Wearables, Sustainable Manufacturing of Electronic Goods, Intelligent Energy and Low Carbon Technologies, Ocean Monitoring, Food and Beverage, Art, Entertainment, Music and Literature and Technologies to Combat COVID-19. Notably, the Applications Accordion section of the radar has become a Unique Selling Point and differentiator for the radar. It is the most visited area as users tend to identify with the application sectors first and foremost.

The radar has been promoted via a number of different communication channels. LinkedIn and direct promotion at technology-specific and sector-specific events (e.g., Smart Agriculture, Ocean Monitoring, Entertainment), technologies (e.g., AI) or with SME and Mid-cap targets (e.g., DIH events) have proved to be the most effective according to metrics and feedback gathered. The stakeholder engagement has been wide going beyond SMEs and Mid-caps, to large well-known companies and also other stakeholders, such as national government and EC policymakers. The reaction to the radar is very positive and this has also been reflected in the workshops run on the radar. Currently, there have been 703 views of the radar predominantly within Europe, but also with worldwide coverage.

Looking to the future, the radar is "live" and thus continually improves with more content. To help in this process, maintenance tools are being developed to allow a non-html expert user to edit existing content, add new content, remove old content, and preview the radar before the content is published. These tools are already helping THHINK sustain the radar as part of commitments to build on and maintain the radar.

Finally, a key outcome of WP4 is to provide a clearer picture of future opportunities and make strategic recommendations for the SAE Initiative within the new Digital Europe Program. As part of this the gathering of the radar data and creation of the applications accordion provide a strategic resource and insights into where future opportunities lie (particularly with the emphasis on green opportunities) within the twin green and digital transformation.

8 General References

[1] https://ec.europa.eu/research/innovation-union/index.cfm?pg=etp
[2] www.thoughtworks.com
[3] https://ec.europa.eu/info/horizon-europe_en
[4] https://digital-strategy.ec.europa.eu/en/activities/digital-programme
[5] https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1596443911913&uri=CELEX:52019DC0640#document2
[6] https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1588581905912&uri=CELEX:52020PC0080

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