2.4 Foresight Scenarios Kit M34

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Contents

1. Introduction

This foresight kit is designed within the scope of Work Package 2 for implementation within Work Package 4 of the **SAM** (**S**ector **S**kills **S**trategy in **A**dditive **M**anufacturing) Project. Foresight can be described as systematic, participatory, future-intelligence-gathering and medium-to-long-term vision-building process aimed at enabling present-day decisions and actions. This foresight kit can be used as a tool (i.e., a list of questions and methods) to evaluate and forecast the developments and skills required within AM in 10 years. The implementation of this kit will enable data collection through multiple rounds (i.e., Skills Forecast Workshop and Delphi Method) from AM experts, which will be subsequently analysed and reported. The ten-year forecast obtained using this kit will be presented on the SAM website and the AM Observatory. Following implementation, this kit will be improved and updated (if necessary).

2. Target Groups

During the data collection and feedback phase, the gathered skills' gaps and shortages are framed according to different scenarios in SAM project (1, 3 and 10 years respectively).

In terms of Scenario 3 (10 years), two groups will be selected as targets for the Foresight Scenario with the aim of predicting to which extent skills applied/need to be addressed within 10 years. The involvement of these groups is explained in Table 1.

Table 1: Target groups and their descriptions

Target group	Description
Industry/Employers	To find out their long-term needs with regards to AM skills and anticipate possible coming gaps
Research / Technology Centres	To find out long term R&D&I lines and thus, possible novel skills needed

3. Methodology

Figure 1 summarises the methodology to be followed in the foresight scenario in order to identify the skills to be addressed.
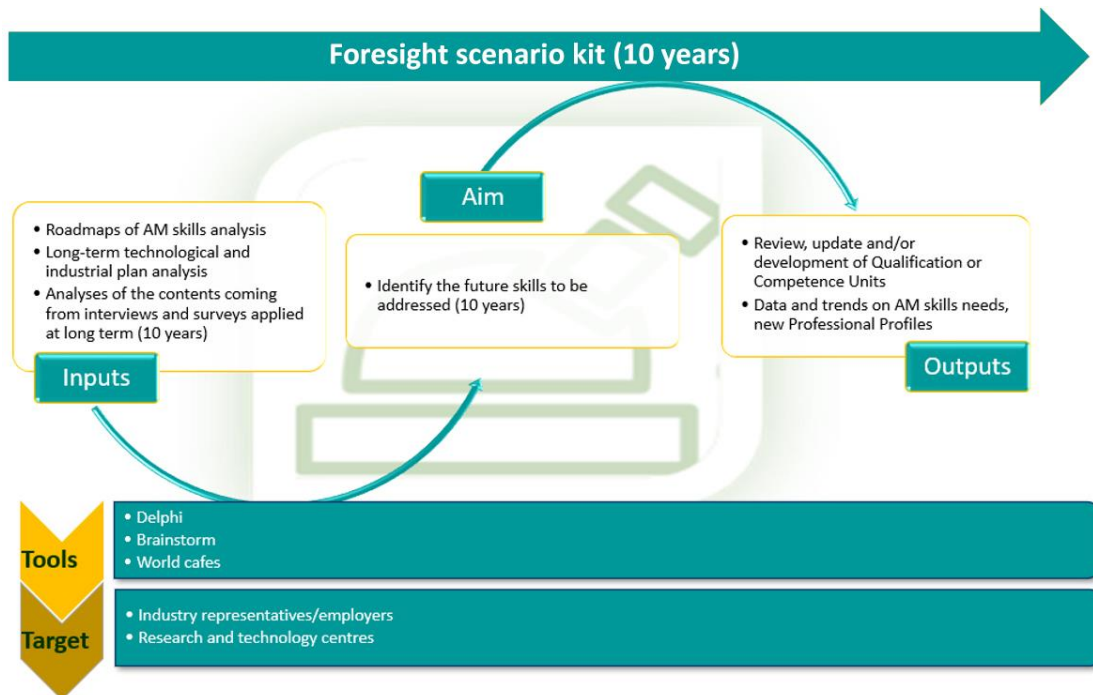
Figure 1: *Methodology applied for the Foresight scenario*

4. Tools and templates

The Foresight phase comprised translation and interpretation of the information gathered to produce an understanding of its implications for the future. In order to evaluate and forecast the skills required, trends and developments within the AM sector in 10 years, several tools, email templates and questions are used to gather and analyse the data. As mentioned in Figure 1, the tools to be used are Delphi surveys, Brainstorming and World Cafe. Below those developed for the different target groups in scenario 3 are detailed.

4.1 Delphi method

The Delphi method is used as an exploratory technique to address the identification of the AM skills to be deployed in 10 years. One of the main objectives in applying this technique is to capture the opinion of different experts in order to reach a common understanding of the future in AM.

The Delphi method is an expert survey implemented in two or more rounds, where in the second and later rounds of the survey, the results of the previous round are provided as feedback.

In SAM, the technique is designed to produce a description of AM main drivers, market opportunities, new core tasks likely to be required in the future, existing tasks that will be more in demand, tasks likely to disappear and especially, future skills need, (e.g., AM and sector-related), how skills can be formed (initial education, on-the-job training) and what can be done.

The method is normally implemented in the following phases:

1) Definition of objectives/problem

This first phase sets out the formulation of the general objective on addressing the skills needs to be deployed in 10 years.

2) Expert's selection

Participants: Around 20-40. They will be selected taking into account their competence, backgrounds and sectors tackled. Expert needs to have AM knowledge and experience of at least 3 years.

3) Preparation 1st round of questionnaire

In Delphi Round 1 the purpose is to acquire information from experts on the future skills and curriculum content for Additive Manufacturing. The questionnaire is prepared in a way that facilitates the response by respondents, as responses need to be quantified and weighted. Contributors reply by adding their rankings and comments.

4) Analysis and summary of the information received

The answers are compiled and analysed to verify if there is consensus among the experts. If consensus is reached, then the survey ends. If not, a second round of surveys takes place with the same group of experts.

5) 2nd round application of the Delphi questionnaire

In the second round the results/feedback from the 1st one is presented, and new improved questions are formulated. This process is repeated along with a series of rounds (normally three) until it reaches a final consensus.

6) Final analysis

The SAM approach to Delphi was **adapted into four stages** which are explained in Table 2 and Figure 2. Table 2 gives an overview and Figure 2 shows the flowchart. This methodology follows the Delphi method (a 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 next 10 years. The templates for the invitation emails are provided in the appendices.

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 opinions and thoughts of 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 2: *Overview of SAM's approach to the Delphi Method*

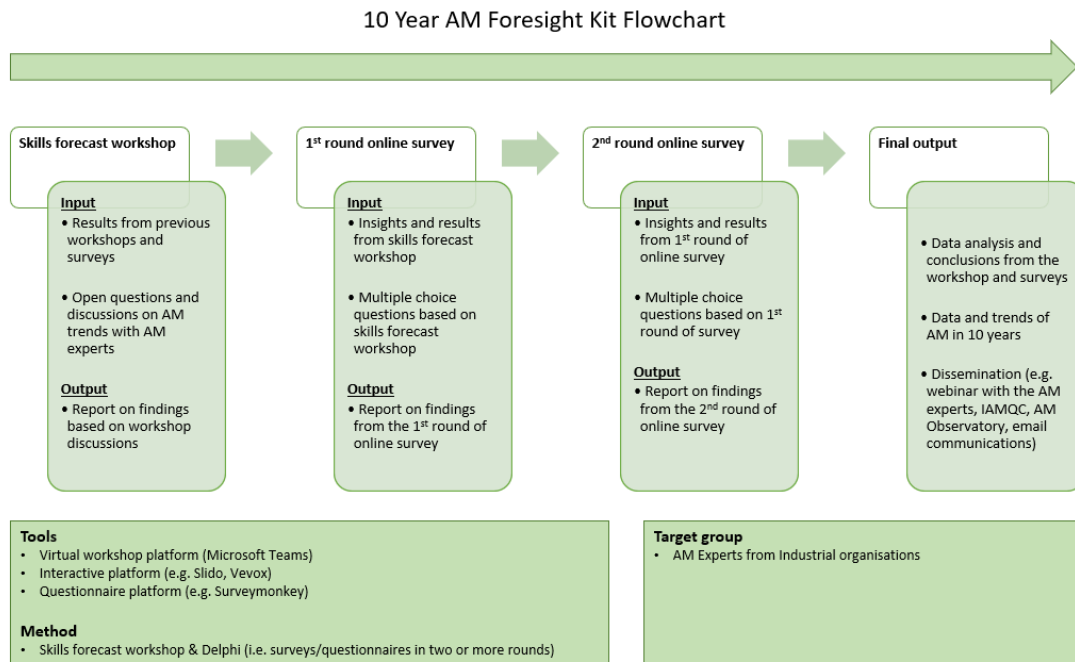| Aim	To evaluate and forecast the skills required, trends and developments within the AM sector in 10 years
Tools	Brainstorming and World Cafe during Workshops with Experts Follow-up surveys /Delphi (Expert surveys in two or more rounds) • Free Online Surveys, Survey Monkey Virtual Workshop platform • Microsoft Teams Live interactive platform to show live questions and answers, for example: • Vevox, Microsoft Forms, Slido, Mentimeter, Miro
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) Roadmaps of AM Skills analysis. b) Long-term technological and industrial plan analysis. c) Analyses of the contents coming from previous results/questions applied at long term (10 years). d) Virtual Workshop (Open questions (without choices) related to the AM sector in 10 years). e) 1st round Online Survey/Questionnaire - based on responses from the workshop. f) 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	10 years

Figure 2: *Flowchart of the SAM's approach to the Delphi Method*

1) First Stage - Skills Forecast Workshop

The skills forecast workshop will entail 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 will provide initial answers to open questions related to the AM sector's skills and developments in 10 years. Different platforms such as Slido, Mentimeter, and Vevox can increase engagement and interactivity during the skills forecast workshop. Also, the responses from the AM experts during this workshop will form the questions of the 1st round of follow-up online survey.
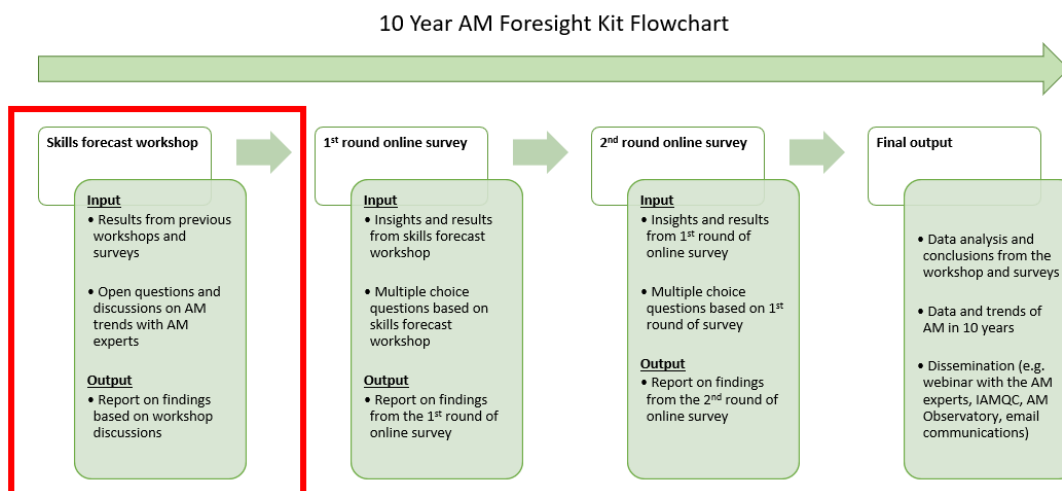

Figure 3: *Flowchart of the 10 years AM foresight kit (skills forecast workshop)*

Invitation Email for the Skills Forecast Workshop

Title: Foresight Workshop Invitation – Where do you see Additive Manufacturing in 10 years?

Dear NAME,

I am contacting you on behalf of the **SAM** (**S**ector **S**kills **S**trategy in **A**dditive **M**anufacturing) Project consortium (www.skills4am.eu). SAM is a European Funded Project focused on addressing the skills needs and labour market demands in the AM/3D Printing Sector. The project is led and coordinated by the European Welding Federation (EWF).

As part of this project, we would like to request your participation as an AM Expert in a Virtual Foresight Workshop focussed on identifying the skills required and developments within the AM sector in the next 10 years. This session will take place on **DD MM YYYY at XX: XX CET** and is expected to take about **XX hours**.

This session will entail:

- Introduction of the SAM Project.
- Summary of results from previous forecast sessions (e.g., surveys & interviews).
- Live and Interactive questionnaire session with the participants regarding the skills required and developments within the AM sector in 10 years.

After this session, we will analyse the data and summarise the findings and formulate two rounds of questionnaires.

At the end of the exercises, we will analyse the data, show the charts, trends, and insights, which will be shared with you.

Your contribution will enable a better understanding of the skills required and developments within the AM sector in 10 years.

Please can you reply by confirming this email by **DD MM YYYY at XX: XX CET**.

We look forward to hearing from you.

Kind regards

NAME

SIGNATURE

Questions for the Skills Forecast Workshop

The questions are divided in two sections, one related to the participant's background and the other on AM forecast for the next 10 years,

Part A: Participant's Background

Q1. Gender

- o   Male
- o   Female

Q2. Age Range

- o   18 – 25
- o   26 – 35

o   36 – 45
o   Over 45

Q3. Current Role or Position

o

Q4. Country Based

Albania	Germany	Poland
Andorra	Greece	Portugal
Armenia	Hungary	Republic of Moldova
Austria	Iceland	Romania
Azerbaijan	Ireland	Russia
Belarus	Israel	San Marino
Belgium	Italy	Serbia
Bosnia	Kazakhstan	Slovakia
and Herzegovina	Kyrgyzstan	Slovenia
Bulgaria	Latvia	Spain
Croatia	Lithuania	Sweden
Cyprus	Luxembourg	Switzerland
Czechia	Malta	Tajikistan
Denmark	Monaco	Turkey
Estonia	Montenegro	Turkmenistan
Finland	Netherlands	Ukraine
France	North Macedonia	United Kingdom
Georgia	Norway	Other

Q5. Sector

o   Aerospace
o   Automotive
o   Construction
o   Consumer goods
o   Defence
o   Electronics
o   Energy
o   Health
o   Industrial equipment and tooling
o   Other

Q6. Years of Experience in Additive Manufacturing

o   0 – 5
o   6 – 10
o   11 – 15
o   16 – 20
o   Over 20 years

Part B: Skills Forecast for Additive Manufacturing in 10 years

Give at least **three (3)** answer(s) each.

Allow about **three minutes** for initial responses (before revealing all answers to the attendees).

Allow **five- ten minutes** for discussion after each question.

Q7. What are the expected developments and technological trends in Additive Manufacturing technology in 10 years?

Secondary questions to foster engagement:

- o Will there be new or improved materials, AM processes, AM machines, CAD software, AM standards, AM post-processing techniques?
- o Will it be faster and more sustainable?
- o Will it include the use of Machine Learning and Artificial Intelligence?
- o Will the uptake of AM significantly increase?

Q8. What will be the main implications of such developments /trends in the AM labour market (e.g., required occupation) in 10 years?

Secondary questions to foster engagement:

- o Will this lead to the development of new jobs or replacement of current jobs in AM?
- o How will this affect the required knowledge and skills of people working in AM
- o What challenges are expected?
- o What are the expected benefits?

Q9. Which Additive Manufacturing Processes will be mainly used in 10 years?

Secondary questions to foster engagement:

- o Will new AM processes appear?
- o Will there be an increase in using certain AM processes?
- o Will there be a reduction in using certain AM processes?

Q10. Which Additive Manufacturing Materials will be mainly used in 10 years?

Secondary questions to foster engagement:

- o Will new AM materials appear?
- o Will there be an increase in using certain AM materials?
- o Will there be an increase in using multi-materials or composites?
- o Will more natural or sustainable materials be used in AM?
- o Will there be a reduction in using certain AM materials?

Q11. What are the predicted Occupations Additive Manufacturing in 10 years?

Secondary questions to foster engagement:

- o What will be the impact on current job occupations in AM?
- o Will current AM occupations be at stake?
- o Will the trend be related to individuals multi-tasking (e.g., covering various responsibilities/activities across the AM value chain) or specialised in one activity?

Q12. Which Sectors/Industries will be heavily influenced by Additive Manufacturing in 10 years?

Secondary questions to foster engagement:

- o Will a particular sector increase its use of AM?
- o Will new sectors using AM emerge?
- o Will it affect current sectors utilising AM?

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2)Second Stage - 1st Round of Follow-Up Online Survey (~ three weeks after the workshop)

The 1st round of follow-up online survey will be based on the responses, insights, and results from the skills forecast workshop. This enables the collection of more specific responses compared to the skills forecast workshop. Several survey platforms such as Free Online Surveys, Survey Monkey can be used to gather the responses from the AM experts. The results from the stage will form the 2nd round of follow-up online survey.
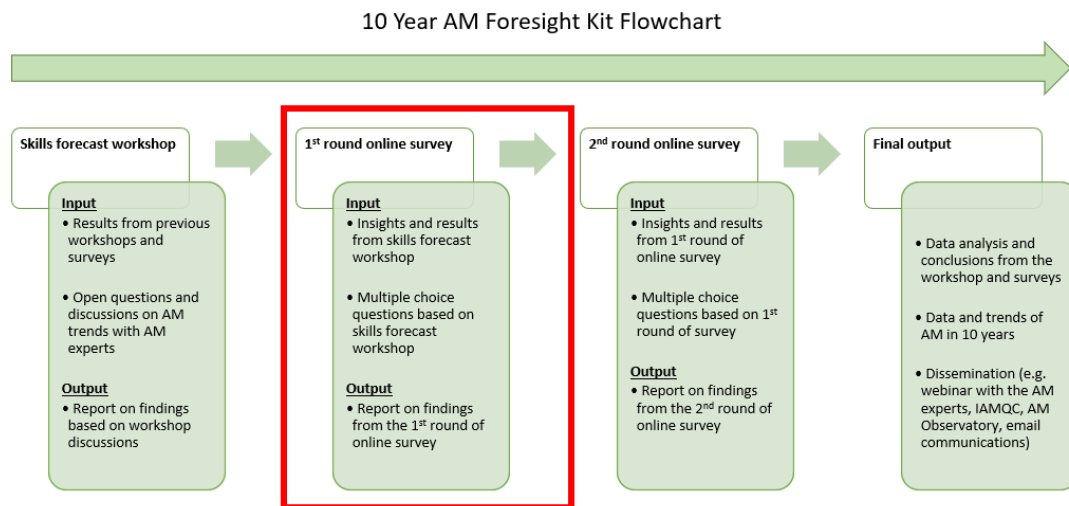

Figure 4: Flowchart of the 10 years AM foresight kit (1st round online survey)

Invitation Email for the 1st Round of Follow-up Online Survey

Title: 1st Round of Follow-Up Online Survey – Where do you see Additive Manufacturing in 10 years?

Dear NAME,

Thank you for participating in the foresight workshop that took place on **DD MM YYYY**.

As promised, we have now analysed the preliminary data provided by the experts during the workshop, which form the basis of this follow-up online survey (*__Insert link__*), which should take you **X minutes** to complete.

Once this online survey has been completed, we will collate the data and summarise the findings, which will form the basis of the 2nd round of the online survey.

Subsequently, the final data analysis showing charts and insights from the session will be shared with you and included on the European AM Observatory.

Your contribution will enable a better understanding of the skills required and developments within the AM sector in 10 years.

Many thanks

Kind regards

NAME.

Questions for the 1st Round of Follow-up Online Survey

Title: Where do you see Additive Manufacturing in 10 years?

Q1. What are the expected developments and technological trends in Additive Manufacturing technology in 10 years? (Maximum 4 answers)

- o   AM established in series production
- o   Reliable simulation will be available for most AM technologies
- o   Simplification of the current workflows (starting from sketch and idea to final product)
- o   New materials
- o   New technologies
- o   Sustainability
- o   AM in difficult areas (where other technologies are difficult to implement)
- o   Supply chain considerations
- o   Large dimensions
- o   New alloys
- o   New design features (e.g., lattice structure)
- o   Waste reduction via in-situ data monitoring and control
- o   AM qualification and certification
- o   Reduction of pre-processing
- o   Multi-material
- o   Hybrid processes and materials
- o   Faster AM processes
- o   More public standards available in different areas (design, feedstock, processes, personnel, machine, etc.).
- o   Large scale AM
- o   Reduction of costs
- o   Reduction of post-processing
- o   Improve flexibility (e.g., powder change in SLS, etc.)
- o   Digital twins
- o   Other (please name which(s))

Q2. 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)

- o   Simulation needs input
- o   Knowledge of the whole process chain compulsory
- o   More digital experts (data managers, niche experts for processes and algorithms, etc.)
- o   More qualifications in all roles (e.g., operators, engineers, designers)
- o   More access to training
- o   High-level profiles capable to redesign products
- o   Computer science and data mining necessary
- o   Monitoring the process
- o   Creativity and capability to compare products market and value
- o   Reskilling people from the "conventional" processes to AM technology
- o   Other (please name which(s))

Q3. Which Additive Manufacturing Processes will be mainly used in 10 years? (Maximum 4 answers)

- o   Directed Energy Deposition (DED)
- o   Metal Binder Jetting (MBJ)
- o   Material Extrusion (ME

- Powder Bed Fusion (PBF)
- Binder Jetting (BJ)
- Vat Photopolymerization (VPP)
- Wire Arc Additive Manufacturing (WAAM)
- Two-photon stereolithography (SLA)
- Laser Powder Forming (LPF)
- AM processes for bioprinting
- Other (please name which(s))

Q4. Which Additive Manufacturing Materials will be mainly used in 10 years? (Maximum 4 answers)

- Concrete
- Composite
- Inconel
- Recycled polymers
- Polymers
- Ceramics
- Hybrid materials
- Recycled steel
- Aluminium
- Titanium
- Copper
- Magneto-caloric graded-metals
- Coated-metals
- Other (please name which(s))

Q5. What are the predicted Occupations in Additive Manufacturing in 10 years? (Maximum 4 answers)

- Process Validation Manager (conducts quality analysis on products and equipment)
- Process Leader (determines and manages budgets and resources)
- Data Manager (develops and manages data-oriented systems)
- Process Monitoring Manager (monitors and evaluates activities related to processes)
- Process Expert (develops, implements and optimises processes)
- AM Designers (designs AM solutions for different processes, ensuring and validating those parts are made cost-effective and efficient)
- System Operators (monitors and controls the operation of hardware and software)
- Powder Specialists (responsible for safe storage and handling of powders)
- AI Systems Specialist (handles data generated from the system and transfers process steps and relations of parameters into algorithms)
- Strategic and Value Analyst (responsible of technology foresight, deciding investments and compare alternative solutions for AM)
- Postprocessing manager (responsible for thermal treatment and finishing)
- Quality manager (responsible of quality inspection and final check on desired performances)
- Sustainability manager (able to evaluate the impact of design/material/process choices on the value chain with interest to the environment)
- R&D expert (new solutions/new processes/new material/ new tools for data augmented AM
- Other (please name which(s))

Q6. Which Sectors/Industries will be heavily influenced by Additive Manufacturing in 10 years? (Maximum 4 answers)

- Aerospace
- Automotive

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SAM
SECTOR SKILLS STRATEGY
IN ADDITIVE MANUFACTURING

- o Construction
- o Medical sector
- o Energy
- o Machine tools
- o Creative industry
- o Electrical industry
- o Other (please name which(s))

Q7. Additional comments

- o

3)Third Stage - 2nd Round of Follow-Up Online Survey (~ three weeks after the 1st round of survey)

The 2nd round of follow-up survey is based on the responses, insights, and results from the 1st round of follow-up online survey. Furthermore, this enables 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 will be analysed and used for the final stage.
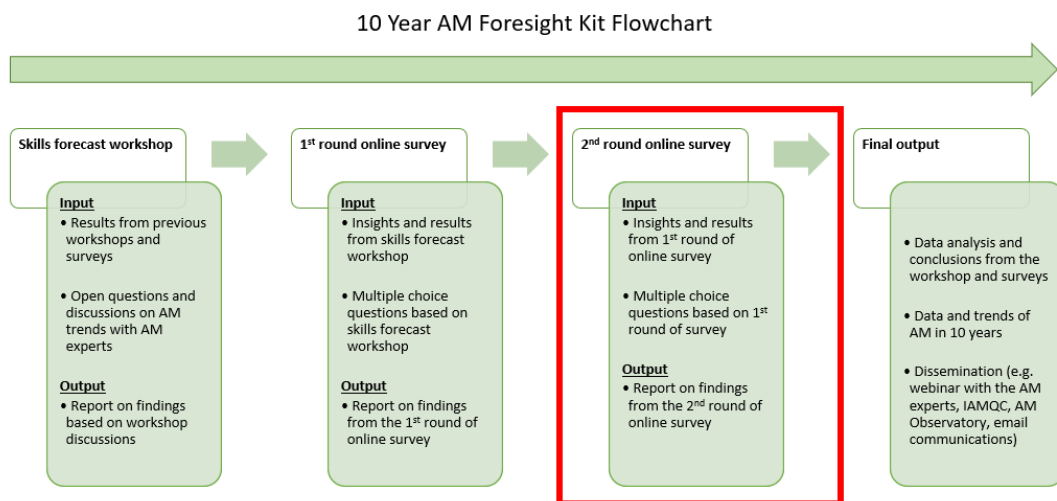

Figure 5: *Flowchart of the 10 years AM foresight kit (2nd round online survey)*

Invitation Email for the 2nd Round of Follow-up Online Survey

Title: Round 2 of Follow-Up Online Survey – Where do you see Additive Manufacturing in 10 years' time?

Dear NAME,

Thank you for participating in the foresight workshop and 1st round of the survey.

As promised, we have now analysed the data from the 1st round of the survey, and here is the link ((*Insert link*)) to the 2nd and final round of the online survey, which should take you **X minutes** to complete.

Once the online survey has been completed, we will collate the data and summarise the findings.

The final data analysis showing charts and insights from the session will be shared with you and included on the European AM Observatory.

Your contribution will enable a better understanding of the skills required and developments within the AM sector in 10 years.

Many thanks

Kind regards

NAME

SIGNATURE

Questions for the 2nd Round of Follow-up Online Survey

Title: Where do you see Additive Manufacturing in 10 years?

Q1. 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)

- o Design and Modelling
- o Materials
- o Processes
- o Personnel
- o Equipment and Software
- o Other (s)

Q2. For the expected developments and technological trends in Additive Manufacturing technology, please indicate what new materials will appear in the next 10 years?

- o

Q3. 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?

- o

Q4. 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?

- o Machines /equipment
- o Materials /feedstock
- o Design of AM Parts
- o Post-processing
- o Other (s)

Q5. 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?

- o Welding coordinators
- o Welding Inspectors
- o Welding Operators

Q6. 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?

- o Data managers)
- o Specialists for processes and algorithms
- o Cybersecurity experts
- o Other (s)

Q7. What parts will be commonly produced for the Aerospace sector in the next 10 years? (Maximum 3 answers)

- o Air Foils
- o Guide Vanes
- o Turbine Blades
- o Fuel Nozzles & Systems
- o Propellant Tanks for Satellite
- o Other (s)

Q8. What will be the application in AM for the Medical sector in the next 10 years? (Maximum 3 answers)

- o Implants
- o Hearing Aids
- o Prosthetics
- o Surgical Models
- o Bio – Tissue Implants
- o Nanoscale Medicine
- o Other (s)

Q9. What will be the application in AM for the Automotive sector in the next 10 years? (Maximum 3 answers)

- o Spare parts
- o Embedded Sensors
- o Engine Components
- o Low Volume Interior Parts
- o Other (s)

Q10. Additional comments

4) Final Stage - Presentation of Results (~ three weeks after the 2nd round of survey)

The final stage (i.e., presentation of the results) will entail the analysis of the responses and insights from the initial skills forecast workshop and two rounds of online surveys. This can then be disseminated to the AM experts, AM Observatory, website, email communications and other communication channels.

4.2 Brainstorm method

The brainstorm method is a creative technique aiming at encouraging group thinking and the generation of new ideas. The focus is on the quantity of responses and independent of where they come from.

In SAM, brainstorming is used in the initial stage of forecast and a complementary tool during the workshop to identify the skills needs and trends in AM for the next 10 years.

There are two main steps in it's the implementation, namely:

1) Setting the environment and theme/problem for the brainstorm activity by the moderator;

Each participant provides his/her idea(s) on the subject, without interference of the remaining participants, meaning no comments neither criticism area allowed, also no answer is perceived as undesirable.

2) Discussion and evaluation

After collecting all ideas, the moderator invites participants to analyse and validate the answers. In this stage the "better" ideas are selected. The SWOT analysis can be used as a complementary technique to discuss and validate the results.

Below is the template that can be used for Brainstorming:

BRAINSTROM Theme: e.g.   The Profile of a person working in 2030 will be….
List all participants ideas   Moderator
Evaluation of the answers (SWOT analysis might be used)
Final list of ideas

4.3 World Cafe method

World Cafes can be implemented with large groups, since participants are organized into small discussion groups. Below is presented a template (already filled in with a concrete example) and instructions for implementation of world cafes:

WORLD "CAFÉ" – Main Theme e.g. How is AM going to be implemented within 5 years?
Duration - e.g., *45 minutes – 3 rounds of 15 each* **Moderators - 1** *per table*
Phases *1)Setting: Create a "special" environment (Toast to start- Port wine/biscuits); - All participants.* *2) Introduction: (explain objective of the activity + dynamic) – Host of the World Café.* *3) Small Group Rounds / Questions: (15 minutes each) x3 – In each round new insight are given by the participants regarding the theme; Moderators explains outcomes from previous round and launch complementary questions if necessary to generate new insights). Results should be written in flipchart / Post-it Notes – All moderators.* *4) Wrap Up: These results are reflected visually in a variety of ways, most often using <u>graphic recording</u> in the front of the room – All moderators.*

Group 1 – e.g., 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 harmonized qualifications will we 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?

Group 2 – e.g., AM Processes	(Moderator: 1)

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 used of metal binder jetting? What will be the challenges/opportunities in using the identified processes in AM. Which AM knowledge and Skills will be required?

Group 3 – e.g., Sectors	(Moderator: 1)

Objective: e.g. *Identify the sectors where AM will have major impact in the next five years. Related 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 five years? What products will be produced? Which Professional Profiles will be involved? New Harmonized profiles? Or Upskilled/reskilled workers? Which AM Knowledge and Skills will be required?
Materials: Flipcharts, Pens, blocks of paper, Post Its, etc.	

The results achieved during the world cafe should be collected and analysed after the session.