SECTOR SKILLS STRATEGY
IN ADDITIVE MANUFACTURING

Additive Manufacturing Foresight Report

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Executive Summary

This foresight report deals with evaluating and forecasting the skills, trends, and developments related to Additive Manufacturing (AM) until 2030. The methodology and activities entailed an initial skill forecast workshop, two rounds of follow-up surveys (i.e., implementing the Delphi method) with AM experts from industry, academic institutions, research, and technological centres. The participants were from various sectors, including aerospace, construction, defence, energy, industrial equipment, and tooling. In addition, a presentation of the results was carried out at the Design for Additive Manufacturing (DfAM) in Education workshop.

Some of the key findings from the foresight analyses are shown below:

1. The main AM materials that will be used in the next 10 years are Aluminium, Copper, Inconel (i.e., nickel-chromium-based superalloys) and Titanium.
2. The new AM materials that will be developed in the next 10 years include composites, functionally graded materials, and metal alloys.
3. The main AM processes that will be used in the next 10 years are AM processes for bioprinting, Directed Energy Deposition (DED), Metal Binder Jetting (MBJ) and Powder bed fusion (PBF).
4. The major sectors/industries that will be heavily affected by AM in the next 10 years are the aerospace, automotive and health sectors.
5. For the aerospace sector, the main parts that will be produced with AM are fuel nozzles and systems, guide vanes and turbine blades. For the automotive sector, the main parts that will be produced with AM are spare parts, low volume interior parts and engine components. For the medical sector, implants, prosthetics, and surgical models.
6. The main occupations in AM in the next 10 years will be AM designers, process experts and R&D experts.
7. The main expected developments and technological trends in AM in the 10 years include the establishment of AM in series production, availability of more public standards available in different areas (design, feedstock, processes, personnel, machine, etc.), development of new materials, cost reduction and more reliable simulation techniques for most AM technologies.
8. The major implications of the developments/trends on the AM labour market will lead to more digital experts (data managers, niche experts for processes and algorithms, etc.), reskilling people from the "conventional" processes to AM technology and more robust simulation techniques.
9. The main AM areas that will foresee a reduction of costs in the next 10 years are AM machines and equipment, AM materials and feedstock and AM post-processing stages.
10. The major AM areas that will require the development of professional standards are AM materials, AM processes, AM design and modelling, and AM equipment and software.

Additional findings and results are presented in the conclusion section of this report. These findings will be used to improve the AM skills strategy and influence the development of future training programmes and courses for AM personnel. This foresight exercise ensures a good alignment between the demand and offer of training programmes and will inform decision making, policy reform and future funding programmes.

AM value chain and trends for the next 10 years (2021 – 2030)

AM value chain	Expected developments and technological trends	Impact on skills and occupations
Modelling & Design	• Availability of more public standards for modelling & design • More reliable simulation techniques for most AM technologies	• More training, qualifications, and public standards to ensure the widespread application of AM technologies • Increased need for more AM supervisors, digital experts, data managers and specialists to develop new AM processes and algorithms • Training for different roles, such as AM supervisor, AM engineer, AM designer to become qualified • Predicted occupations include process experts, data managers/miners, AM designers and AM operators • Increased need for AM workers to know the overall AM process supply chain • Occupations that will benefit the reskilling from "conventional" processes to AM technology include welding inspectors, coordinators, operators and designers • Higher uptake of AM across more industries and sectors
Materials	• Cost reduction across AM materials and feedstock • Main materials will include aluminium, copper, Inconel (i.e., nickel-chromium-based superalloys) and titanium and emerging materials will include hybrid materials, composites, functionally graded materials and metal alloys • Availability of more public standards for materials	
Processes	• Main processes will include bioprinting, directed energy deposition, metal binder jetting and powder bed fusion • Cost reduction across AM machines and equipment • Workflow simplification, increased automation and establishment of AM in series production • Combination of multiple AM processes for efficient manufacturing • Availability of more public standards for AM equipment and software	
Post-Processing	• Cost reduction for post-processing • Availability of more public standards for post-processing stages	
Products	• AM products with larger dimensions • Cost reduction and development of standards for AM products • The major sectors will be the aerospace, automotive and medical sectors • For aerospace, the main AM parts will be fuel nozzles and systems, guide vanes and turbine blades • For automotive, the main AM parts will be spare parts, low volume interior parts and engine components • For medical, the main AM parts will be implants, prosthetics and surgical models	
End-of-Life	• Availability of established processes and more public standards for end-of-life processing • Cheaper end-of-life processing options	

1. Introduction

Sector **S**kills **S**trategy in **A**dditive **M**anufacturing (SAM) ERASMUS+ project is a strategic approach to skills in Additive Manufacturing (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.

This foresight report, developed in the framework of the *AM Observatory* (within Work Package 4), is based on the implementation of a foresight kit (D2.4) designed within the scope of Work Package 2 of the SAM project. This 10-year foresight methodology is part of SAM's objectives which involves the prediction of skills mismatches and gaps in the AM sector through the auscultation of AM experts across various industries. The report evaluates and forecasts the developments and skills required within AM in 10 years. Also, it is based on data from multiple rounds of activities, including an initial skills workshop with AM experts, two rounds of follow-up surveys (i.e., Delphi method) with the experts, analysed and reported.

The initial skills workshop entailed an interactive workshop with open questions to the AM experts, which formed the input for the first round of the follow-up surveys. Subsequently, the results of the first round of surveys were analysed, which was used to design the second round of the survey. At the end of the second survey, the results (i.e., 10-year forecast of skills and developments in AM) were analysed and presented at a Design for Additive Manufacturing (DfAM) in Education workshop, which comprised AM experts and practitioners from around the world. Also, the final results covering the 10-year forecast of skills and developments in AM, are summarised at the end of this report.

2. Methodology

This methodology follows the Delphi method (series of questionnaires in two or more rounds), which entails an initial virtual and interactive workshop then two follow-up surveys based on the responses from the previous rounds. The responses are then compiled and analysed to evaluate the AM trends in 10 years.

The benefits of this approach include:

- Collection of as many ideas and responses within a short timeframe from the AM experts
- Encourages open and creative thinking
- Enables interactivity (i.e., during the initial workshop)
- Less bias - prevents participants' authority, personality, or reputation from dominating others during the process
- Patterns and trends begin to emerge after the data analysis and follow-up surveys.

The aim is to get the responses from different AM experts from industry, academic institutions, research, and technological centres about the skills required, trends and developments within the AM sector in 10 years.

Table 1 gives an overview of the SAM's Delphi Method from the foresight kit, and Figure 1 shows the flowchart. In addition, the questions are provided in the appendices.

Table 1: Overview of the SAM's Delphi Method from the foresight kit

Aim	To evaluate and forecast the skills required, trends and developments within the AM sector in 10 years
Tools	Virtual Workshop platform • Microsoft Teams Live interactive platform to show live questions and answers, for example: • Vevox, Microsoft Forms, Slido, Mentimeter, Miro Follow-up surveys • FreeOnlineSurveys, Survey Monkey
Target group	AM Experts (20 – 40) from industrial organisations
Performance indicator and impact	Number of participants (i.e., AM experts) Number of responses
Input	a) Summary of **previous results/questions** from surveys and workshops b) **Virtual Workshop** (Open questions (without choices) related to the AM sector in 10 years) c) **1st round online survey/questionnaire** - based on responses from the workshop d) **2nd round Online Survey/Questionnaire** - based on responses from the 1st round online survey/questionnaire
Output	Data and trends relating to the skills required and developments within the AM sector in 10 years
Timeline	Every 10 years

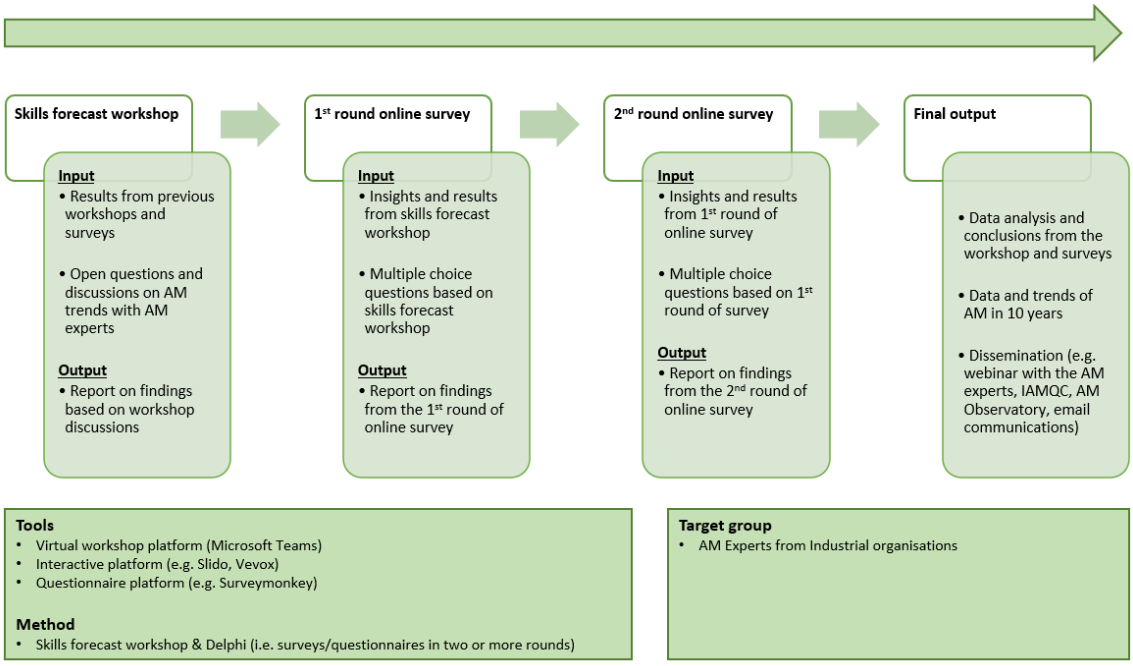


Figure 1: Flowchart of the SAM's Delphi Method from the foresight kit

3. Selection of AM experts

The AM experts were selected from SAM's list of invited industrial organisations. These experts are part of the Industrial Council and are included in the European AM Observatory. Also, these experts had direct and specific years of experience within the AM industry. A total of 14 participants (including the organisers) were at the actual workshop. To increase the number of answers to 25 in the subsequent rounds of follow-up surveys, additional AM experts from the Qualification Council were contacted in order to extend the outreach of AM experts at the initial stage.

4. Dates and Timeline

First Stage - Skills Forecast Workshop (10th May 2021)

The skills forecast workshop entailed the collection of the AM expert's backgrounds (e.g., expertise, years of experience, sector, gender proportion), an initial interactive questionnaire session and discussion with the AM experts. This provided initial answers to open questions related to the AM sector's skills and developments in 10 years. Different platforms, including Slido, Microsoft Forms, Vevox, were used to increase engagement and interactivity during the skills forecast workshop. Also, the responses from the AM experts during this workshop formed the questions of the 1st round of follow-up online survey.

Second Stage - 1st Round of Follow-Up Online Survey (2nd June 2021)

The 1st round of follow-up online survey was based on the responses, insights, and results from the skills forecast workshop. This enabled the collection of more specific responses compared to the skills forecast workshop. FreeOnlineSurveys (i.e., a survey platform) was used to gather the responses from the AM experts. The results from the stage formed the 2nd round of follow-up online survey.

Third Stage - 2nd Round of Follow-Up Online Survey (26th June 2021)

The 2nd round of follow-up survey was based on the responses, insights, and results from the 1st round of follow-up online survey. Furthermore, this enabled the collection of more specific responses compared to the 1st round of follow-up online survey. The results from this stage, alongside the initial stages, were analysed and used for the final stage.

Final Stage - Presentation of Results (13th July 2021)

The final stage (i.e., presentation of the results) entailed the analysis of the responses and insights from the initial skills forecast workshop and two rounds of online surveys. This was disseminated to AM experts and professionals at a Design for Additive Manufacturing (DfAM) for Education workshop. The results will also be included in the AM Observatory and project website.

5. Results of the Skills Forecast Workshop

An initial virtual foresight workshop took place on 10th May 2021, focusing on identifying the skills required and developments within the AM sector in 10 years (see Figure 2). The workshop entailed:

- An introduction of the SAM Project
- Summary of results from previous forecast sessions (e.g., surveys & interviews)
- Live and Interactive questionnaire session (e.g., structured into part A - Background and part B - Skills Forecast in 10 years) with the participants regarding the skills required and developments within the AM sector until 2030

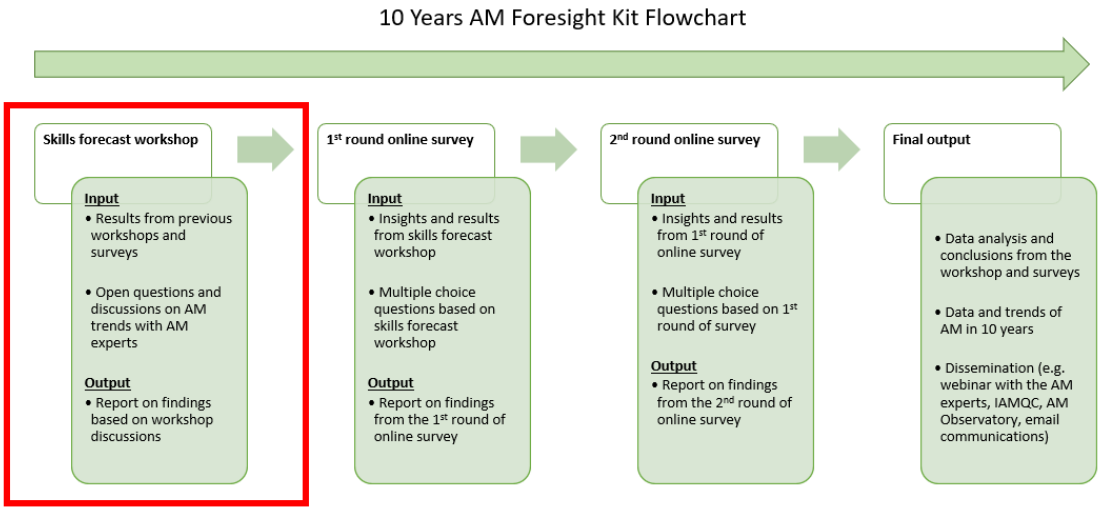


Figure 2: Flowchart of the 10 years AM foresight kit (skills forecast workshop)

Part A: Participant's Background

The AM experts from different six European countries took part in this initial workshop. The countries were Belgium, Denmark, Germany, Italy, Portugal, and Spain. The participants comprised seven males and two females across different sectors, including aerospace, construction, defence, energy, industrial equipment, and tooling. The majority (56%) of the AM experts had 0 – 5 years of experience in AM. However, 22% of the AM experts had 6 – 10 years of experience, and the remaining 22% had over 20 years of experience in AM. The proportion of the age ranges were 22%, 33% and 44% for 26 – 35, 36 – 45, and Over 45, respectively.

Part B: Skills Forecast for Additive Manufacturing in 10 years

The AM experts were asked the following questions, and the responses are shown below each question.

Open Question

What are the expected developments and technological trends in Additive Manufacturing technology in 10 years?

Open Responses

- AM established in series production
- AM processes need to be faster compared to what is possible today, including automated data preparation, part production and post-processing, all digital AM process chain.
- AM will be used in difficult areas (where other technologies are difficult to implement)
- Big metal pieces
- Develop new material on AM
- Developments: will include AI and fully automated production
- Further established AM technologies in industry
- Hybrid material pieces
- Hybrid processes
- In-situ data monitoring

- Large dimensions
- More public standards available to ensure the proper application of AM industry in different areas (design, feedstock, processes, Personnel, machine, etc.).
- Multi-material
- Multiple processes (binder jetting, DED, WAAM)
- New alloys
- New design features (e.g., lattice structure)
- Not necessarily to substitute "conventional processes"
- Qualification
- Reduction of pre-processing
- Reliable simulation will be available for most AM technologies
- Simplification of the current workflows (starting from sketch and idea to final product)
- Supply chain considerations
- To establish AM has a solid technology in different industries.
- Trends: new materials will come, new technologies as well, sustainability,
- Very long time 10 years, very long... Too risky

Open Question

What will be the main implications of such developments /trends in the AM labour market (e.g., required occupation) in 10 years?

Open Responses

- AM but also traditional technologies will require completely different worker's profile.
- Computer science and data mining will be the new math
- Creativity and capability to compare products market and value
- Digital transformation is about to start and will require more digital experts, datalike managers, niche experts for processes and algorithms, etc.
- Knowledge of the whole process chain will become more important
- Labour market is going to ask for high-level profiles being able to redesign products
- Reskilling people from the "conventional" processes to AM technology
- Simulation needs input - so technicians/engineers will have to know more process details than today
- Supervising the process rather than running it
- To have more people qualified in this technology (e.g., operators, engineers, designers)

Open Question

Which Additive Manufacturing Processes will be mainly used in 10 years?

Open Responses

- Binder jet printing with different materials
- DED for big, massive parts
- E and L-LPF for complex parts
- FDM or SLS
- Material extrusion and Vpp for small industry
- MBJ for parts with lot sizes up to 100,000 parts per year
- PBF (both laser and EBM), DED and WAAM, BJ, Extrusion, Two-photon SLA, bioprinting
- PBF, DED and Binder Jetting for big industry
- Powder bed fusion with metals

- The ones will be able to produce consumers goods
- The ones will exploit circular economy
- Today none of the technologies is ready

Open Question

Which Additive Manufacturing Materials will be mainly used in 10 years?

Open Responses

- Aluminium
- Ceramics
- Coated-metals
- Composites
- Concrete
- Copper
- Hybrid materials
- Inconel
- Magneto-caloric graded-metals
- Metals
- Polymers
- Recyclable polymers
- Recycled steel
- Titanium

Open Question

What are the predicted Occupations Additive Manufacturing in 10 years?

Open Responses

- Data manager
- Data miner
- Designer
- Powder specialists
- Process experts and designers
- Process leader
- Process monitoring manager
- Process validation manager
- System operators
- Translators of process parameters to ai systems

Open Question

Which Sectors/Industries will be heavily influenced by Additive Manufacturing in 10 years?

Open Responses

- Aerospace and automotive (areas where customizations are needed)
- Construction
- Creative industry
- Electrical industry
- Energy
- Machine tools

- Medical (especially with bioprinting)

6. Discussion on the Skills Forecast Workshop

The responses from the AM experts during the workshop showed that the expected developments and technological trends in AM in 10 years are linked to the **advancement of current AM processes** (e.g., improved speed, increased automation, workflow simplification, reduced pre-processing, reliable simulation techniques, and in-site data monitoring) as well as the **combination of multiple AM processes for efficient manufacturing**. The results also showed that **novel AM materials**, including hybrid materials and AM products with larger dimensions, will be developed. Additionally**, AM further establishment across more industries and sectors** is expected, and more **training, qualifications, and public standards will be available** to ensure the widespread application of AM technologies. These sectors and industries include the aerospace, automotive, construction, energy, electrical, health, machine tools and creative industries. This will mainly be as a result of customisation needs and bio-printing for the health sector.

The main AM processes in the next 10 years will comprise directed-energy deposition (DED), binder jetting (BJ), material extrusion (ME), fused deposition modelling (FDM), selective laser sintering (SLS), powder bed fusion (PBF), wire arc additive manufacturing (WAAM), and bioprinting. Furthermore, these AM processes will be used with a range of different materials to make large and complex parts with increased production rates (e.g., 100,000 parts annually). The main AM materials will be metals, polymers, concrete, ceramics, composites, and recycled materials.

As a result of the aforementioned points, the main implications of the expected developments in the AM labour market will entail **training people across different roles such as AM supervisor, AM engineer, AM designer to become qualified.** Furthermore, this will require AM workers to have knowledge of the overall AM process supply chain and an increased need for **AM supervisors, digital experts and data managers and experts for the development of new AM processes and algorithms.** In line with these responses, the experts linked the predicted AM occupations in 10 years to process experts, data managers/miners, AM designers and AM operators.

7. Results of the 1st Round of Follow-up Online Survey

Following the initial skills forecast workshop, the results were collated and analysed. Thereafter, a 1st round of follow-up online survey was developed based on the responses from the workshop (see Figure 3).

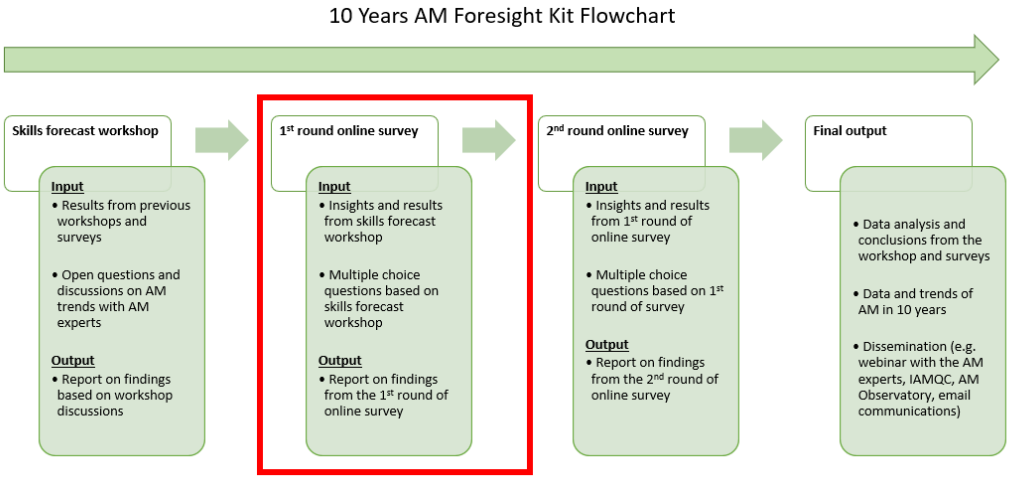
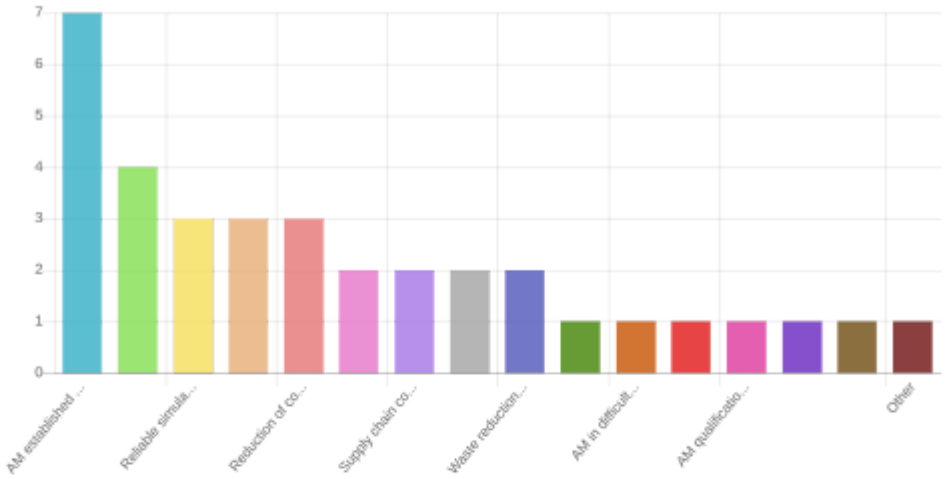


Figure 3: Flowchart of the 10 years AM foresight kit (1st round online survey)

Question: What are the expected developments and technological trends in Additive Manufacturing technology in 10 years? (Maximum 4 answers)

Responses



78% (7)
AM established in series production

44% (4)
More public standards available in different areas (design, feedstock, processes, personnel, machine, etc.).

33% (3)
Reliable simulation will be available for most AM technologies

33% (3)
New materials

33% (3)
Reduction of costs

22% (2)
New technologies

22% (2)
Supply chain considerations

22% (2)
Large dimensions

22% (2)
Waste reduction via in-situ data monitoring and control

11% (1)
Simplification of the current workflows (starting from sketch and idea to final product)

11% (1)
AM in difficult areas (where other technologies are difficult to implement)

11% (1)
New alloys

11% (1)
AM qualification

11% (1)
Reduction of pre-processing

11% (1)
Hybrid processes and materials

11% (1)
Other

35
Responses

Figure 4: Expected developments and technological trends in Additive Manufacturing technology in 10 years

Question: What will be the main implications of such developments /trends in the AM labour market (e.g., required occupation) in 10 years? (Maximum 4 answers)

Responses

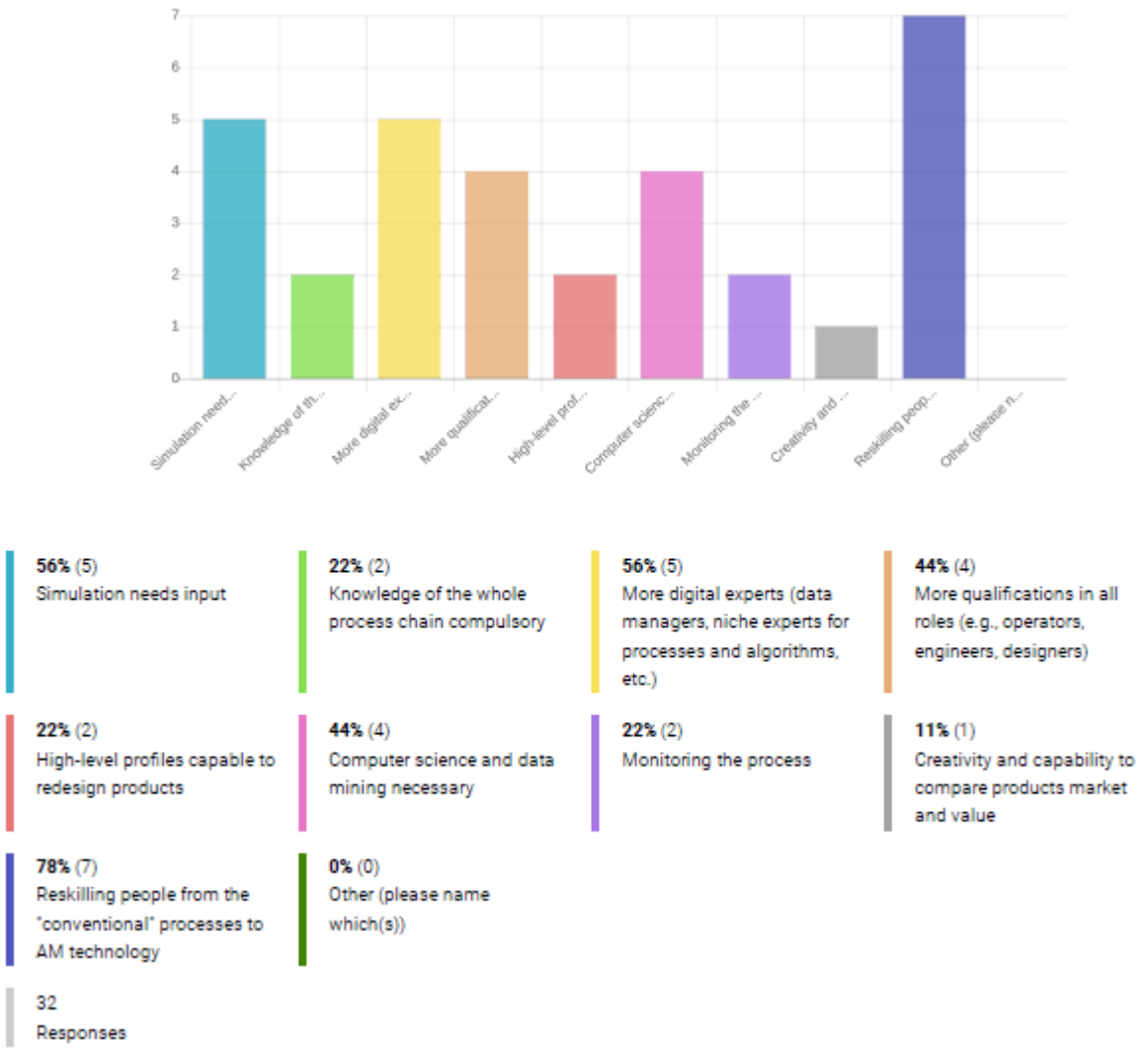


Figure 5: Main implications of such developments/trends in the AM labour market

(e.g., required occupation) in 10 years

Question: Which Additive Manufacturing Processes will be mainly used in 10 years? (Maximum 4 answers)

Responses

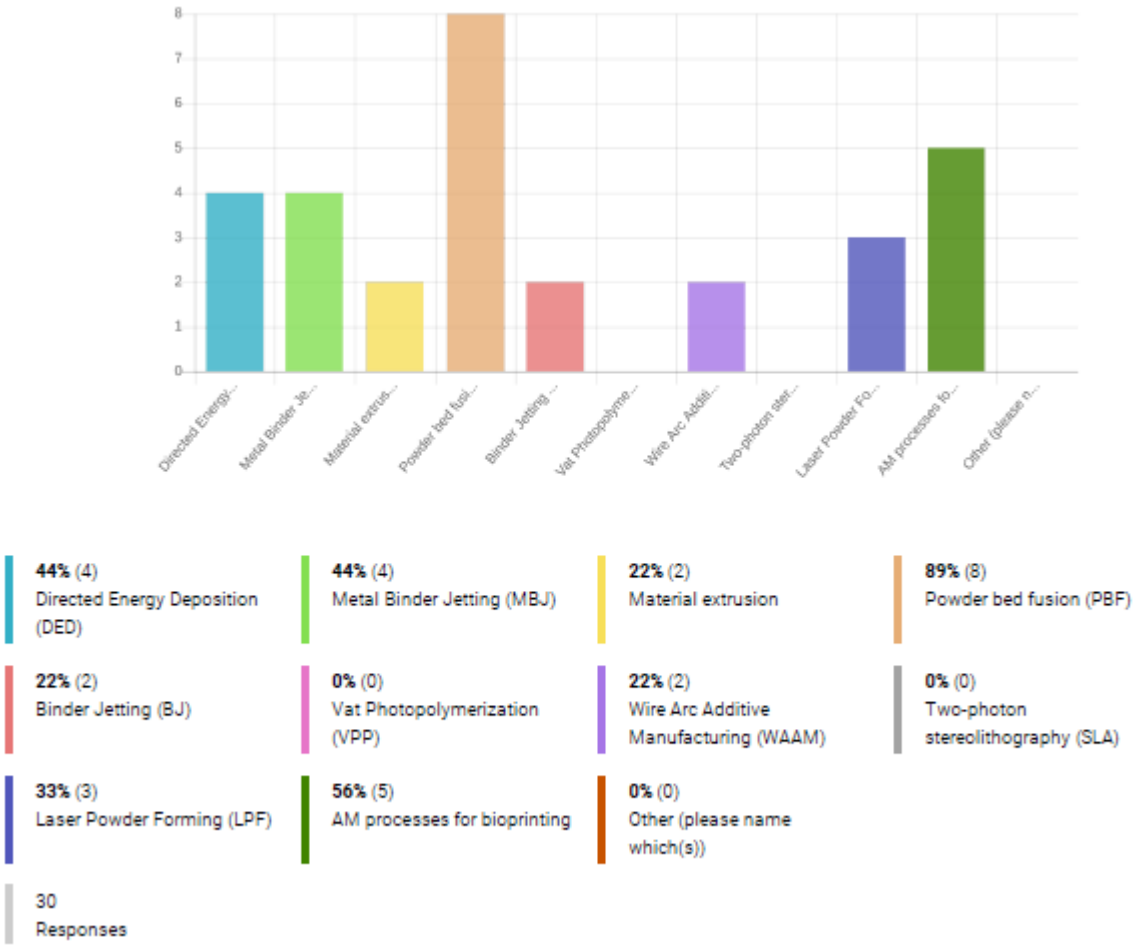
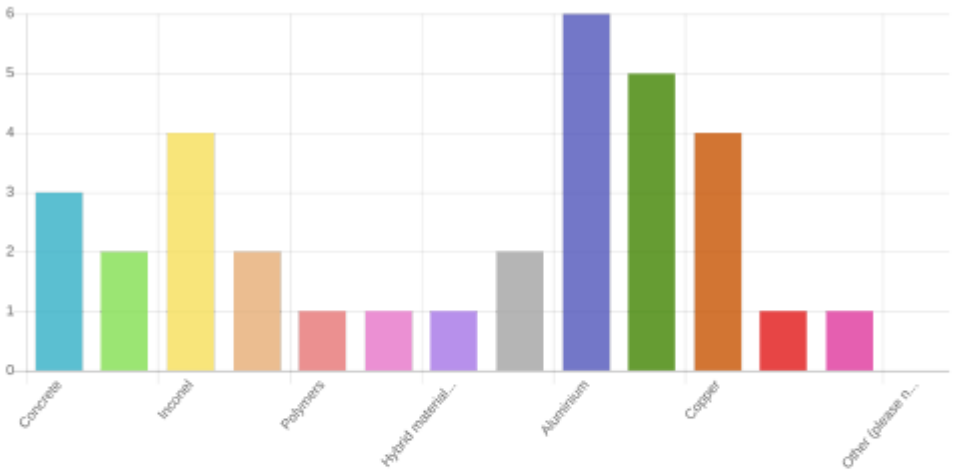


Figure 6: Additive Manufacturing Processes that will be mainly used in 10 years

Question: Which Additive Manufacturing Materials will be mainly used in 10 years? (Maximum 4 answers)

Responses



33% (3) Concrete

22% (2) Composite

44% (4) Inconel

22% (2) Recycled polymers

11% (1) Polymers

11% (1) Ceramics

11% (1) Hybrid materials

22% (2) Recycled steel

67% (6) Aluminium

56% (5) Titanium

44% (4) Copper

11% (1) Magneto-caloric graded-metals

11% (1) Coated-metals

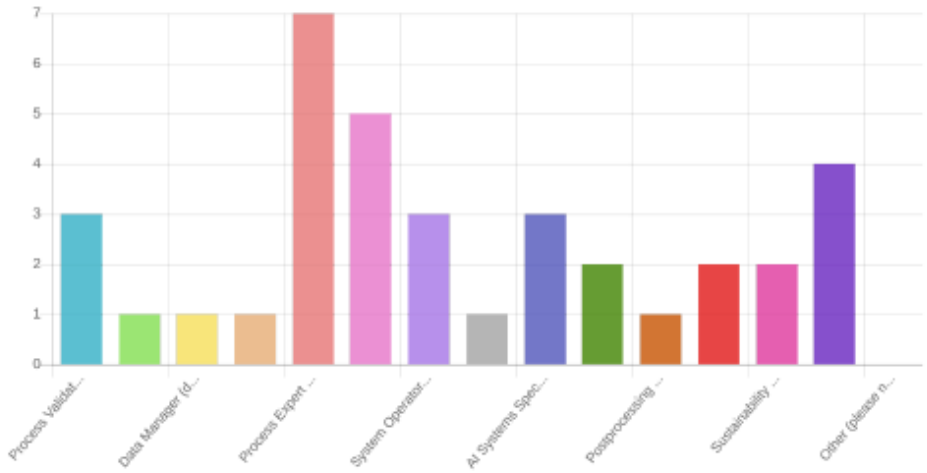
0% (0) Other (please name which(s))

33 Responses

Figure 7: Additive Manufacturing Materials that will be mainly used in 10 years

Question: What are the predicted Occupations Additive Manufacturing in 10 years? (Maximum 4 answers)

Responses



33% (3)
Process Validation Manager (conducts quality analysis on products and equipment)

11% (1)
Process Leader (determines and manages budgets and resources)

11% (1)
Data Manager (develops and manages data-oriented systems)

11% (1)
Process Monitoring Manager (monitors and evaluates activities related to processes)

78% (7)
Process Expert (develops, implements and optimizes processes)

56% (5)
AM Designers (designs AM solutions for different processes, ensuring and validating that parts are made cost-effective and efficient)

33% (3)
System Operators (monitors and controls the operation of hardware and software)

11% (1)
Powder Specialists (responsible for safe storage and handling of powders)

33% (3)
AI Systems Specialist (handles data generated from the system and transfers process steps and relations of parameters into algorithms)

22% (2)
Strategic and Value Analyst (responsible of technology foresight, deciding investments and compare alternative solutions for AM)

11% (1)
Postprocessing manager (responsible for thermal treatment and finishing)

22% (2)
Quality manager (responsible of quality inspection and final check on desired performances)

22% (2)
Sustainability manager (able to evaluate the impact of design/material/process choices on the value chain with interest to the environment)

44% (4)
R&D expert (new solutions/new processes/new material/ new tools for data augmented AM)

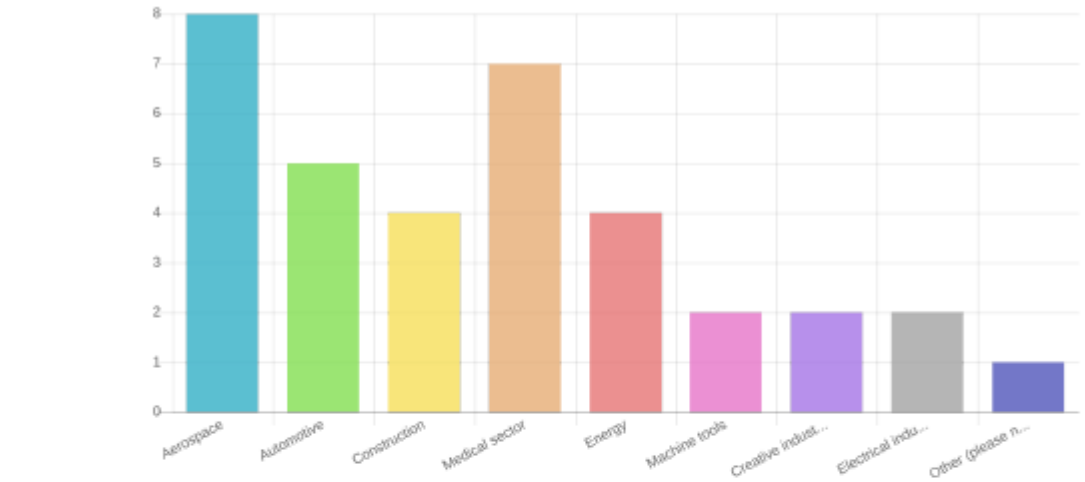
0% (0)
Other (please name which(s))

36
Responses

Figure 8: Predicted Occupations Additive Manufacturing in 10 years

Question: Which Sectors/Industries will be heavily influenced by Additive Manufacturing in 10 years? (Maximum 4 answers)

Responses



89% (8) Aerospace

56% (5) Automotive

44% (4) Construction

78% (7) Medical sector

44% (4) Energy

22% (2) Machine tools

22% (2) Creative industry

22% (2) Electrical industry

11% (1) Other (please name which(s))

35 Responses

Shipbuilding

Figure 9: Sectors/Industries that will be heavily influenced by Additive Manufacturing in 10 Years

8. Discussion of the Results for the 1st Round of Follow-up Online Survey

This first round was used to obtain more specific answers to the findings discussed in the skills forecast workshop. Consequently, the questions focused on very concrete aspects related to expected developments and technological trends, implications of such developments on the AM labour market, AM processes and materials that will be mainly used, predicted AM occupations and sectors affected in the next 10 years.

Regarding trends, almost all the experts agreed that AM will be established in **series productions**. The availability of more public standards was also chosen. A third of the total chose **new materials** and **reliable simulation**. About the influence of these trends on the labour market, the experts (78%) considered it necessary to **reskill people** to **adapt them to AM processes**. More than half of the experts (56%) also highlighted the need for **more digital experts** and **simulations need input**, which cover the need for material and process properties**.**

Experts (89%) practically agreed that Power Bed Fusion (PBF) would be used more in 10 years. In addition, several experts mentioned the bioprinting process interest (56%). Regarding materials, experts continue to emphasise the use of metals (Aluminium, Titanium, Copper, Inconel) in 10 years. A large proportion (78%) chose Process Experts as the likely AM occupation in 10 years, followed by AM Designers (56%). Based on the sectors/industries, Aerospace (89%) will be heavily influenced, which was followed by the Medical (78%) and Automotive (56%) sectors.

9. Results of the 2nd Round of Follow-up Online Survey

Following the 1st round of follow-up online survey, the results were collated and analysed. Thereafter, a 2nd round of follow-up online survey was developed based on the responses from the 1st round (see Figure 10). This second round was focused on obtaining more specific details about the information obtained in the workshop and the 1st round (e.g., about new materials, direct AM applications in the most influenced sectors, etc.) of surveys, and get information about additional information (e.g., professional standards).

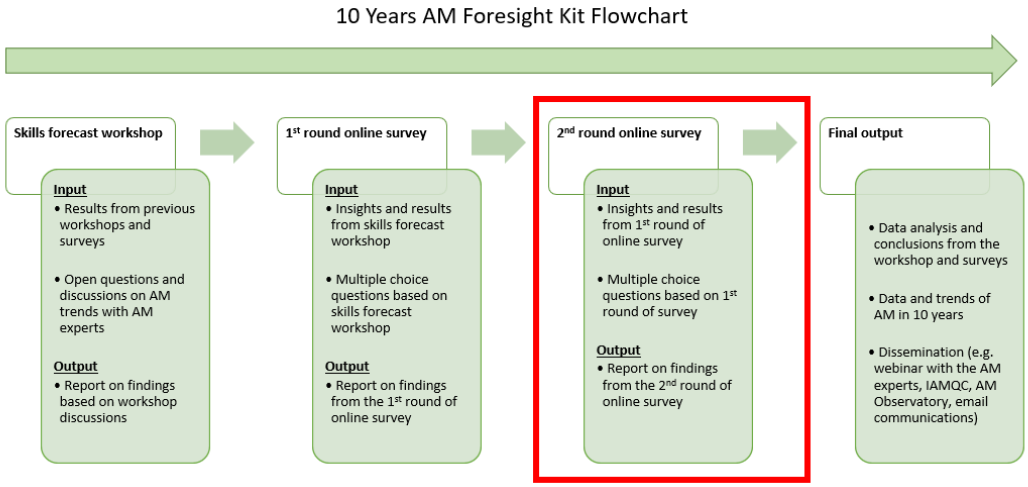


Figure 10: Flowchart of the 10 years AM foresight kit (2nd round online survey)

Question: For the expected developments and technological trends in Additive Manufacturing technology in the next 10 years, please indicate which area(s) will require the development of professional standards? (Maximum 3 answers)

Responses

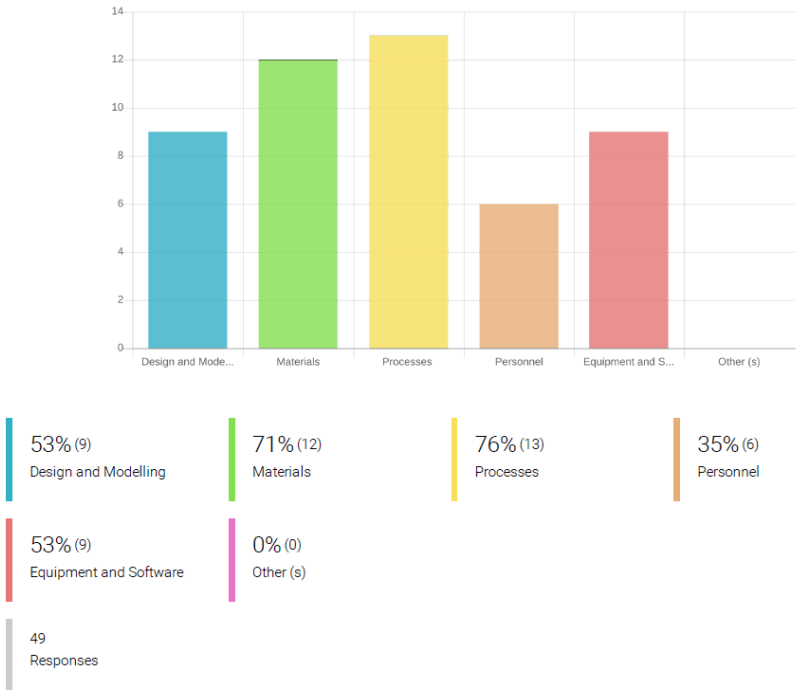


Figure 11: Areas that will require the development of professional standards in the next 10 years

Question: For the expected developments and technological trends in Additive Manufacturing technology, please indicate what new materials will appear in the next 10 years?

Responses

- Adapted and metals; composites
- Aluminium
- AM specific alloys. Better mechanical properties while reducing process limitations
- Based on composites and functionally graded materials
- Concrete, Inconel, Copper
- Copper and Aluminium for Metal Binder Jetting and other Sinter-based AM technologies, Metallic glasses for LBM
- Copper, hydrogels, polymeric composites as metal replacement (e.g., graphene-based)
- For WAAM, no significative development expected
- Glass, Wood, Food items, medical bio tissues, hybrid metal alloying during printing process, hybrid materials e.g., ceramics-metal mix, concrete
- HEA, custom wire for AM-DED, custom powder for AM-DED
- Materials developed for AM increase, both metallic alloys and polymers, in particular bio-based and biodegradable, polymers. We will see an increase in filler and additives that will be used to enhance polymer properties. Development in metals continue strong for, where more technical alloys will also have versions adapted for AM. Increased us of AM for repair may stimulate increased use of functionally graded composition in metallic matrix materials
- More polymeric materials, functionally-graded materials, multi-material forming with AM, 4D-printed materials.
- New alloys with peculiar characteristic (high conductivity, magnetic properties, shape memory, etc.)

Question: For the expected developments and technological trends in Additive Manufacturing technology in the next 10 years, please indicate how AM will be established in serial production?

Responses

- 3d printing hardware will be shared by companies or will become a service in loco (production on demand, on location, customized)
- Adoption to focus on non-critical applications and obsoleted parts.
- AM in serial production always brings that little question of what is meant by "serial", how many are required to be a series? Are dental implants, and dental aligners serial production? -The products are customized, but the number are high... Machine productivity and automation of post building operations will open more possibilities, but even more important will be improvements in product development, that will enable users to design products and build production systems that will be more efficient and have more benefits by AM
- AM mass production will strengthen in automotive, biomedical, aerospace for sure, but also certain general-purpose application such as in furnishing items and fashion will be affected
- As an additional process to milling, machining, etc., to produce more customized parts and in some sectors will be highly used due to its customization (medical, aerospace, etc.)
- Customization stations in hybrid production sites will be based on AM and will find widespread in production and repair.
- Funded programs, national and European Initiatives e.g., AI - AM; Education programs I guess there are still AM technologies established in serial production by today. AM manufacturing technology is too general to outline specific developments
- High productivity
- It will be used for mass individualized production
- Mainly metal AM in an integrated process chain with postprocessing and NDT, plastic AM will face threats by environmental discussions and the growing B to C market with cheap entry level desktop printers
- Metal Binder Jetting will make its way into serial production through robust and standardised processes as well as an automated depowdering and green part handling.
- Need of standards, and clear validation steps for new applications, minimizing costs for companies, monitoring and control for quality assurance (AI developments), robust solutions for workers health minimizing contacts with dangerous materials
- Series production of different products/ parts
- The availability of qualification standards (such as ISO/ASTM 52920) will allow end users to require compliance to these standards before placing orders, thereby giving them the confidence in the AM technology without having to fully understand it themselves. The use of in-process monitoring will also help to establish AM as a process for serial production, initially by reducing the amount of post-build inspection and testing required, and subsequently by allowing adaptive control of the AM process to prevent errors before they occur and fix errors during the build when they occur.

Question: For the expected developments and technological trends in Additive Manufacturing technology, please indicate which areas of AM will foresee a reduction of costs in the next 10 years?

Responses

Figure 12: Areas of AM that will foresee a reduction of costs in the next 10 years

Question: Concerning the implications of AM developments /trends in the AM labour market (e.g., required occupation) in the next 10 years, please indicate which occupations will benefit the reskilling from the "conventional" processes to AM technology?

Responses

Figure 13: Occupations that will benefit the reskilling from the "conventional" processes to AM technology

Question: Concerning the implications of AM developments /trends in the AM labour market (e.g., required occupation), please indicate which of the following digital experts are expected to benefit from training in AM in the next 10 years?

Responses

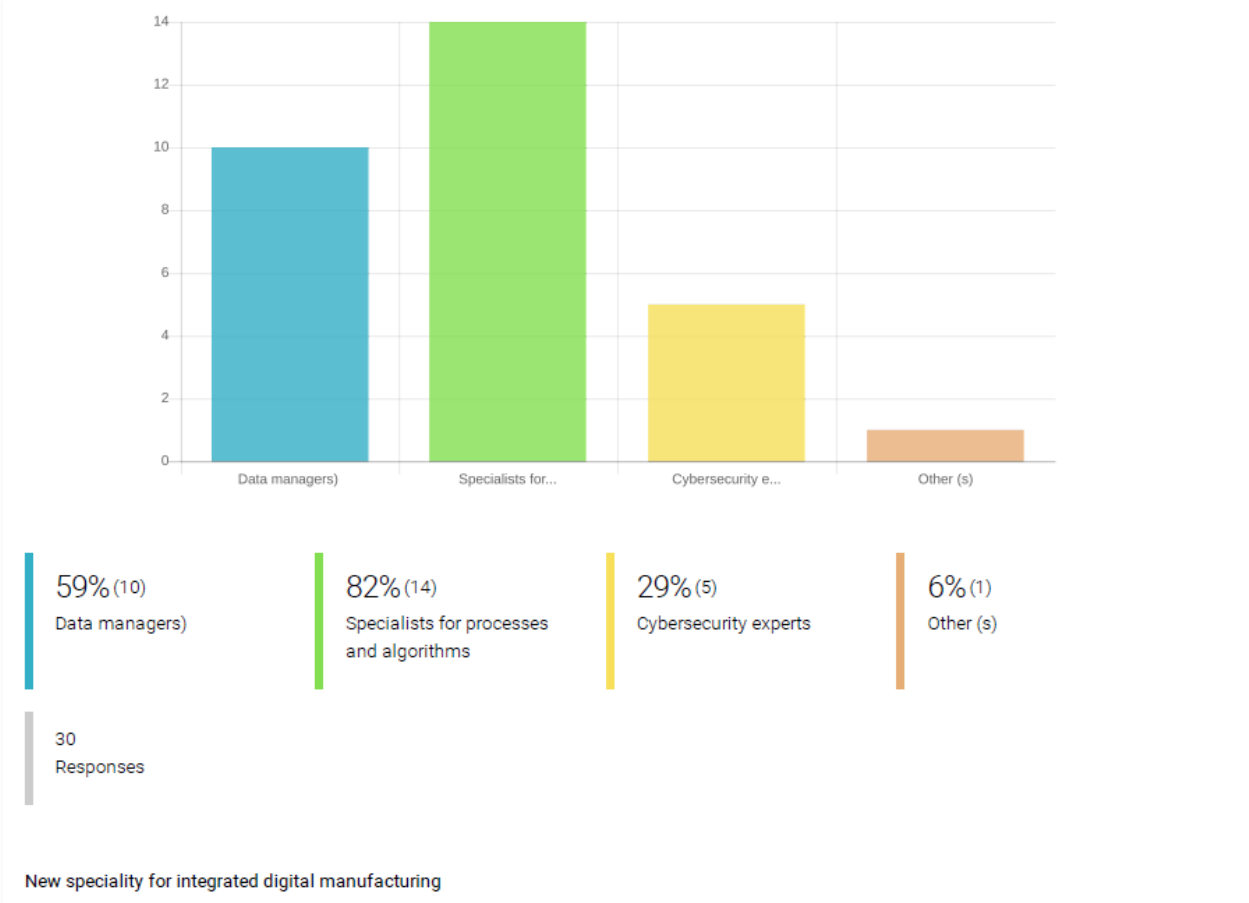


Figure 14: Digital experts expected to benefit from training in AM in the next 10 years

Question: What parts will be commonly produced for the Aerospace sector in the next 10 years? (Maximum 3 answers)

Responses

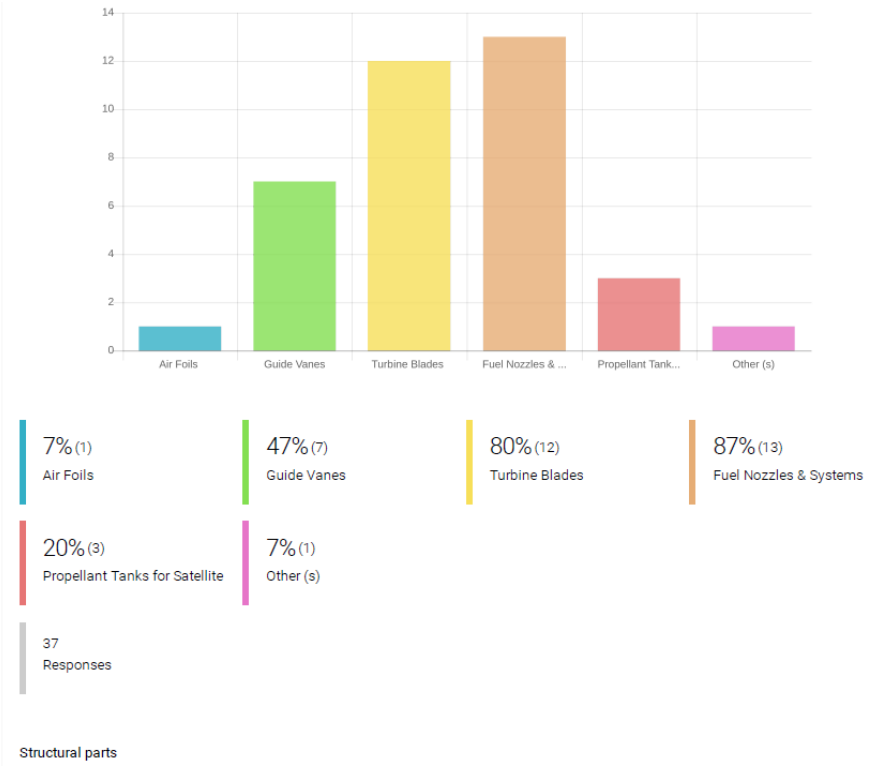


Figure 15: Part that will be commonly produced for the Aerospace sector in the next 10 years

Question: What will be the application in AM for the Medical sector in the next 10 years? (Maximum 3 answers)

Responses

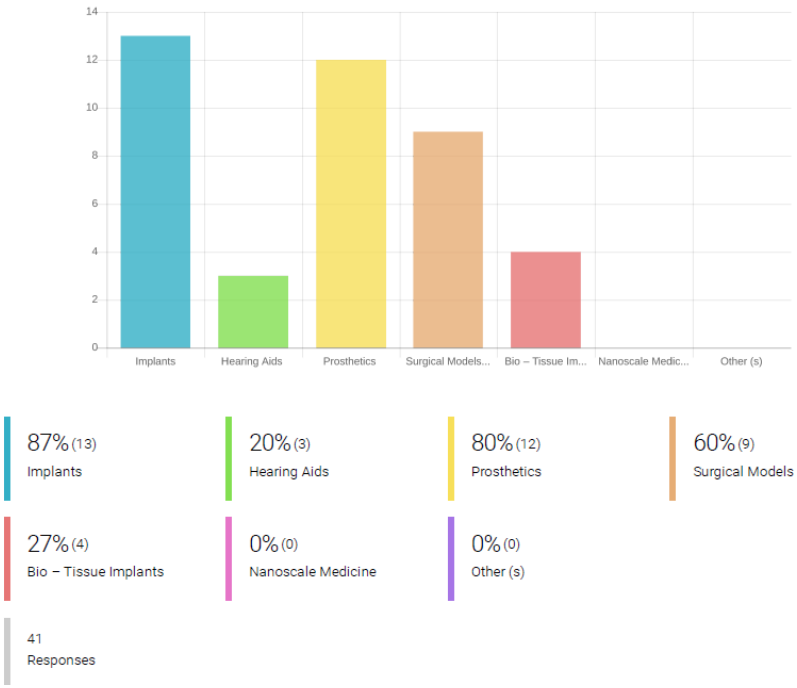


Figure 16: Application in AM for the Medical sector in the next 10 years

Question: What will be the application in AM for the Automotive sector in the next 10 years? (Maximum 3 answers)

Responses

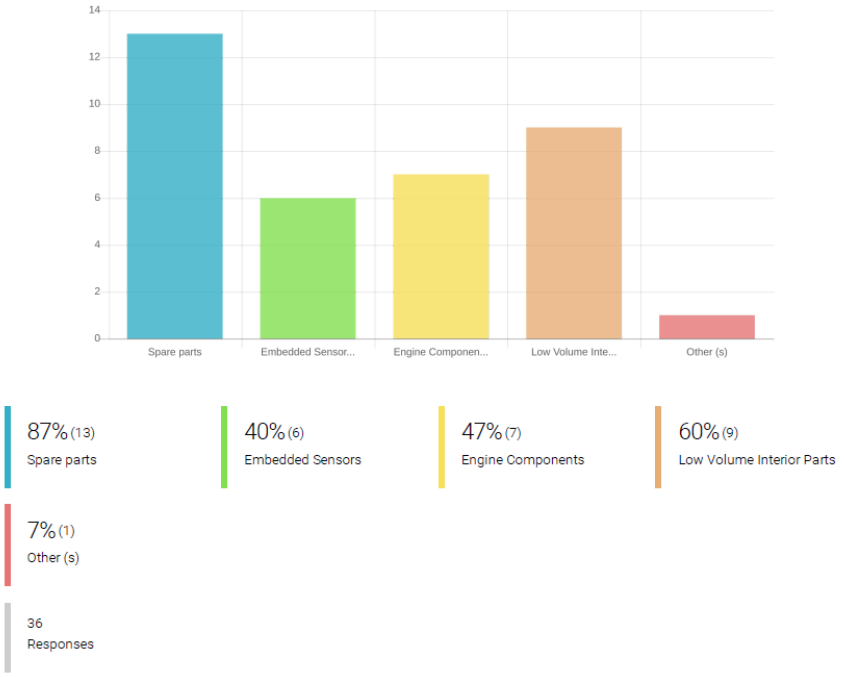


Figure 17: Application in AM for the Automotive sector in the next 10 years

Additional comments

Responses

I think other sectors, such as Energy (includes oil & gas), Marine and Construction will all see significant adoption of AM technologies in the next 10 years.

10. Discussion of the Results for the 2nd Round of Follow-up Online Survey

Processes (76%) and Materials (71%) are the areas where most experts consider will require professional **standards.** On the other hand, Personnel was the option less supported (35%). Regarding the materials section, an open question enabled the confirmation of the interest of the experts in metals (especially aluminium) as a combination of materials (e.g., hybrid materials, multi-materials, composites, alloys).

A second open question was related to how AM will be established in **serial production,** and the experts emphasised the importance of **customisation and the development of standards**. More specifically, in relation to the **reduction of costs, machine/equipmen**t (71%) and **materials** (71%) will be the predominant areas affected.

The 2nd round of survey also allowed the definition of the occupations that need reskilling. Results showed that welding professionals would benefit from reskilling, especially the welding **inspectors, which was confirmed by** (69%) the experts. The experts chose Specialists for processes and algorithms (82%), followed by Data managers (59%) and Cybersecurity experts (29%), as the digital experts that will benefit from training in the next 10 years.

The questions related to **the parts produced in the Aerospace, Medical and Automotive sectors** showed that Fuel nozzles and systems (87%), Turbine blades (80%) and Guide vanes (47%) would be majorly used in the Aerospace sector. In the Medical sector, Implants, Prosthetics and Surgical models were the most selected, whereas Spare parts, Low volume interior parts and Engine components were the most selected for the Automotive sector.

11. Conclusion

This foresight report entails the evaluation and analysis of the developments, trends and skills required within AM in the next 10 years when applying the SAM's Delphi tool from the foresight kit (D2.4). The report is based on data from multiple rounds of activities, including an initial skill forecast workshop with AM experts, and two rounds of follow-up surveys (i.e., Delphi method) with AM experts.

Based on the foresight evaluation, the AM trends related to materials and processes in the next 10 years are listed below. The main AM materials that will be used in the next 10 years are shown below:

- Aluminium
- Copper
- Inconel (i.e., nickel-chromium-based superalloys)
- Titanium

New AM materials that will be developed in the next 10 years include:

- Composites
- Functionally graded materials
- Metal alloys

The main AM processes that will be used in the next 10 years are shown below:

- AM processes for bioprinting
- Directed Energy Deposition (DED)
- Metal Binder Jetting (MBJ)
- Powder bed fusion (PBF)

Based on the foresight evaluation, the AM trends related to different sectors and industries in the next 10 years are listed below. The major sectors/industries that will be heavily affected by AM in the next 10 years are shown below:

- Aerospace sector
- Automotive sector

- Medical sector

The main parts that will be produced with AM in the aerospace sector include:

- Fuel nozzles and systems
- Guide vanes
- Turbine blades

The main parts that will be produced with AM in the automotive sector include:

- Spare parts
- Low volume interior parts
- Engine components

The main parts that will be produced with AM in the medical sector include:

- Implants
- Prosthetics
- Surgical models

Based on the foresight evaluation, the AM trends related to occupations in the next 10 years are listed below. The main AM occupations in the next 10 years are shown below:

- AM designers
- Process experts
- R&D experts

The main occupations that will benefit from reskilling from conventional processes to AM processes include:

- AM designers and developers
- Welding coordinators, inspectors, and operators

The main digital experts expected to benefit from training in AM in the next 10 years include:

- AM processing and algorithm specialists
- Cybersecurity experts
- Data managers

Based on the foresight evaluation, the main expected developments, and technological trends in AM in the 10 years are shown below:

- AM established in series production
- More public standards available in different areas (design, feedstock, processes, personnel, machine, etc.)
- New materials
- Reduction of costs
- Reliable simulation will be available for most AM technologies

The major implications of such developments/trends on the AM labour market include the following:

- More digital experts (data managers, niche experts for processes and algorithms, etc.)
- Reskilling people from the "conventional" processes to AM technology
- Simulation needs input

The major AM areas that will require the development of professional standards are shown below:

- AM materials
- AM processes

- AM design and modelling
- AM equipment and software

The main AM areas that will foresee a reduction of costs in the next 10 years include:

- Machines and equipment
- Materials and feedstock
- Post-processing stages

The summarised set of results are the predicted trends, skills, and developments in AM, which are expected in the 10 years. These findings will be used to improve the AM skills strategy and influence the development of future training programmes and courses for AM personnel. In addition, this foresight exercise ensures a good alignment between the demand and offer of training programmes, and will inform decision making, policy reform and future funding programmes.