SECTOR SKILLS STRATEGY
IN ADDITIVE MANUFACTURING

Report on the Analysis and Validation of Needs

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Full Version

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1. Executive summary

Implementing Additive Manufacturing (AM)/3D printing requires preparing the coming workers and reskilling the current workforce in order to successfully adopt these technologies. In this sense, it is needed to better anticipate the current and future AM skills needs at manufacturing workplaces in Europe.

During SAM project data collection and feedback phase, the gathered skills' gaps and shortages were framed according to different scenarios:

- Scenario 1: Real case, in which extent skills need to be addressed in less than 6 months.
- Scenario 2: Short-term, how relevant skills / trends need to be addressed in the less than 2 years.
- Scenario 3: Foresight scenarios, how relevant skills / trends need be addressed in the future, within the next 10 years.

The current report constitutes the **baseline to identify skills gaps and demands** of the **AM** Sector **for the real case and short-term scenarios**. It is the first out of four Reports on the Analysis and Validation of Needs, which correspond to the 1st round of auscultation with key target groups, namely Companies, and Research and Technology Development Organisations (RTOs)

The report addresses the priorities in terms of AM skills development using a combination of methods to collect data from industrial organisations and RTO experts operating in different industrial sectors. Moreover, the document addressed the technology trends needed to be considered until 2025. The validated data will be used as reference to support the European AM Skills Strategy and to revise existing training courses and develop new ones.

In a nutshell, the skills gaps and demands for each scenario revealed that:

Currents skills needs and gaps (Real Case Scenario, 2019)

AM Professional Profiles

Process Engineer, Designer and Materials Engineer

Business related profiles

Materials: Metals followed by Polymers

Technological Skills

Certification, Validation, Topology Optimisation, Design, Numerical modelling, Standards

Entrepreneurship, Digital and Green Skills

Costs, Resource Efficient Management/ Sustainability

Short term skills needs and gaps (Short - term Scenario, from 2020 to 2021)

AM Professional Profiles

Process Engineer, Designer and Materials engineer

Materials: Metals followed by polymers

Technological Skills

AM processes, Testing & Quality Control, Design, Pre-processing & Material Handling, Topology Optimization, Certification and Validation

Entrepreneurship, Digital and Green Skills

Resource Efficiency/Sustainability, Marketing and Sales

Technology Trends that will need to be considered in the near future (Foresight Scenario, from 2022 to 2025)

AM Professional Profiles

Designer, Process Engineer, Non- destructive testing and Inspection Technicians

Materials: Metals followed by polymers

Processes PBF and DED

Technological Skills

Numerical Modelling, Non-destructive Testing, Metallurgical analysis and characterization, Pre-processing & material handling; Data analytics Design, Materials and process development.

Entrepreneurship, Digital and Green Skills

Resource Efficiency/Sustainability

AM technology trends for R&D&I

Trends for 2020-2025

Real time control / monitoring systems, New materials, Zero-defects manufacturing

Upskilling / Reskilling Existing Professionals (independent analysis from the scenarios)

Consultants, Civil engineers, Mechanical engineers, Design Engineers, Inspection Technicians (NDT/DT Technicians, DT Technicians), Project Managers, Process Managers, RTD Professionals from different industries and what to change in industry, Software Personnel; Business developers; programmers.

AM Training / Education (Data collected from RTO that include training in their activity)

From the RTO relying to the surveys, the majority (67%) is involved in training activities. The training/education courses correspond mostly to internal courses followed by technological workshops (>1 day) and external training at customers' location.

Training courses mostly target AM Processes, followed by Design, Post-processing and Topology Optimization. Skills less addressed are linked to non-technological areas, namely Communication, Marketing and Sales, and Resource Efficiency / sustainability.

Four criteria were used to determine the priorities to tackle the above-mentioned skills needs and gaps, which were: sectors relevance in alignment with ISO activities, urgency, impact on employability and relevance towards raising awareness on AM.

The next steps in SAM project foresee to continue the identification of current needs with industrial organisations, educational centres and AM professionals/workers, in order to identify emergent AM skills gaps and needs. Also, the forecast analysis will be implemented with a smaller group of experts. In parallel, a set of activities will take place aiming to review and/or design new qualifications/professional profiles and units of learning outcomes.

2. Introduction

SAM project is a strategical approach to skills in AM, which is developing a dynamic forecast methodology focused on skills gaps, shortages and mismatches identification, anticipation and validation, in order to develop and / or revise qualifications and profiles in AM with the engagement of relevant stakeholders within the European and National landscapes.

The starting point of the forecast methodology addressed within SAM, consisted in a market research to determine skills mismatches and gaps in the AM sector by implementing a set of online surveys with representatives from industry / employers in AM and from research and technology centres.

In parallel, other complementary activities were conducted using forecast methods, enabling to discuss on future AM applications, challenges and solutions to tackle AM skills needs.

After collecting the data, their analysis was performed during an internal workshop / working session, thus defining the skills priorities and areas that needed further exploitation in the next stage of data collection through interviews.

Finally, the last step of this 1st round of auscultation, corresponding to the first year, of forecast methodology implementation, consisted in the validation of skills needs with external stakeholders during a dedicated workshop.

In this context, the current report, developed in the framework of the AM Observatory (Work package 4), is the baseline to define the next activities to be developed in the project. The report gathers the main findings and conclusions taken from the application of developed forecast tools (Work package 2).

In terms of structure, the report is organised in six sections, as follows:

- Section I - includes the description of the methodologies used to collect data as well as the results achieved with each tool (i.e. surveys, interviews, world cafe and workshop). The results from the surveys regarding AM Skills Needs and Technology Trends are presented separately, since these were covered by different surveys conducted with specific target participants, namely industry representatives and organisations involved in research and development/innovation activities.
- Section II - addresses the comparison between findings;
- Section III - includes the description of the validation process, conducted along a workshop with industrial experts;
- Section IV - addresses the conclusions achieved and reflection on the next steps, thus pointing out the priorities to follow in SAM to address skills, profiles and qualifications development.
- Section V - includes all annexes and supporting documents (i.e. agenda, attendance list, satisfaction; interview and surveys scripts, among others).

3. SECTION I - AM DATA COLLECTION AND ANALYSIS

3.1 Methodology to collect and analyze data

For AM data collection and analysis, surveys, interviews and internal workshops where carried out. The current chapter about the methodology describes in detail the conditions in which the tools were applied.

3.1.1 Surveys

The implementation of the surveys aiming at gathering data among the relevant stakeholders (see Figure 1). In this context, only online surveys were conducted, which were promoted through personal mails, included in newsletters and disseminated during specific events and networks, such as the the AM-Platform, CECIMO, EPMA, EWF, among others. Also, a QR code was created to facilitate the access via smartphone or another electronic device.

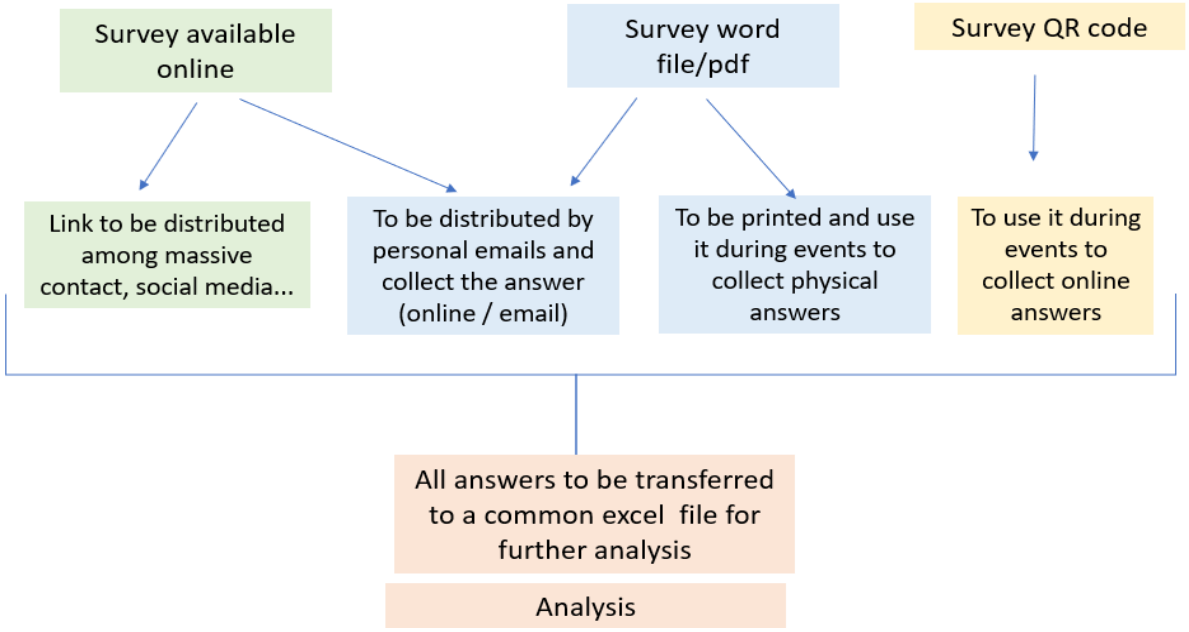

Figure 1 - Summary of surveys' implementation methodology

Two different types of surveys were carried out, which differ in terms of objectives and target groups, namely:

- **Industry Survey on AM Skills –** to find out **employers/industry** needs with regards to AM skills and identify current and possibly future gaps;
- **Survey on AM Skills and Technology Trends** – to find out **among Research and Technology Development (RTD's)** which new technologies are appearing, and consequently which skills will be required in the future.

The **survey on AM skills needs for industry** was available on Survey Monkey for a period of five months. Its structure followed a hierarchical approach, meaning the set of available questions would be adjusted depending on the answer given in the previous one. For instance, if the companies were already applying AM or planning it, then the participant would reply to the full set of questions, while if the participant was not using AM neither intended to use it in the future, the surveys would be automatically shortened. For this reason, the completion time would vary from five to 10 minutes maximum. The survey was structured into two sections: Section 1 aiming to gather general information enabling the characterization of the participants' background and section 2 aiming to identify the AM skills needs and profiles for the next six months and two years. A total of 27 questions

were addressed by the survey, ranging from checkboxes, dropdown questions, open questions and multiple choice questions.

The survey to Research/ Technology Centers was available in Survey Monkey for three months. As the previous survey, it was structured in a hierarchical way, where the available questions were adjustable depending on the answer to the previous questions, taking between eight to 10 minutes to be completed. Three sections where defined: section 1 aiming to gather general information enabling to characterize the participants' background, section 2 aiming to identify the AM technology trends in use, as well as the trends to be applied in two years and five years, section 3 aiming to identify AM profiles and knowledge required in the next two and five years. A total of 25 questions were addressed by the survey, ranging from checkboxes, dropdown questions, open questions and multiple choice questions.

After each period of survey implementation, data was collected and globally analyzed to enable a more detailed analysis during the working session, which is described in section 3.2.5.

3.1.2 Interviews

Interviews were conducted as complementary tools to the surveys, every time the results were not clear or were incomplete. In this sense, the interview was prepared with open questions on AM challenges and needs, some of them already addressed in the survey, and new ones to further explore results in order to help defining which Profiles, Qualifications and Competence Units would require development. Moreover, interviews were also conducted with respondents that didn´t reply to prior inquiry.

Interviews were conducted during three months, from December 2019 to February 2020, with representatives from industry. Interviewees were selected from representative's companies, according to the following criteria:

- At least a representative from each type of company (e.g. SME; Start up; Large company; industrial Association).
- All the sectors should be represented.
- Consider different types of AM related profiles.
- Variability in terms of countries and gender balance.

The estimated duration of the interview was from 30 minutes to one hour.

A common script was used to conduct the interviews (please refer to WP2 – D2.1 Survey and Interviews Kit) and to compile the results. Moreover, each interviewer was required to provide a summary of the main conclusions. All steps are illustrated in Figure 2.

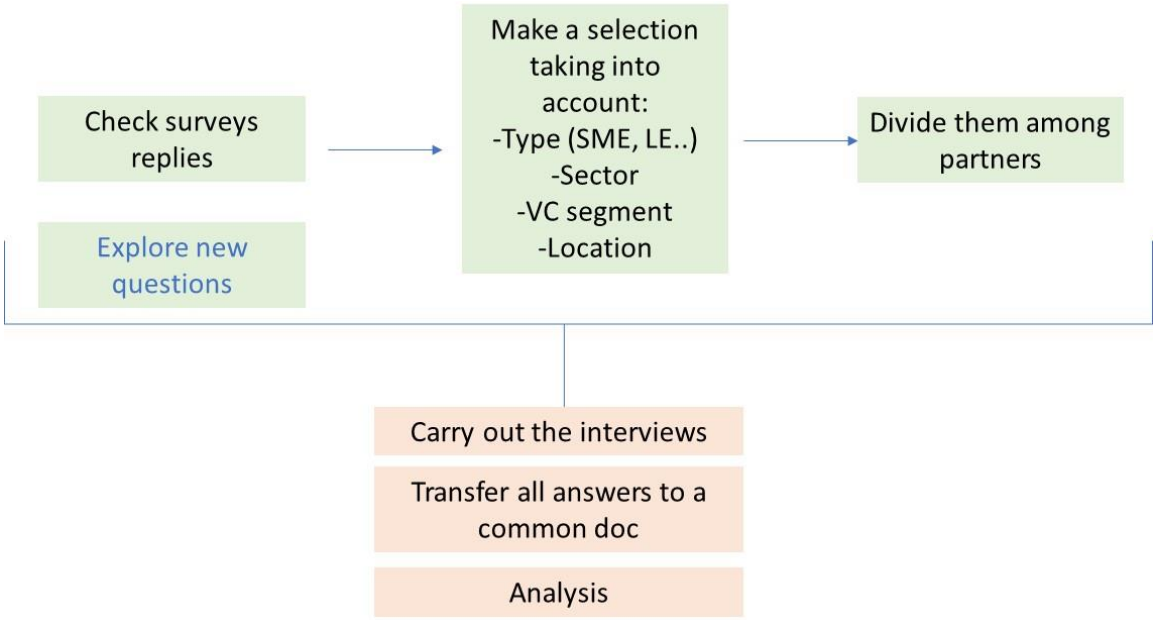

Figure 2 -Summary of interviews' implementation methodology

3.1.3 World Cafe

The world cafe activity took place during a workshop organized by EWF (4th AM Workshop) on the 28th October 2019 in Porto Salvo, Portugal. The objective of the activity was to discuss and collect data from industrial and VET experts, to support the identification of trends regarding AM application in terms of Materials, Processes and Sectors and overall challenges until 2025. Please refer to the attendance list in Annex 7.1 in the annex section.

Several steps and rules were followed to implement the world cafe, namely:

1) Setting*:* A "special" environment was created to put participants at ease.

2) Introduction*:* the dynamic and objectives of the activity were explained to participants. The world cafe supposed the composition of three groups that would circulate through three different sections to debate given topics. Each section had a "fixed" moderator that launched the theme and specific questions (see Table 1).

Table 1- Topics addressed during the world cafe

Section 1 – AM Materials	(Moderator: 1)
Objective: e.g. *Identify the materials to be used in the next 5 years and relating them with required AM skills.*	**Possible Questions** What harmonised qualifications will be need for AM with composites/plastics in the next 5 years? Which materials are typically not used, but will become in the next 5 years? What will be the challenges/opportunities in using the identified materials in AM? Which AM knowledge and Skills will be required?
Section 2 – AM Processes	(Moderator: 2)
Objective: e.g. *Identify the processes to be used in the next 5 years and relating them with required AM skills.*	**Possible Questions** What will be the most used processes within the next 5 years? What will be the expected use for Metal Binder Jetting? What will be the challenges/opportunities in using the identified processes in AM?

	Which AM knowledge and Skills will be required?
Section 3. Sectors	(Moderator: 3)
Objective: e.g. *Identify the sectors where AM will have major impact in the next 5 years. Relate the type of products produced with the required AM Knowledge and skills.*	**Possible Questions** Which sectors (Construction, Defense, Health, Automotive, Aerospace) will be more influenced by AM in the next 5 years? What products will be produced? Which Professional Profiles will be involved? New Harmonised profiles or Upskilled/reskilled workers? Which AM Knowledge and Skills will be required?

3) Small Group Rounds / Questions*:* A total of three rounds of 15 minutes each were conducted. In each round, new insights were given by participants regarding the given topics. Moderators explained the outcomes from previous rounds and launched complementary questions, if necessary, to generate new insights.

4) Wrap Up: Finally, the results were reflected visually in a flip chart and shared among all participants at the end of the activity.

3.1.4 Workshop for data analysis

The workshop for data analysis took place on the 11th December 2019 in Milan, Italy in the context of SAM 3rd project meeting. The objective of the workshop was to analyze and discuss the results coming from the surveys, in order to define the priorities in terms of skills gaps, professional profiles to be addressed in the next six months, two years and five years.

A specific agenda occupying a full morning was established to guide the working session implementation (see Table 2)

Table 2 -Agenda of the 1st Internal workshop to analyze data and validate priorities

9.00	**Welcome participants - Start of Day 2**		
09.15	**Workshop Validation of Needs & Define priorities (EWF)**		
09.20	Introduction to findings and data gathered in WP2 (IDONIAL)		
09.35	**Group 1** ** Partners TBD* Analyse and validate skills gaps	**Group 2** ** Partners TBD* Analyse and validate Professional Profiles and or/ Competence Units	**Group 3** ** Partners TBD* Validate technology trends and related skills
11.15	**Coffee Break** *(15 minutes)*		
11.30	**Discussion and Wrap up on the Definition of priorities linked to the 3 scenarios**		

The first part of the activity was conducted by EWF and consisted in a short introduction to the workshop aim, organisation and expected outcomes.

Then, IDONIAL, leader of WP 2 (Forecast methodology), provided an overview on the main findings.

The second part of the workshop was dedicated to group discussions. To facilitate the results analysis, three groups were set, with five partners each, which. All project partners participated in the activity - please refer to the workshop attendance list in Annex 7.2 in the annexes section.

Groups 1 and 2 tackled the results coming for the industry survey, thus performing the analysis and validation of skills gaps and professional profiles and defining the priorities for the different scenarios, meaning real case (less than 6 months), short term (less than 2 years) and foresight (within the next 10 years). On the other hand, group 3 tackled the results coming from the RTD surveys, thus interpreting the main findings and related skills.

Each group nominated a rapporteur responsible for presenting the conclusions about each subject.

Finally, the workshop ended with a wrap up and definition of the next steps regarding the development and review of Qualifications or competence units to be addressed within the next 6 months. A detailed description can be found in chapter 3.2.5.

3.2 Data on AM Skills Needs and Technology Trends - Surveys Results

The survey's results are described in this chapter, using as reference the main clusters: General information and background, AM technology trends and AM skills and professional profiles needs.

3.2.1 Findings on the surveys conducted with industry

The survey for industry was open from July to November 2019, gathering a total of 164 responses.

General information and background

In terms of general information and participants' background, one of the key variables was thein which type of company participants work. As can be observed in Figure 3, most of the answers come from Large Companies (40%) and followed by SME's (25%), which is in accordance to the initial objective of these surveys. Moreover, all types of companies are significantly represented in this survey.

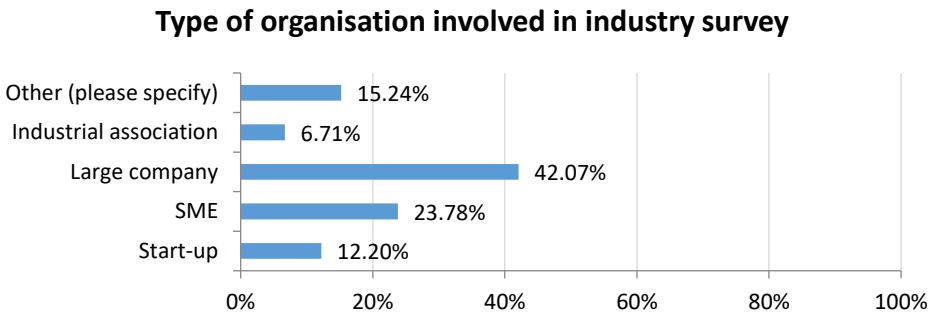

Figure 3 -Type of company represented by industrial participants

In terms of coverage, participants belong to industrial organisations from over 20 countries, being most represented countries Romania (15%), Spain (14%), Germany (12%), France (8%), United Kingdom (6%), Belgium and Italy (5% each).

Furthermore, the activity of the identified companies was mapped regarding the targeted sectors. This way, it is concluded that the most represented sectors are Industrial Equipment and Tooling (30%), followed by Aerospace (27%) and Automotive (24%). The graphic below (see Figure 4) illustrates the answers to this question on the survey.

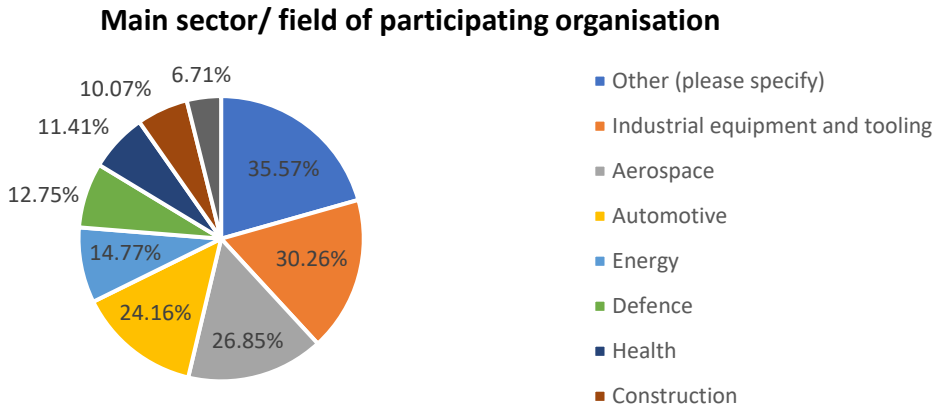

Figure 4 - Industrial Sector(s)/filed participants belong to

These values are not conclusive in terms of the most represented sectors on the generality of the AM market in Europe, because of the amount of answers and also because participants selected more than one option, as they are involved in several sectors simultaneously.
The highest percentage of responses (35%) was for "other" sectors, being the most mentioned ones: Software (4 responses), Powders (4 responses), Transportation (4 responses), Automation (2 responses) and all sectors (2 responses). Also mentioned once were: Electrical and precision Engineering; Mechanicals, Hydraulics; Welding, Siderurgy, Telecommunication, Naval, Consultancy, Education and Research.

Several other topics were addressed at an initial stage of the survey to map the profile of the participants. For instance, 78% of the participants mentioned to be currently (in 2019) using AM in their activity and 52% believe that their organisation is "Well prepared" to meet AM skills challenges, followed by 24% believing to be "Very Well Prepared" and 23% feeling "Less prepared". These results are linked to the profile of the participants, which represent fields of activity where the technology is applied, meaning that possibly the assessment of "self-preparation" is linked to the sector in which the company operates and will vary according to it.

Finally, the place in the supply chain where the entity is positioned was mapped. The results show that most of the companies are positioned on the R&D side (40%), followed by End-users (15%). The Figure 5 illustrates the answers obtained on this topic.

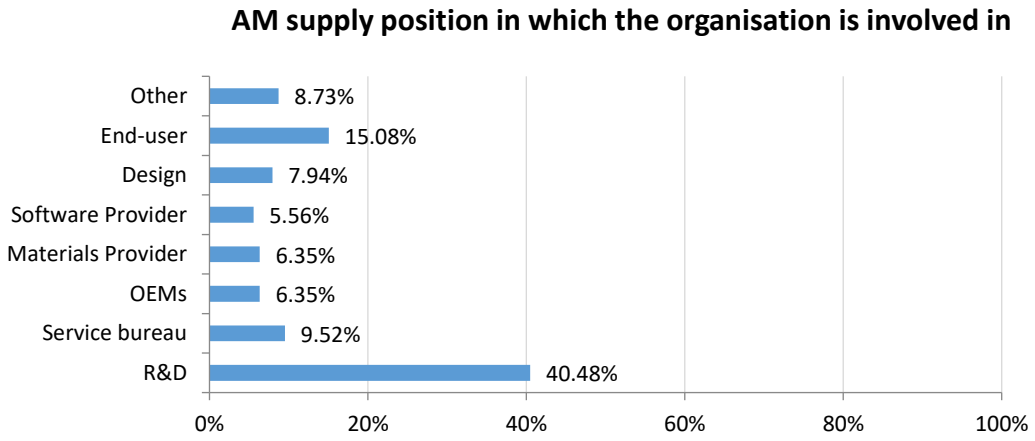

Figure 5 - Value Chain Segment's industrial participants are involved in

When questioned about the materials (see Figure 6) used by the companies that participated in the survey, participants mentioned metals as the predominant material (72%), followed by plastics which are becoming more relevant these days, with 62% of use, independently of the sector.

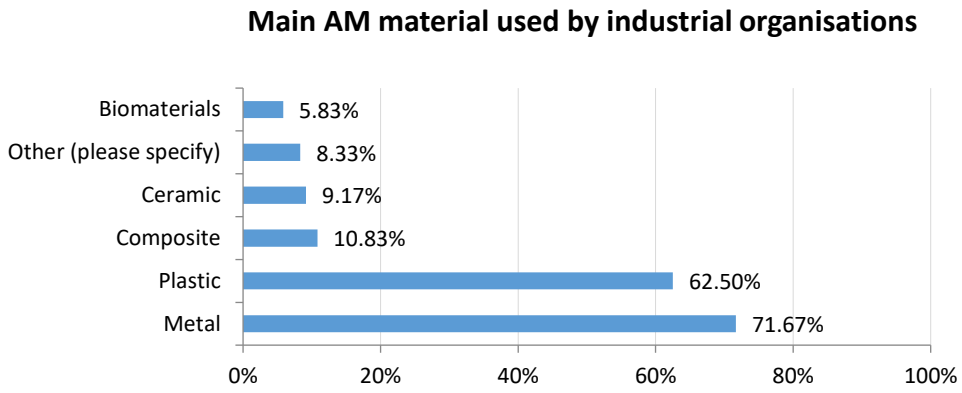

Figure 6 - Materials currently used by Industrial participants

When cross checking the company background and specific sector with the type of materials used, results confirmed the predominance of metals in all sectors, except for automotive where things are changing (see Figure 7 to Figure 9).

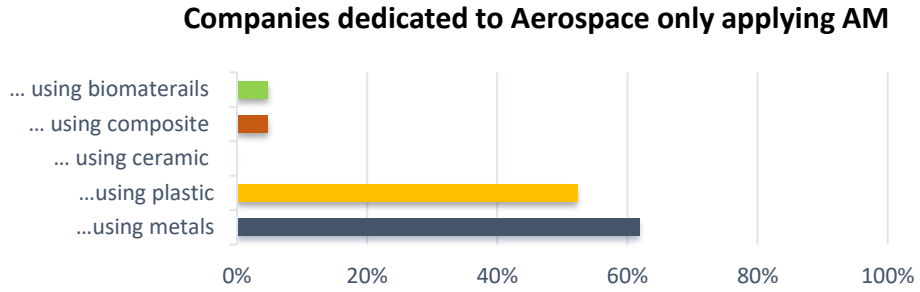

Figure 7 - Materials used within the Aerospace Sector only

In fact, it is observed (see Figure 7) that companies dedicated to the aerospace sector only, mainly use metal followed by plastics.

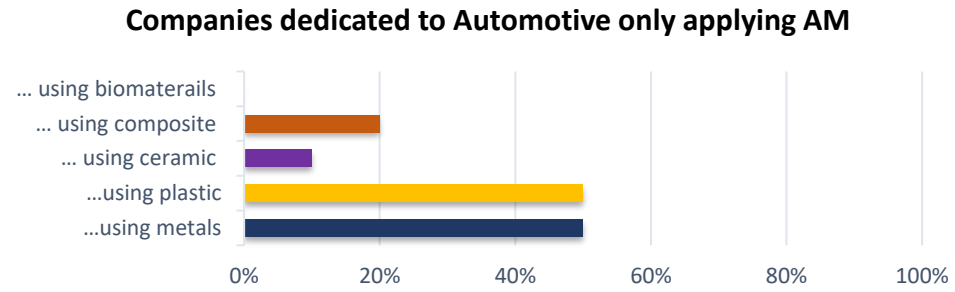

Figure 8 - Materials used within the Automotive Sector only

For companies dedicated to the automotive sector only, the market is divided between the use of plastics and the use of metals (50 - 50). Moreover, the use of ceramic and composites is way more representative on the Automotive sector than on the aerospace (see Figure 8).

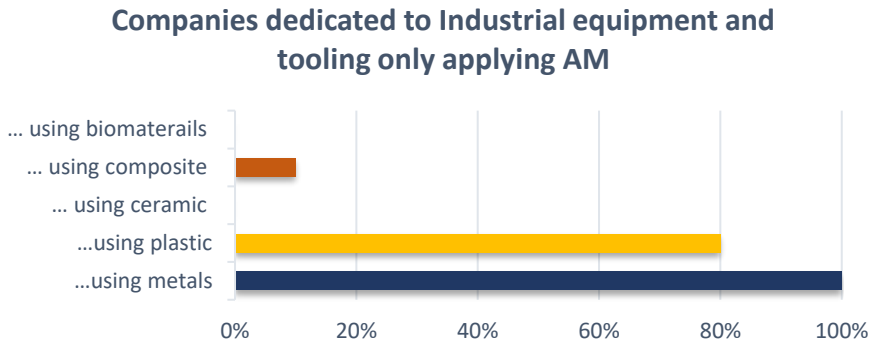

Figure 9 - Materials used within the Industrial Equipment and Tooling sector only

With regards to the Industrial Equipment and Tooling, there are no companies working with composite neither ceramic, being metals more relevant than plastic in this sector. Nevertheless, plastic still has a high representation in this sector (see Figure 9).

The above graphics sustain the understanding that plastic needs to be addressed in terms of skills development with almost as much relevance as the metals for the most representative industry sectors.

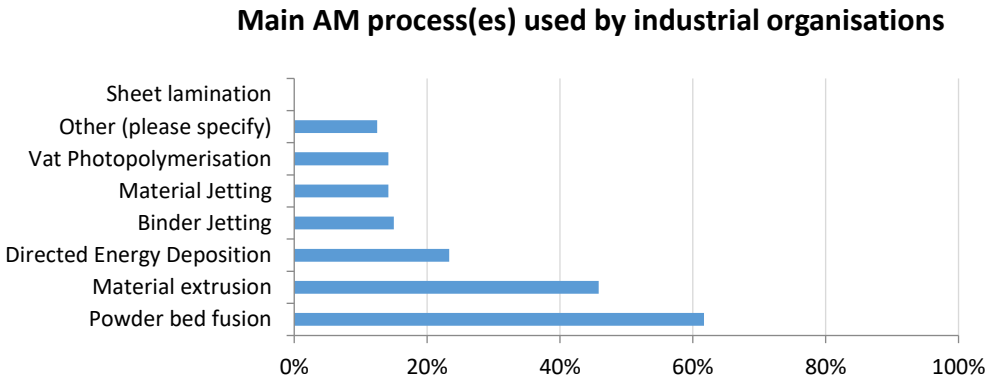

Figure 10 - AM Processes used by participants

When questioned about which AM process the participants' companies use (see Figure 10), most of them answered Powder Bed Fusion (62 %), followed by Material Extrusion (46%) and Direct Energy Deposition (23%), being the PBF and DED the most relevant processes' groups for Metal AM, and Material Extrusion the most relevant process group for plastics. Again, the relevance of plastics in the future of the AM skills market was highlighted.

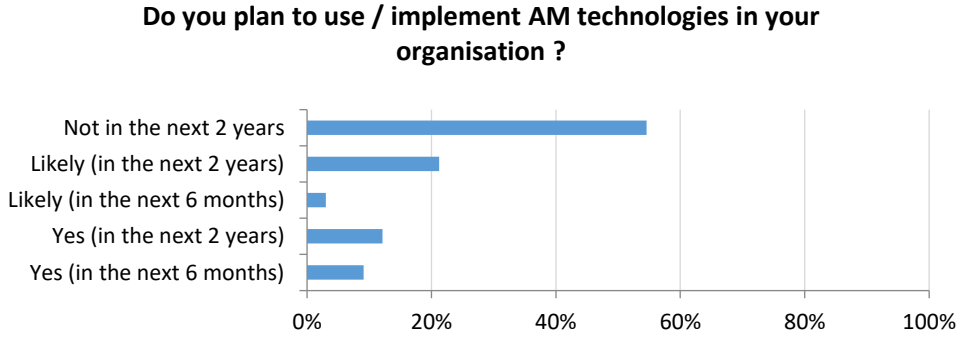

Figure 11 - Plans towards the Implementation of AM Technologies

This question targeted only companies that are not using AM at the moment, which correspond to 22% of the total number of answers. The answers to this question show that in the upcoming years, the needs of AM skilled personnel will evolve (see Figure 11). Even if there is still a large majority (54%) that does not consider that AM will be relevant for their organisation in the upcoming two years.

Skills and profiles' needs

On section two of the survey, participants were asked on specific questions directed to AM skills needs. The results are promising in terms of mapping skills needs, which will support the project development and direct it to new objectives.

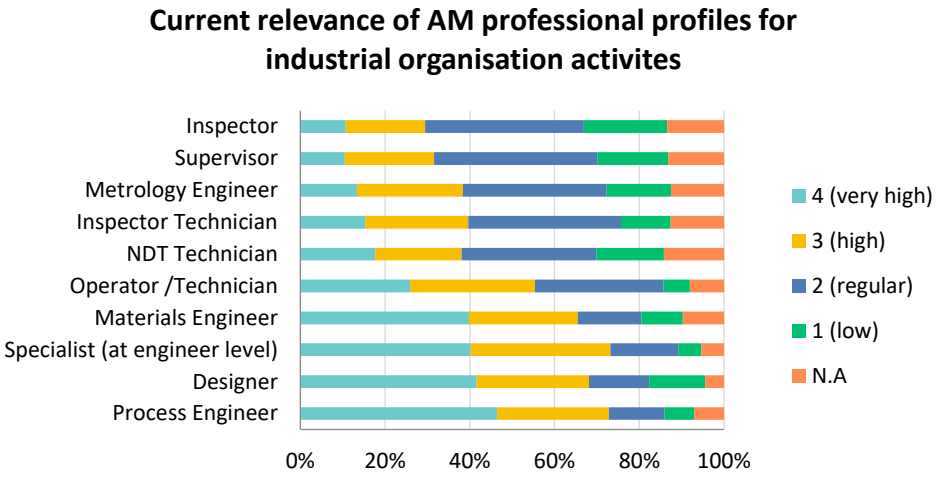

Figure 12 -AM Professional Profiles Relevance

The results obtained with this question are crucial in terms of mapping the current needs of the AM Professional Profiles (see Figure 12) . 111 of the respondents indicated that the profile most wanted in the market is the AM Process Engineer (48% of very high relevance), followed by the Designer profile (42% of very high relevance), the Specialist (41% of very high relevance) and the Materials Engineer (41% of very high relevance). Particular attention should be given to this last profile (i.e. Materials Engineer) when settling the new objectives of SAM project, as the remaining profiles are already being tackled by other EU funded projects, such as CLLAIM and ADMIRE.

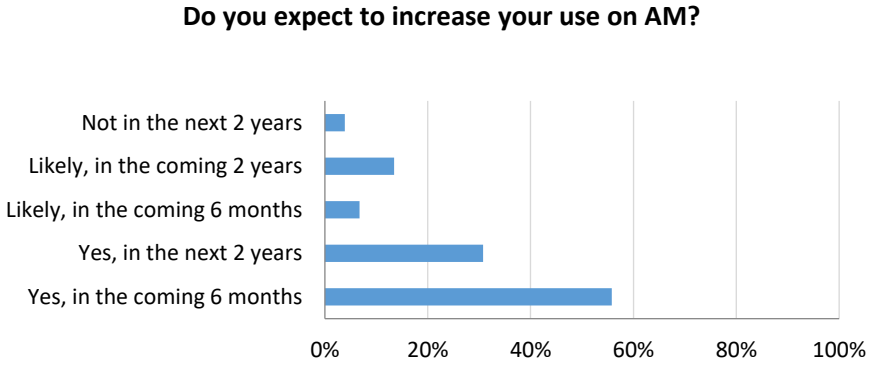

Figure 13 - AM Increase in the Future

From the results to this question (see Figure 13), which was addressed to those who are already using AM in their organisations, it can be foreseen that the use of AM will increase in the upcoming 6 months (58 out of 104 participants indicated so, corresponding to 56%) and on the upcoming 2 years (32 replies corresponding to 31%).

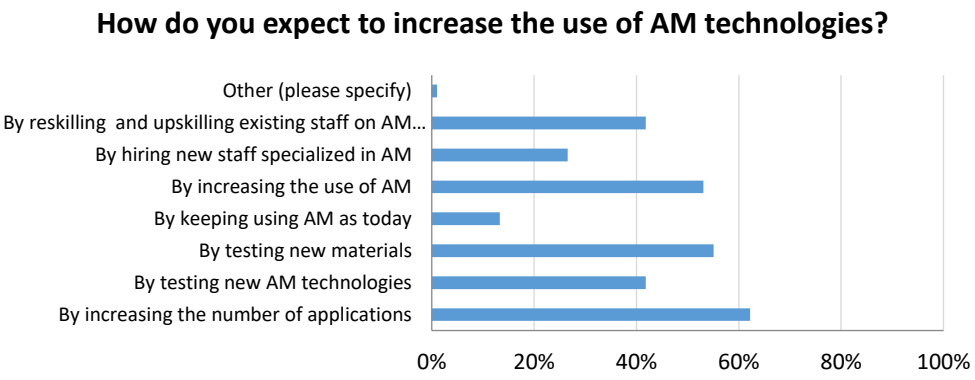

Figure 14 - Solutions to increase AM use in the Future

Figure 14 addressed most suitable solutions indicated by the participants to lead to an increased use of AM technologies. According to participants' opinion, the increased use of AM is expected to happen by either increasing the number of applications (62%), testing new materials (55%) and increasing the use of AM (53%) will lead to an increase of AM technologies. It is important to highlight that also a high number of organisations consider to re-skill and up-skills existing staff towards AM (42%).

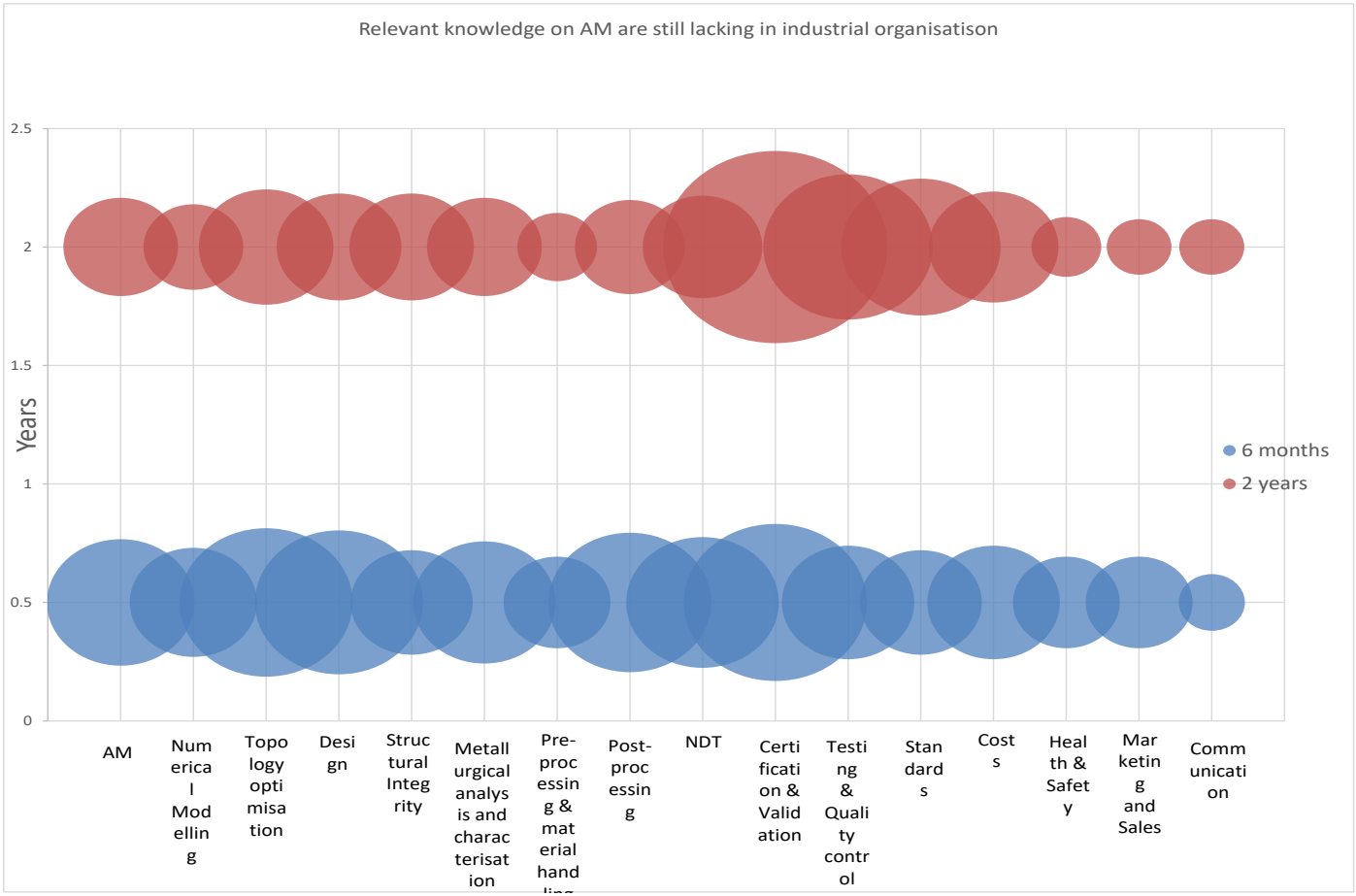

Figure 15 - Relevant Knowledge lacking for a wider use of in AM

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The question above (see Figure 15) is highly important to map the objectives of SAM project. From the results, it can be withdrawn that the most relevant knowledge (*represented by the blue circles*) still lacking in the upcoming six months refer to Certification & Validation (37%), Topology Optimisation (35%) and Design (34%). When it comes to the relevant knowledge evolution from the upcoming six months to two years (*represented by the red circles*) it is expected that Certification & Validation (45%), Testing & Quality Control (34%) and Standards (32 %) will be the expected to increase (until 8%) in relevance by then, while all the remaining knowledge is expected to decrease in relevance.

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3.2.2 Findings on surveys conducted with organisations involved in research, development and innovation

The survey was carried out from September to November 2019, involving 90 participants, namely organisations involved in research, development and innovation (RTOS).

General information and background

Looking into the background of participants (see Figure 16) , the conclusion is that the majority (46%) belongs to Universities, followed by representatives from Research Centers (27%) and Technology Centers (12%). The remaining represent other types of organisations (16%) of the total participants.

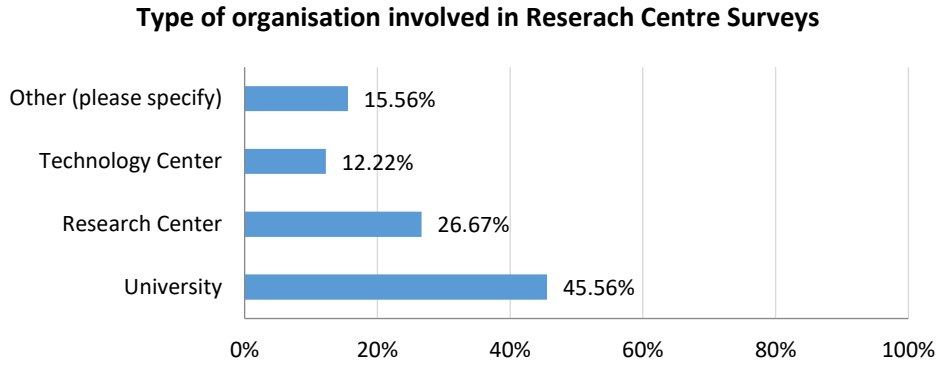

Figure 16 - Type of organisations represented by RTO participants

The most represented countries were Spain (21 participants) and Germany (16 participants), followed by France with 13 participants. Countries outside the EU were also represented in this survey, with a participation of four people from Turkey and other countries, specified as Singapore and Cyprus. This engagement enables to infer that SAM is having also an international reach and impact (see Figure 17).

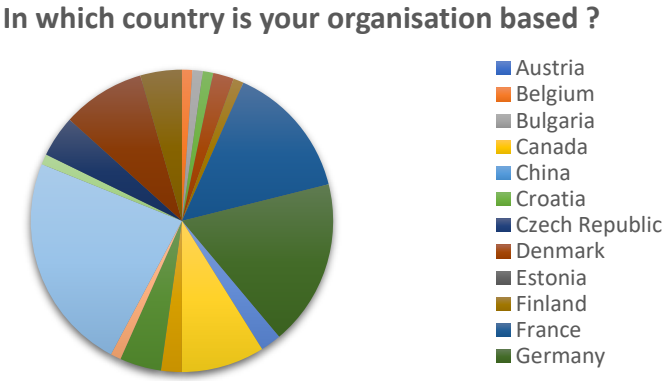

Figure 17 - Countries represented by participants

Participants were requested to indicate the main operating sector / field of activity of their organisations with regards to AM. Results show (see Figure 18) that the main sectors represented in this survey are Aerospace (47%), Industrial equipment and tooling (46%), Automotive (34%) and other sectors (32%).

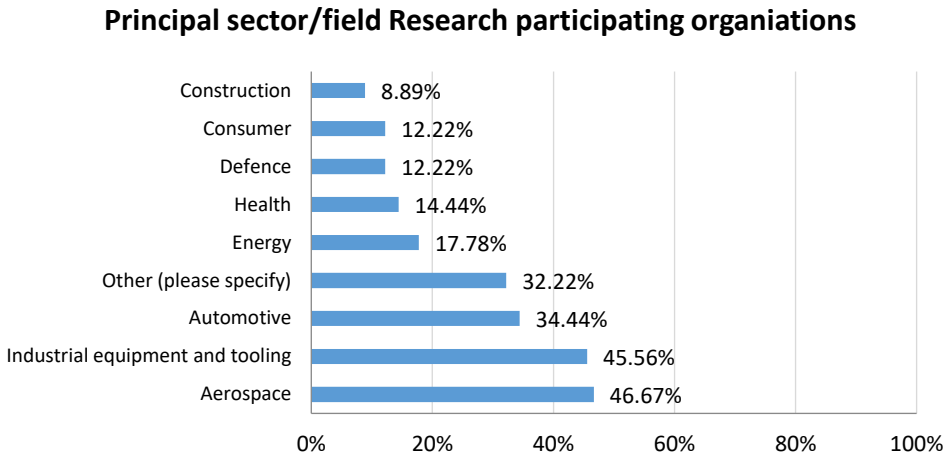

Figure 18 - Sector(s)/fields participants belong to

In terms of AM value chain position (see Figure 19) , 62% of the organisations were involved in Process (including ICT and Equipment), followed by Design (52 %) and Post-Processing (50%).

Modelling/simulation and Product (including Quality Assurance & Testing) were the next AM value chain positions with more representations (49% and 40%, respectively).

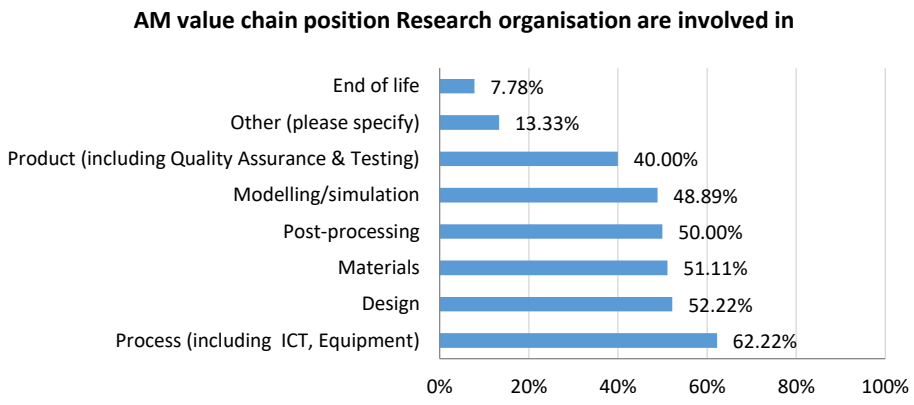

Figure 19 - AM Value Chain Segments participants are involved in

When asked about the Materials mainly used by participants, the ones with more replies were Metal (82%) and Plastic (58%).

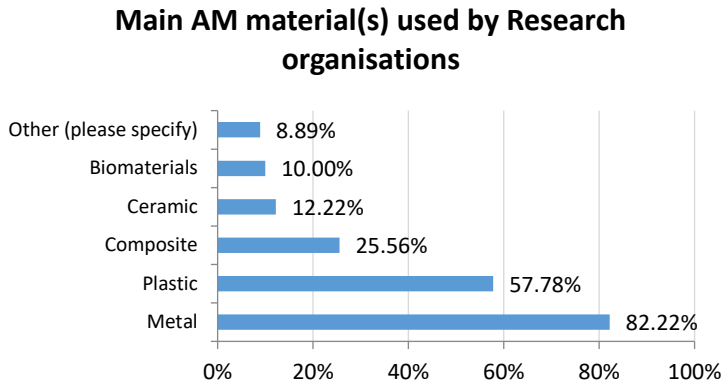

Figure 20 - Materials currently used by RTO participants

When organised in decreasing order of use, it is possible to see (Figure 20) that materials used by participants and their organisations are Metal, Plastics, Composite, Ceramics and Biomaterials.

As for Processes, participants tend to use and investigate mainly Powder Bed Fusion (69%), followed by Material Extrusion (with 50%) and Directed Energy Deposition (44,4%), as indicated in Figure 21.

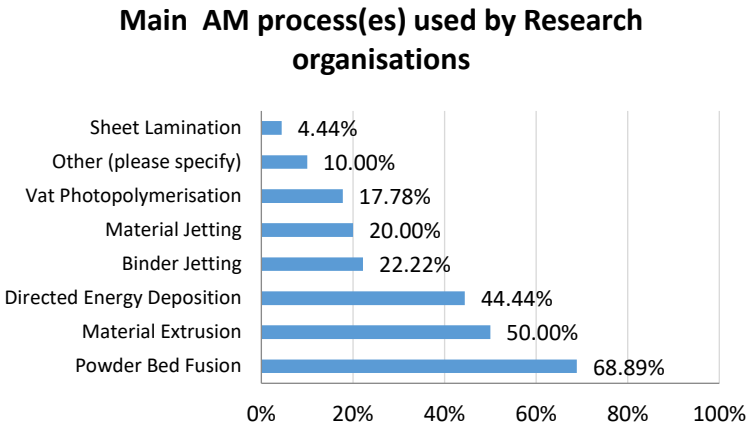

Figure 21 - Processes currently used by the survey Participants

Most of the participants (67%) belong to organisations that offer AM training/education courses, more specifically internal courses (84%), technological workshops (49%) of more than one day and external training at customers' location (46%). Remote or Internet-based courses are not usually provided by the represented organisations, with only six participants (11%) indicating that this is a service carried out by their organisations (see Figure 22).

Figure 22 - Training services provided by Participants' organisations

This information helped the SAM consortium to understand the characteristics of the survey participants in terms of experience and know-how, crucial for the pertinence of the collected results to the project's purposes.

In terms of skills addressed by the training courses (see Figure 23), they mostly target AM Processes (95%), followed by Design (68%), Post-processing and Topology Optimization (both with 47% each), while the skills less addressed are linked to non-technical areas, namely Communication (2%), Marketing and Sales (4%) and Resource Efficiency / sustainability (5%).

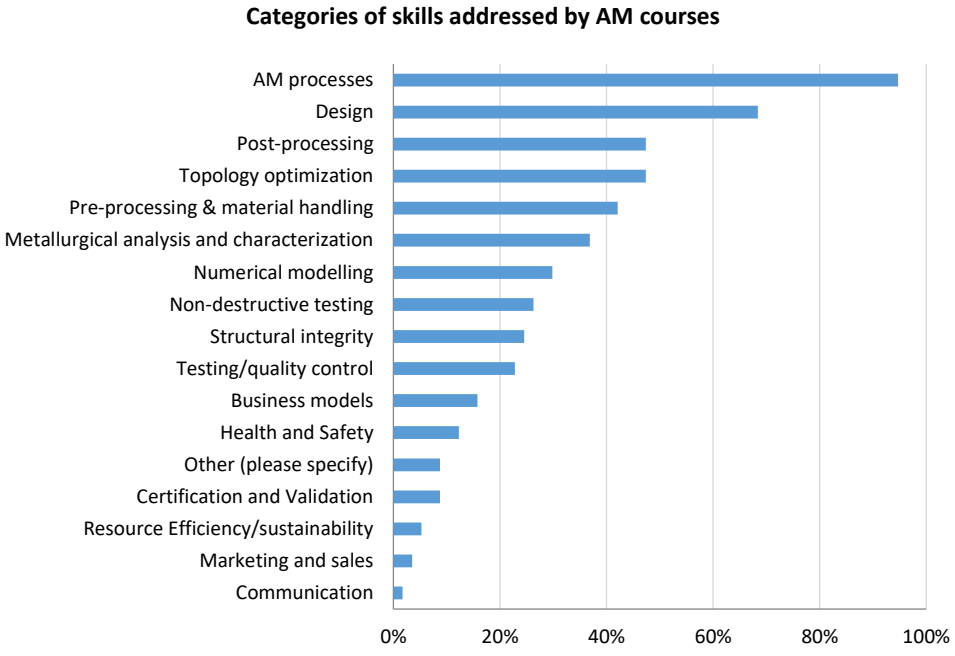

Figure 23 - Skills addressed by the courses.

AM Technology Trends

The survey also focused on Technology Trends, in the sense of identifying the AM Sectors, AM Value Chain, AM Materials and AM Processes to be used by the participants within their organisations in the future.

In view of these results, it became important to know the participants' opinion on how these trends are expected to evolve in the next years, more specifically in the periods between 2020-2021 and 2022-2025, focusing on the relevance of Sectors, Value Chain, Materials and AM Processes for R&D&I activities.

In this sense, participants were asked to indicate what they think are the most and the least investigated AM sectors currently, and what they think will be the trends for the periods between 2020-2021 (represented graphically in green in Figure 24) and 2022-2025 (represented graphically in blue in Figure 24), for each industrial sector (i.e. Industrial equipment and tooling, Automotive, Aerospace, Consumer goods, Electronics, Health, Construction and Energy).

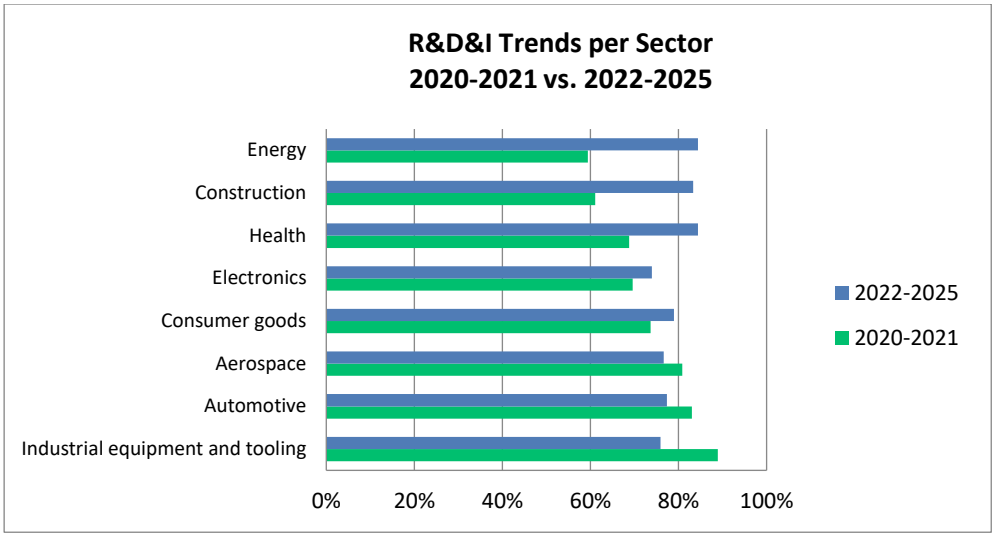

Figure 24 - R&D&I Trends for different periods (scenarios)

Results show that, in participants' opinion, the most currently investigated sectors are Industrial Equipment and Tooling (89%), Automotive (83%) and Aerospace (81%), being the less investigated Health (69%), Construction (61%) and Energy (59%).

However, a change of focus is expected within the investigated sectors from 2022 and 2025, where Health (84%), Energy (84%) and Construction (83%) are expected to be increasing and the remaining slightly decreasing.

Based on these results, SAM consortium wanted to know participants' impressions about which stage of the AM value chain will R&D&I activities focus on in the period of 2020-2021 and 2022-2025.

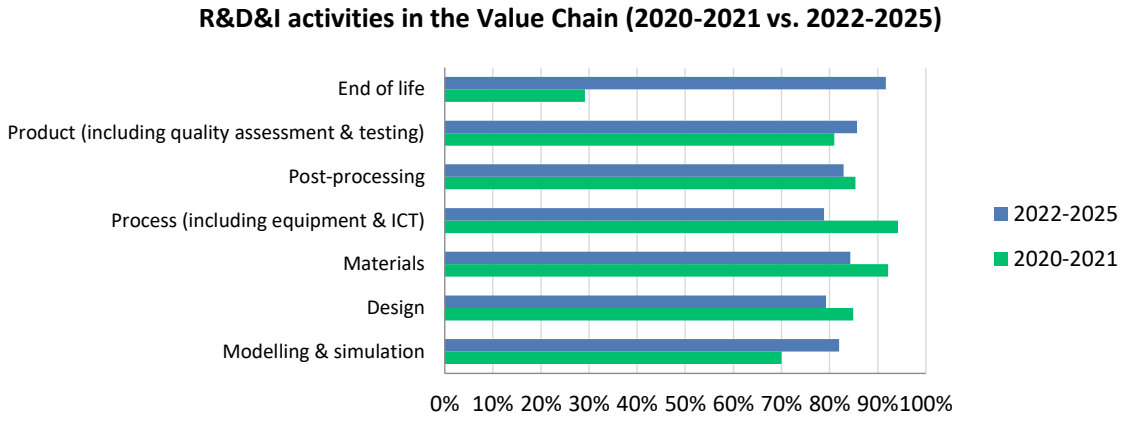

Figure 25 - R&D&I activities in AM Value chain for both periods/scenarios

The results show (see Figure 25) that investigation currently focuses more on the Process (94%), Materials (92%), Post -processing (85%) and Design (85%). However, although in the future the more interesting sectors for R&D&I activities and investigations will remain the same, it is expected an impressive growth of End-of Cycle (92%), followed by an increased investigation on Product (85%) and Modelling & Simulation (82%) areas.

Moreover, according to participants' responses, the trend will be for metal to remain the most relevant material until 2025, followed by polymers. Composites will tend to lose relevance in research over the years, and all other materials will tend to gain relevance, with an emphasis on Ceramics, which show the greatest growth for relevance (see Figure 26) .

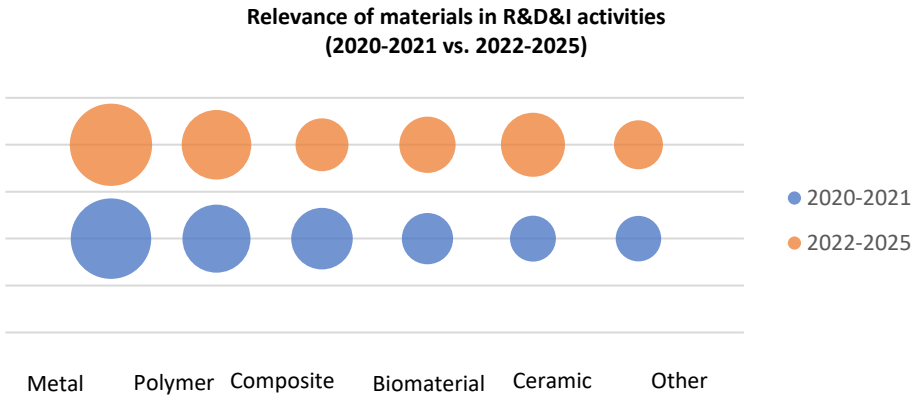

Figure 26 - Main results for AM materials' trends for the periods of 2020-2021 and 2022-2025

Similar questions were made, but regarding the trends for the different AM Processes to be addressed by participants' activities on both referred periods (see Figure 27).

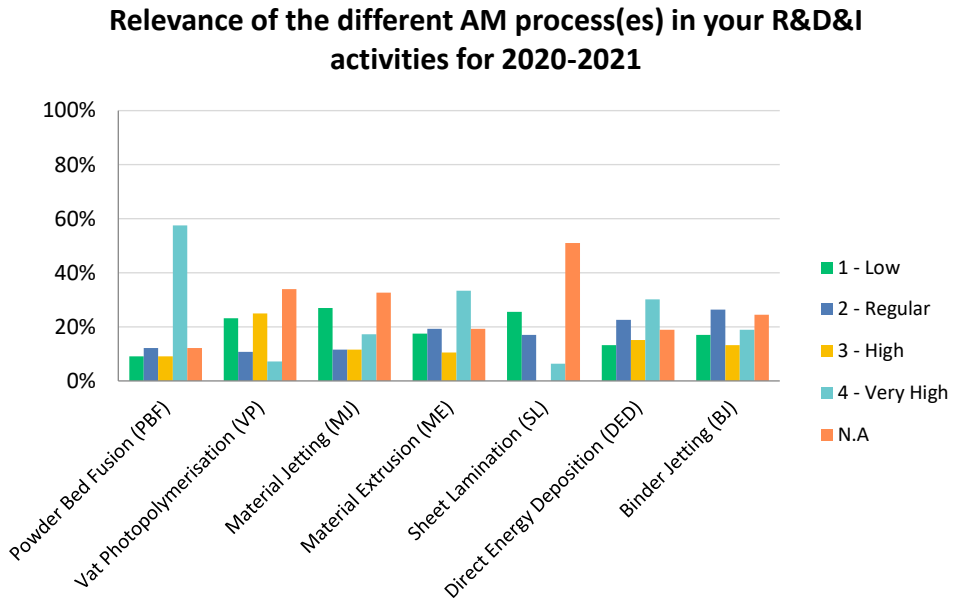

Figure 27 - Main results obtained for AM Processes at short term, 2020-2021

The results indicate (see Figure 28) the trend will be the same for this period than the one for the previous one, meaning that between 2022 and 2025 Powder Bed Fusion, Material Extrusion and Directed Energy Deposition will be the trendiest processes in AM (rated 4 - Very High).

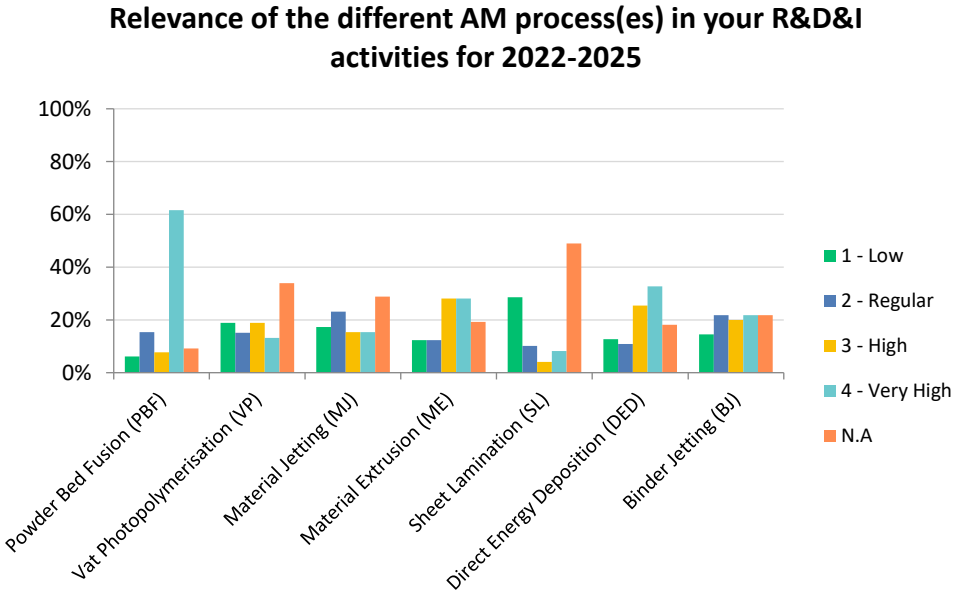

Figure 28 - Main results obtained for AM Processes at long term, 2022-2025

Then, participants were asked to rate the relevance of different AM technology trends for 2020-2021 in terms of R&D&I activities.

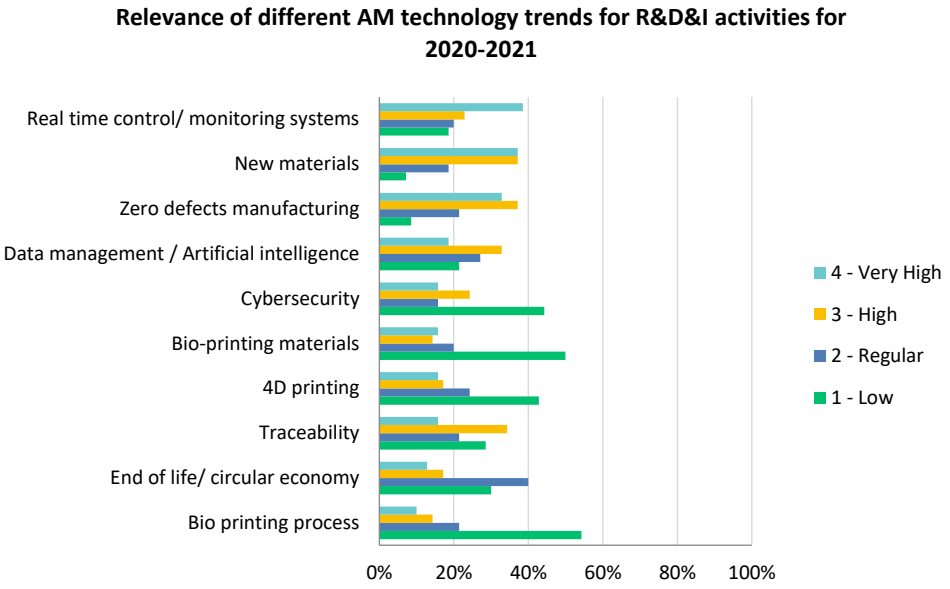

Figure 29 - R&D&I activities in terms of AM technology trends at short term, 2020-2021

The results indicate (see Figure 29) that the most relevant AM technology trends for R&D&I activities in 2020-2021 will be Real time control / monitoring systems (39%), New materials (37%) and Zero-defects manufacturing (33%).

Regarding the future trends until 2025 (see Figure 30), Bio-printing materials are not considered very relevant, since about 50% of the participants considered its relevance low. While the remaining trends remain the same for this period: New materials (64%), Zero-defects manufacturing (54%), and Real time control/ monitoring systems ((51%). However, the order of relevance is slightly different.

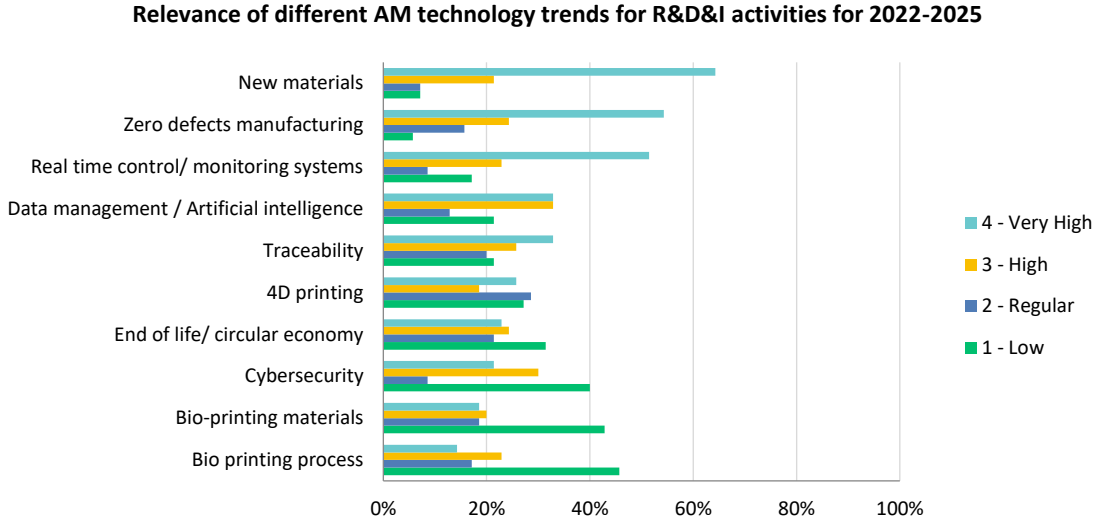

Figure 30 - R&D&I activities in terms of AM technology trends at long term, 2022-2025

Skills and profiles' needs

Considering that the AM sector is constantly growing, another issue that has been addressed by SAM project's Survey on AM Skills and Technology Trends was the identification of needs in terms of Professional Profiles and Skills for AM. Specific questions were asked to participants regarding this subject.

Regarding the relevance of the Professional Profiles for R&D&I activities required between 2020-2021 (see Figure 31), 64 of the 90 participants have identified the AM Process Engineer (55%) as the most relevant one, followed by the Materials Engineer (47%) and AM Designer (45%). For 2022-2025 the relative relevance continues to be the same.

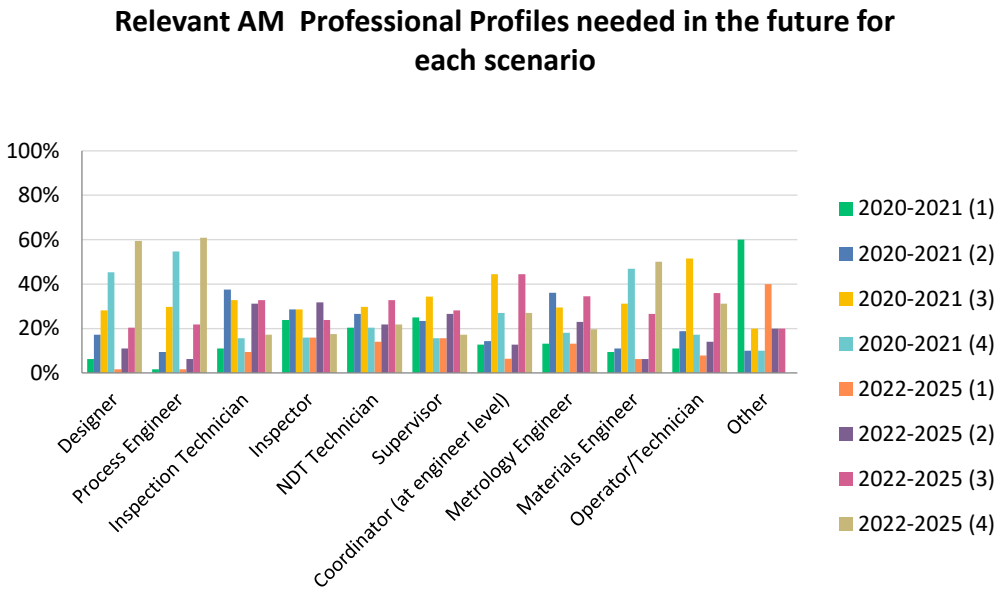

Figure 31 - AM Professional Profiles relevance in a short and long term, 2020-2021 and 2022-2025

Regarding the relevant knowledge required in terms of AM related matters, participants were asked to characterize the current lack of knowledge from a given list. The results show (see Figure 32) that participants consider that knowledge about Numerical modelling (43%), Standards (40%), Topology Optimization (39%), and Certification and Validation (37%) are the ones lacking the most in AM market/workforce.

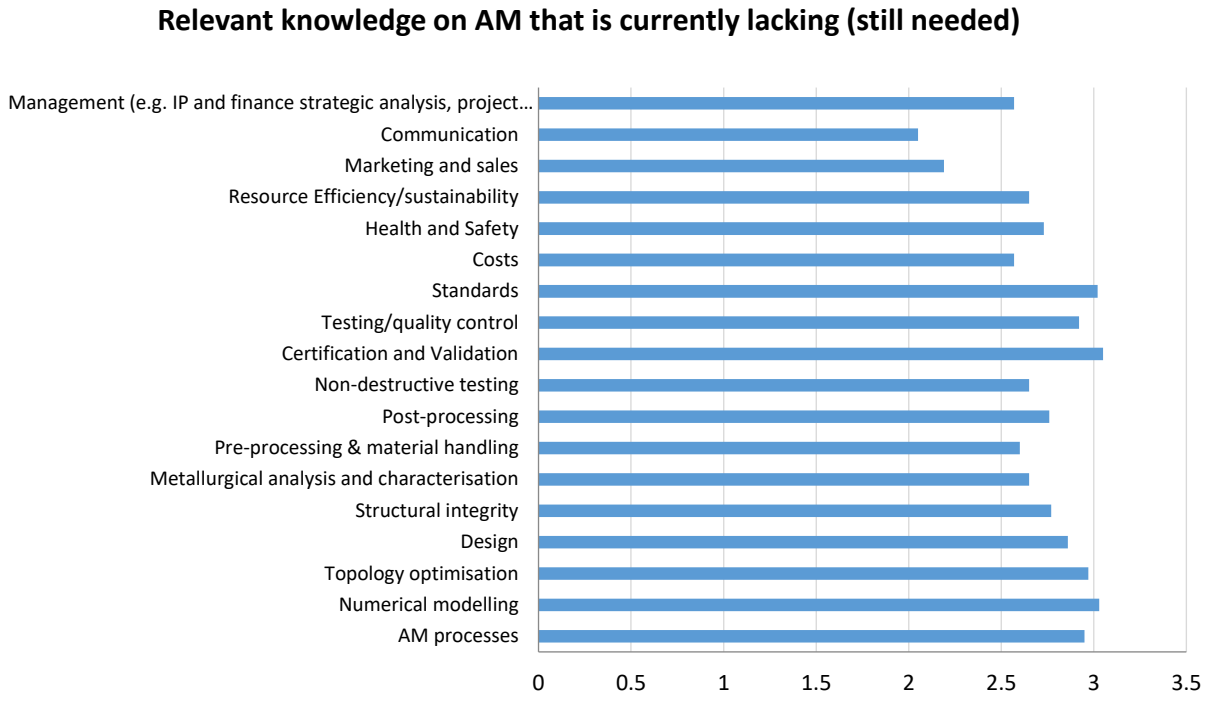

Figure 32 - Lacking AM knowledge, currently (2019)

In terms of evolution, according to 64 of the 90 participants, it is expected that relevant knowledge on AM for R&D&I activities required for 2020-2021 will be AM process (58%), Design (44%) and Numerical Modelling (34%) and that it will remain the same in the period of 2022-2025 (see Figure 33).

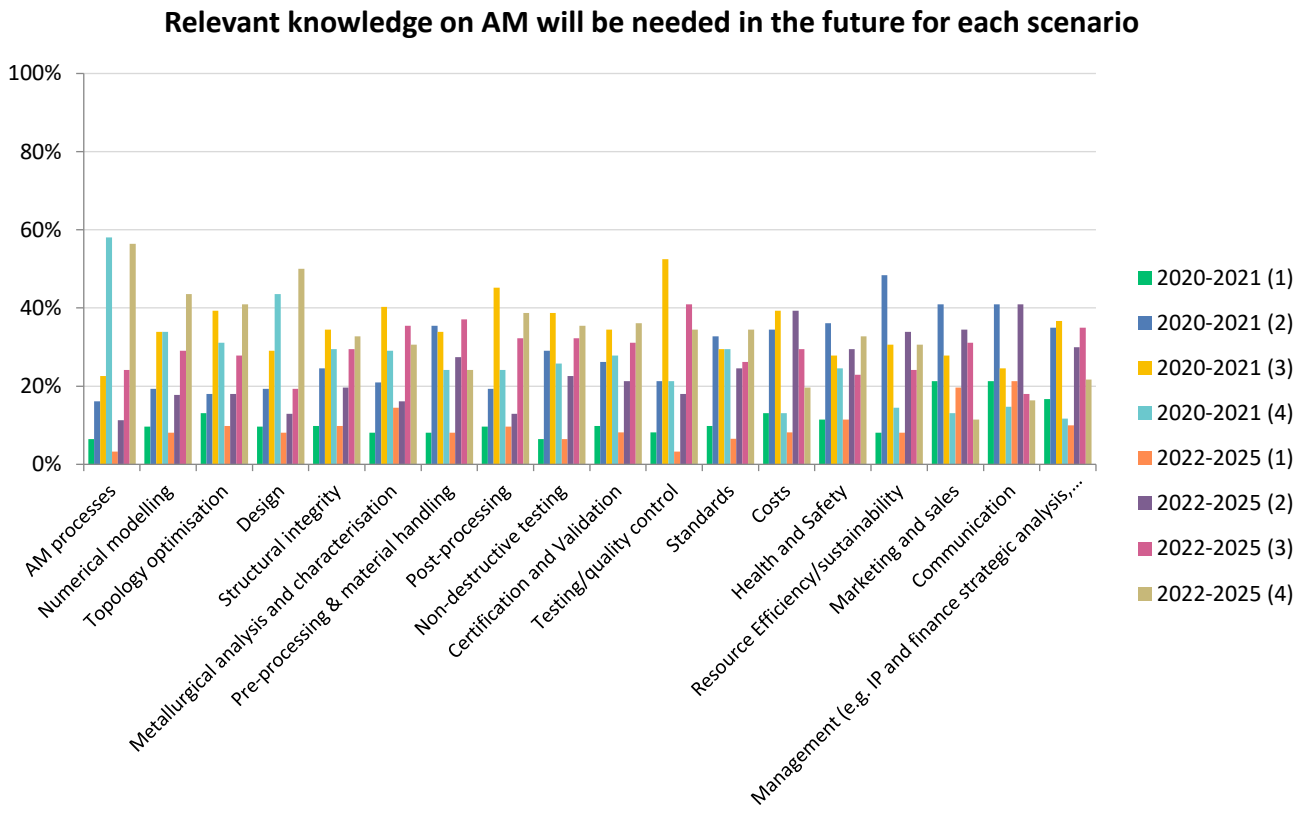

Figure 33 - Knowledge on AM lacking for R&D&I activities in short and long term, 2020-2021 and 2022-2025

3.2.3 Data on AM Skills Needs - Interview Results

A total of 15 interviews were conducted with industrial organisations in the field of AM in Europe. Findings were compiled within this chapter and described into three main clusters, namely: General information / background, AM skills needs and future trends and training. Out of these 15 companies, six had participated earlier in the industry survey. Both a quantitative and qualitative approach was used to analyze the interviews' results.

Background Information

Most of the participants involved in the interviews were representatives from large companies (60%), followed by start-ups representatives (13%) and small and medium-sized enterprises (??%). These companies are based in six European countries, namely France (20%), Spain (20%), Italy (20%), UK (13%), Denmark (7%) and Netherlands (7%). Moreover, 2 of the interviewees represent companies that are based in several countries (13%).

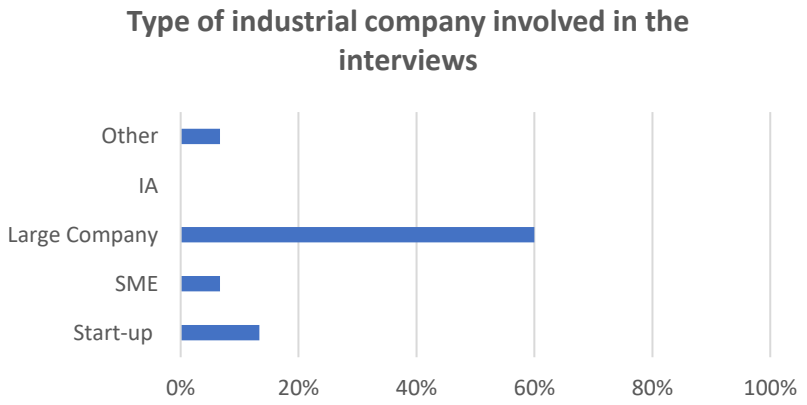

Figure 34 - Type of company interviews belong to

In terms of represented sectors (see Figure 35), interviewees came mostly from companies that are operating in Aerospace (40%), Industry Equipment and Tooling and Energy (both with 33%) sectors. Four interviewees operate in several sectors, which includes the ones already mentioned and different sectors such as Oil and Gas, Foodtech, Dental and General industries. Finally, 33% are operating in other areas, such as Recruitment and Consultancy, while one of the interviewees is active in the Construction/architecture (6%) industry.

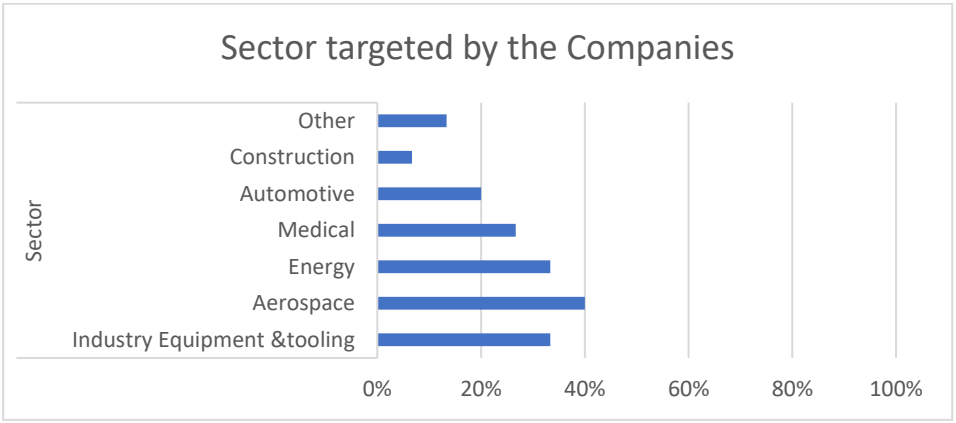

Figure 35 - Sectors represented by the interviewees

In terms of materials used (see Figure 36), interviewees mentioned to be mostly using metals (87%), plastic (53%), composites and ceramics (both 13%). Some interviewees involved in Consultancy and Construction also mentioned the use of different kinds of materials, such as Sand and Regolith.

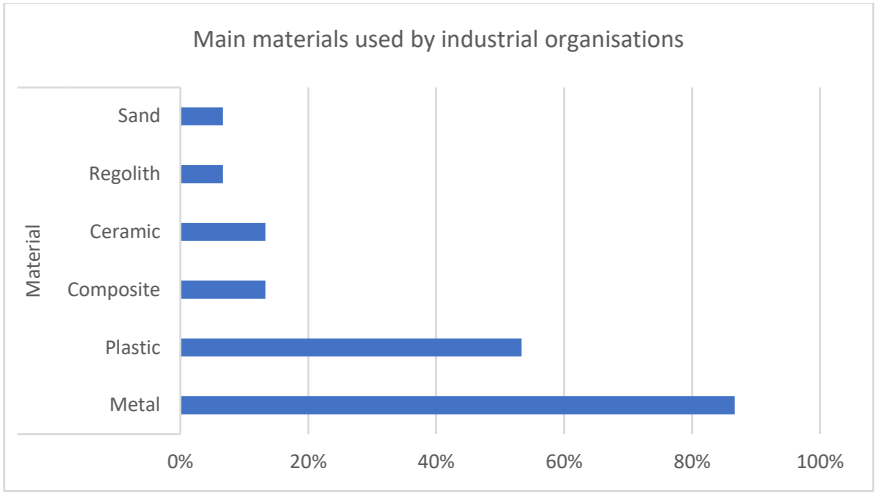

Figure 36 - Materials currently in use by the companies represented by the interviewees

AM Skills Needs

Within the AM Skills Needs cluster analysis, the main findings on AM skills challenges, availability of AM Professional Profiles, required set of skills needed and relevance of technology trends are presented next:

- Challenges

Although, most of the interviewees (67%) mentioned their company is prepared to meet the AM skills challenges (see Figure 37), they were able to identify several barriers linked to those skills appropriation.

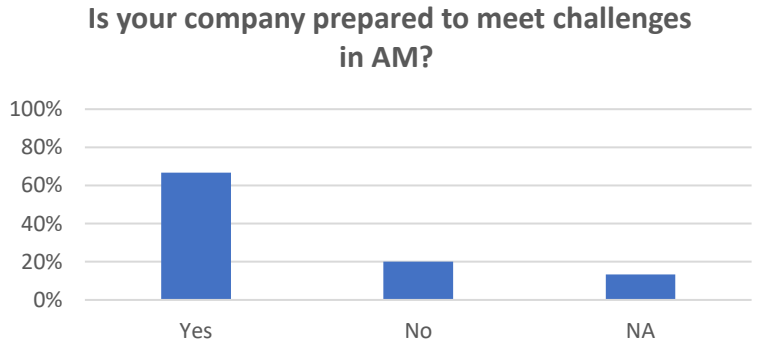

Figure 37 - Self-assessment towards facing the challenges in AM

Those barriers are linked to the **lack of technological knowledge, which hampers** to **cover the entire AM Value chain (from design to post-processing including inspection and Quality Control)** and difficulties in **finding qualified personnel with the suitable set of skills**. Moreover, interviewees mentioned challenges for upskilling other professionals dealing indirectly with AM, that will need to reinvent certain processes to enable AM to its full potential: legal, IP, IT (cybersecurity, integration with ERP systems), Logistics (traceability), Quality Management System, Health and Safety, etc.

To summarize, the list of technological knowledge and skills challenges is related to the following segments /subjects of the AM Value chain (see summary of AM skills challenges in Figure 38) :

Modelling and Design – Advanced design skills specially in the path to AM industrialization; Design for AM with focus on support strategies; Design for AM – design of new parts (no re-industrialisation) – mass reduction and performance improvement – actually 12 references certified for flying; expertise in process modelling and simulation; fixture design and tools.

Materials - materials behaviour in the process, microstructure and new materials.

AM Process - Process optimization; Integration of AM process within traditional manufacturing processes in terms of part and process design; process knowledge; Numerical analysis with respect to collected data/monitoring coming from the machines – integration of those data to help decision making; Process monitoring and quality assurance; LPBF Process simulation to reduce scraps and help component designers in options' evaluation; develop and produce for customization - short batches – on demand versus mass production: cost-time-effort trade-offs can be different for AM; Customized printing tools.

Post Processing – Post-processing enhancement.

Product – Certification, namely how to certify a part – special process – key parameter control to certify that the product will fit the requirements.

No reference to End of life

Additional challenges (i.e. soft skills, qualification and training) - multidisciplinary competences (mech/bio/material/manuf. engineering); openness flexibility, fast learning curve, being able to cope with the lack of references as the technology is 'newer', creativity - "think out-of-the box"; innovation spirit; ability to translate in a smart and fast way from the idea to the final part; Qualification and Training for internal employees fast enough, focusing on developing the right skills that are needed the most, rapid evolution of technology, supply and demand - few people in labor market with these skills and increasing demand.

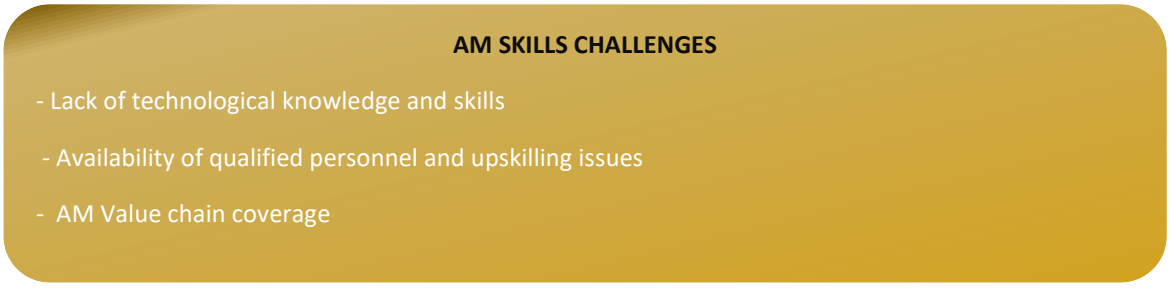

Figure 38 – AM Skills Challenges mentioned in the companies' interview

Moreover, interviewees identify success factors to guarantee the suitable preparation to meet the above challenges, being the core variables **training, innovation, workforce profile and monitoring mechanism** (see Figure 39).

IDENTIFIED FACTORS TO TACKLE AM SKILLS CHALLENGES

- Availability of different programmes for training and for AM applications studies.

- Commitment with innovation; collaboration with R&D; investment in new technologies.

- Training strategy organisation in 3 parts: R&D component; external training with a robust AM machine builder; internal process for continuous improvement; (combined internal/external training)

- Skilled/trained workers covering the entire value chain.

- Multidisciplinary and complementarity of Experts Profiles (i.e. Technology Specialist, Senior vs junior)

- Close and continuous assessment of costumers' interests and needs; feedback mechanisms; continuous improvement.

Figure 39 - Factors to tackle AM skills challenges mentioned in the companies' interview

Also, interviewees identified the investment in more practical training, rotational programmes (to enable faster and broader exposure to design, materials, industrialization, and technician knowledge), more mature standardization; clearer qualification and certification systems as required measures to improve the skills and knowledge in AM within their company.

The main difficulties in implementing AM in the companies depend on the sector. For instance, within Industrial equipment and tooling industry, this is partially related to the lack of AM skills or lack of AM professionals in the current industry, while for the construction sector, this difficulty is linked to lack of standards and regulations on the construction industry.

Availability of AM Professionals

The difficulty in finding qualified personnel in AM is a cross-cutting problem for all identified sectors (ie. Aerospace, Automotive, Equipment and Machine Tooling, Energy, Medical and Construction), being mentioned by 67% of the companies' representatives. The most requested profiles refer to: AM Operators, Consultant for Metal Applications; AM Process engineers; Lab engineers that can adapt standard testing methods to AM needs, as there is a lack of standardization for AM; Program managers, Product managers, Project managers that are experienced and flexible in extremely fast moving markets and Modelling FEM engineers. The lack of available qualified staff has consequences for the companies' activities (see Figure 40).

IMPLICATIONS RELATED TO THE LACK OF AM PROFESSIONALS

- senior workers are responsible for providing training within the company

- investment in training on the job implies losing time and money, before taking back results

- allocation of human resources into training, instead of production activities

- less investment in AM technology exploitation

- quality problems / lack of growth

- delay in hiring, gaps in skill sets, relying on the same few people for many critical projects/business needs.

Figure 40 - Implications to the lack of professionals mentioned in the companies' interview

Based on the prior survey findings, interviewees were asked to relate the need of AM Professional Profiles with Materials and Processes, in order to validate the next steps towards the review and/or development of those qualifications and profiles.

The global perception of the interviewees is that the relationship is significant, due to the fact that these topics are linked to the implementation of AM, which occurs in terms of process and materials. Nevertheless, this relationship will deserve an in-depth analysis with Polymers Experts to be assigned to the design and of qualifications working sessions.

Another aspect to be validated in the interviews conducted was if a specific **AM Metrology and inspection profiles would be required.** Although all participants recognised the crucial role of these profiles for the quality of parts, the overall opinion on this need differs**: most of the interviewees mention that metrology and inspection** of AM parts use the inspection methodology applied on conventional parts. Understanding the limitations/resolutions of the inspection techniques is critical to how parts are defined on the drawings (dimensions, tolerances, and inspection notes). Moreover, some interviewees mentioned that having specific AM Inspection and metrology professionals is not a priority need yet.

Finally, interviewees pointed some actions to adopt within their companies to guarantee the increasing use of AM (see Figure 41). The majority (80%) mentioned to increase the number of applications as well as testing new materials, followed by the transfer of prototyping into production (67%). Reskilling /upskilling existing staff was equally referenced as hiring specialized AM staff (60%).

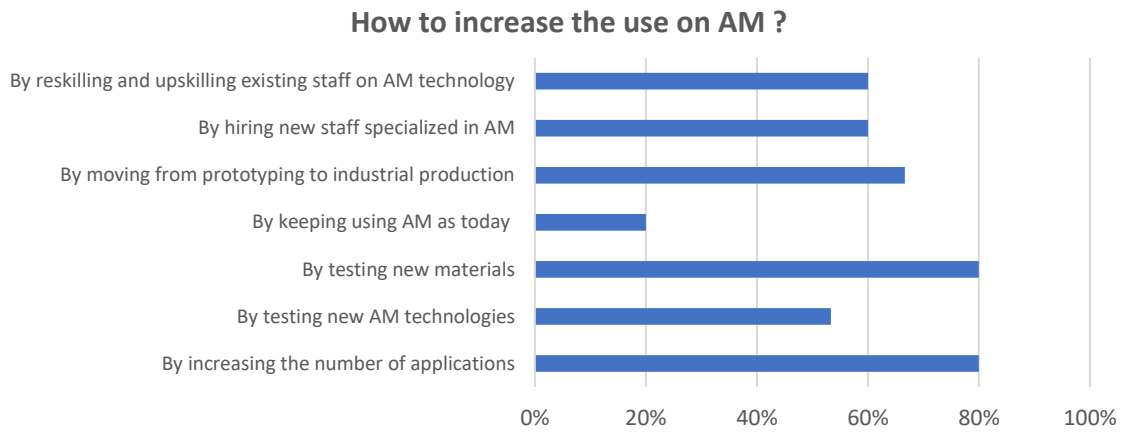

Figure 41 - Actions to Increase AM use

The interviewees pointed some directions on what the concrete actions for increasing the AM applications would consist off. Some examples are listed below for the most frequently mentioned actions (see Figure 42).

EXAMPLES OF ACTION TO INCREASE AM APPLICATIONS

- Increasing the number of applications - more applications in the concerned main sector (i.e., aerospace, industrial equipment and tooling, automotive) and in future new market niches.

- Testing new materials – mostly linked to metal materials, due the companies background. The following is mentioned: metal alloys, materials that can stand higher temperatures, thermomelt, copper, bronzes, steels. Other materials such as: polymers, custom made, composites, timber & Biodegradable.

- **Moving from prototyping to industrial production** - was mentioned towards automotive, lot production and having a pipeline in development to feed production.

- Reskilling/upskilling existing staff towards AM - on AM design and Process Simulation. Existing profiles such as Consultants, Civil engineers, Mechanical engineer degrees and R&D professionals from different industries and what to change in industry.

- Hiring new specialized staff in AM - namely mid-level profiles (VET profiles), Operative Technicians, Application Engineers, Design Engineer/Application Engineers. And if design offices do not evolve rapidly enough, Designer, Process, Materials, Manufacturing Engineer.

Figure 42 - Examples of actions to increase AM use

Skills relevance and AM Technology Trends

Interviewees were asked to indicate how they think AM Technology Skills will evolve until 2021. Although all technological skills were identified as having an increasing demand, the ones related to Simulation, Certification and qualification, quality monitoring and control, followed by CAD modeling are in the front line (see Figure 43). On the other hand, the need for personnel with knowledge on: Pre-processing & material handling, and Post-processing is decreasing.

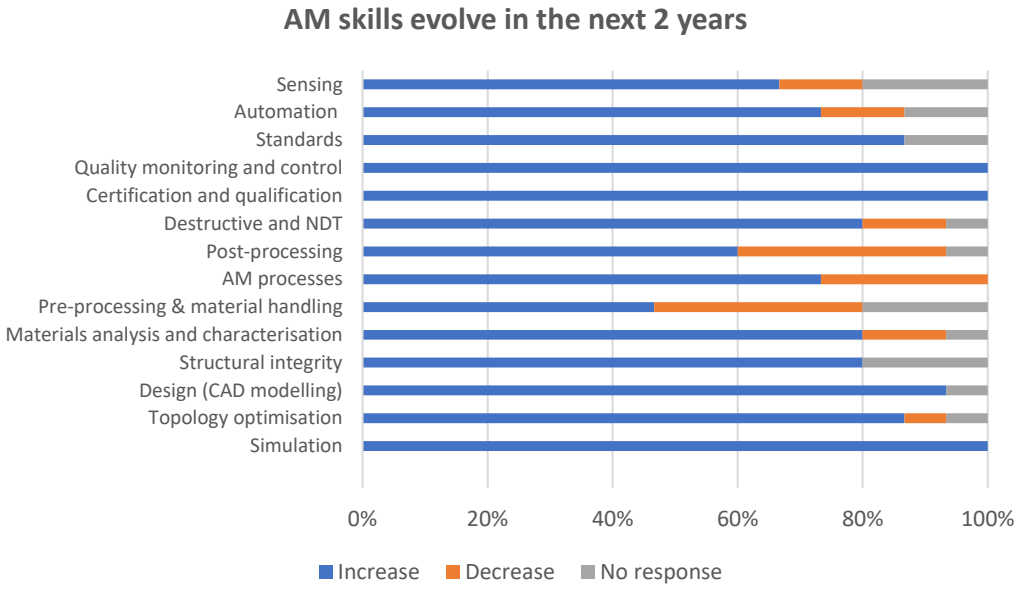

Figure 43 - Interviewees opinion on AM Technological Skills evolution until 2021

Moreover, they were invited to indicate the level of relevance of non-technological (see Figure 44) and transversal skills (see Figure 45).

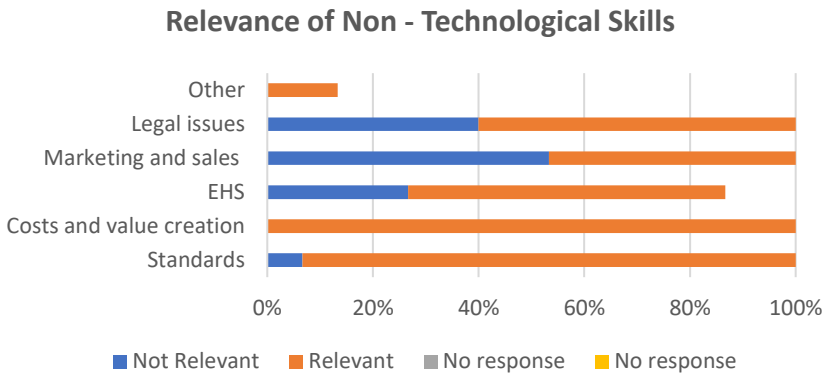

Figure 44 - Interviewees opinion on Non-Technological Skills relevance

Costs and value creation (100% rating as "relevant") **and Standards** (93 % rating as "relevant") were considered the most crucial non-technological skills. In opposition, Markets and sales (53% rating as "not relevant")**,** and Legal issues (40% rating as "not relevant") were considered less relevant.

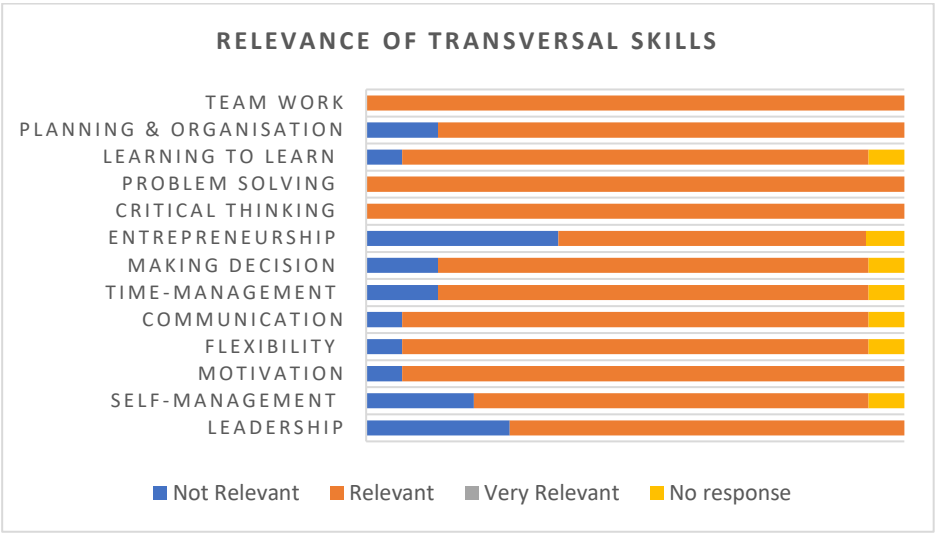

Figure 45 -Interviewees opinion on Transversal Skills relevance

No transversal skills were considered of outmost importance (see Figure 45), but globally there is a consensus on the importance on targeting these skills in AM. The most crucial ones were considered: **Critical thinking, Problem solving and Team work (**100% rating as "relevant")**, followed by Motivation (**73% rating as "relevant"). The less relevant was considered Entrepreneurship (33% of rating as "not relevant"),

In terms of AM trends relevance for the companies activities (see Figure 46), the ones that were considered most relevant were: Zero defects manufacturing (80% rating as "very relevant"), Real time control/ monitoring systems, Traceability and Data management / Artificial intelligence (67% Rating as "very relevant"), while the less relevant were Bio printing (67% rating as "not relevant"), 4D printing (60% rating as "not relevant), and Hybrid Technology and End of Life (33% of rating as "not relevant").

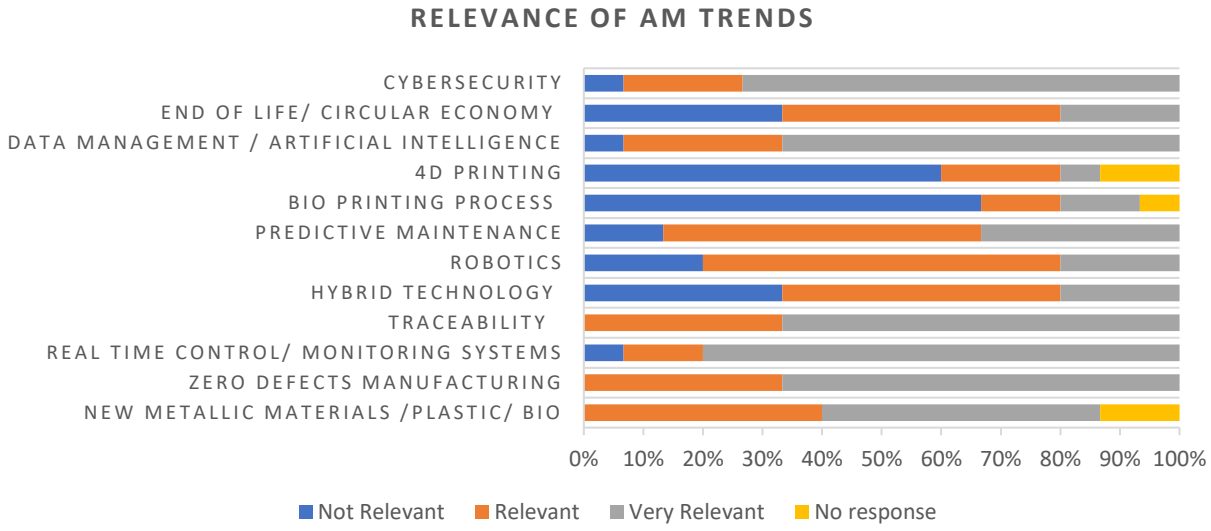

Figure 46 - Interviewees opinion on the relevance of AM Trends

Training

Some insights were provided by the interviewees towards the suitability of some training practices (see Figure 47) and tools (see Figure 48) within AM.

The best training practices in AM identified by participants was on job training (either internal or external) as well as classroom lectures. Classroom training was indicated as most suitable for skills development within the next six months, while on job training was equally mentioned as suitable for skills development in the next two years. The remining training options, such as Apprenticeship, blended learning, online and virtual courses were not identified.

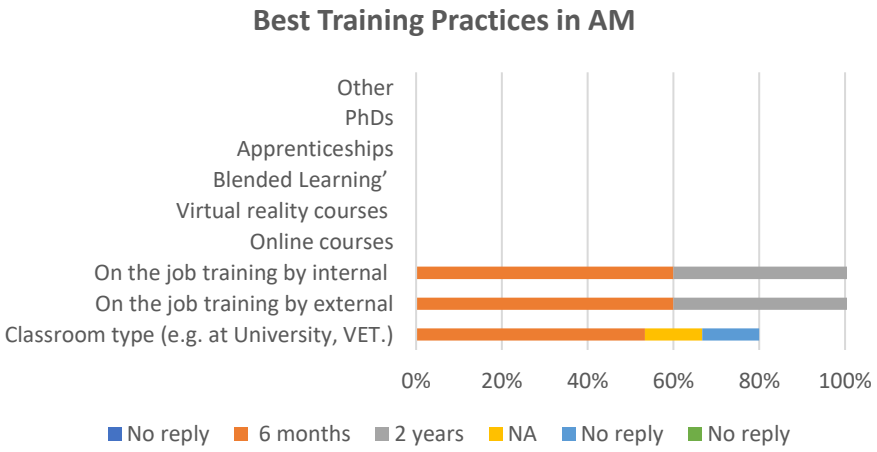

Figure 47 - Interviewees' opinion on Training practices suitability, short term scenario

Finally, interviewees confirmed the suitability of using Makers' spaces and fab labs (100%) as well as Industrial experience accelerators (80%) in AM training (see Figure 48).

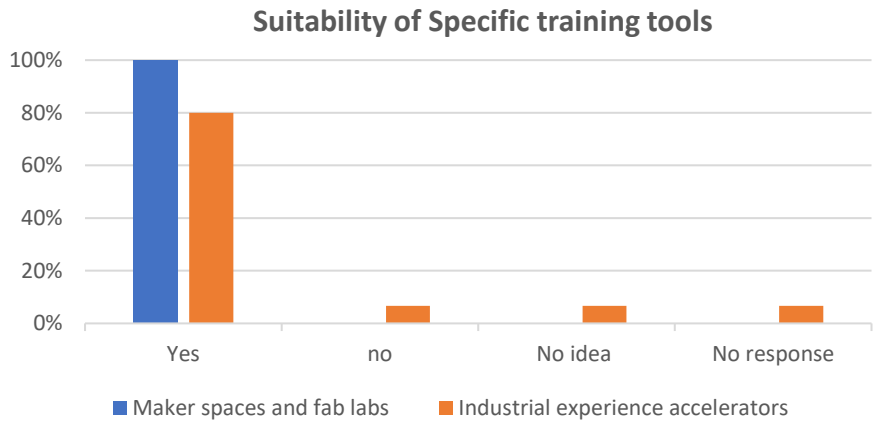

Figure 48 - Interviewees' opinion on Specific Training suitability

3.2.4 World Cafe Results

The world cafe was conducted with a group of 15 AM experts belonging to AM companies, research organisations, technology centres and educational institutions across Europe.

Along this activity, participants were invited to discuss about AM future application and challenges for the next five years (until 2025). Three main topics were addressed for reflection in three rounds/sections, namely: AM Materials, AM Processes and AM Sectors.

Group discussion

Fours questions were launched related to **AM Materials** trends for the next five years, as described below for each group (new round), see from Table 3 to Table 6 :

Figure 49 - World cafe group discussion

Table 3 - World Cafe results on materials applied to AM until 2025

Q1. Which materials are typically not used, but will become important in the next 5 years?
Group 1 (G1) • New types of ceramic • Non-weldable materials • Multi/hybrid materials • Biomaterials **Group 2 (G2)** • Invar for tooling production • High Speed Steels (HSS) • Multi-materials • Hybrid materials **Group 3 (G3)** • Copper • Semi-conductors • Ceramic • Multi-materials

Table 4 - World Cafe results on challenges/opportunities towards the use of "new" materials

Q2. What will be the challenges/opportunities in using the identified materials in AM?
G1 • Technological capabilities available might represent a bottleneck for the applicability of certain materials. • Creation of standards/methods of qualification for such materials are an opportunity. The challenge lies on doing this in a cost-efficient way. **G2** • Pairing / combining materials and applications is challenging, Nonetheless, this imposes an opportunity to "push" research. **G3** • Opportunities in e-Mobility and Space applications (NASA, ESA, etc.)

Table 5 - World Cafe results on required Qualifications for polymers /composites until 2025

Q3. Which European qualifications will we need for AM with composites/plastic in the next 5 years?
G1 • Replicate what is being done for European Metal AM **G2** • Tooling Inspector • Operator (Process Specialised) • Designer (Process Specialised) • Engineer (Process Specialised) • Supervisor **G3** • Operator • Engineer • Designer • Inspector • A more critical focus should be given for Operator, Engineer and Designer Qualifications

Table 6 - World Cafe results on required knowledge and skills until 2025

Q4. Which AM knowledge and skills will be required?
G1 • Continuous monitoring of the process (data analytics) and based on this construct qualifications. • Speed up technology adoption. **G2** • Design • Process chain • Data analytics • Guarantee that the knowledge and skills are aligned with successful industrial application. **G3** • Skills and knowledge must be aligned with the industry need • Continuous material and process development

Only one question was launched to discuss which **AM Processes would be required for** the next five years, as described below for each group (new round), see Table 7.

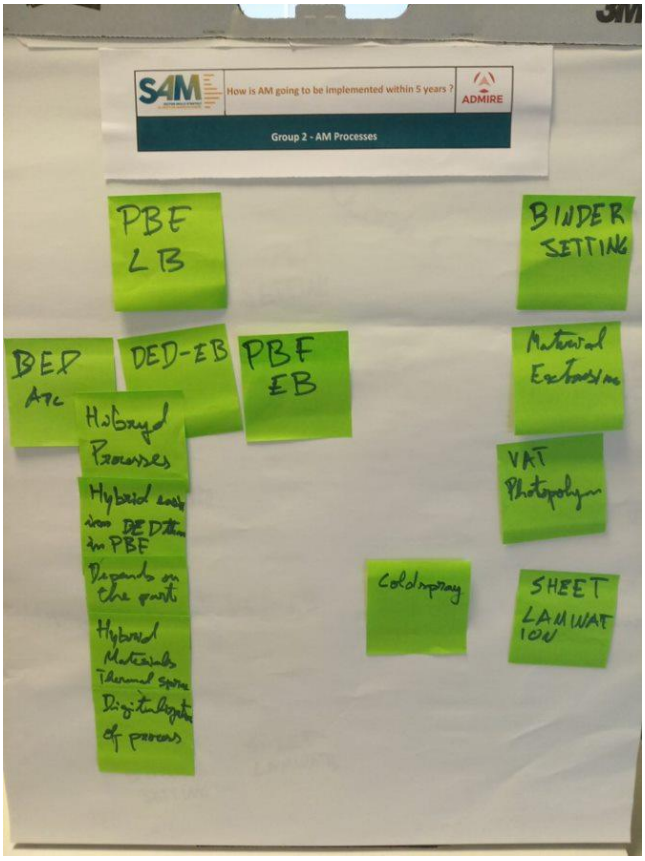

Figure 50 - World cafe results about AM process use until 2025

Table 7 - World Cafe results on processes applied to AM until 2025

Q1. Identify which AM Processes will be used in the next 5 years and rank them by more to less used.
G1 • PBF-LB (1st) • DED-Arc; DED-EB; PBF-EB (2nd) • Hybrid Processes (more with DED eventually all DED will be Hybrid) Hybrid Materials • Binder Jetting • Material Extrusion • VAT Photopolymerization • Cold Spray • Sheet Lamination **G2** Metal: • PBF-LB • DED-LB • Binder Jetting • Hybrid processes • DED-Arc • FDM • Cold-Spray; PBF-EB; DED-EB • Sand Binder Jetting • Sheet Lamination Plastic: • Binder Jetting

- FDM composite plastic
- VAT Photopolymerization
- Material Extrusion

G3

- Bio-Printing
- Hybrid
- FDM
- PBF-EB
- SLS
- Hybrid Material
- SLA
- DED-Arc
- PBF-LB (Large Parts)
- Material Extrusion
- 3DCP
- Friction Stir AM

Comment

Some processes like Cold-Spray are quite recent in the market and not all participants were aware of it. The results differed one another. Between different groups All groups agreed that PBF, DED and Hybrid Processes there will be the most relevant processes within the next five years.

The irregularity of results between the different groups sustains the theory that the AM market is unpredictable, due to the fact that it is in its beginning and growing exponentially.

Finally, in terms of **Sectors** where AM is expected to be used in the future, fours questions were addressed, as described below for each group (new round), see from Table 8 to Table 9 :

Figure 51 - World Cafe group discussion

Table 8 - World Cafe results on sectors influenced by AM until 2025

Q1. Which sectors (e.g. Construction, Defense, Health, Automotive, Aerospace) will be more influenced by AM in the next 5 years?
G1 • Aerospace • Automotive • Energy (nuclear power) • Health Industry • Tooling **G2** • Oil and Gas • Maritime • Railways • Retail and Fashion • Machinery **G3** • Construction, plus all the before mentioned sectors

Table 9 - World Cafe results on examples of products to be produced until 2025

Q2. What products will be produced?
Aerospace **(G1)** • They have the largest users in Metal for performance and material saving; • In one year, the materials used will be composite. After, the sector will use titanium, nickel alloys and aluminum to build parts inside the aircraft, engine components, space propulsion pieces and primary/secondary structure components). **Automotive** **(G1)** • Car body parts and power train, using metal mass production for avoiding initial investment and ensuring cost-efficiency; • Aluminum and steel for structural parts; • Mixture of tires; • Seat components/structural (internal) components; • Customize 3D printed dashboards; • Composite materials to replace plastics; • Heath exchanging components. **Energy (Nuclear power)** **(G1)** • Inspection technology, blades for steam turbines, senses technology in 3D, spare parts; • Usage of stainless steel, which is not so expensive) to improve performance and save material (nickel alloy) **Health/Medical Industry** **(G1)** • Organ transplants using laser beam processes. [AM] It is a very fast emerging technology that allows customization; • Prosthetics, limbs, surgery guides, hip replacements, teeth, cosmetics, organs (e.g. ears, liver components, hearth components).

Tooling
(G1)
- For fixture, for stamping tools;
- Example: for drilling, we can create specific tools with AM;
- Create tools for performance, functionalization and cost-effectiveness;
- Molds, internal channels for cooling, injection molding and tooling.

Oil and Gas
(G2)
- Drill bits and process pipes.

Maritime
(G2)
- For spare parts and building structures;
- Obsolete parts and components;
- Customization.

Railways
(G2)
- Obsolete and spare parts;
- Controls.

Retail and Fashion
(G2)
- Shoes in carbon;
- Dresses and jewelry;
- Intelligent clothing.

Machinery
(G2)
- AM used for enhancing performance;
- High temperature resistant components.

Other comments:

"We are using plastic mass production nowadays, but in the future, sectors will be using **FDM** (fused Deposition for Metal) and **BJD** (Binder Jetting Deposition), which is still under development but will be used for mass production."

Table 10 - World Cafe results on required AM and existing Professionals until 2025

Q3/Q4. Which Professional Profiles will be involved? New Harmonised profiles or Upskilled/reskilled workers? / Which AM Knowledge and Skills will be required?
G1 • Energy (nuclear power) – AM Quality Engineer **G2** • Oil and Gas - AM Quality Engineer **G3** • For all sectors will be required an **AM Quality Engineer, with specification for each sector**. EWF can develop such specialization, defining how they can fit in different sectors. • Such professional would control quality of production chain, need to know all processes and manage quality for all processes' requirements. • (e.g. Metal AM Engineer, with an add-on in AM Quality Engineer)

Other comments

For the Construction sector, we can also consider the Building Contractor as a professional profile, with a specialization in AM. This professional would be able to use materials such as smart concrete, used in earthquake-proof buildings. This professional would have to know how materials behave and how they work together in a construction.

Workshop conclusion / future implications

The workshop enabled participants to get to know more about AM applications, thus enabling them to develop their knowledge and share their perspectives on how AM is likely to be applied until 2025.

In terms of future **materials for AM,** it was interesting to see that Ceramics and Multi/hybrid materials were mentioned in two rounds as the materials which currently are not used, but have the potential to grow in use in the future. Participants highlighted challenges which are also opportunities to push AM further, namely linked to the possibility of creating standards and methods for classification of those materials; and combining applications. So, the use of new materials will have implications towards the development of standards, research and qualifications /skills.

In terms of **AM processes**, it was clear that PBF – LB will continue to be in the top, according to experts, followed by DED-Arc; DED-EB; PBF-EB. In the bottom of the list are processes such as Sheet Lamination, Material Extrusion, 3DCP and Friction Stir AM. The processes' positioning within the ranking varied from group to group, also depended on the material used.

Participants provided an extended list of **sectors** to be influenced by AM in the next five years, which globally include the "traditional" AM sectors: Automotive, Aerospace, Tools & machinery, Health, Energy, Maritime and Construction. It was interesting to see in the list Retail and fashion. Some examples were also provided regarding the products to be obtained in these sectors by applying AM technology.

Finally, participants were unanimous in identifying the future required qualifications and professional profiles, which are **AM Quality Engineer, Tool Inspector, Operator, Engineer and Designer.**

3.2.5 1st Workshop for Data Analysis & definition of priorities - Internal workshop report

The analysis of data described in section 4 was performed during the first internal workshop for data analysis, held on the 11th December 2019 in Milan, during the 3rd project transnational meeting, where all project partners participated.

In order to analyze and discuss the results coming from the surveys conducted with industry and RTD, and to define the priorities in terms of skills gaps and professional profiles to be addressed in the next six months, two years and five year 5 years, partners were equally grouped into three groups (see Table 11) in order to guarantee expertise and gender balance.

Table 11 – Internal Workshop Group's Composition

Group 1 Analyse and validate skills gaps	**Group 2** Analyse and validate Professional Profiles and or/ Competence Units	**Group 3** Validate technology trends and related skills
Materialise EPMA IDONIAL EC Nantes Granta	MTC CECIMO LAK EWF Lortek	ISQ UBRUN POLIMI AITIIP LMS

Preliminary results per group

The results of the validation workshop were shaped into preliminary reports, which are demonstrated below (see from Table 12 to Table 14) and enable the validation of findings during the next stage of the project, with external stakeholders. The output of the workshop is the definition of priorities regarding the development or review of Qualifications or Competence Units to be addressed in the next period.

Table 12 - Group analysis on skills gaps

1st WORKSHOP VALIDATION OF NEEDS & DEFINE PRIORITIES _ NEEDS ANALYSIS GRID
Group 1 - Analyse and validate skills gaps
1. Relevant data about AM skills gaps
78,8% of the companies were applying AM; 51% are well prepared against 29% that are very well prepared The ones that are not using AM, don't plan its use in the next 2 years 54.5%; only 9% for the next 6 months and 12 % for the next 2 years. **Barriers identified in use**: *There are no technical specifications and without them our public clients do not allow us to use it; We use mechanical parts fabricated with AM from sub-contractors nonetheless.* **Current situation on AM technology use:** Materials 71,6 % are using metals >62.50 plastics; AM processes: used: DED/PBF/ ME continue the most used currently. **Current situation on required Professional Profiles and skills and knowledge needs**: In terms of lacking knowledge for the next the 6 months required knowledge on post processing is needed; in terms of evolutions only certification and validation knowledge are increasing, the others reduce; **Regarding up skilling and re-skilling needs:** R&D, process manager and project manager (but this needs further validation due to the low number of responses) From the organisation that are currently not using AM, but plan to do it in the future, 45% refer they will requiring upskilling of the existing professionals.
Skills types /categories

Technological:	**Transversal (soft):**	**Green:**	**Digital:**	**Entrepreneurship:**
To add: Robotics/automation To change metallurgical by Materials analysis and characterization	To add: costs/ value creation	LCA needs to be added	To add: -Digital continuity -Coding/ programming	

2. Data to be further explored (e.g. through interviews; surveys for next period, other method)
To ask in the context of interviews with experts: Further explore the reasons in the interview to lower needs of Metrology engineers and inspections profiles Up skilling and re-skilling needs of the current workforce To analyze how prototyping versus series industrial production is evolving and try to ask this in the 3 scenarios to be able how this influence in the skills needs To ask about number of workers in AM /turnover to be able to "weight" answers To learn more on knowledge transfer internally at companies

3. Priorities for the SAM scenarios (identify the skills in AM)		
Scenario 1	**Scenario 2**	**Scenario 3**
Knowledge on pre and post processing + new materials Knowledge on how the quality control system works Certification & validation, Topology optimisation, design, post processing and NDT (> 30%)	Certification & validation, testing &quality control, standards	

Table 13 - Group analysis on Professional Profiles and Competence Units

1st WORKSHOP VALIDATION OF NEEDS & DEFINE PRIORITIES _ NEEDS ANALYSIS GRID
Group 2 - Analyse and validate Professional Profiles and or/ Competence Units
1. Relevant data about AM Professional Profiles and or/ Competence units
We have >31% (high and very high) demand for Designers; process engineers; specialists; Materials Engineer and operators; while lower ratings for Inspectors and supervisors
2. Data to be further explored (e.g. through interviews; surveys for next period, other method)
To ask in the context of interviews with experts: Which are the professions will suffer major changes with up skilling and reskilling (professions with major impact until 2030)? Focus on the description of the profiles that are more likely to be of importance. These should be addressed in the project in relation to materials such as metal and polymers. Make sure that interviewees understand what is meant by a specialist profile? Make sure that Professional Profiles with lower ratings are not critical to implementation AM, e.g. Inspectors and AM Engineers – if there are new specific /competence units; • Clarify if industry really NEEDS A NEW PP FOR AM IN NEXT 6 MONTHS? • Decide If the next 6 months to 2 years, it is more relevant to EXPLORE THE QUALITY RELATED TO PROFESSIONAL PROFILES in metals or EXPLORE IF NEW PROFILES in metals are required? • We need to clarify in interviews what competence units are needed • To ask what needs to be created in terms of competence units based on top skills! • Address in the interview – if recycling parts will be important (special issue for polymers) – skills on life cycle;

3. Priorities for the SAM scenarios (identify the Professional Profiles and/or Competence unit in AM)		
Scenario 1	**Scenario 2**	**Scenario 3**
Develop Competence units on Quality and post processing **No need for new Professional Profile – but need for 1 new qualification** **What to review?** 1 Professional Profile /qualification Process engineer, designer and specialist (at engineer level), ? materials engineer (above 40%) **1 new Professional Profile and 1 new Competence unit** – post processing	**New 1 qualification not a Professional Profile**	**To create a Competence Unit on** Life Cycle Analysis

Table 14 - Group analysis on Technology Trends and related Skills

1st WORKSHOP VALIDATION OF NEEDS & DEFINE PRIORITIES _ NEEDS ANALYSIS GRID
Group 3 - Validate technology trends and related skills
1. Relevant data about Technology Trends and related skills
Current situation /characterization: 66, 7 % provided trainings in the following subjects (most rated): AM processes, Design and Post processing **Regarding AM technology evolution:** The materials trends remain the same (1st metals then polymers) Process DED/PBF/ and ME (Metal Extrusion) continue to be the most used currently and in the future Binder jetting increases slightly Trends in terms of sectors evolution - automotive, aerospace and industrial tooling are the most selected (but results are strongly influenced by the nature of existing networks); RTD activities are expected to change/ increase in other sectors: construction, Health, Energy. **Current research activities focus on the VC segments** - top is post -processing; process; materials. **The evolution of the value chain research is**: end of life cycle; products, post process, Modelling and simulation; Trend of RTD activities on AM Materials: 2020-2021 and 2022-2025 – Seem to be the same in the short and long term: Metals and Polymers are the dominants ones, although composites and biomaterials will increase their relevance in the long term RTD activities on processes: 2020-2021 and 2022-2025- PBF; ME; DED Trends of technology: new materials + zero defects+ real time control, data control Evolution: trends continue the same but with different orders. AI and traceability will gain relevance. **Regarding the AM skills needs:** Current needs are referred are numerical modelling, standards and topology Future needs: AM processes, design and numerical modelling **The majority of AM knowledge transfer is done internally by the individual entities (SAM can contribute to the externalization of this AM knowledge and AM community's training**

2. Data to be further explored (e.g. through interviews; surveys for next period, other method)
Comments during global discussions: **To ask in the context of interviews with experts or cross check with other sources:** Confirm the trends about the sectors, processes, materials, namely by cross check information form survey, world cafe with the interview? Interview specific industrial sectors (Medical sector) for the equivalent material trends (Biomaterials)
3. Priorities for the SAM scenarios (identify the skills; PP and Competence units in AM)
Scenario 1 (short term vs long term SAM strategy)
Crucial Skills (possible gap): 1. Health and Safety 2. Quality Control 3. AM Processes 4. End of life segment will increase dramatically R&D activities Professional profiles: 1. Coordinator at the engineering level, relevance decreases. 2. The rest remains approximately the same or slightly increasing. Competence units: The relevance of the Certification and Validation knowledge is drastically increasing in the long term. The percentage of the other units' remains the same in terms of short- and long-term interest.

Conclusion and implications

Globally, the internal workshop was a fruitful activity for the partner organisations, which enabled them to better understand the industry and RTD skills needs in AM, to get new insight and to actively collaborate in the analysis of the surveys data. Moreover, the workshop was useful for partners to agree on a set of elements to be considered in the future as "lessons learnt", when conducting the next round of surveys and interviews, and for reporting survey's results.

For instance, it was clear that the interview with an expert shall help to clarify upskilled and reskilled needs of the current workforce, most required vs less required profiles, as well as which approach to use to develop the next Professional Profiles and Qualifications in AM for the different scenarios (real Case, short terms and foresight).

The internal workshop ended with a short presentation conducted by each rapporteur on the main topics discussed and conclusions, which are summarized in the table below.

The workshop enabled the consortium to identify and agree on a list of skills / classification that will be used on the future for the AM Sector, which is composed by **technological, entrepreneurship, green and digital skills** (see Table 15).

Table 15 - SAM Skills Categories

AM Skills Types / Categories			
Technological	**Entrepreneurship ***	**Green**	**Digital**
AM processes Numerical modelling Simulation CAPP (Computer Aided Process Planning) for AM Topology optimization Design Structural integrity	Spotting opportunities Creativity Vision Valuing ideas Ethical and sustainable thinking Self-awareness and self-efficacy	Digital data analytics (Artificial intelligence, Machine learning) Digital data management (big data, statistics…) Ability to think in 3D Cybersecurity Coding / programming	Resource efficiency management Green awareness LCA (Life Cycle Analysis) Eco-Design Circular economy Green resources

Materials analysis and characterization Pre-processing & material handling Post-processing Non-destructive testing Certification and Validation Tolerances/Testing/quality control/metrology EHS (Environment, Health and Safety) Robotics/automation Sensing Standardization AM applications AM Equipment Acquisition AM machine handling and feedstock handling Part evaluation for AM production feasibility	Motivation and perseverance Mobilising resources Financial and economic literacy Mobilising others Taking the initiative Planning and management Coping with ambiguity, uncertainty and risk Working with others Learning through experience *** Transversal skills reference in the Skills Panorama instrument: (for future feeding of the Skills Panorama)** Communication Team working Costumer handling Problem solving Learning Planning and organisation		Green products

Based on the findings, partners concluded that it would be important if training toward AM could differentiate two inspection areas (one for metrology and other Non-destructive Testing) and two levels of competence units for engineers and operators.

Probably, in the future, it will not be necessary to develop new professional profiles, but rather to develop qualifications or learning units to tackle the specific training needs mentioned above. Another conclusion was that, and since some of the most mentioned Professional Profiles are already being integrated in the European Metal AM Qualification System, namely the Designers and Process Engineers and Specialist/ Coordinator at Engineering level, it would make sense to keep these Profiles updated and to develop new European AM Qualifications for polymers. Nevertheless, this decision, will be taken after the validation workshop.

In terms of **priorities** for the **development and/or review of Professional Profiles Qualifications and Skills linked to the 3 scenarios,** the following was concluded:

Real case (next 6 months)

- Review of one of the following Professional Profile/ Qualification for Metal AM: Process engineer, Designer and Specialist
- Development of new learning units for quality, post-processing and new materials.

Short Term (within 2 years)

- Development of a new Qualification for Polymers
- Explore the development of Qualification for current sectors (i.e. automotive, aerospace and tooling/machinery).

Foresight (within 10 years)

- Development of learning unit for LCA
- Explore the development of Qualification for current sectors (i.e. Health, Construction and Energy)– Skills per sector

4. SECTION II - RESULTS COMPARSION

This section contains a brief comparison between the findings from the Industry and RTO surveys gathered using different tools and applied for the different target groups (Please refer to Section 1 for a detailed description on applied tools and target groups), and in some cases with the same target groups. Cross-checking is a valuable validation technique which enables to determine the consistency of the results achieved on AM skills needs.

4.1 Agreement between experts: Industry vs RTO surveys results

As summarized in Table 16, both surveys for industry and RTO aimed to identify the AM skills needs for different timeframes (scenarios). Although there was no overlap of scenarios regarding the identification of current and future AM Professional Profiles, it is possible to confirm the agreement towards the AM Professional Profiles required. In fact, the current most relevant profiles will continue to have relevance in the next 2 years.

Industry and RTO agree that the current AM knowledge missing is Certification and validation as well as Topology optimisation. While for the next two years they are also consistent in identifying testing and quality control. In addition, specific relevant knowledge on AM was identified as being missing by both target groups.

Table 16 - Comparsion between Industry and RTO surveys results

Scenarios	Industry Survey - results	RTO Survey – results
Relevance of AM **Professional Profiles** for **current activity**	Process engineer, designer, and materials engineer	N.A
	Specialist (at engineer level)	
Relevance of AM Professional Profiles within **2 years** (2020-2021)	N.A	Process engineer, materials engineer and designer
Relevant **AM knowledge** lacking for **current activity** (2019)	Certification and validation and Topology optimisation	
	Design	Numerical modelling and Standards
Relevant **AM knowledge** expected lacking in **2 years** (from 2020-2021)	Testing & quality control	
	Certification & validation Standards	AM processes, Design, Pre-processing & material handling, Resource Efficiency/sustainability, Marketing and sales

	Common
	Specific

4.2 Agreement between surveys vs interviews results

Both surveys and interviews to industry enable to identify and compare results within the AM skills needs for a short-term scenario. While a comparison between the technological trends was also possible between RTO and industrial representatives for the next 2 years. This comparison is addressed in this section.

Industry experts were consistent towards the AM knowledge missing the next 2 years (Short-term scenario), which are Certification, Quality monitoring and control. Although, companies identified non-technological skills less relevant when compared with technological ones, they considered that Costs and Communication will be kept stable but with less relevance. In addition, specific relevant knowledge on AM was identified as being missing as detailed below (see Table 17)

Table 17 - Comparsion between Industry surveys and interviews results

Scenarios	Industry Survey - results	Industry Interviews– results
Until 2021, relevant **AM knowledge** expected to be lacking in **2 years**	Certification Quality monitoring and control	
	Validation Standards	Qualification Simulation CAD Modelling
Until 2021, relevance of **Non-Technological skills for AM currently lacking and in 2 years**	Costs	
		value creation
Until 2021, relevance of **transversal skills** for AM **currently lacking and in 2 years**	n.a	Critical thinking, problem solving, learning to learn, working with others.

In terms of trends affecting the AM technology in a short term, both RTO and industry representatives attribute the same level of importance to zero manufacturing and real time control/monitoring System. Some disagreement was verified regarding the new materials trends, traceability and data management / Artificial Intelligence, which were specifically addressed by each one of the target groups (see

Table 18).

Table 18 - Comparsion between RTO surveys and industry interviews results

Scenarios	RTO Survey - results	Industry interview– results
Until 2021, importance of trends for AM professional activity	Zero defects manufacturing Real time control/ monitoring systems	
	New materials	Traceability, Data management / Artificial intelligence

	Common
	Specific

4.3 Agreement between experts: RTO surveys vs World cafe

Both activities, RTO surveys and World cafe, aimed to identify trends in terms of AM applications for same timeframe (foresight scenario – until 2025), although with different target groups, since the survey was specially addressed to organisations involved in research and development, while the world cafe gathered stakeholders belonging to different fields of expertise (i.e. industrial organisations, training providers and RTOs.

In terms of sectoral application in the future, responses opinion match regarding the increase use of AM in construction. As for the materials use in AM, different materials were mentioned, possibly because the question was formulated with difference sense. Participants in both activities agree that PBF and DED will continue to be the most used processes. Finally, in terms of required Professional Profiles and skills for the future, opinions are matching towards the need of AM Designers and Process Engineers, although the other elements vary (see Table 19).

Table 19 - Comparsion between world cafe and RTO surveys results

Scenario	World Cafe - results	RTO survey - results
Until 2025, Sectors influenced by AM / Sectors where R&D&I will be focused	Growth of applications in construction sector	
	All sectors are mentioned	Growth of application in Health, and Energy
Until 2025, materials typically not used will increase / relevance of AM Materials for R&D&I	Ceramics and Multi / Hybrid Materials	Metals and Polymers
Until 2025, more used AM processes / relevance of AM processes for R&D&I activities	PBF-LB DED-Arc; DED-EB; PBF-EB	PBF DED
	Hybrid Processes	ME BJ
Until 2025, relevance of the required AM Professional Profiles	Designer Process Engineer	
	Quality Engineer Operator Tooling Inspector / Inspector	Inspection Technician NDT Technician
Until 2025, lack of AM knowledge	Data analytics Design Materials and process development	Numerical modelling Non-destructive testing Metallurgical analysis and characterization, Pre-processing & material handling; Resource Efficiency/sustainability

	Common
	Specific

5. SECTION III - AM DATA VALIDATION

The 1st SAM workshop to validate skills needs took place on the 27th February in Brussels. The workshop aimed to address the following objectives:

- to promote the awareness on AM, and its importance at political and industrial levels;
- to discuss the skills needs and future qualifications priorities that will support the growth of the sector.

In order to achieve these goals, the workshop counted with a plenary session, where the European Commission (EC) and industry perspectives on the AM relevance was shared.

5.1 Methodology to Validate Skills Needs

The methodology applied for the validation of results consisted in plenary session for introducing participants to SAM objectives and results, followed by a hands-on activity with parallel group discussions on specific subjects:

- *Training needs in AM*
- *Reskilling workforce*
- *Solutions for national implementation*

The selection of the above topics is linked to the findings achieved through the market research conducted through online surveys. Specific training needs emerged from this auscultation which required an additional exploitation performed though the interviews with experts. At the same time, some findings required additional validation, namely regarding the identification of reskilling needs of the existing workforce. Also, it was important to understand expert's opinion on how the implementation of training should be conducted.

Each group had a moderator guiding the discussions, using a specific script with summary information on each topic. Please refer to the attendance list (Annex 7.3) in the annex section.

5.2 1st Workshop to Validate Skills Needs - External Workshop Results

Plenary session

The validation workshop was conducted with a group of 16 selected AM stakeholders (such as OEM, training center, industry national associations etc.). Project partners CECIMO, EWF, Materialise and IDONIAL also participated, being responsible for presenting the objectives and the motivation that brought the consortium to develop SAM project, as well as the first project results, meaning addressing the 1st round of auscultation in 2019 on current and short terms skills needs. Please refer to the attendance list (Annex 7.4) in the annex section.

The workshop counted with a plenary session, where the EC and industry perspectives on AM relevance were shared among participants.
The opening presentation was delivered by Carlo Scatoli, Senior Expert in DG Employment at the EC. In his presentation, Mr Scatoli outlined the challenges that the EU currently faces in developing the right set of skills in a fast-changing industrial job market. The EC is currently finalizing the new EU Skills strategy, which should be published in the same days as the Industry Strategy, to highlight the importance of moving these two topics together. Read full presentation here.

Michel Janssens, Materialise, explained the company's reason for joining the project. He underlined that it is essential to work on fostering education throughout the whole AM value chain as the technology and applications continue to develop and expand.

Eurico Assuncao, EWF, gave the audience some background information about the project, looking at the reasons why we need a strategic approach in the development of AM skills and profiles at European level. Read full presentation here.

The workshop continued with the presentation of the firstyear project results. Paula Queipo Rodriguez, IDONEAL, presented the AM skills needs and technological trends, which are the results of a series of surveys with industry and academia experts. Read full presentation here.

Group discussion

The results achieved regarding each subject, are gathered and described below in Table 20, Table 21 and Table 22.

Table 20 - 1st External Workshop results on current training needs in AM

Group 1 - Training needs in AM
Group composition: • JAKAJIMA B.V. – High Tech Industry Representative • Additive Industries - Industry representative / equipment manufacturer • MTA • VDW
1. What are the training needs priorities of your company/clients?
• To help them to overcome the "traditional" thinking, especially from the engineering side • Design is a priority as it affects the process, post-process…Tools for current design differs from AM design. Creativity is also important. • It is needed to tackle all levels of the value chain (VC), including also those people in the purchase, management, departments… • Some kind of training there is also necessary to get the dull AM market implementation. It is a two axis action, horizontally, all along the AM VC and vertical all along the different departments of an organisation.

2. Comments /relevant observation on graphic's 1 and 2 *(refer to the Annex 7.3 of this report)*		
In general, the group agrees with the results shown in the graphic 1. However, it is considered that in the future the materials part will become less important. Moreover, it is considered that materials and process engineers in the future will be just gathered in one professional profile. Good metallurgists can be employed directly for AM. It will be good to use those skills and incorporated this knowledge The operator needs to have some digital skills (at certain level) to be able to transfer files, and this kind of tasks. On graphic 2: Topology optimization is the key and knowledge and professionals in this area are needed. Also post-processing. Powder safety is also important. Simulation is not so much specific for AM: it is more the process and the material.		
3. Priorities for the SAM scenarios (identify the skills; Professional Profiles in AM)		
Scenario - current needs	**Scenario 2 – until 2021**	**Scenario 3 – 2022 to 2030**
Ok with current needs results: The four profiles highlighted are ok. But to include also the business related profiles	Profiles: same as scenario 1, but the Designer is the most critical one in terms of skills and materials will go down. Skills: • Design • Safety • Certification ad validation	Skills: • Cybersecurity • Multi-material • Machine learning • Printed electronics

Table 21 - 1st External Workshop results on upskilling needs of the industry workforce

Group 2 - Reskilling the industry workforce
Group composition : • ASTM – Standardization body • Materialise - AM Industry representative • GE Additive (Product Safety and Complaints) - Machine Producer; Regulatory side.
1. Which of these professionals either, from the companies/ clients', needs to be trained in AM ? **2. Which updates would be required in terms of knowledge and skills?**
1. From the list provided, participants experts confirmed that the following professionals require training in AM: Designers; Design Engineers and Inspection Technicians (NDT/DT Technicians) Additional Profiles requiring upskilling (not mentioned in the list): Software Personnel; Business developer; programmers; Application Specialists /Biomedical Engineers. **2.** Examples of Knowledge required: standards for machine (foresight need), knowledge about regulation, written for coding and know how about the process (for software skills personnel).
2. Comments /relevant observation on graphic's 3 and 4 *(refer to the Annex 7.3 of this report)*
Agreement with data provided in Graphic 4 (Professionals requiring training/update in AM), although Project Manager should be in 1st place, instead of Process Manager. Other comments: "There is the need to Upskills 100% of employees for AM" Solutions for upskilling – companies provide training on the job. Normally personnel employed in Materialise have Mechanical Engineering Background /curriculum; Open-mind specialist. Bio medical engineer

Table 22 - 1st External Workshop results on how to implement European training scope

Group 3 - Solutions for national implementation of EU scope
Group composition: • Aimen - Technology Centre • Lloyds Register – Certification Centre • EPMA – Umbrella organisation • CECIMO - – Umbrella organisation
1. National implementation with an European Scope - Which solutions?
1. The solutions for the national Implementation of an European Training scope are: • To establish an European Framework 100% • National support from large industries to support the qualifications • Modular Qualifications´ • Network of training centres (ATBs) • Standardisation (but this is at international level) • Event with all the national qualification agencies • Engaging with national engineering societies • France – SNIPF • Germany - VDI
2. Comments /relevant observation on graphic's 5, 6 and 7 *(refer to the Annex 7.3 of this report)*
The UK has national strategy for AM that is the reason UK has strong universities that look at attracting foreign students The info on the graphics might to be updated

Conclusion & implications for the future work in SAM project

The workshop with external stakeholders enables to consolidate prior findings and bring new elements of reflection that will be considered in the next stage of the project, namely to shape the next rounds of surveys and interviews, as well as for the selection of priorities for the 1st and 2nd stage piloting.

In terms of **validation of needed AM qualifications and professional profiles**, experts have confirmed that industry currently is requiring Process AM Engineers, AM Designers and AM Specialists for the Engineering level, which is aligned with the survey's findings. Within this scenario (i.e. Real Case), the input was given to include business related profiles. At short term, the need for AM profiles will be the same, but AM Designers will probably be more required.

In terms of **validation of knowledge and skills currently required by industry,** they are linked to Topology Optimization and Certification and Validation, which is aligned with prior findings. The same applies to the required knowledge until 2021, which will be focused on Design (not aligned with surveys, where skills in Design decrease in the next 2 years), Certification and Validation (which is aligned with the growth identified in the surveys until 2021).

At long term, experts identified new knowledge emerging referring to Cybersecurity, Multi-materials, Machine learning and printed electronics.

The recommendation was made to tackle skills development / training namely, to adopt two-axis actions, meaning horizontally, all along the AM Value Chain and vertically, all along the different departments of an organisation.

Regarding the **validation of needs for upskilling and/or reskilling** the current workforce, experts validated that the professionals are: Designers; Design Engineers, Inspection Technicians (NDT/DT Technicians), Project

Managers, Process Managers, RTD, followed by Software Personnel; Business developer; programmers; Application Specialists and Biomedical Engineers.

The examples of knowledge required for these professionals are: standards for machine (foresight need), regulation, written for coding and know how about the processes.

Finally, the solutions presented by the participants to address the implementation of the European Curricula /Training Scope for AM (i.e. European AM Qualification System) revealed to be aligned with the principles and approach being used in SAM (WP3) to develop and review Units of Learning outcomes and Qualifications. These solutions refer to align Qualification with industrial standards, use an European AM Framework, modular approach and engage with a diversity of stakeholders.

5.3 1st Workshop to Validate Skills Needs – Participants satisfaction

A satisfaction questionnaire *(Refer to D2.8 Kit for workshops and working sessions)* was applied for gathering participants feedback about the event.
The questionnaire addressed specific aspects, from logistics to technical issues:

- Identification of the participants background.
- Evaluation of the organisation (i.e. programme / agenda, amount of prior information)
- Evaluation of speakers / facilitators performance
- Relevance of topics addresses and
- Evaluation in terms of relevance of the covered themes, discussions, among others.

A total of 9 satisfaction questionnaires were filled out by the participants.

The analysis revealed that attendants' profile was quite homogenous, being composed by Industry Representatives (44%), other organisations, such as Organisation involved in Commerce, Certification Body and RTO/ Training Organisation (33%) and Employers Association (22%).

The reason most frequently evocated for participating in the workshop (see Figure 52) was the interest in obtaining and sharing new ideas and perspectives on AM industry needs (78%), followed by the interest in discussing existing skills gaps and making new contacts (both with 44%). All participants had heard from the event through invitation (89%).

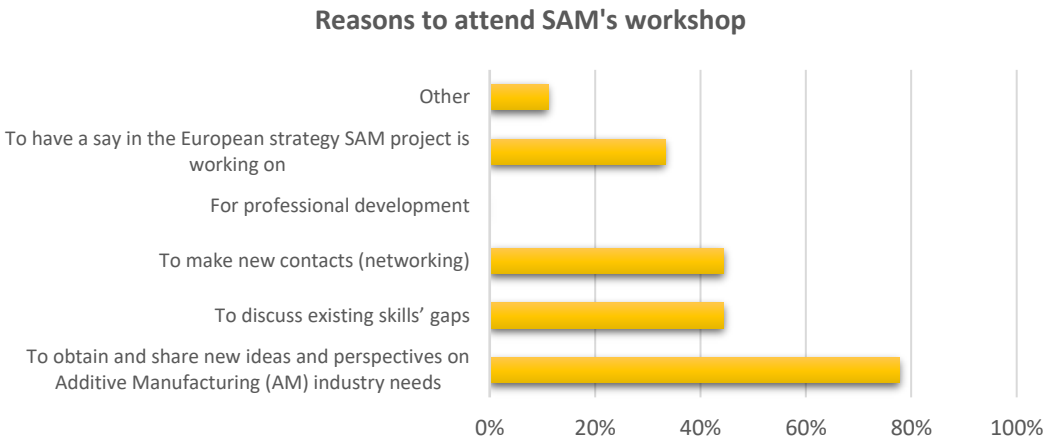

Figure 52 - Reasons for the workshop attendance

Concerning the global event organisation (see Figure 53), including registration process and arrangements, were the best rated topics (67% responses on the best rating), followed by the programme / agenda (56% provided best rating). A medium low rating was also given to the agenda, amount of information prior to the event and relevance of other participants (22% response with medium low rating). Some suggestions were given to improve the organisation, namely more time for presentations (timekeeping).

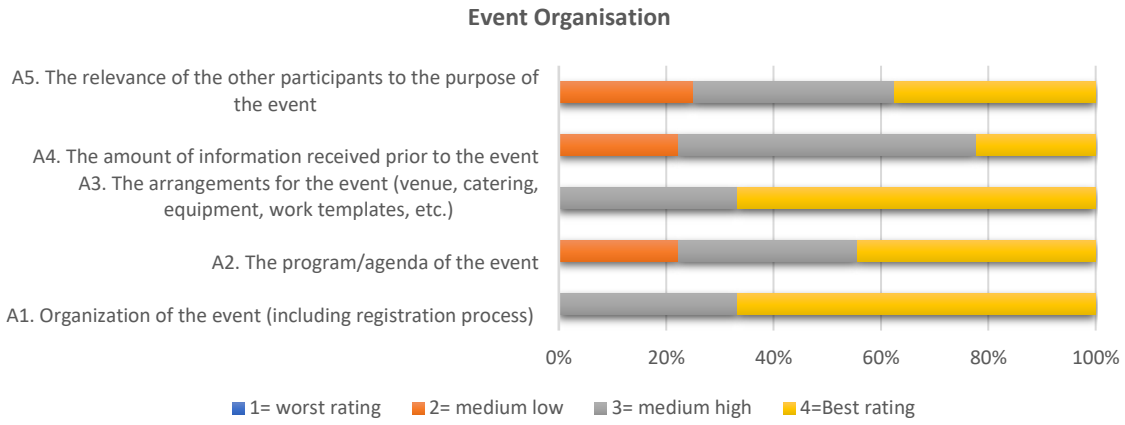

Figure 53 - Feedback on workshop organisation

In terms of speakers / facilitators performance (see Figure 54), participants were very satisfied regarding the way facilitators addressed the discussion (67% responses with best rating) and conducted the event (56% responses with best rating). One participant revealed to be not satisfied with the quality and format of the materials (11% responses with worst rating).

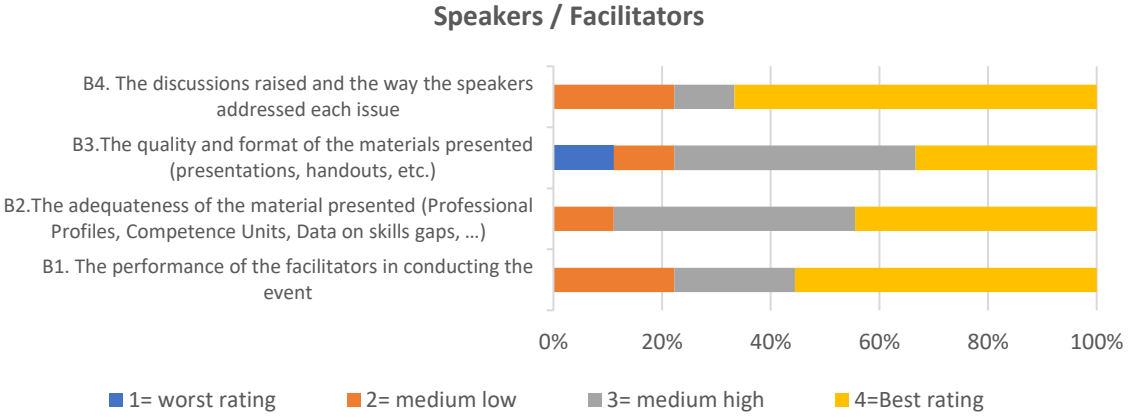

Figure 54 - Feedback regarding the performance of speakers / facilitators during the workshop

Participants considered as most relevant aspects of the workshop (see Figure 55), the discussion about the European Sector Skills Strategy SAM is defining (67% responses with best rating), followed by the relevance of the project for the sector, relevance of the skills need identification and qualifications for the own organisation, the relevance of data presented for AM training and education (44% with best rating).

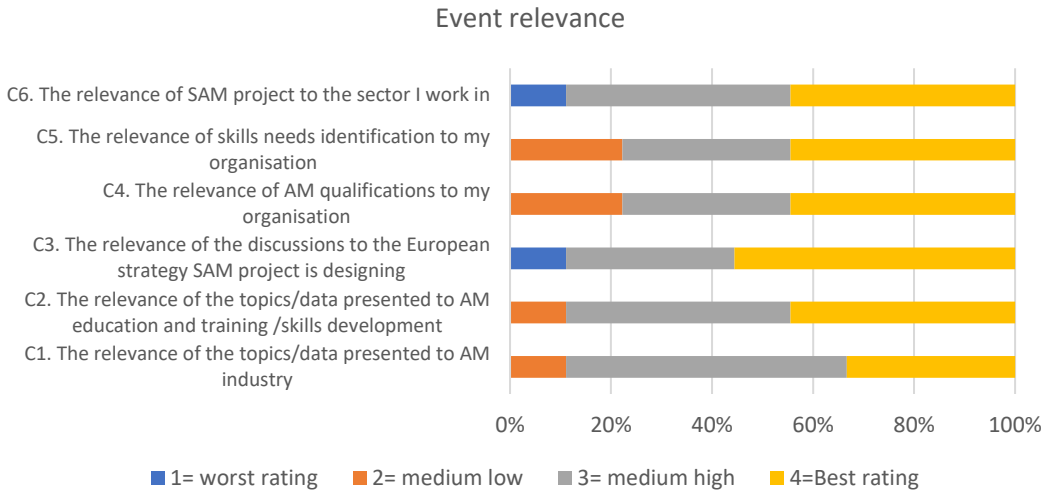

Figure 55 - Feedback about the workshop relevance

Finally, in terms of conclusion, participants confirmed that event was worthwhile (see Figure 56), enabling them to gain new perspectives (89 % say "Yes") and stablishing networking (100% say "Yes"), although not enough sectors were represented (67% say "No"). Participants considered SAM project as relevant for their organisations.

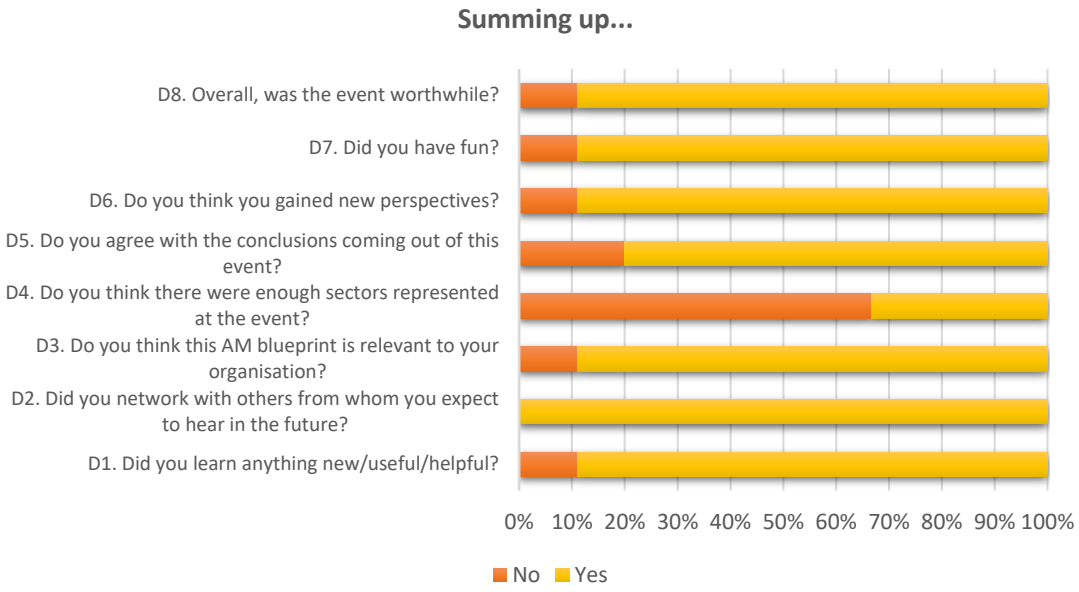

Figure 56 - Overall satisfaction with the workshop

Some suggestions were given to include in next event more end-users and to address also skills needs regarding polymers.

6. SECTION IV - CONCLUSION

The objective of this report was to document the priorities in terms of AM skills development considering the inputs from industrial organisations and RTO experts operating in different industrial sectors.

The report was the first out of four Reports on the "Analysis and Validation of Needs" which correspond to the 1st round of auscultation with key target groups, namely Companies, and Research and Technology Development Organisations. The report constitutes the baseline to identify skills gaps and demands of the AM Sector for current and short-term scenarios, thus influencing the European AM Skills Strategy (WP4) and the AM pilots pilot courses to be performed in less than 6 months (WP5 - 1st and 2nd stage of Real Case Scenario) and less than 2 years (WP5 - Short term Scenarios), see Figure 57 and Figure 58. Moreover, the document addresses the Technology Trends that will need to be considered in the near future until 2025 (see Figure Figure 59).

The major conclusions towards the skills gaps and demands for each scenario were:

Currents skills needs and gaps (Real Case Scenario, 2019)

AM Professional Profiles

Process Engineer, Designer and Materials Engineer

Business related profiles

Materials: Metals followed by Polymers

Technological Skills

Certification, Validation, Topology Optimisation, Design, Numerical modelling, Standards

Entrepreneurship, Digital and Green Skills

Costs, Resource Efficient Management/ Sustainability

Figure 57 – 1st Round findings on current AM skills gaps

Short -term skills needs and gaps (Short - term Scenario, from 2020 to 2021)

AM Professional Profiles

Process Engineer, Designer and Materials engineer

Materials: Metals followed by polymers

Technological Skills

AM processes, Testing & Quality Control, Design, Pre-processing & Material Handling, Topology Optimization, Certification and Validation

Entrepreneurship, Digital and Green Skills

Resource Efficiency/Sustainability, Marketing and Sales

Figure 58 – 1st Round findings on AM short-term skills needs and gaps

Technology Trends that will need to be considered in the near future (Foresight Scenario, from 2022 to 2025)

AM Professional Profiles

Designer, Process Engineer; Non-destructive Testing and Inspection Technicians

Materials: Metals followed by polymers

Processes PBF and DED

Technological Skills

Numerical Modelling, Non-destructive Testing, Metallurgical analysis and characterization, Pre-processing & material handling; Data analytics Design, Materials and process development.

Entrepreneurship, Digital and Green Skills

Resource Efficiency/Sustainability

AM technology trends for R&D&I

Trends for 2020-2025

Real time control / monitoring systems, New materials and Zero-defects manufacturing systems.

Figure 59 - AM technology trends until 2025

In addition, the 1st round of auscultation enabled to conclude about which existing workers could benefit from complementary training in AM (see Figure 60) and characterise some of the RTO training activities (see Figure 61).

Upskilling / Reskilling Existing Professionals (independent analysis from the scenarios)

Consultants, Civil engineers, Mechanical engineers, Design Engineers, Inspection Technicians (NDT/DT Technicians), DT Technicians, Project Managers, Process Managers, RTD Professionals from different industries and what to change to industry, followed by Software Personnel, Business developer; programmers.

Figure 60 - Findings on upskilling /reskilling existing professionals

AM Training /Education (Data collected from RTO that include training in their activity)

From the RTO relying to the surveys, the majority (67%) is involved in training activities. The training/education courses correspond mostly to internal courses followed by technological workshops (>1 day) and external training at customers' location.

Training courses mostly target AM Processes, followed by Design, Post-processing and Topology Optimization. While the skills less addressed are linked to non-technological areas, namely Communication, Marketing and Sales and Resource Efficiency / sustainability.

Figure 61 - 1st round findings on AM training and education

6.1 Actions for the next period

SAM is addressing and giving priority to technological skills linked to Health and Safety, Quality Control, AM defects (per group of process/process based), AM Processes and End of life, which were identified as crucial skills gaps. Nevertheless, along the project the remaining categories of skills will be tackled.

Since the findings of the 1st round of auscultation lead to the conclusion that Metals will continue to be required and the most required AM Professional Profiles are already integrated in the European Metal AM Qualification System, namely the Designers and Process Engineers and Specialist/ Coordinator at Engineering level, it would make sense to keep this Profiles updated and to develop new European AM Qualifications for metals and polymers.

Four criteria were used to determine priorities to tackle the above-mentioned skills needs and gaps, which are: sectors relevance in alignment with ISO activities, urgency, impact on employability and relevance towards Raising Awareness on AM.

Table 23 highlights the main indicators and priorities to be covered in SAM project for two scenarios.

Table 23 - Indicators and contents covered in SAM for real case and short-term scenarios

Scenario	Outcome
Real Case Scenario **Training to be delivered in less than 6 months**	- 1 PP/Q revised *(previous projects)* **AM Process Engineer LPBF revised**
	- 1 learning unit revised **- CU 61 Simulation Analysis** **- CU 62 Execution (Optional CU linked to Simulation);** **-**
	1 new Professional Profile/Qualification **New Q/PP for Designers for Polymers (non-Engineers)** **NEW Q on AM for Non – manufacturing personnel***
* to Be confirmed in the 2nd Round (2nd stage)	- 1 new learning unit **New CU for Certification/ Standardization** **New CU for Business for AM** **New CU Project management** **New CU Materials replacement /transfer metallic parts for polymer parts**
Short -term Scenario **Training to be delivered in less than 2 years** * to Be confirmed in next short-term auscultation	1 new Professional Profile/Qualification **- Sectoral Qualifications** **- New Qualification for Polymers** **- Review Supervisor**
	- 1 new learning unit - TBD

Next actions in the project until 2022 foresee to continue the identification of current needs with industrial organisations, educational centers and AM professionals /workers, in order to identify emergent AM skills gaps and needs. Also, the forecast analysis will be implemented. In parallel a set of activities will take place aiming to review and design new qualifications/professional profiles and units of learning outcomes. Moreover, the development of educational resources will be organized, along with training activities as summarized below (see Table 24).

Table 24 - Summary of actions to be conducted in SAM until 2022

Action Type	Description	Goal
Skills needs identification and forecast	Analysis of **AM Educational Training Practices** Survey Results **– Real Case Scenario – 1st Round** **Target groups: Training Centres, Higher Education Institutions**	Analyse the results and compare them with the demand (1st round of auscultation of industry and RTO) and with the results from the training offer
	Conduct **AM Professionals** auscultation **– Real Case Scenario – 1st Round** **Target groups: Existing Industrial Professionals /workforce**	Identify the immediate skills to be addressed and compare with previous results;
	Conduct auscultation with **industrial companies, Training centres and AM Professionals** on emergent skills needs and gaps **– Real Case Scenario – 2nd Round** **Target groups:** Companies, Training Centres and workforce	
	Conduct the **foresight** analysis for **skills** required the **next 10 years - Foresight Scenarios** **Target groups: Small group of selected experts belonging to Industry, Research and technology centres**	Identify the future skills to be addressed (10 years)
AM training design and tools development	**National working** sessions in collaboration with external experts **to review** qualifications and learning units **in less** than **6 months – 1st stage of Real Case Scenarios** **Target groups: Associated partners with relevant expertise belong to industry, academia, research centres, training centres, recruitment agencies, etc.**	Review existing AM Professional Profile /Qualification and Learning Unit Review learning and assessment tools (if applicable)
	National working sessions in collaboration with external experts **to develop new** qualifications and learning units **in less** than **6 months – 2nd stage of Real Case Scenarios** **Target groups: Associated partners with relevant expertise belong to industry, academia, research centres, training centres, recruitment agencies, etc.**	Design new AM Professional Profile /Qualification and Learning Unit Develop new learning and assessment tools (if applicable)
	National working sessions in collaboration with external experts **to review** qualifications and learning units **in less** than **2 years – Short Term Scenarios** **Target groups: Associated partners with relevant expertise belong to industry, academia, research centres, training Centres, recruitment agencies, etc.**	Develop new AM Professional Profile /Qualification and Learning Unit Develop new learning and assessment tools (if applicable) **Review** existing AM Professional Profile /Qualification and Learning Unit Review learning and assessment tools (if applicable)
Train the Trainers	Two training the trainers will take place for preparing trainers to conduct pilots and to share pedagogical approaches and tools in AM training towards the implementation of the AM Qualification System. **Target groups: Teachers and trainers with technological know-how in AM and related technologies**	Share best practices on how to deliver training in AM; Fostering trainers pedagogical and technical skills

Guidelines developments	Guidance document containing **curriculum and tools –** to be applied in **1st stage of Real case scenarios event** **Target groups: Teachers and trainers**	Support the implementation of training in AM
	Guidance document containing **curriculum and tools –** to be applied in **2nd stage Of Real Case scenarios event** **Target groups: Teachers and trainers**	
	Guidance document containing **curriculum and tools –** to be applied in **Short term Scenario event** **Target groups: Teachers and trainers**	
AM training Delivery / Pilot testing	Pilot testing of Qualification/ PP and learning unit - **1st stage of Real case scenarios** **Target groups:** Students	Validate the capacity to undertake the design and/or review of Qualifications and Learning Units delivery for the different Scenarios Validate the adequacy, relevance of the curriculum, pedagogical approaches and tools in the context of AM training
	Pilot testing of Qualification/ PP and learning unit - **2nd stage Of Real Case scenarios** **Target groups:** Students	
	Pilot testing of Qualification/ PP and learning unit - **Short term Scenario** **Target groups:** Students	
	Pilot testing of Qualification/ PP and learning unit - **Real Case and Short-term scenarios** **Target groups:** Students	**Implement** SAM's final forecast methodology
AM Qualification Catalogue	Online catalogues containing information on Available training in AM in Europe -two editions will be issued **Target groups: End-users**	Promote AM Training in Europe

7. SECTION V - ANNEXES

7.1 Attendance List World Cafe

7.2 Attendance List of the 1st Internal Workshop to Analyse Data

Organiser	**Venue**
Politecnico di Milano (POLIMI)	Department of Management Engineering, Building BL26, via lambruschini 4/b, 20156, Milan, Italy

Day 2 - 11th December 2019

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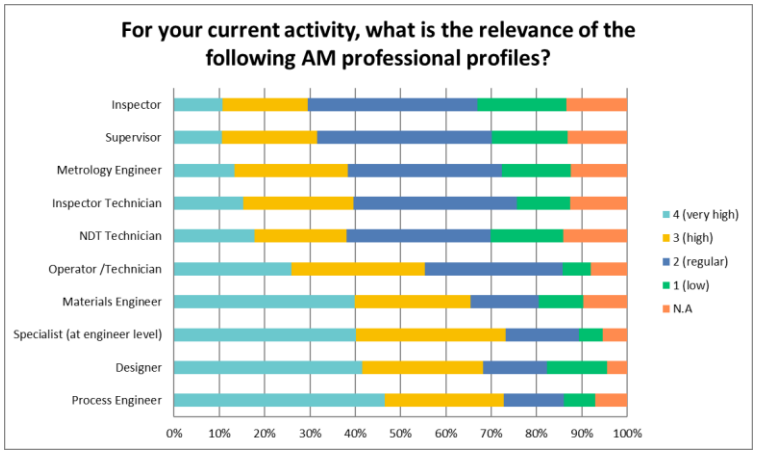
7.3 Supporting documents used in the 1st External Workshop to Validate Skills Needs Group session

SESSION OF TRAINING NEEDS IN AM

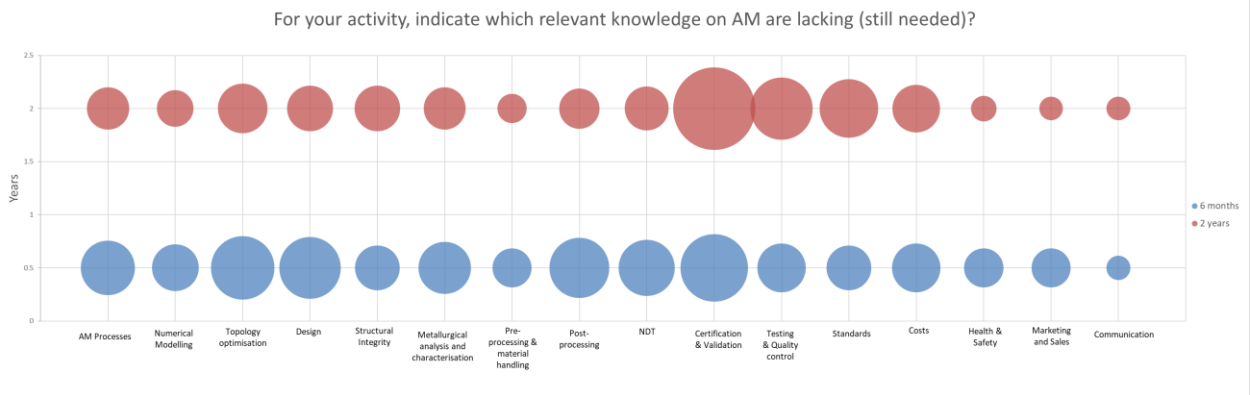
1- Core question to be discussed

The objective is to identify and detail as much as possible the needs of the participation organisations **What are the training needs priorities of your company/clients?**

2- Relevant facts about AM skills needs



Graphic 1 – Priorities of AM Professionals according companies



Graphic 2 - Relevant knowledge on AM still needed 2019 to 2021 according companies

SESSION ON RESKILLING THE INDUSTRY WORKFORCE

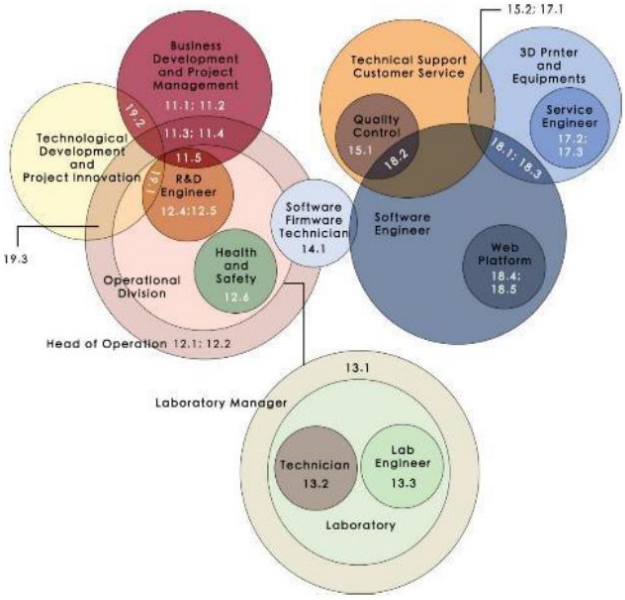
1- Core question to be discussed

The objective is to identify and detail as much as possible the needs of the participation organisations

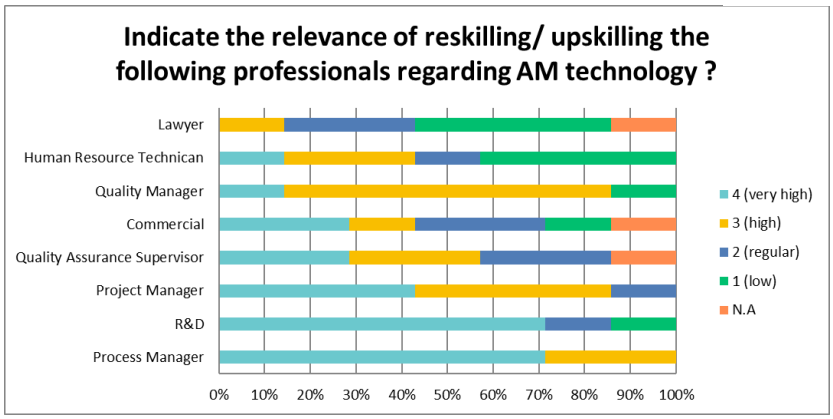
Which of these professionals either, from the companies/ clients', needs to be trained in AM ?

2- Relevant facts about AM skills needs

- CNC Technicians
- NDT /DT Technicians
- R&D Technicians
- Robots Operators
- Welders
- Welding Inspectors
- Welding Coordinators
- Designers
- Design Engineers
- Materials Engineers
- Others



Graphic 3 - Overlap of AM Professional Profiles



Graphic 4 – Professionals requiring training/update in AM

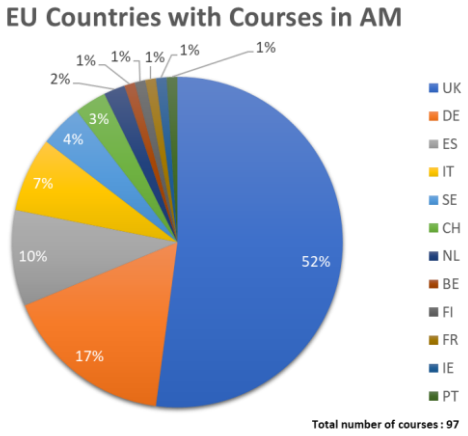
SESSION ON NATIONAL IMPLEMENTATION WITH AN EUROPEAN SCOPE

1- Cor question to be discussed

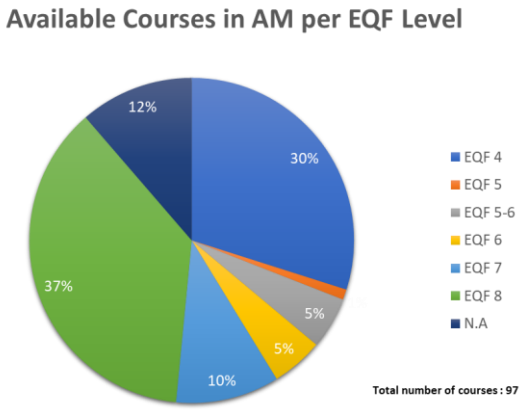
The objective is to discuss and agree on solutions for the implementation of training for trans-national curricula

National implementation with an European Scope - Which solutions?

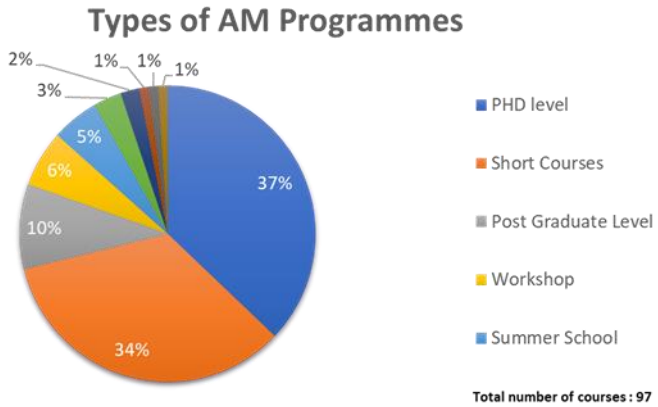
2- Relevant facts about AM National Training Initiatives



Graphic 5 –Countries with AM training Offers



Graphic 6 – EQF levels of the AM training Offers



Graphic 7 – Types of AM training Offers

7.4 Attendance List of 1st External Workshop to Validate Skills Needs

Co-funded by the Erasmus+ Programme of the European Union

1ST SAM WORKSHOP FOR VALIDATION OF NEEDS IN ADDITIVE MANUFACTURING

Thursday, 27th February 2020

Organiser	**Venue**
European Association of the Machine Tool Industries and related Manufacturing Industries (CECIMO)	PENTAHOTEL Chaussée de Charleroi, 38, 1060 Brussels

Name	Surname	Organisation	Country	Signature
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Adelaide	Almeida	EWF	Belgium	
Ambroise	Vandewynckèle	AIMEN	Spain	
Bram	Smits	Materialise	Belgium	
Camille	Mommer	AGORIA	Belgium	
Eurico	Assunção	EWF	Belgium	
Fatih	Pitir	Ermaksan Machinery	Turkey	
Harry	Kleijnen	Additive Industries	Netherlands	
Joshua	Doungale	MTA	UK	
Kenan	Boz	EPMA	Belgium	
Louis	Friedricks	ASTM INTERNATIONAL	USA	
Luis	de Prada	EUCAR/ACEA	Belgium	
Michel	Janssens	Materialise	Belgium	
Mike	Kelly	ThreeD Ltd		
Nicolas	Parascandolo	Symop	France	
Nuno	Araújo	AIMMAP/CATIM	Portugal	
Paula	Queipo	IDONIAL	Spain	
Pieter	Hermans	Jakajima B.V.	Netherlands	
Savas	Dilibal	Istanbul Gedik University	Turkey	
Simon	Koelking	GE - Concept Laser	Germany	

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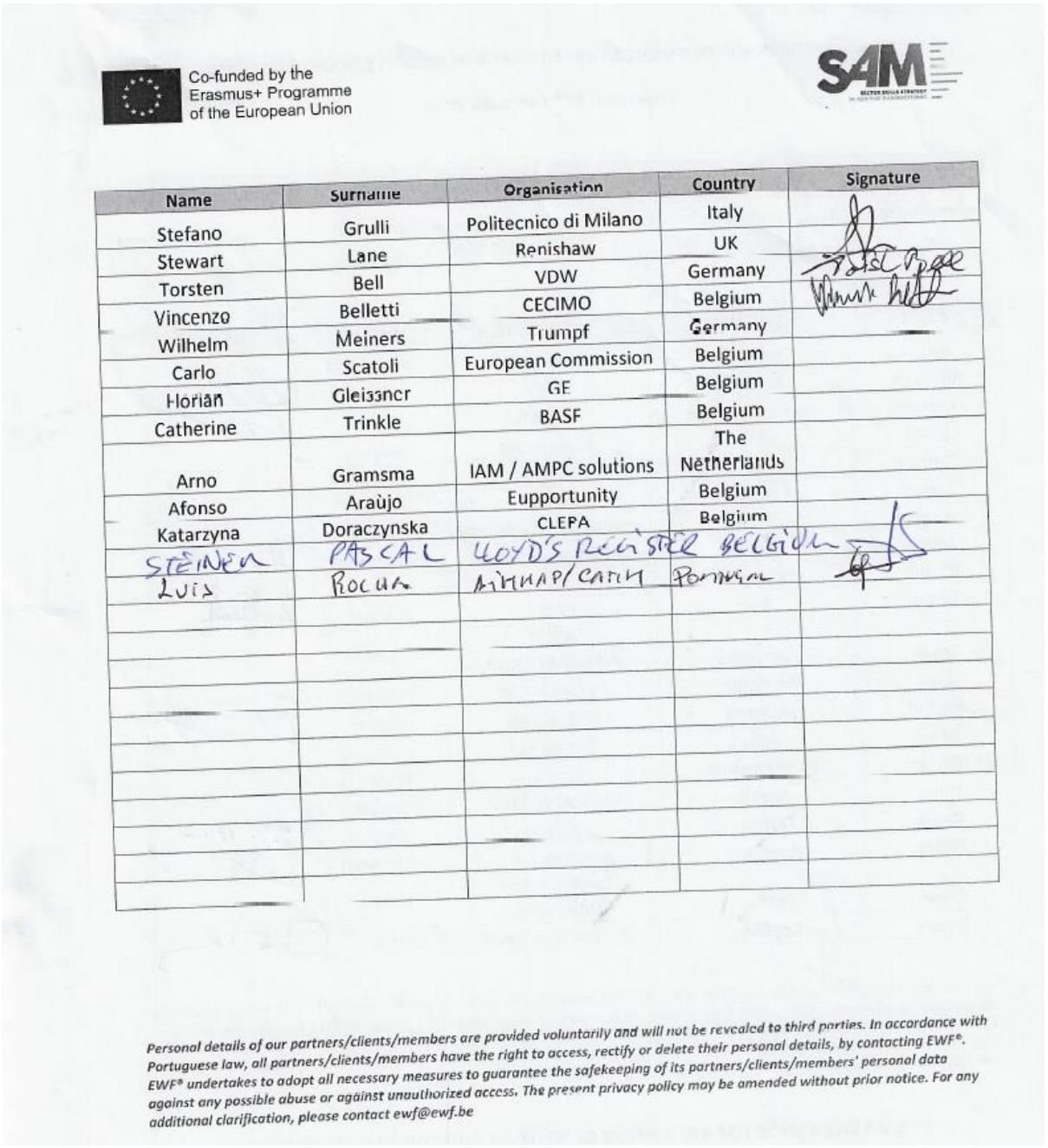

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