An analysis of drivers, barriers and readiness factors of EU companies for adopting advanced manufacturing products and technologies

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Abbreviations

3D	Three Dimensional
AMT	Advanced Manufacturing Technologies
CAD	Computer Aided Design
CAM	Computer Aided Manufacturing
CECIMO	European Association of the Machine Tool Industries
CEN	Comité Européen de Normalisation (European Committee for Standardisation)
CENELEC	European Committee for Electrotechnical Standardization
CEO	Chief Executive Officer
CNC	Computer Numerical Control
COSME	Competitiveness of Small and Medium-sized Enterprises
CPR	ESIF Common Provisions Regulation[1]
CSA	Cooperation and Support Actions (CSA) under Horizon 2020
DIH	Digital Innovation Hub
EEN	Enterprise Europe Network
EFFRA	European Factories of the Future Research Association
EFSI	European Fund for Strategic Investments
EMS	European Manufacturing Survey
ESIF	European Structural and Investment Funds
ETSI	European Telecommunications Standards Institute
EU	European Union
FabLab	'Fabrication Laboratory', a type of Makerspace
GPRS	General Packet Radio Service
H2020	Horizon 2020
HR	Human Resources
ICT	Information and Communication Technology
INNOSUP	An action line under Horizon 2020 with the objective to develop the ecosystem of innovation support to SMEs in Europe
INTERREG	A series of five programmes to stimulate cooperation between European regions, funded by the European Regional Development Fund

[1] Regulation (EU) No 1303/2013 of the European Parliament and of the Council of 17 December 2013 laying down common provisions on the European Regional Development Fund, the European Social Fund, the Cohesion Fund, the European Agricultural Fund for Rural Development and the European Maritime and Fisheries Fund and laying down general provisions on the European Regional Development Fund, the European Social Fund, the Cohesion Fund and the European Maritime and Fisheries Fund and repealing Council Regulation (EC) No 1083/2006

KIC	Knowledge and Innovation Community
KIC AVM	Knowledge and Innovation Community on Advanced Manufacturing
LED	Light-Emitting Diode
LEIT	Leadership in Enabling and Industrial Technologies (Horizon 2020 Programme Section)
NACE	Nomenclature Statistique des Activités Economiques dans la Communauté Européenne (Statistical Classification of Economic Activities in the European Community)
OEM	Original Equipment Manufacturer
PCB	Printed Circuit Board
PLC	Product Life Cycle
R&D	Research and Development
RTO	Research and Technology Organisation
SBIR	Small Business Innovation Research Program (US)
SBRI	Small Business Research Initiative (UK)
Sirris	Collective centre for innovation in the technological industry
SME	Small and Medium Sized-Enterprise
TRL	Technology Readiness Level
VR	Virtual Reality

Executive Summary

Manufacturing is among the key driving forces of the European economy. It provides about 20% of all jobs in Europe (above 30 million) and generates a turnover of about €7 000 billion in 25 industrial sectors and over 2 million companies, dominated by SMEs. In a comprehensive manner, therefore, industrial modernisation is of crucial relevance for economic dynamism in Europe and the lasting creation of growth and jobs in the EU. In ways going far beyond mere digitalisation, seminal transformations of the production system appear on the horizon in which firms and EU Member States will only participate if they succeed in adopting advanced manufacturing technologies (AMT) in due course.

Consequently, the European Commission's Directorate General for Internal Market, Industry, Entrepreneurship and SMEs has launched and continues to develop a large number of relevant initiatives to support Industrial Modernisation at the European level.

Against this background, this study on the 'analysis of drivers, barriers and readiness factors of EU companies for adopting AMT' identifies relevant steps and actions towards not only the development of better manufacturing technologies but also the uptake of industrial modernisation in a more general sense in a threefold manner.

Firstly, and most importantly, it takes an unrelentingly **uptake- and technology-user-centred** perspective that focuses on the potential of AMT for broad-based industrial modernisation as well as on factors enabling or limiting AMT uptake. In that approach, it differs from the majority of pre-existing technology-based studies.

Secondly, it establishes a **robust empirical framework of reference** (qualitative and quantitative) which not only goes beyond anecdotal evidence but also covers Member States, various types of technologies as well as firms in a broader way than any available study. Thus, it will allow **policy-makers** to put various requirements into perspective and to prioritise them

Thirdly, it puts forward policy recommendations not only as general headline objectives but also at the level of **concrete suggestions for future actions driven by various actors**, developed in the light of those already available. Thus, it outlines a **prioritised, multi-level strategy for European industrial modernisation**.

Findings

On an aggregate level, the empirical findings of this study can be summarised as follows:

While it has been shown clearly that the uptake of AMT is beneficial from not only a technological but also an economic perspective, **a strong need remains to accelerate their uptake, in particular amongst SMEs**. So far, moreover, the spread of AMT has remained too focused on specific countries and certain sectors to spur meaningful, broad-based industrial modernisation across the continent. In particular, this holds true with respect to complex technologies but even with respect to basic capabilities more needs to be done.

Overall, main **drivers for investing in AMT were found to be largely internal, resulting from a combination of commercial and technological considerations**: reducing production costs, improving the quality of products and services, improving the firms' employees' productivity and the reduction of production lead time. With the partial exception of sustainable manufacturing technologies, therefore, the use of AMT seems so far not to have been prompted by favourable external framework conditions.

Key obstacles to AMT investments, in contrast, are made up by a mix of internal and external factors. For nearly three quarters of the firms, the most important barrier is the high cost of investments in AMT acquisition and the lack of financial resources. Moreover, about half of all firms indicate difficulties in assessing the performance and the potential business return of such technologies and/or the lack of skilled personnel required to adopt and adapt relevant AMT. Finally, market uncertainty and turbulences play a major role.

Based on the surveyed firms' own statements, the analysis suggested that policy action will be required in the following fields: provision of risk-compensating financial resources for AMT uptake (in SMEs), support for qualification efforts to address prevalent competence and skills issues (in SMEs), creation of new frameworks and infrastructures for cooperation along value chains, creation of comprehensive yet efficient networks of service provision, and a consolidation of the existing multi-level support framework.

In order to better understand how these generally perceived requirements are being addressed so far, a **comprehensive mapping of relevant policy measures and service offerings** at European, national and regional levels was conducted. While no such effort can ever be complete, the relevant part of the study integrates not only detailed information on actions at the European level, but, in addition, presents the results of an extensive review of topical data sources like all Regional Innovation Monitor regional reports or national level documentation, including that from extra-European countries like China or the United States.

Subsequently, the list of policy needs expressed by the enterprises surveyed and interviewed for the study and the mapping of available support policies were compared, interpreted and consolidated into a number of **key issues along a structured framework of relevant themes** derived from earlier analysis (finance, funding, competence and skills, technology, supply chain cooperation, service offerings, policy framework). Furthermore, all issues were classified as **either internal or external**, referring to whether firms can address them on their own or not.

Finally, key issues were taken up and integrated into **eight headline policy recommendations** on grounds of relatedness and available political options. In each recommendation, needs for political action were identified and headline objectives defined. Beyond this, concrete and detailed proposals for specific policy actions were developed in consultation with experts.

Policy Recommendations

In summary, these findings are translated into recommendations under four headings:

I. Strengthen capacity for SMEs

Currently, many European firms do not yet have sufficient capacities to adopt AMT. Related shortcomings include know-how, human capital as well as organisational and managerial capacity. Without a better **AMT ecosystem for SMEs** that supports the building of such capacities **in all areas of advanced manufacturing** more advanced support offers will be less relevant.

II. Promote High-end AMT uptake

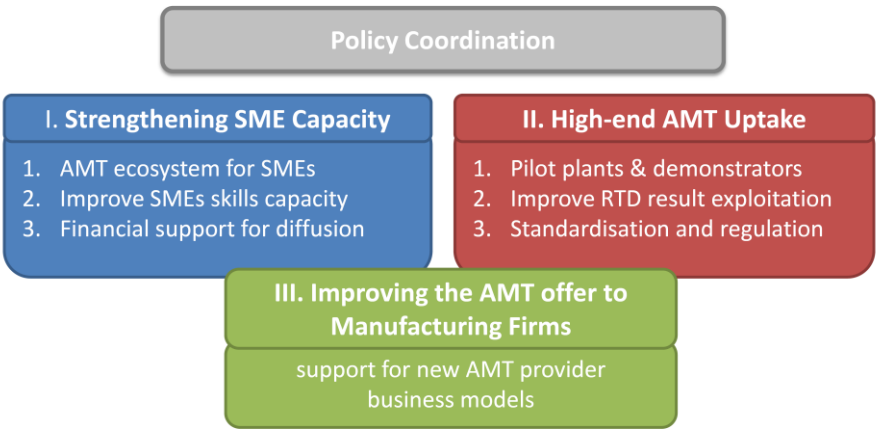
For already more advanced industrial SMEs, **high-quality demonstration environments and suitable framework conditions** need to be created which allow them to pilot and implement the most recent technologies and relevant research results in cooperation with research and technology organisations (RTOs) as well as other relevant AMT firms.

III. Improve the AMT offer to manufacturing firms

Currently, many AMT providers openly concede that they do not understand their relevant markets well and have not yet developed suitable business models to effectively reach out to potential clients. To strengthen the uptake of AMT, new **business models for technology firms** have to be promoted that **allow their SME clients to invest under conditions of uncertainty**.

IV. Strengthen policy coordination

While many pertinent support measures are already available in the EU, their coordination across different levels of policy making needs to be improved, in particular if new ones shall be added to the existing portfolio.



I. Strengthen capacity for SMEs

Recommendation I.1
Improve and extend the "AMT ecosystem for SMEs" across all the EU

Efforts to create reliable innovation infrastructures in many EU Member States have been notably undertaken in the course of the I4MS initiative (with main focus on ICT). Similar initiatives have been promoted from ESIF sources at national and regional level. EU industrial policy should seek additional ways to support EU countries and regions in their efforts to improve their AMT service provision systems by leveraging the role of clusters and other SME intermediaries as well as by creating in collaboration with RTOs a broader innovation infrastructure covering the whole spectrum of AMT.

More specifically, it is suggested:

i.) **at the European level:** to support the establishment of Innovation Digital Hubs, which should provide support to manufacturing SMEs beyond ICT services, and cover the whole spectrum of AMT solutions. Moreover, spread out the concept of excellence based on existing best practices such as the European Initiative for Cluster Excellence, and reinforce the role of the Enterprise Europe Network (EEN) by strengthening cooperation with national and regional initiatives for innovation;

ii.) **at the European level:** to implement a continuous monitoring system to assess AMT uptake[2] by SMEs at national and regional level across all industrial sectors. This system should also take into account and combine statistical data and results from other relevant existing EU analytical tools;

iii.) **at national/regional levels:** to establish new or reinforce existing national and regional initiatives supporting AMT services by combining own resources with ESIF;

iv.) **at operational level:** to raise awareness about AMT benefits to local manufacturing SMEs through clusters and other SME intermediaries. These business organisations should work together with AMT support service providers to identify local SMEs that would be the most interested to adopt AMT solutions.

Recommendation I.2
Improve skills capacity for SMEs

Different models aimed to pool SMEs' resources for developing joint innovation projects, teaching factories, and e-learning tools are already established in a small number of EU Member States and created good opportunities for acquiring basic knowledge by working together on concrete projects. However such offers are neither exhaustive nor available everywhere in the EU.

To overcome this still prevalent bottleneck, new cooperation models for training and co-creating AMT solutions should be promoted, particularly in smart specialisation areas. Through such models, SMEs will be able to collaborate more among them as well as with universities and RTOs.

[2] Monitoring efforts such as the Innobarometer or the European Innovation Scoreboard should definitely be funded further, further analysis of e.g. the 2015 European Manufacturing Survey data could add extra value.

More specifically, it is suggested:

i.) **at the European level:** to support the design of European curricula for AMT, and new educational initiatives for SMEs such as teaching factories, and e-learning tools. Furthermore, disseminate existing successful schemes supporting university-research-SMEs cooperation among Member States and regions;

ii.) **at national/regional levels**: support collaborative models between universities and SMEs (e.g. dual education systems, and joint SMEs-University regional training centres), and collaborative models between RTOs and SMEs (e.g. models pooling SMEs' resources for joint innovation projects (AiF), and secondment of researchers in SMEs). Furthermore, work on collaborative strategic processes to identify SMEs' long-term needs with regard to innovation and skills;

iii.) **to clusters and other SMEs intermediaries**: facilitate regional cooperation between SMEs, universities and RTOs, particularly in smart specialisation areas;

iv.) **to policy-makers and cluster organisations**: exploit the opportunities offered by the forthcoming KIC on Added-value Manufacturing to establish new university-research-industry cooperation models.

Recommendation I.3
Provide adequate financial support for AMT diffusion

SMEs' actual ability to find suitable funding for AMT uptake remains limited today, mainly due to the lack of knowledge about available funding opportunities or a wrong perception about existing funding barriers for their projects (e.g. too often considered as non-bankable).

In recent years, many efforts have been undertaken at the European level to mitigate this issue, such as through COSME and the InnovFin SME Guarantee Facility. However, this study argues that ambitions have not yet been met at a satisfactory level.

To achieve that, existing instruments need to be better promoted and technical difficulties need to be overcome for the benefit of European manufacturing firms.

More specifically, it is suggested:

i.) **at the European level:** to support national/regional efforts aimed to improve SME access to different EU funding opportunities for innovation such as COSME or the InnovFin SME Guarantee Facility managed by the EIF under Horizon 2020. This may include: differentiate eligibility provisions for different types of technologies and geographic areas, and monitor the outreach and impact of existing instruments that will help understanding the barriers that limit SMEs' access to finance;

ii.) **at national/regional levels:** to offer multi-step support to SMEs for identifying any barriers at national and regional level they encounter in different phases of the funding process for AMT uptake, for example through voucher schemes;

iii.) **to clusters:** to disseminate information and assist SMEs using relevant financial instruments for AMT uptake, qualify them to address financial issues, and help them benefit from the activities of the new KIC on added-value manufacturing, and have access to the SME Window under EFSI.

II. Promote High-end AMT Uptake

Recommendation II.1
Promote the development of joint pilot plants and demonstrators

Several actions have been initiated with respect to pilots and demonstrators for example in the framework of the Vanguard Initiative and the Knowledge and Innovation Communities (KICs) established by the EIT. In the framework of smart specialisation such efforts should be further supported for establishing a wide European network of pilot plants and demonstrators anchored within the involved regions but at the same time allowing access, synergies and complementarities with other regions. Such pilot plants and demonstrators should not be only limited to hardware installations, but becoming real ecosystems for innovative solutions where SMEs can have access to the multidisciplinary competences of the service providers for uptake and qualification.

More specifically, it is suggested:

i.) **at the European level:** to create synergies among ongoing and new initiatives such as the Vanguard Initiative, provide support to joint regional initiatives to be established under the recent Smart Specialisation Platform for Industrial Modernisation, identify new suitable business models to open up SMEs access to pilots, and improve the currently limited availability of trans-national funding mechanisms, particularly under ESIF;

ii.) **at European, national and regional levels**: to jointly design mixed public-private funding models for pilot plants and demonstrators;

iii.) **at national/regional levels:** to support the development of pilots especially in smart specialisation areas, and support trans-national/regional cooperation activities. Moreover, leverage trans-national funding mechanisms for the development and exploitation of pilot plants, including peripheral and/or less developed regions;

iv.) **to clusters, technology and service providers:** to participate in the design of pilot plants and demonstrators to address SMEs needs, and support SMEs to fully exploit such advanced infrastructures and providing practical training and offering technical services;

v.) **to policy-makers, clusters and service providers alike:** to use the forthcoming KIC on added-value manufacturing initiative for setting up a European network of pilot plants.

Recommendation II.2
Improve the exploitation of Horizon2020 research by SMEs

Many efforts have been made in the past to improve opportunities for valorisation and commercialisation of research results, e.g. in the context of the SME Instrument of Horizon 2020. However, less has been done so far to make manufacturing SMEs more pro-active in exploiting research results. To better valorise AMT-related research results for SMEs, further efforts should be done, particularly in the framework of the “Factories of the Future” Public Private Partnership (FoF PPP).

More specifically, it is suggested:

i.) **at the European level:** to reinforce the exploitation dimension in Horizon2020 projects, to launch dedicated actions for SMEs to present completed projects, to launch dedicated actions for the uptake and demonstration activities of Horizon2020 research in demonstrators and pilot plants;

ii.) **at national/regional levels:** to better exploit results generated by EU-funded research projects following the smart specialisation principle of "stairway to excellence", and better align their own programmes with European funding;

iii.) **to clusters:** to better communicate to SMEs the opportunities offered by EU research projects working on new ATM-relevant topics, and be better involved in the FoF PPP and other platforms activities. Moreover, support national and regional governments and the EU to identify all not yet exploited synergies between their funding instruments and to support RTOs and universities in diffusing to manufacturing SMEs EU research results.

Recommendation II.3
Adapt standardisation and regulation to the diffusion of AMT

This recommendation addresses barriers resulting from a limited EU engagement in the field of standardisation or a somehow obsolete regulation that hinders AMT investments. In particular, some obstacles are concerned with ICT-enabled (Industry 4.0) and sustainability-related issues in the development of some AMT. So far, relevant discussions have been triggered in the context of CENELEC and ETSI, where the EU is actively trying to keep pace in AMT fields but the constant emergence of new technologies makes this sometimes a real challenge. For example, more active promotion of open standards would increase the interoperability of ICT systems and support the digital uptake of SMEs. At the same time, a targeted review of existing regulations could facilitate the re-use, re-manufacturing and recycling of products and processes and help to implement low carbon based policies and circular economy concepts on a broader scale.

More specifically, it is suggested:

i.) **at the European level:** to ensure that new standards and EU regulation reflect the interests and needs of SMEs (e.g. by creating appropriate communication channels), require participants of relevant European-funded projects to define implications of standards and regulation and invite them to relevant committee meetings;

ii.) **to clusters:** to build awareness about standardisation and regulation for SMEs, aggregate SME opinion to provide relevant inputs on standardisation and EU regulation issues (for example by establishing "standardisation and regulation forums"), and facilitate the participation of cluster members in standardisation committees and other committees proposing amendments to existing national and EU regulation.

III. Improve the AMT offer to manufacturing firms

Recommendation III
Support new service-based business models for the diffusion of AMT

This recommendation addresses risks faced by SMEs for AMT uptake due to their limited capacities for investment and unclear long-term benefits. Market uncertainty, a not yet proven performance and a lack of skills to introduce and operate AMT preclude SMEs from investing.

While the challenge is known and a number of suitable business models have been developed in theory, very limited policy action has been taken in this regard so far, at both European and national levels. Hence, most promising options are not yet available to SMEs.

Alternative to the provision of public support, innovative business models can offer potential users new and better options for risk sharing based on customer-supplier cooperation (e.g. leasing, renting, pay-per-part, pay-per-availability, machine supplier taking responsibility for operations, etc) – that, following basic capacity building, will swiftly increase their readiness to invest. Hence, AMT suppliers should be prompted to increase their involvement in customer-supplier relationships.

More specifically, it is suggested:

i.) **at the European level:** to support the wider implementation of innovative business models capitalising on past research initiatives, stimulate exchanges of experience among more and less advanced Member States and regions as well as establish structured monitoring systems on the diffusion and performance of new business models;

ii.) **at national/regional levels:** to support AMT suppliers and service providers, facilitated by clusters, to set up strategic partnerships to promote new business models;

iii.) **to financial organisations:** to cooperate with technology providers from a perspective of risk sharing, as well as with European-level institutions to find new funding opportunities supporting new business models (e.g. EIF's SME Initiative);

iv.) **to ATM providers:** where available, to exploit existing pilot plants and demonstrators to offer new business models (e.g. for training, technology performance assessment, etc).

IV. Strengthen policy coordination

Recommendation IV
Improve the alignment of EU, national and regional policies

This recommendation aims at addressing the, in the eyes of SMEs, rather evident lack of synergies and complementarities between European, national and regional policies. To gain leverage in this challenging field, it appears necessary to further reinvigorate the processes of a mutual policy learning that have recently been initiated in the context of the smart specialisation agenda. From an 'end-user perspective' a more prevalent uptake of AMT can only be ensured if SMEs have at their disposal an efficient portfolio of instruments that can support and co-fund relevant activities in a complementary and synergic manner. In this effort, all levels of policy-making have to collaborate according to their respective areas of strength.

More specifically, it is suggested:

i.) **at the European level: connect, provide platforms and leverage synergies**
to help European regions elaborate and implement their smart specialisation plans and to subsequently exploit synergies at EU level, to update policies for the next financial perspectives 2021-2027 considering the inputs of updated technology roadmaps as well as of the regional smart specialisation strategies;

ii.) **at national/regional levels: enable place-based industrial development**
to develop place-based industrial policies based on a conscious deployment of ESIF in compliance with existing smart specialisation strategies, considering opportunities offered by other European policies with a view to synergies and complementarities, take advantage of the "Seal of Excellence" label to ensure alternative funding for high-quality projects, empower the role of clusters as technical partners of the policy definition process;

iii.) **to clusters: act as a convenor, enabler and trans-national network node for SMEs**
to diffuse awareness of European policies among SMEs and give them access to a portfolio of funding sources coherent with their specific business objectives, elaborate strategic research and innovation roadmaps making links to European policies, engage in relevant European RIS3 initiatives, such as the Smart Specialisation Platform for Industrial Modernisation and the Vanguard Initiative.

1 Introduction

1.1 Policy Context

Manufacturing is among the key driving forces of the European economy. It provides about 20% of all jobs in Europe (above 30 million) and generates a turnover of about €7 000 billion in 25 industrial sectors and over 2 million companies, dominated by SMEs. During the 2008-09 economic crisis, its crucial relevance to the Europe economic success and the lasting creation of growth and jobs among the continent's population became visible to all. At the same time, seminal transformations of the production system appear on the horizon in which firms and countries will only participate if they succeed in adopting relevant platform technologies in due course.

The competitive global market position of Europe in certain high value-added products and services have been at risk due to a lack of investments in industry modernisation since the beginning of the economic crisis. Today, industry still contributes with 15.3% to the Gross Value Added of the Union economy but this contribution is decreasing. The accumulated investment gap needs to be bridged to allow European companies to produce more innovative products and services using more resource-efficient production processes (less material, less energy and less waste), notably through the deployment of AMT.

Consequently, the European Commission has reinforced its emphasis on industrial modernisation through the design of new measures as well as the improvement and better coordination of existing action lines. Under not only Horizon 2020 and COSME but also the European Fund for Strategic Investments (EFSI) and the European Structural and Investment Funds (ESIF), notable amounts of funding have been made available to AMT research and investment. In parallel, many national and regional governments are launching similar support efforts in the same area.

Nonetheless, Europe's position with respect to advanced manufacturing performance and the uptake of related technologies in large sections of its industrial sector has remained less than satisfactory. With Asia catching up fast and first signs of recovery in the United States, Europe is not in a position to rest on its laurels. While various relevant key enabling technologies are developed by European firms, far too few of them have become commonly adopted while some reports even claim that the age of installed process technology in Europe increases rather than **decreases** – as the existing opportunities for investment would suggest.

Furthermore, recent empirical studies (SYMOP et al., 2014[3]) have suggested that the gap of industrial dynamics was widening within Europe. While the German industry continues to realise positive developments of value added, productivity, profitability and exports, France and, to a lesser extent, Italy seem to be falling behind. In all three countries, employment was decreasing but, once more, France and Italy as well as Germany failed to accommodate rises in productivity. Worryingly, both France and Italy, formerly leading industrial nations, had so far not managed to turn around the decrease in investment dynamic prompted by the 2008-10

[3] SYSOP, DGCIS, Gimélec, Roland Berger (2004): Étude prospective à l'adaption de l'appareil productif français. Rapport Final, May 2014. Paris. (unpublished)

economic crisis. Increasingly, obsolescence of production facilities seems to be becoming a relevant issue within a number of EU Member States. Once more, however, the problem was found to be more pronounced in the United Kingdom and France than in Italy, Spain, Germany or Sweden. Among the latter, however, only Germany and Sweden display active reinvestment so that in few years, Italy and Spain may become affected as well if no turnaround is achieved (SYMOP et al., 2014).

Against this background, there was a need for a Europe-wide empirical study to analyse **from the perspective of potential users** why the required process of technology uptake appears sluggish *despite* notable efforts on the side of key enabling technology producers and innovation policy-makers.

With respect to these drivers and barriers, much of the available evidence in the field remains anecdotal or specific to particular Member States – as in the abovementioned study. At the European level, however, such individual insights cannot suffice as a basis for policy-making. Beyond general information on other countries' good practice, policy-makers need a better understanding of how diverse the situation currently is with respect to the diffusion and impact of various manufacturing technologies (both established and new), the position of the various Member States (both leading and lagging) and the main obstacles encountered by various types of firms (large and small, producers and users).

1.2 Objective

Overall, this study identifies the main drivers, barriers, SMEs' readiness and implications related to the **adoption of AMT** by EU manufacturing businesses. Furthermore, it formulates a number of policy recommendations with the aim of facilitating the adoption of advanced manufacturing in Europe.

In line with the tender specifications, it pursues three specific objectives:

- Based on an in-depth quantitative data analysis, to **illustrate to what extent EU manufacturing** companies are currently **using and investing in AMT** as part of their efforts to increase their productivity, competitiveness and growth,
- To analyse the various **framework conditions and factors that** for manufacturing companies constitute **drivers or barriers to invest in advanced manufacturing**, such as the availability of finance, legislation, skills and the business environment,
- To **analyse the readiness of companies to adopt advanced manufacturing** and possible mid- to long term implications from adopting AMT such as organisational changes, staff trainings, changes of culture and new business practices.

In short, this study puts a specific emphasis on two elements that existing studies have not covered to a satisfactory extent:

- A **user and technology-adoption oriented perspective** that offers new perspectives on SMEs' readiness and new insights into options to unlock a bottleneck that is too often only considered from a technology provider perspective,

- So far unseen **empirical robustness and Europe-wide coverage** due to a large scale harmonised data collection effort unmatched by any existing study which at the same time allows for a differentiated analysis by e.g. country, firm type or technology.

1.3 Methodology

Overall, the study followed a three-step methodology.

Firstly, a **targeted analysis of the most comprehensive statistical dataset available** on the use of AMT was performed to identify first central insights into the current state of play with regard to AMT uptake in Member States. Moreover, it differentiated these findings by country type, sector and company size class and provided first insights into potential impacts of AMT use on European firms.

Secondly, a **literature-based analysis** was conducted to identify types of factors and framework conditions that constitute drivers for, and barriers to, the uptake of AMT in European SMEs. Furthermore, literature-based conceptual work was conducted to develop a more detailed understanding of the various dimensions of SMEs' readiness with regard to AMT uptake.

Thirdly, and most importantly, **this study created the first ever broad-based empirical database on drivers and barriers of AMT uptake and central user-side SMEs' readiness factors** that enable or hinder the often lamented limited uptake of AMT through a large scale own research effort. In personal interviews and through an online survey, data were collected in a both qualitative and quantitative manner. Based on the findings of steps one and two, relevant pilot cases were selected to refine first interview guidelines and design questionnaires for the concluding online survey.

In the ensuing research effort, 19 firms were interviewed in person for one to two hours each and more than 600 firms answered detailed questionnaires on drivers, barriers and readiness factors with regard to AMT uptake. Also, detailed information was collected on the types of AMT that are currently considered most relevant for European firms.

Finally, the study developed comprehensive yet focused policy recommendations with the aim of facilitating the adoption of advanced manufacturing in Europe. They are addressed to both policy-makers and organisations providing SME business support services.

2 Summary of Deliverables

2.1 D 1 – Methodology and Key Findings from Statistical Analysis

In the context of our project, the key objective of Work Package 1 was to set the scene for later analysis. It was aimed at generating first insights and at revealing first patterns to provide a basis for more comprehensive analyses later in Work Package 2.

In Work Package 1 the study provided a broad-based update on the uptake of AMT by European firms and in particular SMEs. In the submitted proposal, methodology and information sources were clearly described. Through an in-depth analysis of the European Manufacturing Survey (EMS), data insights could be gained not only into the prevalence but also the likely effects of AMT uptake[4].

In particular, the agreed EMS approach allows:

- to draw on a **large and extensive dataset** and to derive representative findings beyond reasonable doubt with regard to robustness (rather than limited surveys **etc)**;
- to reflect this study's particular **user and uptake oriented perspective** as stipulated in the Tender Specifications (rather than a producer or KET-oriented perspective);
- to cover relevant country examples from **all major areas of the EU** (rather than non-comparable datasets from individual countries);
- to clearly distinguish between various **fields of AMT as specified in European Commission Policies** (rather than other definitions specific to reports);
- to **gauge possible impacts** that result from AMT uptake by comparing users and non-users with respect to different criteria of performance.

Without these characteristics, it would be difficult to fulfil the specifications of the study in a meaningful and empirically robust manner.

At the point when work under Deliverable 1 was performed, the most recent EMS dataset available dated from 2012. However, it included data on piloting activities and planned AMT uptake by 2015 that features prominently in the analysis below. Prior studies have confirmed the validity and relevance of this information on plans under non-exceptional circumstances as over the period 2012-15. Hence, it can be assumed with certainty that conclusions based on a high-quality, broad-based dataset on planned investment are preferable to only slightly newer but as such much weaker and fragmented datasets on actual uptake – which would neither enable a differentiation according to the European Commission's Taskforce's classification of AMT nor a robust analysis gauging possible impacts. In any case, an analysis of available data revealed that no relevant alternative data sources were available at the time of analysis.

2.1.1 Which AMT to study? – Defining AMT vs. KETs

Before embarking on a study of the use and impact of AMT, is necessary to delineate the AMT concept from related ones – most prominently the concept of Key Enabling Technologies (KETs).

[4] At the kick-off meeting, it was stated that DG GROW acknowledged this approach by awarding the tender.

While all KETs can be relevant to the manufacturing industries as they can improve production processes and technologies, the degree to which they practically already do differs strongly. As it is thus not possible to say that some KETs are, in principle, relevant to manufacturing while others are not it would be mistaken to limit technologies relevant to advanced manufacturing to one single KET – that labelled "AMT". Other KETs, like nanotechnology or new materials, can be just as relevant to modern manufacturing.

While advanced manufacturing studies thus need to take into account various KETs, they do not always have to consider all KETs completely. Other than "pure" KETs studies, they should only consider those KETs that already have an impact on manufacturing processes, i.e. display a relevant potential to transform current processes of production (KETs as a driver and enabler of **process innovation**) or allow for the manufacturing of new, KET-based final products (KETs as a driver and enabler of **product innovation**).

KET-based solutions that are still far from technological realisation or implementation beyond early stages will therefore not be considered in this study as they remain irrelevant for any short to mid-term increase in manufacturing performance. "Industrial biotechnology", for example, has never been explicitly included in the EMS as it is known that its use among the sample population is generally quite limited and concentrated on a few, larger firms in selected countries. Furthermore, the 2012 EMS explicitly decided against the inclusion of "photonics" into the area of the study. While this technology is of course generally relevant, broad anecdotal evidence suggested that, at the time, its practical uptake in production processes remained minimal across most industries. While this situation may now be gradually changing, it was up to subsequent Work Packages of this project to study the role of such early-stage, emerging KETs for production in more detail.

Consequently, AMT uptake and its potential effects were analysed in differentiation for the three main groups of AMT.

High Performance Manufacturing Technologies

- Industrial robots/ handling systems
- Automated Warehouse Management Systems
- Technologies for safe human-machine cooperation
- Processing alloy construction materials
- Processing composite materials
- Manufacturing micromechanical components

ICT-Enabled Technologies

- VR / simulation in production reconfiguration
- VR / simulation in product design
- Supply chain management with suppliers/customers
- Product Lifecycle Management Systems

Sustainable Manufacturing Technologies

- Dry processing/minimum lubrication
- Recuperation of kinetic and process energy
- Control system for shut down of machines
- Combined cold, heat and power (Bi-/Trigeneration)

For the reasons outlined above, the analysis on the usage and possible impact of AMT under Work Package 1 was executed based on data of the *European Manufacturing Survey* (EMS).

The EMS is realised by a consortium of research institutes and universities from and across Europe. The EMS surveys the utilisation of techno-organisational innovations in manufacturing at the level of individual manufacturing sites and the thereby achievable performance increases in the manufacturing sector. The roots of the EMS can be found in the *German Manufacturing Survey*, developed in 1993 by *Fraunhofer ISI*. From 2001 onwards, this survey has developed into the *European Manufacturing Survey* (EMS) by means of its extension to a continuously growing number of European and even global partners. *Fraunhofer ISI* coordinates the consortium.

The EMS is carried out as a written or online survey by each partner in his/her country. In each country, the survey comprises a large random sample of manufacturing firms with at least 20 employees covering the whole manufacturing sector. Manufacturing or plant managers are asked to fill in the questionnaire. The majority of questions in the questionnaire are common questions addressed by all partners and often asked repeatedly across several rounds. To ensure comparability, the questionnaire is translated into the respective national language and pretested in each participating country. Currently, a complete data basis is available from five survey rounds 2001, 2003, 2006, 2009 and 2012. For this project, data was analysed from a sample of 2 700 manufacturing companies from Germany, Austria, France, Spain, Croatia, Slovenia, Portugal, Denmark and the Netherlands.

2.1.2 Current Use of AMT

This chapter includes a descriptive analysis of the use of AMT in industrial companies in ten selected countries based on the EMS data. As a fundamental first step, an extensive descriptive analysis of usage of AMT by country, industry and firm size is delivered. Furthermore, the results of the analysis of the use of AMT by batch size and product complexity are reported.

Use of AMT by European Countries and Country Groups

The analysis of AMT utilisation in the ten selected countries (Figure 1) shows that the high-performing manufacturing technologies are adopted by between somewhat below 40% and nearly 70% of manufacturing firms. In the leading group, involving Slovenia, Sweden and interestingly Spain, the adoption rates reach between 60 and 70%, although in part based on pilot activities. Germany and Austria are not part of this group but of a large middle group in which about 50-60% of all surveyed firms adopt one or more high-performing manufacturing technologies. Notably, the Netherlands falls into this group only due to a comparatively high share of firms piloting technologies while their share of intensive users hardly exceeded 40%, though lower than in the rest of the group. Finally, Croatia, lags behind all other countries with an overall usage rate of less than 40%, including pilot use.

Use of AMT by Sectors

Looking at sectoral differences in the usage of AMT, it becomes obvious that, with the exception of only a few industries, high-performing manufacturing technologies are adopted by between somewhat below 40% and close to 60% of manufacturing firms, documenting similar differences between industries as has been found between countries – which should be borne in mind during later analyses.

By contrast the analysis indicates three main groups of industries regarding the usage of ICT-enabled technologies: higher than 60%, between 40 and 60%, and between 20 and 40%. As is the case for high-performing manufacturing technologies, ICT-enabled technologies were most commonly adopted among manufacturers of transport equipment.

Similar to the findings with respect to high performance technologies, two groups of industries can be distinguished with respect to the adoption of sustainable manufacturing technologies. The leading group, including transport and equipment as well as the metal industry, shows around 45% of intensive, and around 8% of piloting users, i.e. an overall adoption rate of above 50%.

Figure 1: Shares of firms using high performance manufacturing technologies, by country

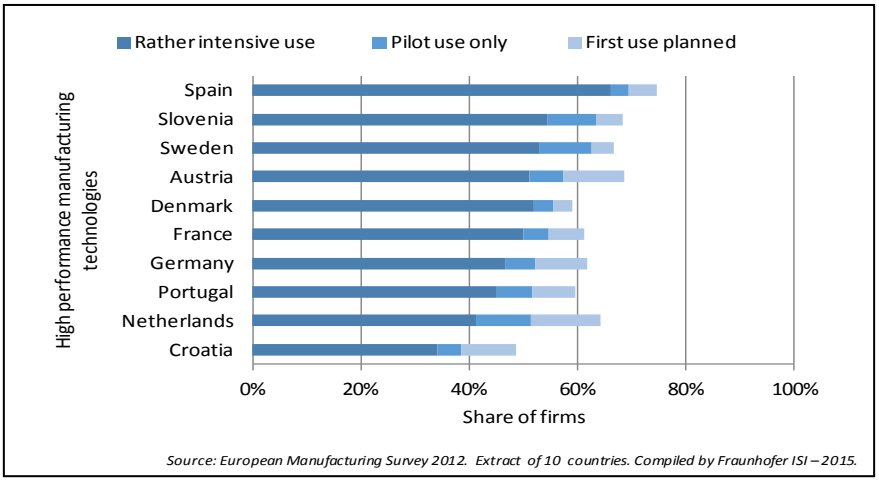


Figure 2: Shares of firms using ICT-enabled technologies, by country

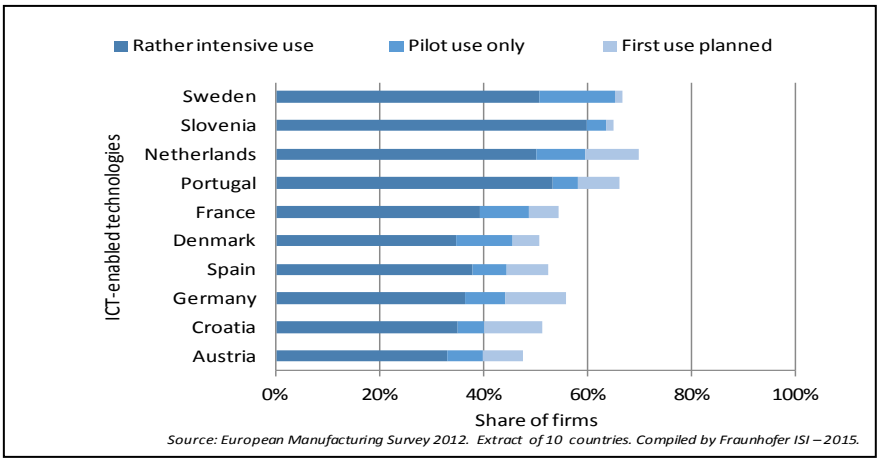


Figure 3: Shares of firms using sustainable manufacturing technologies, by country

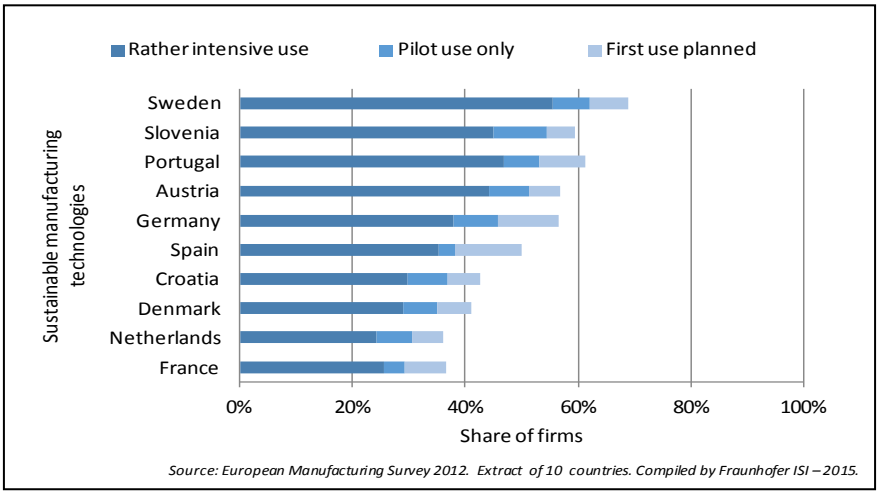
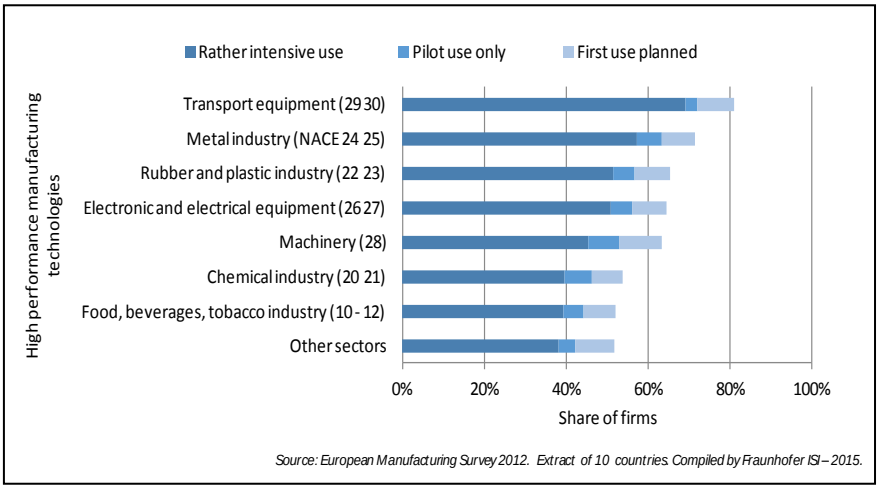
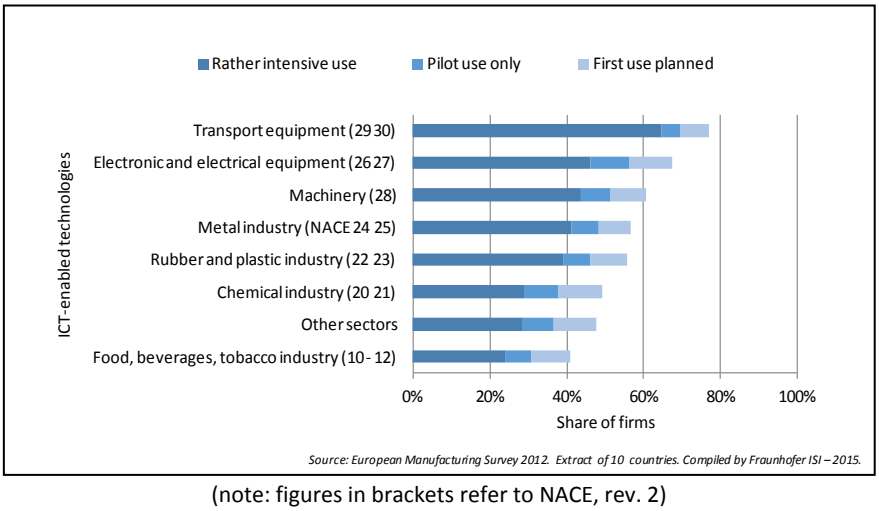


Figure 4: Shares of firms using high performance manufacturing technologies, by industry



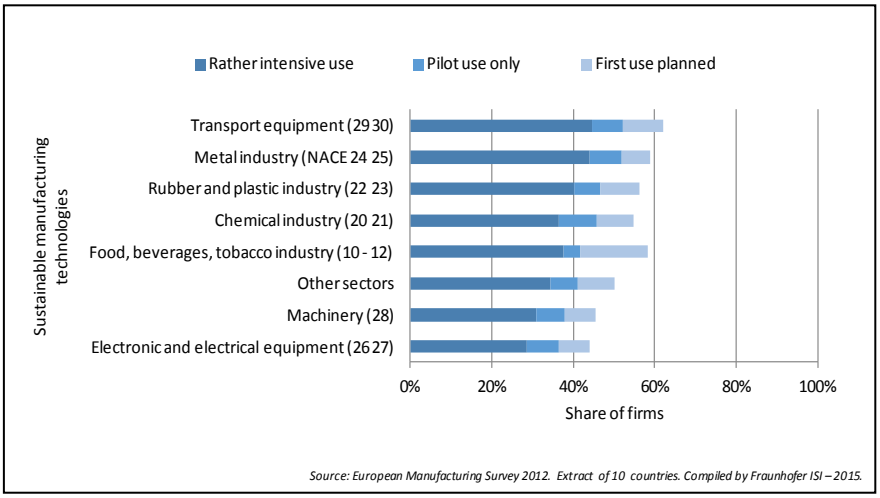
(note: figures in brackets refer to NACE, rev. 2)

Figure 5: Shares of firms using ICT-enabled technologies, by industry



(note: figures in brackets refer to NACE, rev. 2)

Figure 6: Shares of firms using sustainable manufacturing technologies, by industry



(note: figures in brackets refer to NACE, rev. 2)

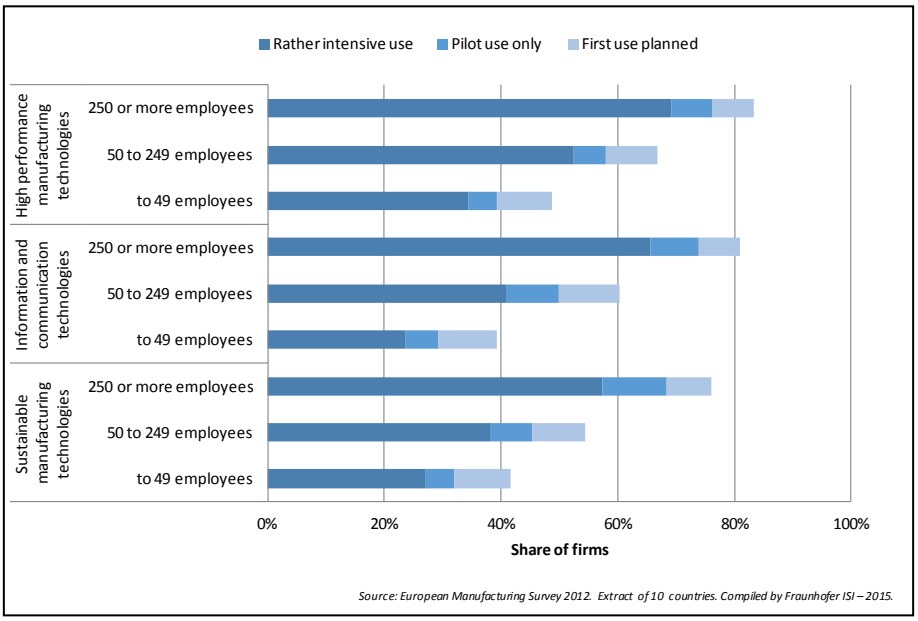
Use of AMT by Firm Size

With respect to the relation between the firms' size and the usage of AMT (Figure 14), the data clearly show that larger firms are making much more frequent use of all examined AMT in their manufacturing processes (more than 60%) than medium-sized firms with 50 to 249 employees (between 40 and 60%) and, in particular, than small firms with less than 50 employees (between 20 and 40%).

An analysis of three technology groups depicts this disparity more precisely. According to the EMS 2012 data, about 40% of all surveyed firms with 20 to 49 employees make use of high performance manufacturing technologies in their factories, about one third use sustainable manufacturing technologies, while only about a quarter of them use ICT-enabled technologies. By comparison, nearly 60% of all firms with 50 to 249 employees make use of high performance manufacturing technologies while only slightly above 50% of all companies in this size group use ICT-enabled technologies and less than half make use of sustainable manufacturing technologies.

This rank order of "high performance"-"ICT-enabled" and "sustainable" is also found for larger firms, rendering smaller firms' lack of uptake of ICT-enabled technologies a notable exception. In conclusion, the adoption rate increases in an almost linear manner with the size of the surveyed companies. Thus, the size of the company, measured by the number of employees, is clearly related to the probability of the use of AMT in European industrial companies. With respect to the share of pilot users or those planning first use, however, the findings do not show significant differences between the three size groups.

Figure 7: Shares of firms using AMT, by company size



Source: European Manufacturing Survey 2012. Extract of 10 countries. Compiled by Fraunhofer ISI – 2015.

2.1.3 Impacts of AMT Uptake as documented in the Data

Table 1: Differences in various dimensions of firm performance between users and non-users of mentioned AMT

Performance Indicator	Use of any, at least one high-performance manufacturing technology	Use of any, at least one ICT-enabled technology	Use of any, at least one sustainable manufacturing technology
Economic performance			
Added Value [Revenue - Input p. Employee, 1000 €]	##	##	##
Return on sales (bef. tax 2011) > 2% [% surveyed firms]	#	##	n.s.
Employment growth (2009-2011) [% annually]	n.s.	n.s.	n.s.
Revenue growth (2009-2011) [% annually]	##	#	#
Total Factor Productivity [turnover - input / depreciation + staff cost]	n.s.	n.s.	#
Innovative performance			
New products [% *among all firms*]	##	##	##
Turnover generated by new products [% among innovative firms]	n.s.	n.s.	#
Turnover generated by new products [% among all firms]	##	##	#
Products new to the market [% innovative firms]	#	#	n.s.
Products new to the market [%among all firms]	n.s.	n.s.	n.s.
Turnover gen. by prod. new to market [% among innovative firms]	##	##	#
Turnover gen. by prod. new to market [% among all firms]	##	##	#
Old products (over 10 years old) [*among all firms*]	n.s.	n.s.	n.s.
Turnover generated by old products [among all firms]	##	##	n.s.

Source: *European Manufacturing Survey 2012. Extract of 10 countries. Compiled by Fraunhofer ISI – 2015.*
Notes: significance level: # p < 0,05, ## p < 0,001. **Green**: desirable outcomes. **Red**: non-desirable outcomes

2.1.4 Summary of the Findings

Overall, our analysis yields the following five main findings with respect to the current use of AMT across Member States and sectors:

Firstly, the analysis' findings clearly underline that it is crucial to distinguish between various AMT sub-fields as both the patterns of use of the related technologies and their impact on firms' performance differ remarkably. Already, this applies to relevant differences between more established high performance manufacturing technologies and more advanced ICT-enabled, Industry 4.0-type technologies. Even more clearly, differences are found between both of those and sustainable manufacturing technologies which, in many ways, prove to be distinct not only in technological means but also in commercial and/or political ends.

Secondly, a 'ranking' of Member States or, more precisely, groups of countries should be interpreted with caution. On the one hand, rankings differ notably with respect to specific technologies while, on the other hand, these rankings are relative in nature and conceal important background information. For example, a middle rank of Austria or Germany does not imply that these Member States were "underperforming" in AMT but simply gives evidence of a broad industrial base that also includes less modern firms.

Thirdly, selected industries and firm types are more prone to constitute a fertile environment for the adoption or use of AMT than others. Notably, most findings with a view to firm size and, to an extent, even sectors prove less technology specific than the patterns of uptake across Member States. Consequently, there seems to be a strong indication that a large share of all national disparities with respect to the uptake of AMT may in fact be due to underlying structural differences in the respective countries' industrial or sectoral structure.

Fourthly, next to all our analyses, equally from which perspective, give evidence of notable dynamics of uptake and diffusion. Although the share of companies implementing at least one technology is – by empirical definition – higher than that of those piloting or planning first uses, the combined share of the latter plays a notable role in many countries, sectors and types of manufacturing firms. Not irregularly, the 'ranking' of Member States with respect to the uptake of AMT differs markedly, depending on whether piloting activities and planned use are taken into account or not. Thus, an ongoing process of diffusion can be identified for a large majority of manufacturing technologies analysed in Work Package 1, irrespective of whether they are already widely used or not.

Regarding AMT uptake's impact on European firms' *economic and innovative performance*, the following findings can be summarised.

In general terms, firms using at least one high performance manufacturing technology display an on average higher performance with respect to added value per employee than others. Equally, a greater share of these firms generated a return on sales greater than 2% and their growth of revenue was higher than that of others. Further, they are more likely to sell product innovations: Among firms using at least one high performance manufacturing technology the share of firms introducing new products is higher. Accordingly, they generate a higher share of turnover by new products and a lower share of turnover by old products. Likewise, the share of innovating firms that sell products new to the market is notably higher. Overall, our findings thus document an undeniable relation between the use of high performance manufacturing

technologies and the innovative performance of firms – accompanied by some positive effects on the commercial side. Effects on employment growth, however, remained absent or mixed.

In general terms, a positive correlation between the use of at least one ICT-enabled technology and higher performance can be identified with respect to added value per employee, the share of firms with a return on sales greater than 2%, the share of firms introducing new products, the share of turnover generated by new products, the share of innovating firms that introduce products new to the market, the share of turnover generated by such products among both all and innovating firms as well as the share of turnover generated by products over ten years old. Overall, our findings document a clear relation between the use of ICT-enabled technologies and almost all key economic or innovation-oriented performance indicators.

In contrast, the non-systemic relation between companies' use of sustainable manufacturing technologies and their innovative performance can be documented. While the use of any such technology goes along with a higher share of firms introducing new products and a slightly higher share of turnover generated by new products, the share of such turnover generated in innovating firms is actually lower than among non-users. Regarding economic performance, the use of at least one sustainable manufacturing technology goes along with a higher added value per employee while, at the same time, it correlates with lower revenue growth in the period between 2009 and 2011. Overall, the use of sustainable manufacturing technologies seems to be less directly related to firm performance than that of other AMT.

2.2 D 2 – Findings about Drivers and Barriers, Literature Review

The objective of Work Package 2 is to identify and analyse the drivers for, and barriers to, the uptake of AMT by companies. In the first phase of Work Package 2 we have completed the literature study and started the case analysis.

2.2.1 Literature study

For the initial identification of sources, the European Commission Taskforce definition was taken up as a search strategy. Accordingly, the study refers to three main groups of AMT:

- **Sustainable manufacturing technologies:** Technologies to increase manufacturing efficiency in the use of energy and materials and drastically reduce emissions (e.g. process control technologies, efficient motor systems, efficient separation technologies, novel sustainable process inputs, product lifecycle management systems);
- **ICT-enabled intelligent manufacturing**: Integrating digital technologies into production processes (e.g. smart factories);
- **High performance manufacturing:** Systems combining flexibility, precision and zero-defect mechanisms (e.g. high precision machine tools, advanced sensors, 3D printers).

All in all, some 11 000 potentially relevant articles were identified through targeted database searches and examined for relevance in the literature study. Following further selection and filtering, a substantive selection of them was read and synthesised into the final report. The full report on the literature study can be found in Annex I to Deliverable 2 of the project.

2.2.2 Advanced Manufacturing Technologies in the Literature

Based on the findings of Work Package 1 and the literature study, we have compiled a list of AMT in Table 2. Building on the definition of the European Commission's Taskforce on Advanced Manufacturing, it provides a comprehensive list of concrete examples for each main area of AMT. Later during the study, this list was used as a common point of reference during the interviews and to define main groups of AMT in the company survey's questionnaires.

The full report of the literature study can be found in Annex I to Deliverable 2.

Table 2: List of AMT

1.	**High Performance Manufacturing Technologies**
-	Industrial robots/ handling systems
-	Automated Warehouse Management Systems
-	Technologies for safe human-machine cooperation, improved usability
-	Manufacturing micromechanical components
-	Additive manufacturing
-	Photonics (other than additive)
-	Processes specific to Advanced Materials
-	Nano-manufacturing
-	Processes for Bio-manufacturing
-	High-performance machinery
-	Modular and adaptable (interoperable) machines
-	Cutting and machining techniques for rapid prototyping equipment manufacture, Rapid time-to-market enabling technologies
-	Self-adaptive production lines
-	Printed electronics/roll-to-roll processes
-	Silicon-on-chip, heterogeneous circuits, and embedded systems, Integrated photonic circuits
-	Microelectromechanical systems (MEMS) and sensor devices
-	Nanoelectronics materials and patterning, Nanoimprint (process and equipment), Precision manufacturing and metrology
2.	**ICT-Enabled Technologies**
-	VR / simulation in production reconfiguration
-	VR / simulation in product design, Digital design technologies, Design platforms for modular, adaptable manufacturing
-	Supply chain management with suppliers/customers, Network-centric production, Optimisation of production networks
-	Product Lifecycle Management Systems, Product Data Management Systems
-	Enterprise Resource Planning
-	Technologies that depend on the use and coordination of information, automation, computation, software, sensing, and networking
-	Mass customisation (three-dimensional printing, direct digital manufacturing)
-	Cyber-physical (production) systems, intelligent components
-	Cloud manufacturing
3.	**Sustainable Manufacturing Technologies**
-	Dry processing/minimum lubrication
-	Recuperation of kinetic and process energy
-	Control system for shut down of machines
-	Combined cold, heat and power (Bi-/Trigeneration)
-	Recycling and waste/disposal management technologies
-	Use of renewable technologies and processes, Low power electronics, Li-ion and thin film battery technology, Photovoltaic cells
-	(Advanced) materials research for green manufacturing, Materials modelling and simulation
-	Alternately fuelled vehicles, Fuel cell technology
-	Green manufacturing and “low carbon” technologies, Green design/ Eco-design
-	Product Life Cycle optimisation, Service Life optimisation

Source: Own analysis (literature analysis)

2.2.3 Identifying Drivers and Barriers

The main findings on drivers for, and barriers to, the implementation of AMT are summarised in Tables 3 to 5 below in each AMT group (for more detail see Annex A). The drivers and barriers are classified on the basis of the context:

- *The environmental context* refers to the arena in which the company conducts its business including the value chain actors such as suppliers, customers, as well as competitors, research institutions, business associations, politics, etc;
- *The organisational context* refers to organisational characteristics of the adopter (size of company, sector affiliation, existing know-how, available technical, financial and human resources, innovation strategy, etc);
- *The technological context* refers to the nature of the technology adopted.

Table 3: Barriers and drivers in ICT-enabled intelligent manufacturing

	Barriers	Drivers
Environmental Context	- Change of role and power in value chains - Management of political, regulatory, juridical, tax and labour environments in various countries - Difficulties in evaluating cost-benefits of investments	- Tax policies supporting innovation and advanced manufacturing - Enhanced company performance in decision-making, reduced operative and admin costs, improved business processes
Organisational Context	- Expectations of non-technology driven management - Increased inter-firm rivalry due to misalignment of motives and behaviours among partners - Resistance to change, challenging culture change management - Lack of skilled labour - Lack of innovative learning approaches and incentives	- Significance of intangible resources for business success - Improved supply chain visibility to improve understanding of the real system - Best practice work patterns
Technological Context	- Difficulties in demonstrating on industrial scale - Difficulties in accessing and retrieving data from partners and other systems - Lack of suitable development tools for highly changeable context	- Revenue growth fuelled by increased responsiveness occurring at lower costs using fewer assets, by reduced manufacturing cycle times, increased inventory turns, improved accuracy and timeliness of information - Quick response to market demands - Allows evaluation during design stage

Source: Own analysis (case studies & interviews)

Table 4: Barriers and drivers in high performance manufacturing

	Barriers	Drivers
Environmental Context	- Difficulties in developing cost-efficient solutions - Difficulties in estimating required precision - Lack of basic processes common to manufacturing	- Cyber-enabled systems for validating - Process documentation for quality control, cost minimisation and efficiency improvements - Reduction of pollutant emission and workers' health problems
Organisational Context	- Lack of managerial skills for advanced planning, user involvement, communication and continuous training - Lack of expert knowledge - Difficulties in conception, design and management of system complexity	- Cloud computing provide hosting platforms for new service models
Technological Context	- AMT do not adapt well to dynamic environments - Selection of system for specific application is challenging - Integration of technologies is non-trivial - Difficulties in managing defects in implementation - Productivity of AMT is low - Lack of standards	- Lower power consumption - Promises of platforms tailored to a vast array of emerging applications: provides versatility, low costs, installation and operational flexibility, safety and reliable operation characteristics - New functionalities through new materials - Production of "impossible" products - Combining abilities of machines with those of humans (intuitive programming of robots)

Source: Own analysis (case studies & interviews)

Table 5: Barriers and drivers in sustainable manufacturing technologies

	Barriers	Drivers
Environmental Context	- Adverse human health effects of nanomaterials - Lack of health and safety practices - Need to balance business profit with environmental impacts and benefits - Life cycle assessment methodologies not mature enough to be applied at the scale of entire product portfolios	- Innovation, manufacturing scale and supply-chain development affect adoption of sustainable technologies - Policies for enhancement of sustainability - New materials form secondary sources or from waste - Increased visibility and awareness of energy consumption
Organisational Context	- Lack of employee buy-in, competence and time - Difficulties in combining multiple expertise - Dual goals of reducing variation and promoting variation	- Environmental implications of product and process innovations - Current IT systems can support collection of needed information for disassembly and recycling analysis
Technological Context	- Difficulties in gaining all information for recycling evaluation - Life cycle assessment methodologies are currently not mature enough - Difficulties in scaling up operations	- Sustained operation with consistent product quality, reduced equipment size, high-volumetric productivity, streamlined process flow, low-process cycle times and reduced capital and operating cost - Improved power monitoring enables energy efficiency and control of process stability - Unique advantages of nanotechnology

Source: Own analysis (case studies & interviews)

2.2.4 Case Studies

In the first phase of the case study, we conducted interviews in seven companies. In this report we present an analysis of these interviews. Here we briefly describe the case companies and present the main findings of the analysis.

Description of case companies

Five of the analysed companies are SMEs and two are large companies. Five companies are both users and suppliers of AMT, and two companies are AMT users. In this set of companies two are from Eastern Europe, four from Southern Europe and one from Northern Europe.

The two AMT user companies are large or mid-cap internationally operating companies producing consumer goods. Financially these companies are on a positive path, but not yet very strong. However, these two companies have the most experience of various types of AMT among the interviewed companies.

Main drivers and barriers in Europe

The interviewees were asked to describe what could be the main drivers and barriers for European companies to invest in AMT and how national and European policies support or prevent investment in AMT in their country or in Europe. Based on the answers, we identified a set of barriers affecting the AMT market in Europe (for more details see Annex B).

Market conditions in Europe:

- The AMT market in Europe is very passive at the moment;
- The AMT market is not unified, but there are national and regional differences. Good examples can be found in areas providing support for investment and in high labour cost countries;
- Asian suppliers of AMT are focusing on low cost markets and have not been successful in Europe so far;
- Industries for which the uptake of AMT could be relevant are facing market concentration and intensified competition from Asia;
- Some European countries are suffering from low productivity of their labour force which is affecting both competitiveness and entrepreneurial climate.

Barriers to investment in AMT:

- Only few companies are prepared to make productivity leaps by investing in new advanced technology. Management is strongly risk-adverse and cautious before putting new technology in production;
- Lack of competence and knowhow about the new technologies is a barrier especially in the case of complex ICT-based systems with a high level of digitalisation (combined electronic and software elements);
- Management of risks related to innovative technologies requires cooperation between AMT users and reliable innovation partners. This is a problem for SMEs whose products are not well known or are very innovative;

- SMEs in a less favourable position as suppliers of AMT since their (limited) budgets do not enable them to offer AMT or they need much more time for development and production of AMT requested by the customer;
- In large global user companies, investment decisions are slowed down by complex organisational structures and organisational cultures that are not supportive of the use of digital means.

Specific drivers and barriers in case companies

The interviewees were asked to identify drivers for investments already made and barriers to technologies the company had not invested in. This gave an additional and to some extent more detailed view on the drivers and barriers. The main findings from this question were:

Drivers:

- AMT increase capacity, improves flexibility and reduces labour costs;
- AMT improve demand through higher customer value, and through higher quality of products and services;
- AMT improve competitiveness of users through differentiation of products and services, through more competitive pricing and improved image of the company;
- AMT can be a necessity to keep up with competition;
- AMT improve the working environment in the factory;
- AMT improve machine usability through improvements in maintenance;
- Regulation can be a market driver creating new markets for sustainable technology and it can push companies to use greener manufacturing technology.

Barriers:

- Weak financial situation and poor access to capital markets;
- Lack of public financial support for AMT investments at a national or EU level;
- Limited demand or uncertainty about future demand is a barrier as return on investment cannot be ensured;
- SMEs do not have enough resources to develop know-how and skills needed for AMT use;
- AMT are not suitable for the type of production (manual assembly, one-of-a-kind), not mature enough or too expensive in comparison with existing technology;
- Existing regulation can be a barrier to adopting AMT;
- Applying for EU grants is bureaucratic and there is a low success rate for applications.

A more detailed description of the drivers and barriers identified here can be seen in Annex C.

2.3 D 3 – Methodology and Key Findings from Statistical Analysis

This work package aimed at collecting and analysing information on factors affecting the uptake of advanced manufacturing by the EU industry. The focus was on understanding how internal and external drivers and barriers have affected decisions to implement AMT and determined the readiness factors affecting decisions. In this work package, 17 case studies were

undertaken, covering 13 SMEs (<250 employees) and four large companies located in various European regions. The insights obtained from the case studies were used to fine-tune the firm-level questionnaire. The aim of the firm-level questionnaire was to find out how companies (SMEs or large companies with less than 2 000 employees) use AMT and why they use or plan to use them. As the questionnaire targets SMEs or larger companies with less than 2 000 employees, it was provided in English, French, German and Italian in order to avoid self-selection due to confusing language that might bias results. In the report, answers from 605 respondents were analysed. The insights were further detailed into specific targeted policy measures and practical recommendations regarding the adoption of advanced manufacturing products and technologies in the next phase of the study.

2.3.1 Qualitative analysis

In order to understand the specific situation in Europe concerning investment in AMT, case studies were carried out on several European companies. In this study, the focus was on factors affecting the ability of the companies to invest in, and implement, existing new technologies. In the case studies, a semi-structured interview approach was used in order to broaden our understanding of AMT and the drivers and barriers to invest in these technologies. Through open-ended questions, the aim was to identify drivers and barriers that had not been identified in previous studies and to learn more about the underlying factors.

Analysis of the case studies

Thirteen of the case study companies are SMEs. The majority of these companies are high performing family-owned companies. They reported moderate to fast growth over the last three to five years. Most companies have a fairly traditional level of automation in their manufacturing department. Eight of the SMEs are AMT producers and although these companies design and produce highly automated machines and equipment, several of them scarcely use automation in their own production processes. One of the AMT producers reported having an automated line for electrical board production. Some use digital means such as CNC machines and robots for welding or material handling. Five companies in this group use AMT. Two of the user companies only reported one single investment in production robots.

Four large companies in Europe were involved in the case study interviews. Three of these companies were users of AMT and the fourth was a producer of AMT. All three user companies are producers of consumer goods in a global market and are struggling with losses or barely breaking even. To these companies, economies of scale and cost-cutting are central drivers. AMT such as industrial robots, automatic handling systems and automated warehouse systems are in use in all of these companies. One of the companies also reported using additive manufacturing. The fourth large company in the case study operates in a business-to-business environment. Here, the market is growing, but competition is tough. Moreover, this company is familiar with industrial robots and 3D printing. It also develops control and sensing technologies and manufactures micro-mechanical components. All four companies reported having experience with ICT-enabled manufacturing technologies and sustainable manufacturing technologies.

Conclusions on drivers and barriers from the qualitative analysis

The qualitative analysis led to many interesting insights. Firstly, several drivers and barriers that emerged from the literature analysis were confirmed. Secondly, additional drivers and barriers were identified in relation to specific technologies, company size, geographic area and value chain position (e.g. sufficient demand is a prerequisite for investment in AMT, some companies lack the skills and resources to apply for public funding). Thirdly, some relevant, strong and unequivocal phenomena could be identified, based on the fact that the majority of companies participating in the case studies outlined the same issues. Hence, the qualitative analysis should be seen as a preliminary phase, providing important input on what is new compared to state-of-the-art and as such provides input for the quantitative analysis.

In particular, the analysis of comments from the interviewees on the AMT investment decisions confirmed that the investment climate for AMT in Europe is indeed an important driver. The analysis also gave more detailed information on how drivers and barriers affect decision making in different situations.

The demand situation stands out as crucial for both SMEs and large companies. When the demand situation is favourable, AMT are used to increase capacity and/or improve process performance. In large companies, AMT are used to improve process efficiency and productivity in order to be competitive in mass-production or mass-customisation markets. Meanwhile SMEs use AMT to distinguish their products and services from those of competitors. The fear of losing process performance due to immature AMT is a strong barrier to invest in emerging AMT. Finance can be a barrier, especially for small companies if internal resources are lacking and if external support cannot be found. Competition can also be a powerful driver. Customer requirements were a driver rather than a barrier to AMT adoption as SMEs compete on the ability to provide customers with unique solutions.

Know-how is very frequently a barrier to investment. A lack of skilled engineers and factory personnel will stop a company from acquiring new technology, even though if properly operated it could improve their processes. The need for know-how depends on not only the technology, but also the size of the company.

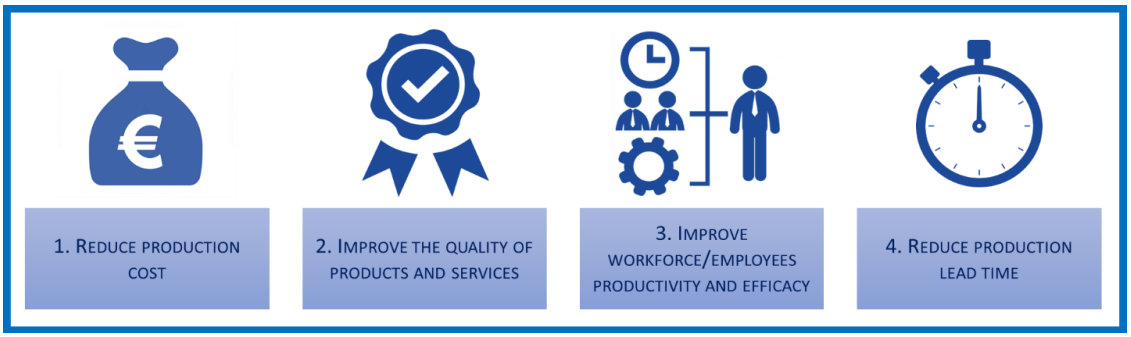
Regulation and the political environment are important overall, both as drivers and barriers, but they seem less important for SMEs than for large companies. Sustainability is considered a chance for new business opportunities, particularly by some SMEs. Many companies invest in this technology, as they see an opportunity to save costs and to improve their brand image at the same time.

2.3.2 Quantitative analysis

A questionnaire was launched to validate the insights obtained in the case studies and the work undertaken in WP1. The focus of the questionnaire was to find out how European companies (SMEs or larger companies with less than 2 000 employees) use AMT, or why they plan to use AMT, what is hindering them to do so and how ready they are to implement them. The questionnaire strongly built upon the insights obtained through the literature review and qualitative analysis.

Analysis of the drivers to invest in AMT

The main drivers to invest in AMT from a user perspective are:

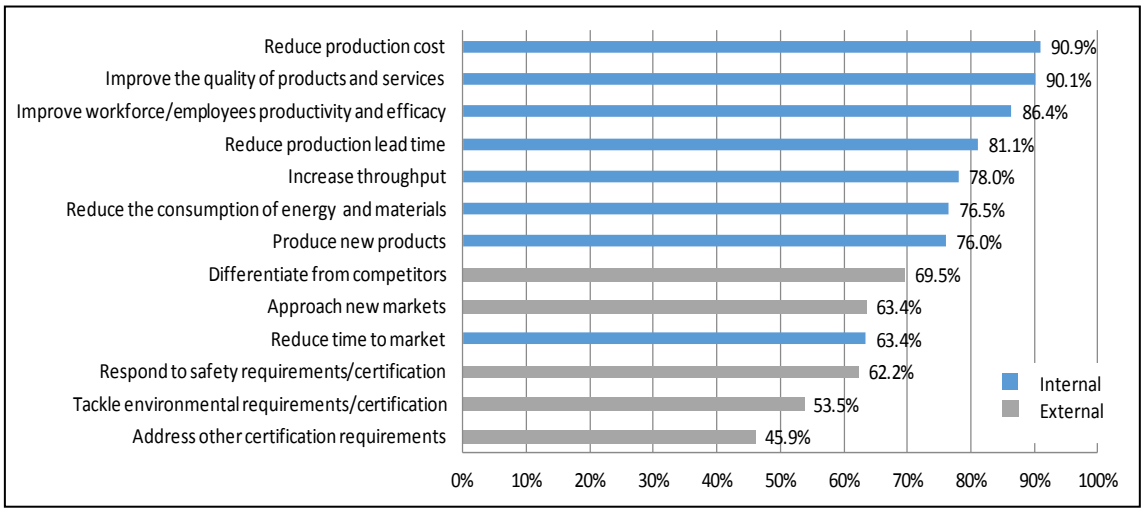


Source: Own analysis

Figure 8 provides an overview of the various drivers to invest in AMT. The top three drivers are: reduction of production cost, improving the quality of products and services, and improving workforce/employee productivity and efficacy. Between 86.4% and 90.9% of the respondents indicated these drivers were the main objectives for their company to invest in AMT. Less than 50% of the respondents indicated that addressing other certification requirements is a driver for investing in AMT.

The various drivers to invest in AMT can be divided into internal and external drivers for the companies. Internal drivers refer to those that are the direct responsibility of a company and which management can influence directly. External drivers refer to those that take place outside the company and result from developments outside the company, over which the company itself has little influence. Figure 8 clearly indicates that the internal drivers (dark blue bars) are more frequently (63.4-90.9%) indicated by respondents as objectives than the external ones (light blue bars) (45.9-69.5%). It seems that the main goals of SMEs and larger companies with less than 2 000 employees aim at increasing efficiency and quality and that they expect AMT to play a role in this.

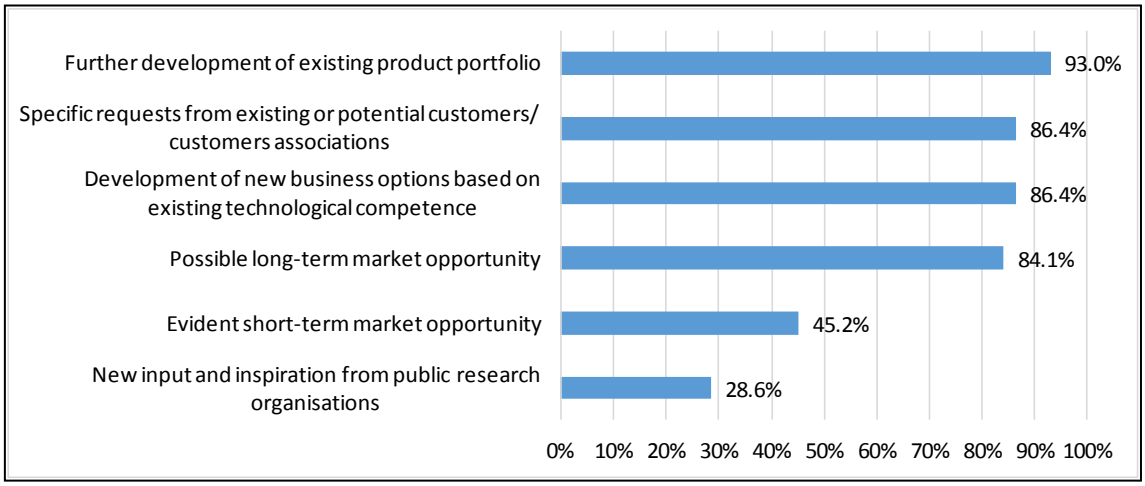
Figure 8: Drivers to invest in AMT (user perspective) (n=141-143)



Note: Scale 0 (no objective) – 1 (objective)

Source: Own analysis

Figure 9: Drivers to invest in AMT (producers' perspective) (n=42-44)

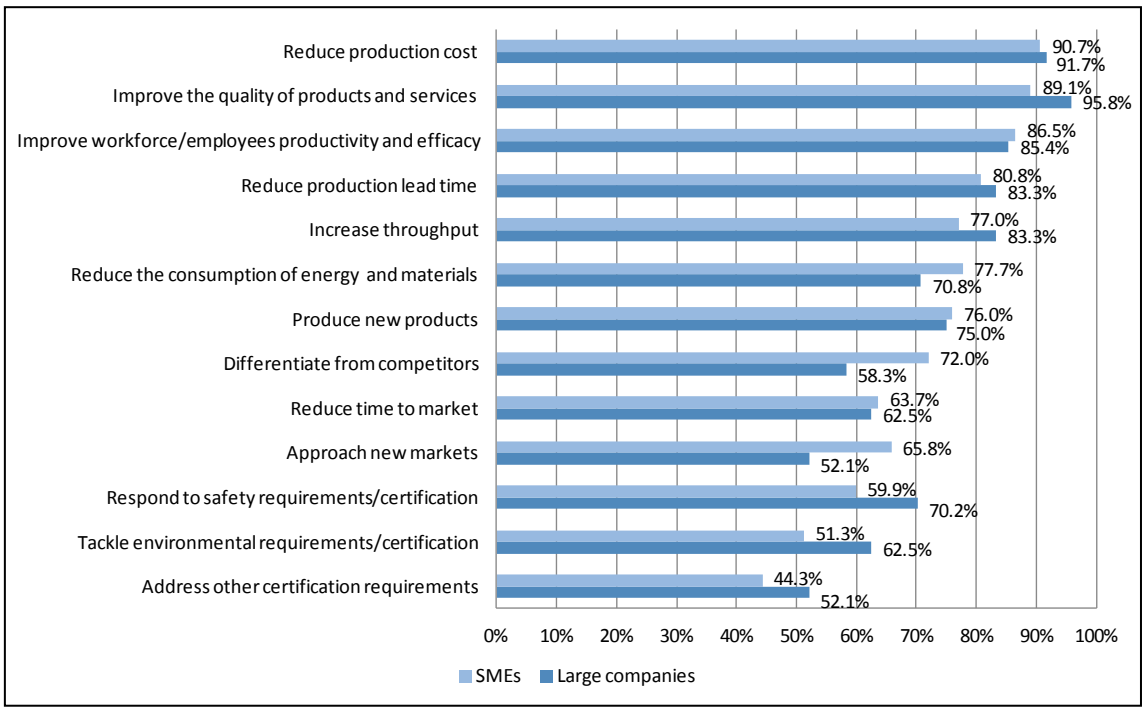


Note: Scale 0 (no objective) – 1 (objective)
Source: Own analysis

Producers indicated that the most important driver to invest in AMT is the further development of the existing product portfolio (Figure 9). Other frequent drivers were: specific requests from existing or potential customers (or relevant associations), development of new business options based on existing technological competencies and the possible long-term market opportunity. Evidence for short-term market opportunities as well as new input and inspiration from public research organisations were less frequently indicated as drivers to invest (45.2% and 28.6%, respectively). Seemingly, public research is not a motivation for producers to develop and sell AMT.

The most important drivers for SMEs to invest in AMT are to reduce production costs (90.7%) and to improve the quality of products and services (89.1%) (Figure 10). For larger companies (below 2 000 employees), the most important driver is to improve the quality of products and services (95.8%). Approaching new markets and standing out from competitors seem to be more important for SMEs than for large companies. Drivers related to certification, safety and environmental requirements are also more frequently identified by large companies.

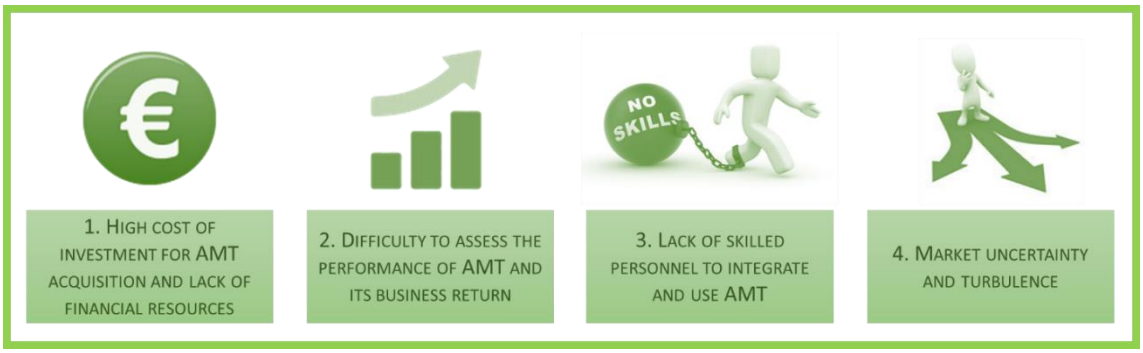
Figure 10: Drivers by company type (user perspective) (n=239-241)



Note: Scale 0 (no objective) – 1 (objective)
Source: Own analysis

Barriers to the adoption of AMT

The main barriers to the adoption of AMT from a user perspective are:

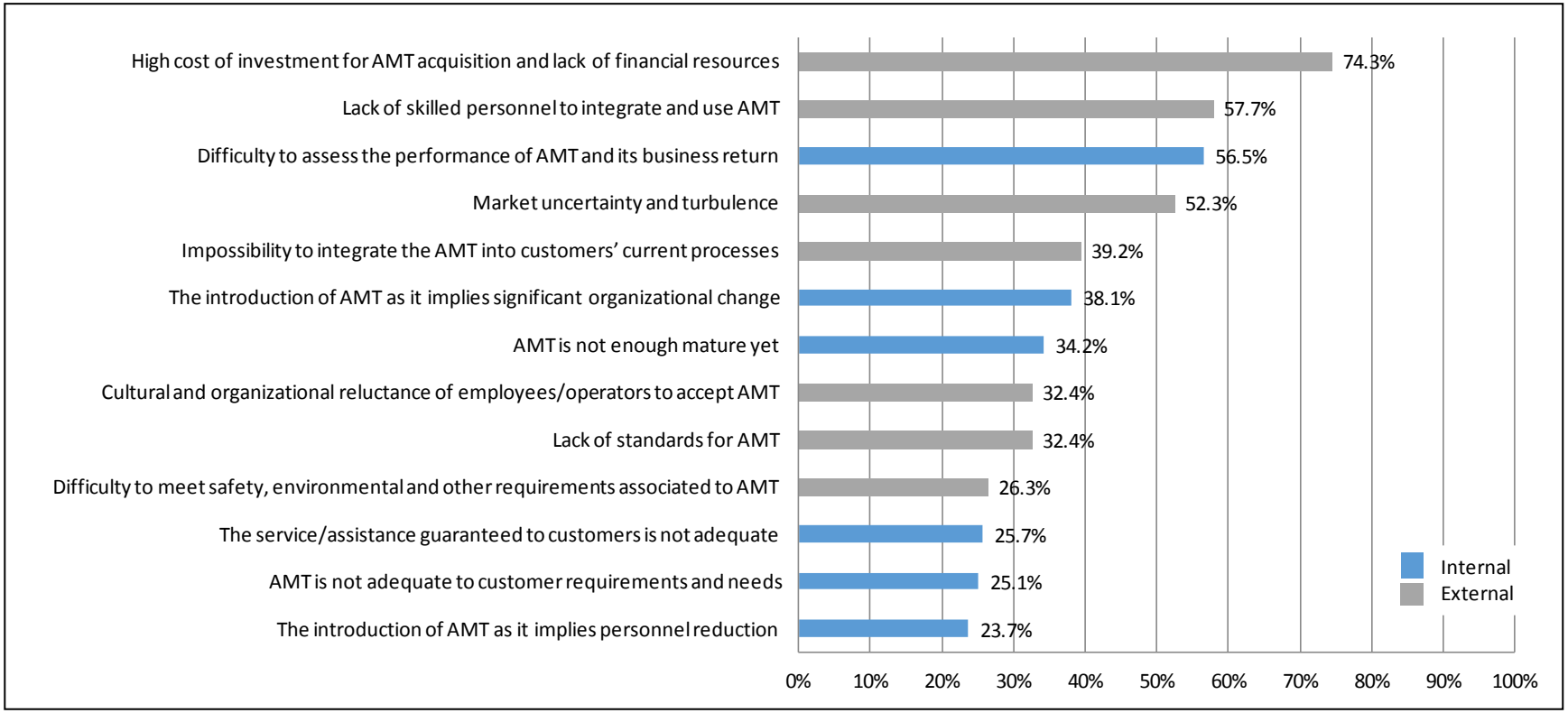


Source: Own analysis

Figure 11 provides an overview of the various barriers to investing in AMT. The most important barrier was the high cost of investment for AMT acquisition and the lack of financial resources (74.3%). Between 52.3 and 57.7% of the respondents indicated difficulties in assessing the performance and business return, the lack of skilled personnel required to integrate and use AMT and market uncertainty and turbulence. Less frequent barriers were the inadequacy of the technologies in terms of customer requirements and needs and the personnel reduction implied by its introduction (25.1%).

As with the drivers, the barriers to invest in AMT can also be divided into internal and external barriers. Internal barriers refer to internal factors companies can influence directly and actively decide upon. External barriers refer to external factors that take place outside the company, resulting from developments outside the company and upon which the company itself has little influence. Figure 11 shows that, compared to the drivers, the barriers for users to investment in AMT are more evenly distributed between internal and external barriers. The most important barrier - high cost and financing - is an external barrier, while the least important barriers are internal to the company.

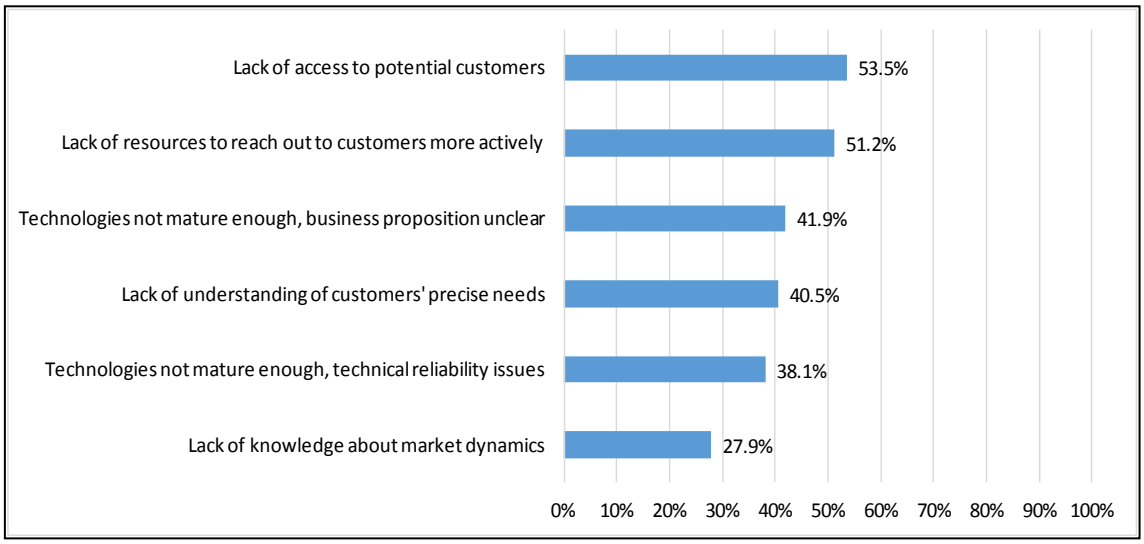
Figure 11: Barriers to the adoption of AMT (user perspective) (n=213-219)



Note: Scale 0 (no objective) – 1 (objective)
Source: Own analysis

From a producer's perspective, the main factors hindering the supply of AMT to additional customers were marketing-related e.g. the lack of access to potential customers (53.5%), accompanied by the lack of resources to more actively reach out to customers (51.2%). A lack of knowledge about market dynamics was not really perceived to be a major barrier, as only 27.9% of the producers identify it as such (Figure 12).

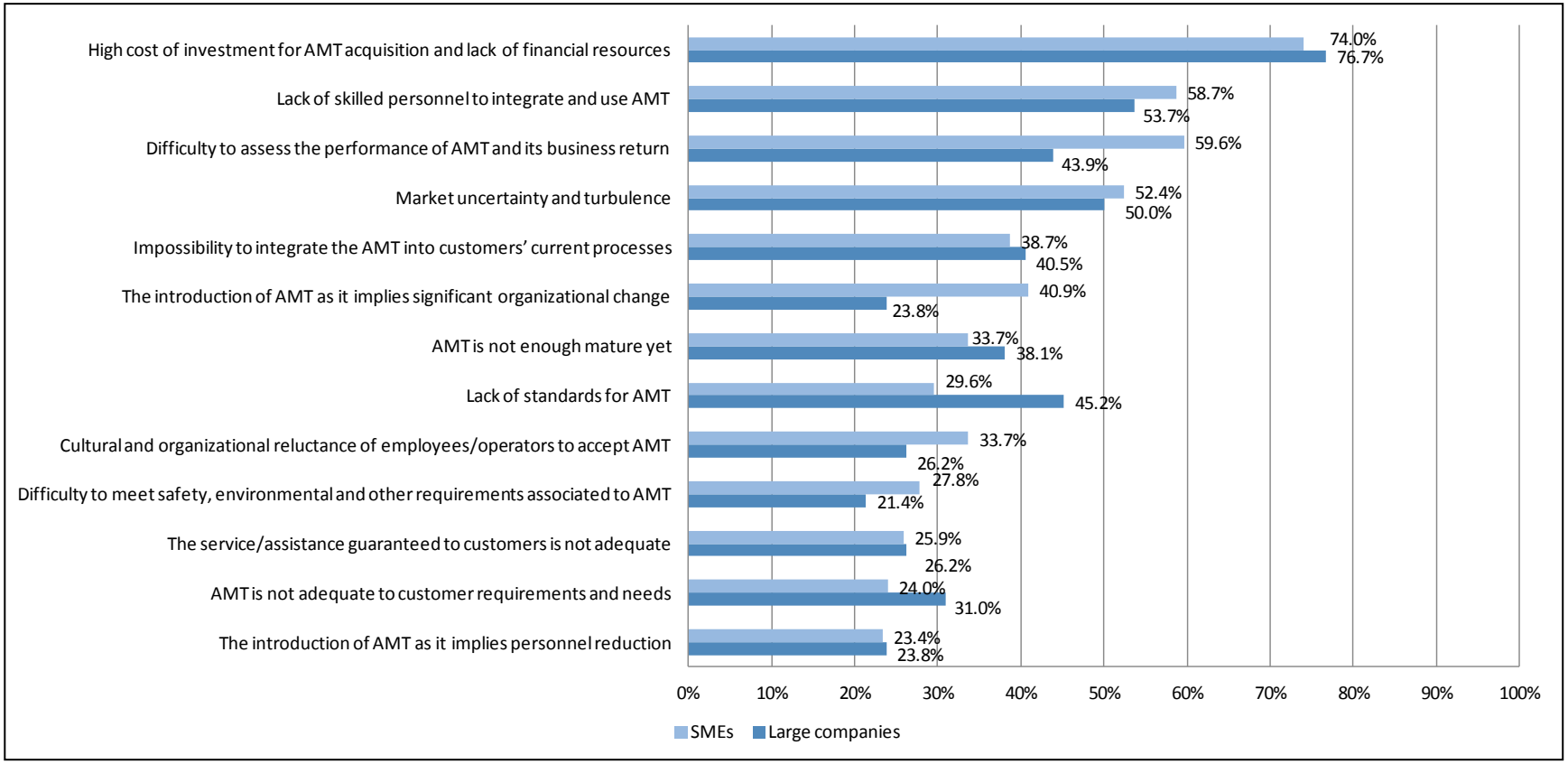
Figure 12: Barriers to supply AMT (producers' perspective) (n=42-43)



Note: Scale 0 (no objective) – 1 (objective)
Source: Own analysis

SMEs and larger companies (below 2 000 employees) indicated that high cost of investment for AMT acquisition and lack of adequate financial resources are the main barrier to adopting AMT (Figure 13). SMEs, as opposed to large companies, more frequently think that the difficulty in assessing the performance of AMT and their business return is a barrier (59.6% versus 43.9%). The lack of skilled personnel and the introduction of AMT, in that it implies significant organisational change, are perceived to be more important barriers for SMEs than for large companies. The lack of standards for AMT is more frequently perceived as a barrier by large companies than by SMEs (45.2% versus 29.6%).

Figure 13: Differences in barriers by company type (user perspective) (n=211-217)



Note: Scale 0 (no objective) – 1 (objective)
Source: Own analysis

Capacity to overcome barriers related to the adoption of AMT

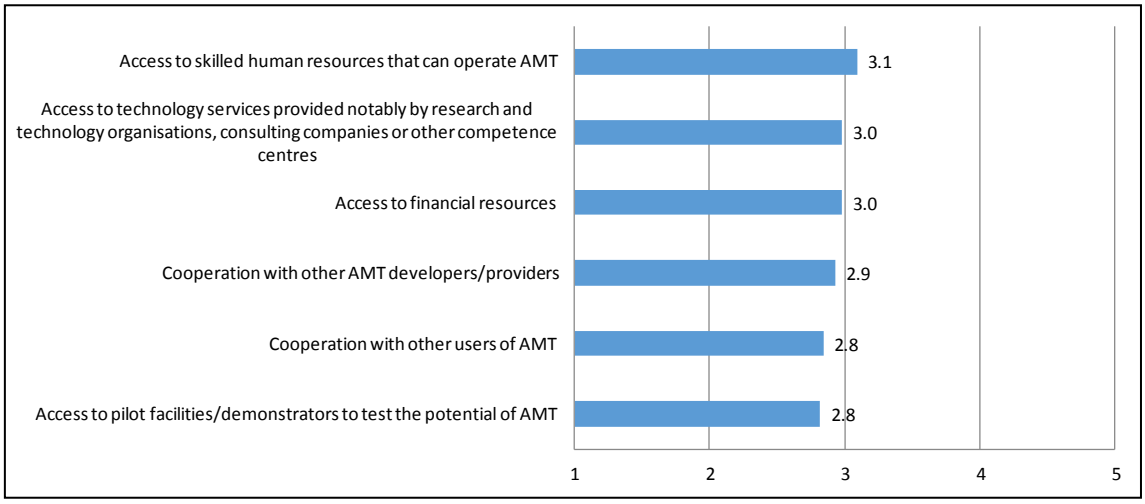
The means to overcome barriers to the adoption of AMT from a user perspective are:

Source: Own analysis

An overview of the readiness to overcome various barriers to the adoption of AMT is provided in Figure 14. Readiness is measured on a scale from 1 (not ready) to 5 (well mastered). There is little difference between the capacity to overcome several barriers or the readiness of companies to overcome these barriers. On average, users consider themselves medium ready to overcome the barriers to adopting AMT: access to skilled human resources that can operate AMT (3.1), access to technology services provided notably by research and technology organisations, consulting, etc (3.0) and access to financial resources (3.0).

There is clearly room to enhance the readiness of users in several domains so that they become more ready to adopt AMT.

Figure 14: Average readiness by AMT (user perspective) (n=219-222)



Note: Scale 1 (Not ready) – 5 (Well mastered)
Source: Own analysis

On average producers feel that they have mastered a general understanding of technological dynamics in the field and an understanding of technological opportunities resulting from the application of AMT (average score of about 4 on a scale from 1 to 5, see Figure 15). They have least mastered access to relevant intermediary organisations of users like associations and

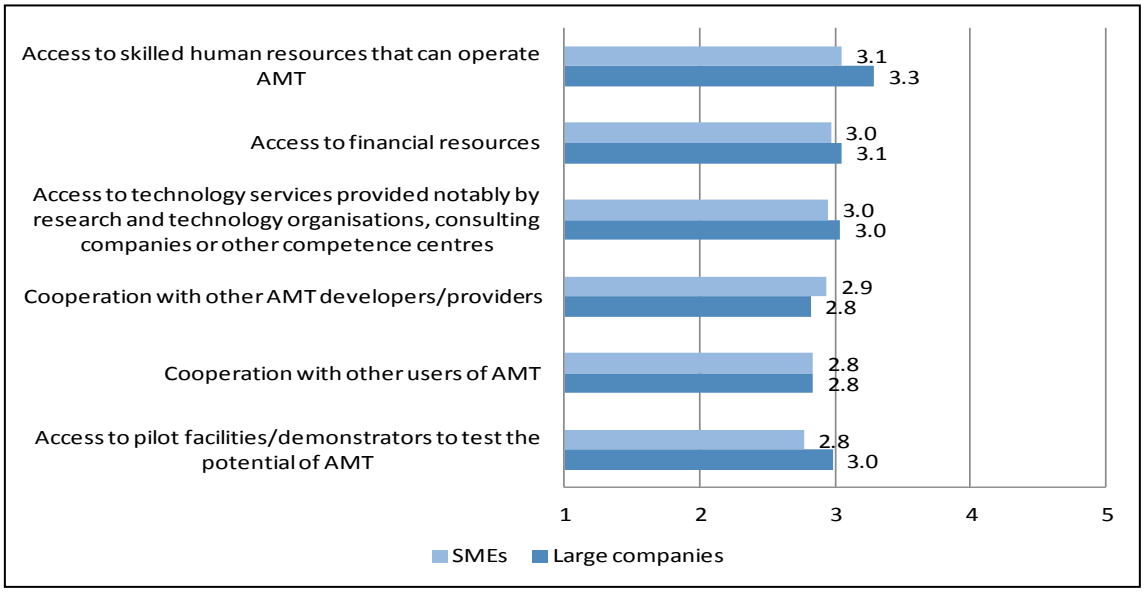
chambers (2.3). Apparently, it is not straightforward for producers to gain access to intermediary organisations of users.

Figure 15: Average readiness by AMT (producer perspective) (n=37)

Note: Scale 1 (Not ready) – 5 (Well mastered)
Source: Own analysis

Large companies are on average more ready to overcome barriers to the adoption of AMT than SMEs, where the only exception is the barrier related to cooperation with other AMT developers/providers (see Figure 16). SMEs evaluate their capacity to overcome the barriers access to pilot facilities and demonstrators to test the potential of AMT and access to skilled human resources to operate AMT at a lower level than large companies do.

Figure 16: Average readiness by company type (user perspective) (n=217-220)



Note: Scale 1 (Not ready) – 5 (Well mastered)
Source: Own analysis

Conclusions from the quantitative analysis

Several insights emerged from the quantitative analysis. Hereby the most important drivers for users to invest in AMT were financially driven and human capital related. Additionally, the main barriers for users to adopt AMT were the high cost of investment in AMT and the lack of financial resources, while the main barriers for producers were related to marketing difficulties. Users did not master the capacity to overcome various barriers to the adoption of AMT, whereas producers felt well prepared to overcome them.

More specifically, t**he most important driver of AMT investment by users is financial and refers to the need to reduce production costs**. **Equally important, however, is the aim to improve the quality of products and services and to improve the productivity and efficacy of employees.** These drivers are rather innovation and HR-related issues in contrast to more traditional competitive arguments that drive producers, e.g. further development of existing product portfolio or specific requests from existing or potential customers and customer associations. Internal drivers are more frequently indicated than external drivers as drivers for investing in AMT.

The main barrier for users to adopting AMT is the "high cost of investment for AMT acquisition and lack of financial resources". Users identify the "difficulty to assess the performance of AMT and their business return to be an important barrier while producers tend to underestimate the importance of this barrier for their users. Vice versa, producers identify the barrier "introduction of AMT as it implies personnel reduction" as important for their users, while for users, this is the least important barrier to adopting AMT. **For the producers, the most important barriers to adopting AMT are the "development of new business options based on existing technological competence" and "possible long-term market opportunity".**

The capacity of users to overcome barriers to the adoption of AMT can be considered to be average. In their evaluation of their capacity to overcome several barriers, **the users feel they do not master the capacity to overcome barriers to the adoption of AMT very well. The producers feel well prepared to overcome the challenges related to the "understanding of technological opportunities resulting from the application of AMT" and the "general understanding of technological dynamics in the field"**. They are less well prepared to "access relevant intermediary organisations of users like associations and chambers" and "access additional markets".

The most important driver for SMEs to invest in AMT is to reduce production costs, while the most important driver for larger companies (below 2 000 employees) is to improve the quality of products and services (user perspective). Both types of company see the high costs of investment for AMT acquisition and lack of financial resources as the main barrier to the adoption of AMT. The difficulty in assessing the performance of AMT and their business return, as well as the lack of skilled personnel, prove to be more important barriers for SMEs as compared to large companies. SMEs are also less ready to overcome barriers to the adoption of AMT. Especially **with regard to access to pilot facilities and demonstrators to test the potential of AMT, SMEs evaluated their capacity to overcome this barrier as significantly lower compared to larger companies (below 2 000 employees)**.

2.3.3 Survey findings on desirable policy measures

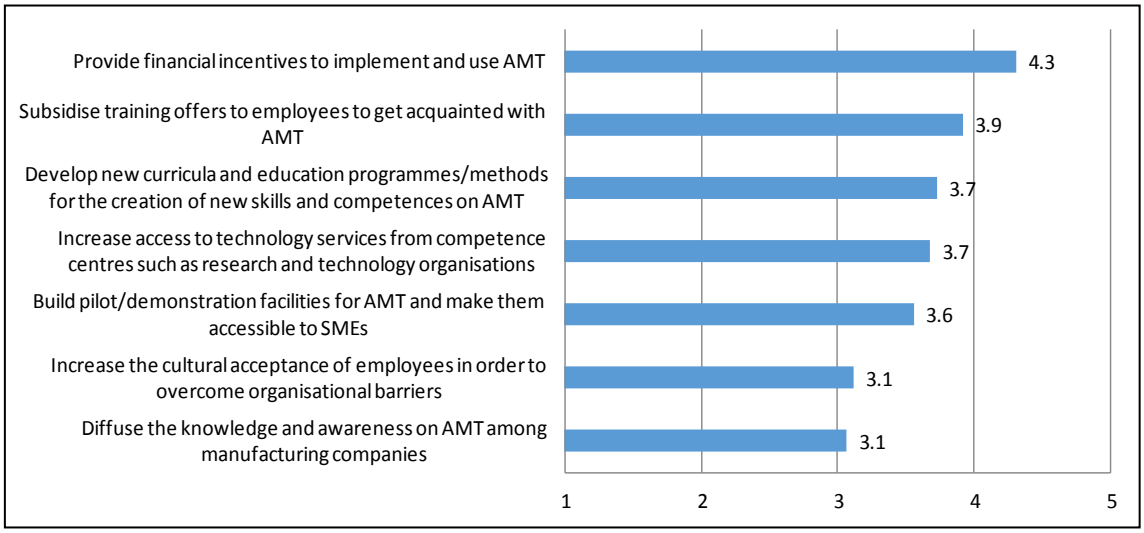
In the case studies, the interviewees are asked what Europe could do to improve the use of AMT in Europe. The insights obtained through the case studies formed the basis for the formulation of questions in the questionnaire with regard to policy measures. The aim was to obtain a quantitative confirmation of the most important policy measures that have the potential to improve the adoption of advanced manufacturing products and technologies. In the next phase of the study, specific attention was devoted to the identification of specific needs for support services that European SMEs require.

Initial insights from the quantitative and qualitative analyses indicated that policy support appears to be welcome in four main areas:

Source: Own survey analysis

The policy measure that was judged to be the most important is the provision of financial incentives to implement and use AMT (4.3), followed by providing subsidies for training offers for employees to get acquainted with AMT (3.9) and the need to develop new curricula and education programmes/methods for the creation of new skills and competencies (3.7). Hence, in addition to financial support, the respondents expressed a clear need for policy measures that are related to skills development. Diffusion of knowledge and awareness creation prove to be less essential for the adoption of AMT in companies (3.1). Also the need for policy measures to increase the cultural acceptance of employees in order to overcome organisational barriers seems to be less prominent (3.1) (Figure 17).

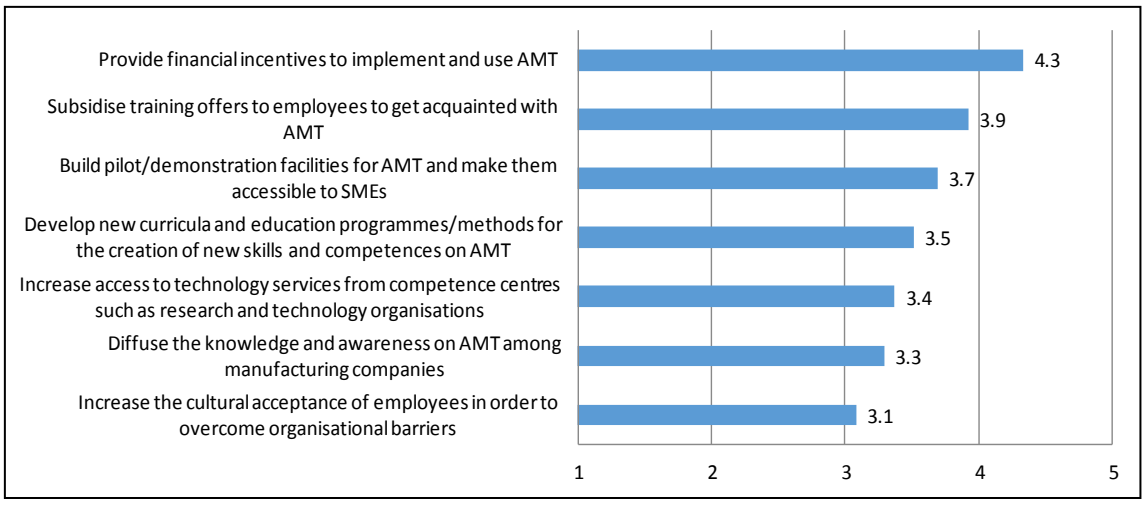
Figure 17: Average policy measures (user perspective) (n=216-219)



Note: Scale 1 (No influence) – 5 (Strong influence)
Source: Own analysis

Producers' opinion regarding policy measures that could motivate/enable their customers to introduce AMT into their companies was also sought. Again, the need to provide financial incentives received the highest score (4.3). The necessity to subsidise training offers to employees in order to get them acquainted with AMT was also acknowledged as important (3.9). Policy measures designed to stimulate the construction and accessibility of pilot and demonstration activities for SMEs are judged by producers to be more important than users judge them to be. This may be due to the fact that users do not always fully understand the benefits of pilot and demonstration activities (Figure 18).

Figure 18: Average policy measures (producer perspective regarding users) (n=35-36)



Note: Scale 1 (No influence) – 5 (Strong influence)
Source: Own analysis

2.3.4 Overall conclusions from the quantitative and qualitative analyses

Financial considerations play a pivotal role as a barrier to adopt AMT as confirmed in the qualitative and the quantitative findings. The high costs of investing in AMT and the difficulty in assessing the business return are regarded as important barriers to the adoption of these technologies. At the same time, financial considerations are also a major driver for users towards investing in AMT with a view to reducing the production costs. This driver is equally important for both large companies and SMEs.

The second most important driver for adopting AMT is human capital related. Investing in AMT is seen as instrumental to improving productivity and efficacy in the workplace. A related barrier, however, is the need for skilled personnel with the right qualifications and specific competencies. A lack of skilled personnel prevents companies from acquiring new technologies; although when properly operated, they could result in optimised processes. For micro companies, human capital-related motives are seen as a barrier rather than a driver.

Thirdly, **users of advanced manufacturing equipment and technologies tend to invest in it in order to improve the quality of their products and services.** This is an equally important driver for both large companies and SMEs. When the demand situation is favourable, AMT are used to increase capacity or improve process performance. A major barrier here, however, is market uncertainty and turbulence. The European market is currently regarded as passive, while increasing competition is now experienced by players active in Asian countries. Producers of AMT, however, see market uncertainty and turbulence as the most important barrier for their customers, indicating that there is still a lack of stable momentum in industrial modernisation.

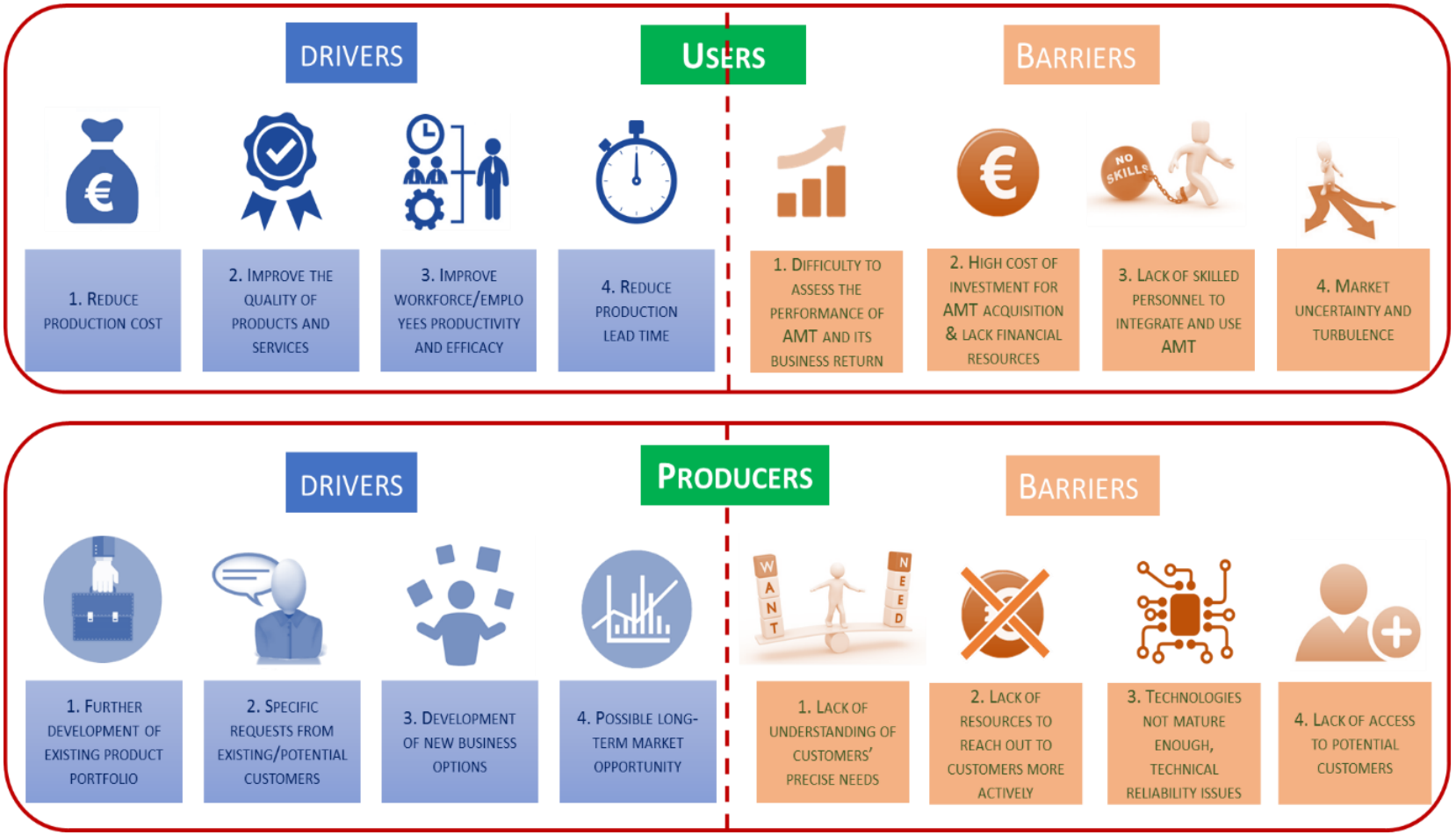
The need for standards or a response to specific requirements and certification issues is seen as less important by users of AMT. It is not regarded as an important driver, nor is it considered to be a major barrier for either large companies or SMEs. This conclusion is also confirmed by the qualitative analysis.

In general, **internal drivers of investment in AMT are more frequently mentioned than external drivers**, indicating that there is positive motivation through observed benefits of advanced manufacturing as a business model, rather than a passive adaptation to external market developments. The perception of producers is quite well aligned with the position of users. The main drivers are nearly all internal drivers, while the main barriers are mainly external and linked to a lack of resources.

On average, **users consider themselves to be medium ready to overcome barriers related to the adoption of AMT**. The **producers**, on the other hand, **master the capacity to overcome barriers related to understanding technological opportunities and associated dynamics quite well.** They feel less comfortable in accessing additional markets and relevant intermediary organisations of users.

In line with our findings, **policy support appears to be welcome in three main areas**. Firstly, the provision of financial incentives to implement and use AMT is important to enable companies to acquire AMT. Secondly, subsidies for **training offers** for employees to get acquainted with AMT and support to new curricula and programmes for the creation of new skills and competences are essential to foster the uptake of AMT in European companies. Thirdly, policy measures that aim at stimulating access to additional markets and relevant intermediary organisations of users might help producers to overcome these barriers. These insights were further detailed into specific targeted policy measures and practical recommendations regarding the adoption of advanced manufacturing products and technologies in the next phase of the study.

Figure 19: Main drivers and barriers to invest in AMT



Source: Own analysis (case studies, interviews and survey analysis)

2.4 D 4 – Policy Recommendations

To elaborate policy recommendations, the results of qualitative and quantitative analyses along with the outcomes of an analytical workshop in the presence of consortium members were used to identify “issues”, i.e. factors that affect the diffusion of AMT among SMEs and that could be influenced by proper policy measures and new behaviour of service providers. In addition, an analysis of existing programmes and services offering systems for the uptake of AMT by SMEs was carried out at European, regional, national levels and outside the EU. Related policy issues were identified accordingly. In order to address recommendations to various targets, all identified issues were divided into “external”, i.e. issues that can be addressed by policy-makers by influencing the framework conditions, and “internal”, i.e. issues that can be addressed directly by companies and service suppliers.

All the policy issues were then clustered, leading to the identification of main actions of improvement that could be implemented by policy-makers and service organisations. For each action of improvement, specific policy recommendations were finally elaborated for the various targets based on the knowledge on drivers, barriers and readiness factors acquired through empirical research, as well as on the best practices in terms of programmes and service offerings surveyed at all geographic levels.

2.4.1 Analysis of existing policies and service offerings

An analysis of the existing policy actions and service offerings was carried out to help identify relevant issues for the elaboration of further policy recommendations, as well as for the identification of potential shortcomings and best practices in the state-of-the-art of policy actions and service offerings. To this end, a set of policy actions (programmes, initiatives and other policy measures set by policy-makers) as well of service offerings to SMEs by service companies and organisations (technology service providers, financial organisations, service companies dealing with legal and IPR service, marketing and strategic consulting companies, etc) were identified, analysed and mapped at regional, national, European levels and outside the EU. Table 6 illustrates the mapping of the analysed existing policy actions and service offerings.

Table 6: Mapping of existing policy actions and service offerings (regional)

	Policy Actions	Service Offerings
Regional	• Creative voucher (*Baden-Württemberg , Germany*) • Innovation Vouchers (*Lombardy, Italy*) • Innovation Vouchers (*Limburg, the Netherlands*) • Creative Credits (*Manchester City region, UK*) • Robotic loan (*Pays-de-la-Loire, France*) • VINCI (*Salzburg, Austria*) • Industry 4.0 training (*Navarre, Spain*) • VIS (*Flemish Region, Belgium*) • GLOBALmidt (*Central Denmark, Denmark*) • Compétences 2020 (*Pays-de-la-Loire, France*) • Innovation Assistants (*Saxony-Anhalt, Brandenburg, North Rhine-Westphalia, Germany; Kärnten, Austria*) • RENOVE Maquinaria (*Basque Country, Spain)* • ClusterAgentur (*Baden-Württemberg , Germany)* • Vanguard Initiative Actions *(Several European Regions)*	• Mittelstand 4.0 Competence Centre *(Berlin, Lower Saxony, North Rhine-Westphalia, Hesse, Rhineland-Palatinate, Thuringia, Germany)* • IBB (*Berlin, Germany*) • ZAB (*Brandenburg, Germany*) • L-Bank (*Baden-Württemberg, Germany*) • Innova creativity (*Basque Country, Spain*) • Finlombarda (*Lombardy*) • FinEmigliaromagne (*Emilia Romagna, Italy*) • EMC2 (*Pays-de-la-Loire, France*) • Proxinnov /BPI (*Pays-de-la-Loire France*) • AFIL (*Lombardy, Italy)* • IAF (*Aragon, Spain*) • ITAinnova (*Aragon, Spain*) • Chalmers Smart Industry Lab (*West Sweden, Sweden)* • DAMRC (*Central Denmark, Denmark)* • Lindholmen Science Park (*West Sweden, Sweden)* • Innovatum (*Trollhättan, Sweden*) • DHBW *(Baden-Württemberg, Germany*) • AMP (*South Yorkshire, UK*) • ADITech *(Navarre, Spain)* • Allianz Industrie 4.0 (*Baden-Württemberg , Germany)* • MecaTech (*Wallonia, Belgium*) • MicroTECSüdwest e.V. (*Freiburg, Germany*) • Cluster Exzellenz *(Baden-Württemberg, Germany)*

Source: Own analysis

Table 7: Mapping of existing policy actions and service offerings (national)

	Policy Actions	Service Offerings
National	**Germany:** • Initiative Industry 4.0 • Digital Agenda 2014-17 • Central Innovation Programme for SMEs – ZIM • KMU-Innovativ • Industry 4.0 Research on the Shopfloor • Go Innovative / Innovation Management Vouchers • *Forschungscampus* – Public Private Partnership for Innovation • FHprofUnt	**Germany:** • Steinbeis • AiF/IGF • KfW • NanoValley (Southwest Germany) • Research for tomorrow's production; intelligent networking in production • Autonomics for Industry 4.0 (Internet of Things)
	France: • Robotstart PME • *Pôles de Competitivité*	**France:** • IRT Jules Verne • BPI France • Cètim
	UK: • Innovate UK • SBRI • Catapult Centres	**UK:** • Catapult HVM • SWMAS • Lloyds Bank Advanced Manufacturing Training Centre
	Netherlands: • Smart Industry	**Finland:** • SMACC • Nivala
	Belgium: • Made Different	**Belgium:** • Agoria
	Italy: • Progetto Bandiera "La Fabbrica del Futuro"	**Italy:** • Cluster Fabbrica Intelligente (CFI)
	Denmark: • MADE • Innovation assistant	**Austria:** • AWS (Federal Promotional Bank) • Cluster Fa

Source: Own analysis

Table 8: Mapping of existing policy actions and service offerings (EU and global)

	Policy Actions	Service Offerings
European Union	• European Fund for Strategic Investments – EFSI • European Structural and Investment Funds – ESIF	• RIS3 Platform for Industrial Modernisation • Enterprise Europe Network (EEN) • European Investment Fund (EIF) • European Institute of Innovation & Technology (EIT) • EBN Innovation Network • COSME EFG • EFFRA (& EFFRA innovation portal)
	H2020: • ActPhast • I4MS • LEIT • FTIPilot • INFRADEV / INFRAIA • LLP (and sub-programmes such as LdV) • Industrial Leadership • INNOSUP • KiCs • KIC AVM • SPIRE PPP • SME Instrument • FOF PPP • Robotics PPP • Photonics PPP • HPC PPP • Eurostars Joint Programme	
	Other: • COSME (and sub-initiatives such as COSME EFG & COSME LGF) • European Cluster Excellence (ECEI) • Stairways to Excellence (S2E) • INTERREG • TREC • Vanguard Initiative • TTO Circle • InnovFin SMEG • Blueprint for sectoral cooperation on skills • ECSEL • RIM Plus • Joint initiative on standardisation • InvestHorizons	
Outside the EU	**United States:** • National Network for Manufacturing Innovation • AMTech • National Robotic Initiative (NRI) • National Photonics Initiative (NPI) • National Nanotechnology initiative (NNI) • Investing in Manufacturing Communities – IMCP • Small Business Innovation Research – SBIR • Small Business Technology Transfer – STTR	**United States:** • Manufacturing Extension Partnership – MEP
	PR China: • Made in China 2025 • Internet Plus	

Source: Own review

In a second step, these existing policy actions and service offerings were critically analysed to acknowledge existing shortcomings as well as opportunities.

On that basis, the main shortcomings in the current support landscape could be identified as:

- fragmentation of policy actions;
- limited number of initiatives for uptake of AMT in SMEs;
- difficulty in accessing pilot infrastructure; and
- lack of mid-range universities linked to SMEs.

On the other hand, the existing opportunities could be identified as:

- training programmes for AMT;
- suitable intermediaries in the regions;
- vouchers and innovation assistants as effective tools at regional level;
- public-private partnership approaches; and
- extra-European practices as benchmarks for Europe.

For each identified shortcoming and opportunity, existing examples and experiences were illustrated to derive inspiration on how to address the challenges. Tables 7 and 8 illustrate the summary of the critical analysis.

Table 9 depicts shortcomings and relevant existing examples addressing them while Table 10 shows the identified existing opportunities and the relevant promising examples to develop them further.

Table 9: Summary of shortcomings derived from critical analysis and the relevant inspiring existing examples addressing the derived shortcomings

		Inspiring existing examples addressing derived shortcomings			
		Regional Level	**National Level**	**European Level**	**Outside the European Union**
Shortcomings derived from critical analysis	Fragmented policy actions	• Innovation Voucher (Lombardy) • GLOBALmidt (Central Denmark) • VINCI (Salzburg)	• Cluster Fabbrica Intelligente (Italy)	• INNOSUP • INTERREG IV • INTERREG MED	• Made in China 2025
	Limited number of initiatives for uptake of AMT in SMEs	• RENOVE Maquinaria (Basque Country)	• RobotstartPME (France)	• ActPhast • I4MS	• SBIR • STTR
	Difficulty in access to pilot infrastructure			• Vanguard Initiative	• NNMI
	Lack of mid-range universities linked to SMEs	• DHBW (Baden-Württemberg)	• Steinbeis (Germany) • FHprofUnt (Germany)		• MEP

Source: Own review

Table 10: Summary of existing opportunities derived from critical analysis and the relevant inspiring existing examples pushing the derived opportunities

		Inspiring existing examples pushing the derived opportunities			
		Regional Level	**National Level**	**European Level**	**Extra- EU Level**
Existing opportunities derived from critical analysis	Training programmes for AMT	• Industry 4.0 training Programme (Navarre, Spain)	• FESTO teaching factory (Germany)	• Lifelong Learning Programme	
	Suitable intermediaries in the regions	• EMC2 (Pays-de-la-Loire, France) • AFIL (Lombardy, Italy)	• Cluster Organisations (Germany)		
	Vouchers and innovation assistants as effective tools	• Innovation assistant (Saxony-Anhalt, Brandenburg, North Rhine-Westphalia/ Germany; Kärnten, Austria) • Creative credits (Manchester, UK) • Innovation voucher (Lombardy, Italy) • Creative voucher (Baden-Württemberg, Germany) • Innovation Vouchers (Limburg, the Netherlands)	• Dutch voucher system (the Netherlands) • Scottish innovation voucher (Scotland, United Kingdom) • Go innovative / Innovation management vouchers (Germany)		
	Public private partnership approaches			• FOF PPP • Photnics PPP • SPIRE PPP	• NNMI
	Practices at extra-EU level as a benchmark				• MEP • NNMI • SBIR • Made in China 2025

Source: Own review

2.4.2 Issues from empirical and policies/service offerings analyses

The issues identified by the consortium partners according to the critical analysis of results of case studies, survey, policy and service offerings state of the art are summarised in Table 9, classified into internal and external issues. While the internal issues require actions by technology and service providers to support SMEs to overcome barriers, the external ones require **policy-makers** to implement contextual actions to modify the policy framework. Considering their nature, issues were clustered in macro-areas.

Table 11: Issues derived from empirical and policy analyses

	Internal Issues	External Issues
Financial issues	• Limited investment capacity against unclear benefit (especially high-performance AMT) • Costs and Revenues of new technologies are not clear and uptake risk is too high	• Market uncertainty and turbulence makes the ROI of AMT uncertain
Funding issues	• Lack of understanding of potential and risks of AMT by private financial organisations	• Fragmentation, complexity and bureaucracy of existing public funding instruments are not affordable for SMEs • Lack of instruments supporting the uptake compared to research/innovation, especially for most mature AMT • Lack of instruments allowing inter-regional cooperation
Competence and skills issues	• Lack of interdisciplinary competence to understand new technologies and their benefits • Lack of interdisciplinary competence to forecast the return on investment in AMT • Lack of skilled workforce to integrate, implement and operate AMT • Lack of skills to identify suitable funding opportunities and to apply for them	
Technology issues	• Robustness and performance not proven • Integration of AMT into existing process is complex and generates a risk of performance and loss of customers (especially for ICT)	
Supply chain cooperation issues	• Weak cooperation between RTOs and industry for the uptake of AMT • Imprecise knowledge of customers' needs and limited marketing action by suppliers • Limited engagement in customers-supplier relationship by technology suppliers	
Service offering issues	• Lack of clear and qualified communication and diffusion about AMT • Lack of a clear map of potential service providers for SMEs • General lack of suitable SMEs-tailored contents and formats in the offering of training and education services related to AMT	• Disparity of access to services and innovation infrastructure in various EU countries • Heterogeneity of regional service ecosystems in Europe with various roles of clusters and service providers • Lack of qualified regional intermediaries able to trigger AMT uptake in a logic of smart specialisation
Policy framework issues	• Sustainable technologies are mainly adopted to cope with regulation	• No regulation approach to create extended value chains through ICT solutions • No clear complementarity among European, National and regional policies • No specific technological focus in many regional and national programmes • programmes for the uptake of AMT are not available in all EU regions

Source: Own review

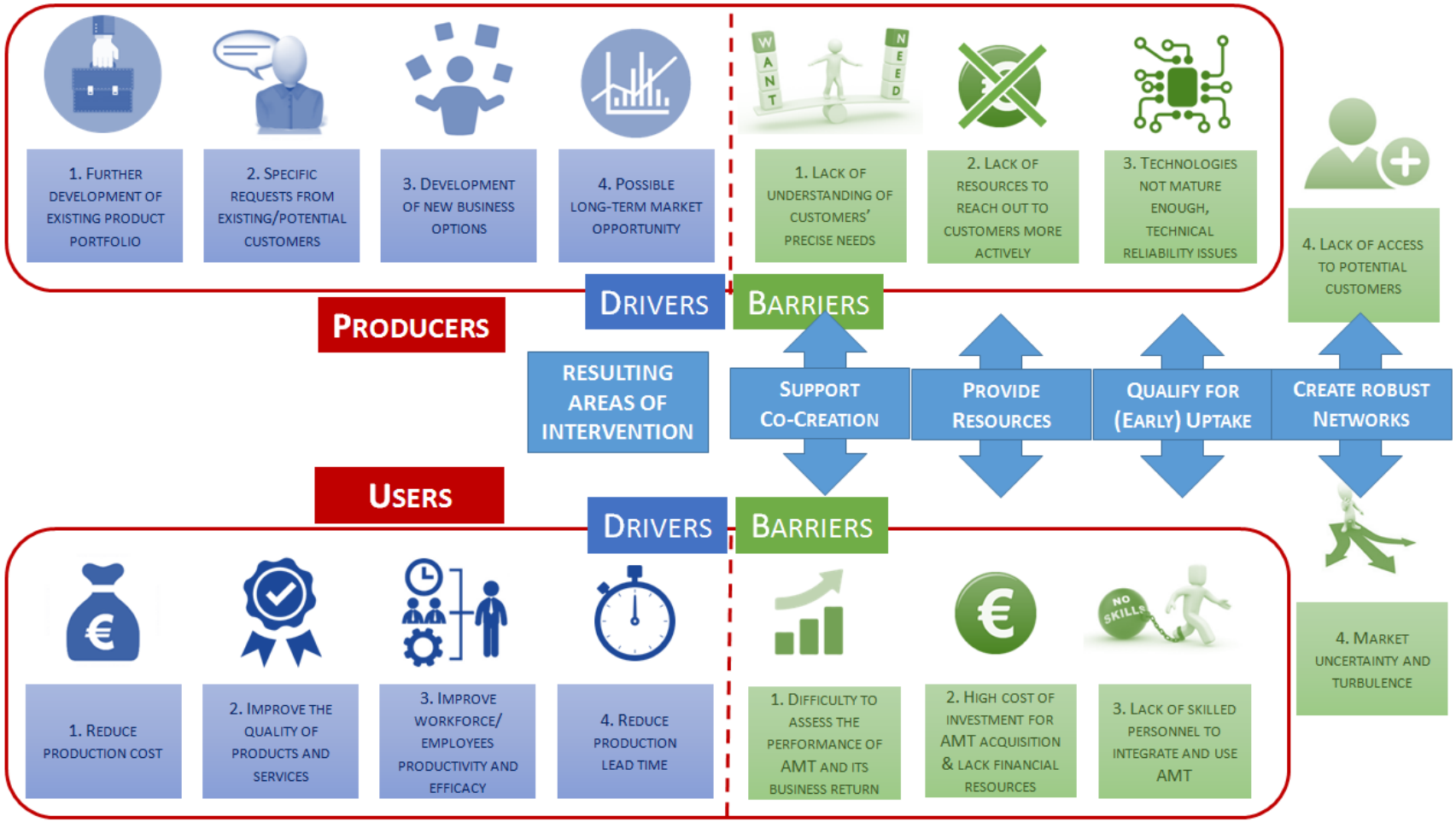
2.4.3 Actions of improvement to address identified issues

The issues proposed in the previous section, as well as the industrially envisaged policy intervention that emerged from the empirical analysis, suggest the necessity to define a set of various actions of improvement which can be implemented by policy-makers and service companies. External and internal issues suggest a set of general recommendations for actions of improvement, to respectively policy-makers and service providers. These are:

- **Provide suitable resources for uptake** to address financial and funding issues that are specific to AMT in the light of the SMEs' peculiarities;
- **Achieve better qualification for uptake** to address competence and skills issues in SMEs, as well as service offering issues (considering that also service providers should achieve a better qualification level);
- **Create new frameworks and infrastructure for cooperation in uptake** to address technology issues affecting the uptake process by SMEs and supply chain cooperation issues;
- **Create diffused and efficient networks of service provision** to address service offering issues policy framework issues;
- **Improve political framework** to address policy framework issues.

Such actions of improvement are suited to overcome barriers outlined by empirical analysis (Figure 20). In the following paragraphs, detailed recommendations to policy-makers and service providers are proposed to implement the identified actions of improvement.

Figure 20: Summary findings on main areas of policy action facilitating the uptake of advanced manufacturing



Source: Own analysis, developing further on Figure 19

2.4.4 Recommendations in the context of readiness

In its several empirical stages, this study collected information on the conditions and industrial frameworks in which certain policy measures can be most relevant, important and effective. While not all related findings were unambiguous, some could repeatedly be confirmed. In the following, these will be summarised from a **readiness-oriented framework**.

As a premise, this framework builds on the three first deliverables' findings that European SMEs' readiness to adopt AMT not only differs in country and firm size, but also depends on the complexity and novelty of the manufacturing technology concerned.

- there is a relevant number of leading manufacturers that can engage in research-driven projects and display a high readiness to adopt and implement cutting-edge technologies. With a view to the entirety of the industrial sector, however, their number is limited;
- nonetheless, there is a substantially larger number of firms that are sufficiently aware of the potentials of adopting high-end AMT and by and large also have a workforce sufficiently qualified to deploy them;
- that notwithstanding, there is still a substantial number of firms – forming the basis of Europe's industrial sector- which have not yet obtained these qualifications and, often, are not sufficiently aware of the inherent opportunities of AMT.

For the central policy recommendations that this report puts forward, this has the following important implications:

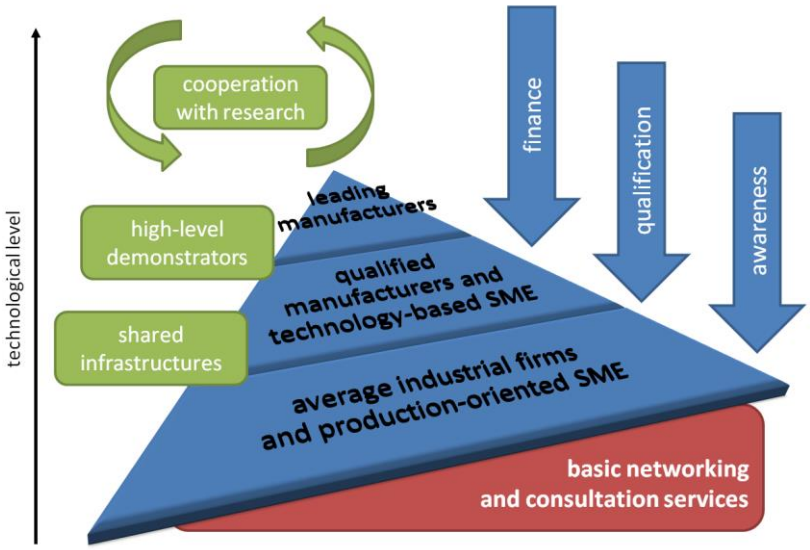
- while supply side measures promoting the uptake of leading-edge technologies by lead manufacturers are integral to maintain and reinforce Europe's global leadership in advanced manufacturing, these will likely remain inaccessible to many other firms that are relevant for the creation of growth and jobs;
- hence, shared pilot plants and demonstrators that illustrate and propagate the immediate technological and economic benefits of adopting novel, yet already established AMT, will have a broader effect on the uptake of advanced manufacturing across the EU;
- moreover, the readiness of many potential users has to be increased through the three following steps - awareness building, qualification of workforce and provision of suitable, risk-alleviating finance - before they dare to adopt more advanced technologies that transform their existing production processes;
- finally, the provision of basic networking and consultation services communicating the fundamentals of advanced manufacturing remains crucial for many firms that first have to meet international standards of production before further and more ambitious transitions become possible.

In summary, the empirical study suggests that the building of capacity will be as important as the creation for new opportunities for high-end AMT uptake. While strong high-level actors will remain essential to establish and maintain a framework architecture for global leadership, a second main strand of support policies should aim at enabling and capacity building measures for those firms that are not yet part of this circle.

In conclusion, an effective, multi-level strategy for industrial modernisation will have to rest on three main pillars, as outlined above:

- measures and actions on the **supply (or provider) side** that improve access to relevant technologies and technological services at various levels of sophistication;
- measures and actions on the **demand (or user) side** that enable and qualify more firms to take part in, and profit from, related offers;
- measures and actions on the **basis of European industry** which ensure that the known benefits of AMT uptake are leveraged by as many firms as possible.

Figure 21: Recommendations to service organisations and firms



Source: Own figure, based on own analysis

2.4.5 A systemically connected set of policy recommendations

To derive concrete recommendations, the critical analysis of this study's empirical findings and the existing policy framework were translated into a number of highly-relevant issues limiting the diffusion of AMT among SMEs. Overall, these were classified in financial issues, funding related issues, skills related issues, technology related issues, supply chain cooperation issues, as well as issues related to service offerings and policy frameworks. Some of them were found to be *internal issues* that can best be addressed by companies themselves while others were more clearly *external issues* that need to be addressed by policy-makers.

Based on the readiness-oriented framework introduced in the last section, the resulting issues were grouped under four main headings to derive policy recommendations:

I. Strengthen capacity for SMEs

Currently, many European firms do not yet have sufficient capacities to adopt AMT. Related shortcomings include know-how, human capital as well as organisational and managerial capacity. Without a better **AMT ecosystem for SMEs** that supports the building of such capacities **in all areas of advanced manufacturing** more advanced support offers will be less relevant.

II. Promote High-end AMT uptake

For already more advanced industrial SMEs, **high-quality demonstration environments and suitable framework conditions** need to be created which allow them to pilot and implement the most recent technologies and relevant research results in cooperation with research and technology organisations (RTOs) as well as other relevant AMT firms.

III. Improve the AMT offer to manufacturing firms

Currently, many AMT providers openly concede that they do not understand their relevant markets well and have not yet developed suitable business models to effectively reach out to potential clients. To strengthen the uptake of AMT, new **business models for technology firms** have to be promoted that **allow their SME clients to invest under conditions of uncertainty**.

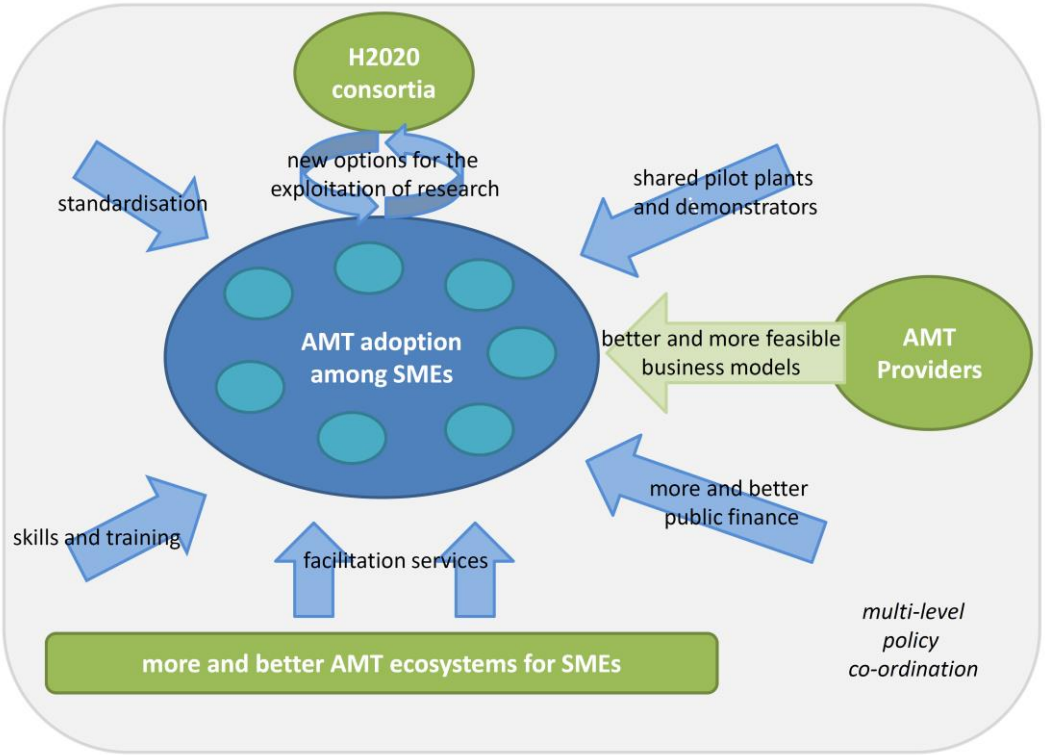
IV. Strengthen policy coordination

While many pertinent support measures are already available in the EU, their coordination across different levels of policy making needs to be improved, in particular if new ones shall be added to the existing portfolio.

Under this overall framework, a systemically interrelated framework of eight detailed policy recommendations was developed. It provides concrete suggestions to policy-makers who address *external issues* at different levels as well as to AMT and other service providers who, in addition, help European SMEs to overcome *internal issues* preventing investment.

To build capacity for AMT uptake by European industry and in particular SME it proposes the creation of more efficient innovation infrastructures for service provision, support for qualification efforts to address prevalent skills issues, and the better provision of risk-compensating financial resources for AMT diffusion. For more advanced firms, it advocates the creation of shared pilot plants and demonstrators, new options to exploit relevant research on high-end AMT, and further efforts in the field of future-oriented standardisation. Furthermore, they refer to the improvement of supply-side business models and policy coordination. All of these recommendations were validated in a workshop with a diverse panel of experts from industry, academia, financial organisations and policy-making.

Figure 22: Systemically interrelated framework of policy recommendations



Source: Own figure, based on own analysis

Below eight detailed recommendations are presented with an indication of the core issues addressed, relevant initiatives already in place and the additional effort needed to achieve the outlined objective. Subsequently, these recommendations outline concrete actions needed to that effect and players who would have to take responsibility for them.

In summary, an overview of the detailed policy recommendations can be given as follows:

Table 12: Recommendations derived from empirical and policy analyses

Strengthen Capacity for SMEs	Promote High-end AMT Uptake	Improve the AMT offer to manufacturing firms	Strengthen Policy Coordination
1. Improve and extend AMT ecosystem for SMEs 2. Improve skills capacity for SMEs 3. Financial support for diffusion	1. Promote joint pilot plants and demonstrators 2. Improve the exploitation of Horizon2020 research by SMEs 3. Adapt standardisation and regulation to AMT diffusion	support new, risk-mitigating business models for AMT providers	better align European, national and regional efforts

Source: Own analysis

2.4.5.1 Strengthen capacity for SMEs

Recommendation I.1:
Improve and extend the "AMT ecosystem for SMEs" across all the EU

This recommendation has been defined to address the following issues derived from analysis:

- Lack of a clear map of service providers;
- Disparity of access to services in different EU countries;
- Lack of multidisciplinary competence to design and introduce AMT;
- Difficulty to identify suitable funding opportunities;
- Lack of clear and qualified communication about AMT;
- Heterogeneity of regional innovation ecosystems including roles of intermediaries;
- Lack of qualified intermediaries to trigger AMT uptake and relate it to smart specialisation.

To overcome the above-mentioned issues, it is recommended that Member States and regions **improve the quality and the availability of service offering systems** for SMEs promoting dedicated initiatives **in the logic of smart specialisation**. It is recommended that **clusters and other intermediaries**, like regional development agencies, **act as orchestrators of regional service capabilities and contact points** for SMEs to improve the access to existing offerings of different types of services (e.g. financial, training, technology, consulting) that, due to the heterogeneity and fragmentation of potential suppliers, risk to be underexploited. In addition, **clusters** have a deep knowledge of the needs of their local member firms and can therefore most effectively **direct SMEs towards suitable support programmes coordinate distributed entrepreneurial momentum and facilitate joint investment projects**.

So far, relevant efforts to create reliable innovation infrastructures in a larger number of Member States have been undertaken in the course of the EU's cluster policy and the digital innovation hubs (DIHs) with their limited technological focus. Furthermore, similar initiatives have been promoted from ESIF sources at the national and regional level.

As documented by the European Cluster Observatory, success cases and best practices with respect to cluster development exist at various levels in many Member States. Some of these best practices have been mentioned above while describing the existing initiatives. However, in many regions the performance of clusters can be significantly improved in order to offer a more efficient support to SMEs. Consequently, it is suggested that the **best practices are to be extended to increase clusters effectiveness**. When further steps are taken to expand the activities of existing clusters or to establish new ones, **a system of quality assurance** such as that of the European Initiative for Cluster Excellence should put in place to define basic criteria that new clusters have to gradually fulfil to receive further funding. At the same time, initial support should **provide new clusters with the means needed to provide professional services** from the outset.

Besides the improvement of cluster-facilitated services, it is recommended that **dedicated initiatives and programmes for the diffusion of AMT are to be established in all Member States** and many more regions to enable and promote a more balanced growth of industrial capabilities. Nonetheless, **inspiring experiences of leading regions should be taken into account** such as "Made Different" in Belgium, the UK Catapult Centres, German Leading-Edge Clusters, etc. Beyond such general insights, however, it is recommended that **local initiatives are tailored to the specific technologies** and needs which are most relevant to local SMEs.

CONCRETE ACTIONS to implement Recommendation I.1

At the European level**:**

- Consider the establishment of **AMT innovation hubs** with a mission beyond pure ICT, modelled on the current digital innovation hubs promoted by DG CONNECT, but **with a technological mandate that covers all areas relevant for industrial modernisation.**
- **Promote, propagate and support suitable models for service offering systems** based on success cases identified in various initiatives such as the European Cluster Observatory, the Regional Innovation Monitor, as well as INNOSUP, INTERREG and TREC projects.
- **Reinforce instruments such as EEN** and **improve their integration into existing national and regional innovation networks** to support SMEs in terms of receiving required service offerings for AMT uptake.
- **Communicate experiences and specific knowledge across Member States and regions** aimed at improving service offerings in regions where it remains necessary to build professional capacity**.** Both the H2020 section on 'Spreading Excellence and Widening Participation' and EU actions supporting 'Cooperation between Regions and Countries' (e.g. INTERREG) can be suitable tools in this regard.
- **Monitor AMT uptake processes and of the performance of regional manufacturing innovation systems**. Support for initiatives like the Regional Innovation Monitor, Re-Confirm, Innobarometer and the future European Manufacturing Survey data could provide relevant leverage in this regard.
- **Exploit the forthcoming KIC on added-value manufacturing to consolidate efficient service offerings in the EU** through better collaboration of academia, research and industry.

<u>At national/regional levels:</u>

- **Incentivise clusters to increase the quality of their services** according to European quality standards, launch dedicated programmes for the diffusion of AMT among SMEs based on regional specialisation and previous successful initiatives.
- Diffuse successful regional service models though **trans-regional/national cooperation**.
- **Launch specific actions to improve the service offering systems and the role of clusters according to the smart specialisation paradigm** taking note of the standards identified and defined by the European Initiative for Cluster Excellence and drawing on existing sources of funding.

To clusters:

- **Act as mediators and orchestrators of technological and business-oriented services in regions** to connect SMEs to service suppliers that can most adequately address their needs with respect to technological issues, organisational development and management challenges.
- **Act as regional intermediaries between the policy level and manufacturing companies**, communicating local SMEs' needs and priorities to regional and national decision-makers while, at the same time, informing those about available support offerings and how they can be combined.
- **Actively engage in the interregional cooperation efforts for the uptake of AMT** establishing strategic relationships with other European clusters under the logic of smart specialisation considering the practical needs of their regional firm population.
- **Leverage existing sources of ESIF and ESF funding to hire qualified cluster managers** with a background in industry and allow them to take part in relevant qualification and training measures (beyond good-practice exchanges) on a regular basis.
- **Aggregate SMEs' demand in front of technology and other service providers and communicate their specific needs and requirements** to better allow AMT producers to understand new markets to which they have had little access so far.
- **Participate in relevant European Initiatives on clusters.**

To technology and other service providers:

- **Cooperate with clusters in order to better access additional markets** and offer own competencies in the framework of an organised regional service offering system.

Recommendation I.2:
Improve skills capacity for SMEs

Through focusing on knowledge and skill transfer, this recommendation addresses the following issues derived from analysis:

- Lack of AMT-related competences in SMEs;
- Weak cooperation amongst RTOs, universities and training organisations for AMT-related training and education;
- Weak cooperation between SMEs and RTOs or universities in the joint development of AMT solutions.

To overcome these barriers, this study recommends **promoting new cooperation models between universities and SMEs for tailor-made training systems focusing on regional smart specialisation.** This can be realised through the establishment of relevant institutional frameworks and initiatives that support collaboration between SMEs and universities for the uptake of AMT and for the development of skills and competences in SMEs.

In some Member States, models pooling SME resources for joint innovation, teaching factories, and e-learning offers are already well established and create good opportunities for acquiring skills both in the context of concrete projects with respect to basic knowledge. Such offers are, however, neither available everywhere nor always exhaustive.

A very important point to meet SMEs needs in terms of education is "practical training" for the acquisition of skills and competences that can be immediately transferred in the companies to operate AMT. To provide such practical training on technologies and industrial applications of real relevance

to SMEs, it is recommended to **focus on industry/university cooperation in selected groups of technologies based on smart specialisation,** introducing new approaches such as **teaching factory and e-learning**. Curricula should be jointly defined by industry, whose active participation is needed in the education process, as has been proven for many years in the context of Germany's different tiers of dual education models. Moreover, new formats such as e-learning and teaching factories should be introduced. To this end, it is recommended to **exploit the experiences of past EU projects** such as "KTRM" and "MIMAN-T" (Leonardo da Vinci), that were specifically funded to develop training systems and contents for the diffusion of AMT among SMEs (in the fields of additive manufacturing and micro-manufacturing).

One of the main reasons for the limited cooperation between SMEs and RTOs is that classical research organisations and universities are traditionally oriented to generate outputs with high scientific impact. Thus, the cooperation between SMEs and RTOs on activities aiming at AMT uptake is often no priority for them, since it does not offer the opportunity to generate high scientific impact. Therefore, it is also recommended to **promote efficient cooperation models between SMEs and RTOs to better co-create AMT solutions**, based on success cases in some Member States. Inspiring examples that specifically address this issue are: the German system of universities of applied sciences that has the specific mission, supported by coherent organisation and career paths for researchers and professors, to generate relevant impacts for companies, both in terms of the uptake of innovative solutions and the development of skills; the Steinbeis foundation stimulating universities and research centres to create service companies that can transfer research results to industry; the recent initiative of the Danobat Group in Spain that has launched a significant industry-research cooperation project for the implementation of AMT in industry supported in the frame of the EIB "InnovFin-EU Finance for Innovators" initiative. Other examples of successful initiatives that stimulate on the SMEs' side the industry-research cooperation are resources pooling models, such as AiF/IGF in Germany or Cétim in France, in which SMEs are incentivised to share challenges for collective pre-competitive innovation activities that are contracted to research organisations or to on-purpose created innovation centres, in order to benefit from a higher critical mass.

Likewise, the forthcoming KIC on added-value manufacturing could represent a suitable framework to setup and diffuse relevant cooperation models for the development of competences and skills.

CONCRETE ACTIONS to implement Recommendation I.2

At the European level:

- **Persist in the strategic effort of designing European curricula for AMT and of finding innovative education paradigms for SMEs** (e.g. teaching factories, e-learning) and build on initiatives like "Blueprint for Sectorial Cooperation on Skills" and "Sectorial Skills Alliance".
- **Promote the exchange of successful** experiences of **cooperation** between **universities-research and SMEs** across nations or regions.
- **Exploit the knowledge generated within existing programmes and initiatives** such as the "Leonardo da Vinci" programme.

At national/regional levels:

- **Provide adequate normative and organisational frameworks** to establish or improve the cooperation between industry and universities (such as dual education systems, joint SMEs-University regional training centres focused on local technology specialisation, etc) and in particular between RTOs and SMEs (such as SME pooling resources models for joint innovation, secondment of researchers in SMEs, and industrial PhDs, etc).
- Activate strategic processes, supported by clusters, universities and RTOs, for the **long-term identification of innovation and education needs of SMEs.**

To training organisations:

- **Design and provide specific multi-disciplinary training offering for the uptake of AMT by SMEs.** Introduce new methods such as effective e-learning systems for companies, the dual-training approach, as well as the teaching factory paradigm, exploiting the available pilot and demonstration infrastructure.

To RTOs and training organisations:

- **Promote the secondment of researchers and students to SMEs** and the realisation of PhDs and Master thesis in SMEs.

To clusters:

- **Facilitate the cooperation among SMEs and universities/research centres**, on regional and national levels as well as their participation in the forthcoming KIC on added-value manufacturing.

To all:

- **Exploit the forthcoming KIC** on added-value manufacturing to setup and diffuse academia-research-industry cooperation models on a stable basis, making sure that significant impacts are generated for SMEs.

Recommendation I.3:
Provide adequate financial support for AMT diffusion

This recommendation is deemed to address the following issues:

- High adoption risk due to limited investment capacity against unclear benefits;
- Fragmentation, complexity and bureaucracy of existing public funding instruments;
- Lack of instruments supporting the uptake (especially for most mature AMT);
- Lack of instruments allowing trans-national and trans-regional cooperation;
- Lack of knowledge of SMEs about available funding opportunities.

As most SMEs can only offer very limited formal guarantees and as it is difficult for private financial organisations to correctly assess technology risk, most banks would be asking prohibitively high interest rates to compensate risks. Hence, **public support is needed to add momentum to the uptake of more proven technologies** on a broader basis and thus contribute to industrial modernisation.

Often, financial obstacles constitute the most relevant barrier if the technology that an SME considers to invest is mature and already provided in a standardised manner (such as robots, handling systems, automated warehouse management systems, standard high-performance machinery, etc). In this context, public support programmes for research and innovation are not very effective as dedicated research or customisation activities are not required. Due to their complexity, however, even investments in more established AMT entail relevant risks and organisational implications for the company that may easily make them 'unbankable'

At the European level, many efforts have been made to take this challenge into account, e.g. in the framework of COSME or the InnovFin SME Guarantee Facility. Moreover, some effective and efficient funding systems can be found in some Member States such as KfW in Germany and Finlombarda in Italy. In most others, however, the issue of access to finance remains – in practice – unresolved. SMEs considering investment in AMT need better access to suitable financial support measures making such investments possible.

To overcome the above-mentioned issues and barriers, it is recommended to **better exploit the potential of existing European instruments.** Even where they are available, such instruments are often unclearly communicated and many SMEs fail to understand their potential. In many others, instruments are simply not available by lack of financially robust local support.

In addition, at regional level, it is recommended to **promote new financing mechanisms and to improve the existing financial models to allow the involvement of technology providers outside the region or even nation of the funding authority.** This is currently not supported by the large majority of existing regional and national instruments. Finally, it is recommended to increase SMEs' awareness of existing financial instruments.

CONCRETE ACTIONS to implement Recommendation I.3

At the European level:

- **Improve regional capabilities to exploit the opportunities of EFSI and ESIF programmes for the uptake of AMT by SMEs**, leveraging the role of clusters in support of establishing efficient services to SMEs at local level.
- **Prolong the EIF's SME Initiative** (drawing on COSME, Horizon 2020 and EIB Group resources) to facilitate European SMEs' access to funding.
- **Differentiate instruments for different types of technologies and geographic areas.**
- **Continuously review and monitor existing instruments** such as the COSME Equity Facility for Growth and of the EFSI SME Facility.

At national/regional levels:

- **Offer multi-step support to SMEs** to overcome the barriers they encounter in the different phases of the funding process. This can be realised, for example, by using voucher schemes dedicated to the different phases (i.e. business planning, identification of funding mix, design of the funding package, etc).
- **Add momentum to the ESIF-funded deployment of public-private financial instruments, in which the public party provides equity funding to SMEs for AMT uptake** on sustainable conditions, limiting associated administrative complexity. Private parties should participate in allocation decisions and constantly monitor the impact of the uptake project.

To clusters:

- **Diffuse awareness of available financial support** for the uptake of AMT.
- **Facilitate participation of SMEs in initiatives that require a critical mass of competences, manpower or investment**, as do the KIC on added-value manufacturing, areas of Horizon 2020 and the investment from the EFSI SME facility.
- Establish cooperation relationships with clusters of other regions/states and facilitate internationalisation of SMEs, based on regional specialisation. Experiences already gained in the Vanguard Initiative should be exploited.

2.4.5.2 Promote High-end AMT Uptake

Recommendation II.1:
Promote the development of joint pilot plants and demonstrators

This recommendation targets some issues which have been mentioned by companies in this study as barriers to the adoption of AMT including:

- Lack of awareness and understanding of AMT and their benefits;
- Doubts about robustness and performance of AMT;
- Difficulty to design solutions integrating AMT into existing processes;
- Disparity of access to service and innovation infrastructure in the EU;
- Lack of specific AMT-related training for SMEs;
- Weak cooperation among research organisations and SMEs.

To overcome the above mentioned issues, it is suggested to **add momentum to the existing effort of establishing and improving a wide European network of regionally-anchored pilot plants and demonstrators open to SMEs with a focus on AMT.**

Up to today, several relevant actions have for example been initiated in the framework of the **Vanguard Initiative**, the EIT **Knowledge and Innovation Communities (KICs)** as well as at in multiple forms and format at Member State or regional level.

Pilot plants should be conceived in the logic of smart specialisation, guaranteeing at the same time synergies and complementarities at the EU level. These pilot plants and demonstrators should offer SMEs access to innovative AMT-based equipment (at sustainable conditions) implementing a Technology Readiness Level suitable for different purposes such as: to understand which novel technological options are available in detail, assess the economic potential for SMEs' specific business, to develop tailored solutions in cooperation with AMT suppliers, to evaluate performance parameters and conduct financial analyses to elaborate concrete business plans, to train personnel "on the machines", etc. Importantly, **pilot plants and demonstrators should be not only hardware installations**

but also ecosystems where SMEs can meet service providers offering the necessary multidisciplinary competences for uptake and qualification. In this way, they will offer SMEs new opportunities for AMT uptake which are so far limited to large companies that can afford the independent construction and use of this type of infrastructure.

In order to meet the needs of SMEs of different European regions it is recommended that **existing pilot plants and demonstrators are improved and, where not available yet, established following the logic of smart specialisation**. In specific regions, the type of AMT and demonstrated industrial applications should be selected based on available technological and service capacities as well as the productive specialisation of the local industrial system that will use the infrastructure as a customer. Moreover, specialised pilot plants in different regions will have to **exploit mutual synergies and complementarities allowing SMEs to easily identify and access those pilot plants and demonstrators** that satisfy their specific needs.

It is recommended to **provide adequate support at all policy levels in order to avoid losing momentum and to accelerate the passage from the design to the implementation** phase. In addition, **existing initiatives need to be interconnected to obtain funding synergies** to achieve critical mass and avoid fragmentation.

It is also recommended to **support the integration of financial mechanisms to fund pilot lines and demonstrators at EU, national and regional levels** in a combined way**.** This can be realised by supporting and promoting alternative funding instruments such as transnational funding and public-private funding models.

CONCRETE ACTIONS to implement Recommendation II.1

At the European level:

- **Continue supporting the existing initiatives on pilot plants and demonstrators and create synergies among them** to achieve critical mass and concentrate funding on a limited number of highly strategic pilot infrastructures. The Vanguard Initiative is a key measure to be further deployed. Moreover, the recently launched "Smart Specialisation Platform for Industrial Modernisation" and the forthcoming KIC on added-value manufacturing can be opportunities to aggregate research, academia and industry for this purpose.
- **Provide enabling support to coordinated regional initiatives** like the Vanguard Initiative, which would benefit from centralised support complementing regional efforts and funding to add momentum to the development of concrete action plans for pilots.

- **Open pilot plants to SMEs and stimulate RTOs and universities to make available existing demonstrators and FabLabs** on a stable basis. In the short term, the Horizon2020 section for Industrial Leadership could be a framework to launch related initiatives. In a long-term perspective, relevant provisions could be added to the coming ESIF support period's CPR. In the long run, transnational funding should be expanded to enable the establishment of networks of pilot infrastructures. In the meantime, INTERREG, INNOSUP and Art. 70 CPR[5] could be leveraged more strongly.

At national/regional levels:

- **Support pilot lines development in the direction of national/regional specialisation**, enable and support transnational/regional cooperation for the development and exploitation pilot plants and demonstrators, including also converging regions.

At all European/national/regional levels:

- **Define, support and implement private-public funding models for the establishment of pilots and demonstrators** by combining available funds from different levels. In doing so, policy-makers can build on existing experiences, e.g. from the Vanguard Initiative. This decentralised process could be supported by the European Commission, for example, under the H2020 section 'Spreading Excellence and Widening Participation'.

To technology providers and clusters:

- **Exploit existing pilot plants and demonstrators to demonstrate and communicate the potential of AMT** and to increase awareness and culture of SMEs about AMT.

To technology providers:

- **Exploit existing pilot plants and demonstrators to collaboratively set-up tailored solutions for SME** and illustrate their viability and concrete applicability to mitigate SMEs' perception of the technological risk of AMT uptake.

To training organisations and universities:

- **Exploit pilot plants and demonstrators to design and implement new education methods according to the teaching factory paradigm**. Exploit knowledge generated in past projects (i.e. "Know-Fact" FP7) and existing practice (e.g. "Festo Teaching Factory"). Furthermore, refer to the "Blueprint for Sectorial Cooperation on Skills" recently launched by the European Commission.

To RTOs and universities:

- **Exploit the existing pilot infrastructure** not only for purposes of academic research, but also **for offering industrial services and technical consultancy to SMEs on a continuous basis**.

[5] Article 70(2) CPR(1) permits the ESIF funding of operations outside a specific ESIF programme area, for instance in other regions of the same country or in other Member States. In practice, it is hardly used.

To all:

- **Take part in the future KIC on added-value manufacturing** to set up a high-level European pilot infrastructure, meeting the needs of advanced industries.

Recommendation II.2:
Improve the exploitation of Horizon2020 research by SMEs

In this study, some companies mentioned barriers to the uptake of AMT solutions generated in EU-funded research projects, after having invested in their realisation. Thus, this recommendation addresses the difficulty in exploiting the results of EU-funded research projects.

In the past, many efforts have been made to improve opportunities for valorisation and commercialisation on the side of research policy e.g. in the context of the SME Instrument under Horizon 2020. However, less has been done to put manufacturing SMEs in a better position to exploit existing research results from a 'pull-perspective'.

In order to overcome this barrier, it is recommended **to valorise AMT-related research results among SMEs**, adding momentum to the existing measures such as in the frame of the FoF PPP. For some years, the European Commission has embraced the logic of clustering research-funded projects of similar thematic areas with the intent of achieving synergies and higher critical mass for exploitation. Clusters of projects can for example share efforts in communication and dissemination activities, enlarge the number of prospects, participate with more weight in standardisation committees, etc. It is also recommended to **draw on existing models for inspiration**.

CONCRETE ACTIONS to implement Recommendation II.2

At the European level:

- **Include exploitation partners in project consortia** from the beginning, in particular in relevant projects supported under the H2020 pillar for 'Industrial Leadership'.
- **Provide clear and measurable targets for projects** with which project partners can engage and on which they can be measured at the end.
- **Encourage consortium partners to better exploit the outcome of their research projects**
- **Launch actions dedicated to the uptake and further development of project results in demonstrators and pilot plants.** Connect available research results generated in European projects to existing and future initiatives on pilots and demonstrators, creating a 'pipeline to practice'.

At national/regional levels:

- **Support the exploitation of results generated in European projects following the logic of smart specialisation**, thus customising developed enabling technologies with respect to specific applications and solutions of local industry**.**
- **Align national/regional programmes with European programmes** in order to exploit complementarities and build upon already existing experiences.

To clusters:

- **Communicate opportunities resulting from the EU-funded research to SMEs**. Adopt a concrete communication style using a language suited to SMEs.
- Maximise the potential of already existing tools for the valorisation of European research results in cooperation with FoF and other similar platforms.
- **Support national and regional governments, as well as the European Commission, in the identification of possible but not yet leveraged synergies between policies** in order to better exploit European results in the logic of smart specialisation.
- **Support RTOs and universities in the diffusion to industry of results** generated in research projects funded by the EU.

Recommendation II.3: Adapt standardisation and regulation to the diffusion of AMT

In this study, companies mentioned standardisation and regulation issues, which make the exploitation of sustainability-related and ICT-related AMT difficult. In fact, the study identified this as one of the main issues.

So far, relevant discussions have been triggered in the context of CENELEC and the European Telecommunications Standards Institute, e.g. through the Joint Standardisation Initiative. Europe is actively trying to keep pace in these fields – but the constant emergence of new technologies makes this challenging.

To better overcome this issue, a **strong commitment to the development of future standards and the improvement of existing regulation** is recommended, since it has the potential to positively influence the diffusion of AMT. According to the study's findings, this is particularly true for ICT- and sustainability-related AMT. The digital manufacturing revolution is beneficial to SMEs because it supports the establishment of efficient and real-time managed extended value chains by connecting a number of SMEs that are geographically dispersed. Thus, considering the structure of the European manufacturing industry, it will contribute to overcoming fragmentation and to achieve higher critical mass. However, this will be possible only if the ICT solutions are interoperable, i.e. if various applicative solutions can easily exchange data among themselves, and if they are customisable according to the various applicative domains of SMEs. Thus, actions are recommended to **support the promotion of open standards allowing interoperability of ICT systems** as an important enabler for the digital revolution of SMEs. Both companies and intermediaries need the necessary resources and time to engage in these discussions with high-level staff. Furthermore, they may need to take dedicated investment in the testing and piloting of specific proposals they want to advocate and further develop.

Concerning sustainable technologies, regulation could play an important role. Thus, it is recommended to improve regulation in order to enable a more agile re-use, re-manufacturing and recycling of products and processes in order to implement circular economy concepts. The diffusion of new sustainable technologies, in fact, seems to be currently limited in many cases because of the normative on waste management, which makes the materials management processes along the supply chain bureaucratic and complicated. In this regard, significant actions are already in place, as is the case in the "Circular Economy Package" of the European Commission. In general, however, the removal of obsolete, uninspired or unintended regulations that negatively impact the already hesitant stance of many firms with regard to AMT uptake remains a challenge. Arenas of discussion need to be set up with all industries and intermediaries concerned to better understand their needs and to act accordingly.

It is recommended that **forthcoming initiatives on standardisation for the diffusion of AMT be aligned** with the Joint Initiative on Standardisation promoted by CEN, CENELEC and ETSI and have high-priority in the agenda of the Annual Union Work Programme for European standardisation.

CONCRETE ACTIONS to implement Recommendation II.3

At the European level:

- **Improve European directives** to enable, facilitate and trigger the establishment of sustainability-related businesses.
- **Participate in the definition of future standards** that will define the evolution of ICT-enabled manufacturing technologies in the coming decade.
- **Stimulate and support the participation of relevant partners of high-level European funded projects in relevant standardisation committees.** Where relevant, stimulate the participation of members of standardisation organisations in project consortia.
- **Support the follow-up of European research projects' implications for standardisation and regulation** after their formal termination.
- **Create a central European point of contact to which concerned SMEs and facilitating organisations can report obsolete and obstructive regulation** and which can communicate it to the relevant services of the European Commission.

By clusters:

- **Aggregate the needs of SMEs to provide relevant inputs in terms of standardisation and regulation** (for example by establishing "standardisation and regulation fora").
- **Support and facilitate the participation of cluster members to standardisation committees and other committees defining the amendment of existing regulations.**
- **Diffuse awareness and increase industrial culture** around standardisation and regulation issues related to AMT.

2.4.5.3 Improve the AMT offer to manufacturing firms

Recommendation III:
Support new service-based business models for the diffusion of AMT

This recommendation is defined to address the following issues derived from analysis:

- high adoption risk due to limited investment capacity against unclear benefit;
- market uncertainty and turbulence;
- not proven performance of AMT;
- lack of multi-disciplinary skills to introduce and operate AMT;
- limited engagement in customer-supplier relationship by technology suppliers.

To address the above-mentioned issues, technology providers need to explore and adopt unconventional business models that **provide novel options for the acquisition of AMT through closer customer-supplier relationships and risk sharing**. Examples of such business models are leasing, renting, pay-per-part models (from the financial perspective), the provision of skilled personnel and support for operations management (from the skills' perspective), models guaranteeing the availability of machinery and adequate production capacity to meet market turbulences or a pre-defined quality of manufacturing (from a technical and operational point of view).

While both challenges and opportunities are well known and while a number of suitable business models have been developed in theory, very limited policy action has been taken in this regard so far, at both European and national levels. Hence, most promising options are not yet available to SMEs.

Such innovative business models offered by technology providers would be particularly needed when production needs to be scaled up in SMEs and relevant knowledge and practical capabilities can no longer be acquired in pilot plants or demonstrators alone. At this stage, potential users of AMT de-

pend on the availability of qualified and reliable accompanying services in the field of finance, maintenance and operations management, skills development, etc. As these new business models help firms move from first demonstration to broad-based uptake, they constitute a crucial contribution to AMT uptake in Europe (in cooperation with other service suppliers such as financial organisations, logistics companies, training organisations, etc).

It is recommended that these service-oriented business models move from the conception to a wider European implementation and diffusion. Considering the above-mentioned existing initiatives and projects focusing on the adoption of a service-based business model, it is also recommended that the **concepts, tools and information obtained from past funded research projects and academic research be exploited for AMT diffusion**.

CONCRETE ACTIONS to implement Recommendation III

At the European level**:**

- **Capitalise the knowledge and experience gained in European projects and initiatives dealing with new business models for AMT uptake**, including also the monitoring of the diffusion and efficiency of such business models. The CSA Instrument under H2020 would be a suitable tool for this purpose.
- **Stimulate the concrete implementation of European industrial transformation towards new business models.** It could be considered to support such projects under a specific headline of the H2020 pillar 'Industrial Leadership' building on experiences of the ICT Innovation for the Manufacturing SMEs (I4MS) challenge.
- **Diffuse successful regional business models**. Less experienced Member States should be encouraged to explore options jointly with partners that already have new business models in place. For this, actions under the 'Spreading Excellence and Widening Participation' framework could be suitable tools.
- **Analyse the diffusion and performance of new business models in the light of national/regional specialisation** by leveraging actions like Re-Confirm or available sources of information like the Regional Innovation Monitor.

At national/regional levels:

- **Leverage ESIF for SME development by setting up relevant support programmes and actions** for new business models diffusion.
- **Support regional technology and service providers (clusters) in their efforts to build strategic partnerships and local service offering systems in the direction of new business models** through approaches that are affordable for SMEs, such as voucher schemes.

To clusters:

- **Improve coordination among regional technology and service providers in order** to support clusters with the design and implementation of new business models.
- **Communicate to SMEs the benefits of novel business models** for AMT uptake.

To financial organisations:

- **Cooperate with technology providers on risk sharing** in order to provide the financial arrangements needed to establish new business models.
- **Cooperate with European institutions**, as for example in the context of the SME Initiative of the EIF, to explore further options for the financing of specific actions.

To technology providers:

- **Exploit existing pilot plants and demonstrators as a support for the offering of new business models** (for example for training purpose, technology performance assessment, etc).

- **Establish strategic partnerships with providers of other services that are needed for the setup of new business models**. Exploit existing facilitation services offered by clusters to build such a service network.

2.4.5.4 Strengthen policy coordination

Recommendation IV:
Improve the alignment of EU, national and regional policies

In principle, the alignment among policies at various levels would allow to better exploit synergies and complementarities, as well as to achieve a higher critical mass of support actions for the uptake of AMT by SMEs. In practice, however, the fragmentation and the complexity of existing policies do not often allow SMEs to be aware of all funding opportunities and discourages them from applying for them. It is thus recommended to put **at the disposal of SMEs a portfolio of all supporting instruments**.

It is suggested to **achieve a better alignment from** both **a policy content point of view** (i.e. the thematic areas supported in different policies) and **a financial point of view** (i.e. enabling the combination of relevant sources of funding). For the former, first important steps have been taken with the establishment of the RIS3 **Platform for Industrial Modernisation**. Importantly, such an alignment of policies cannot be directed from the European level but has to grow from a gradual **process of mutual learning based on regional smart specialisation**.

Policy-makers at all relevant levels should cooperate based on their respective competences. The regional level defines the specialisation strategy driving regional policy, as it has usually the best knowledge of local enterprises' practical needs and can leverage the local system of intermediaries. At the same time, it may lack critical mass to support leading-edge actions. The national level may have higher critical mass and should consider different regional needs and specialisations to design excellence-oriented national innovation policy. The European level, finally, provides an arena for consolidating joint efforts at a higher level, along value chains, co-ordinating mutual good-practice learning, and finance highest-profile projects in the development of more general enabling technologies.

Positive experiences matured in some regions and Member States should be exploited, such as the recent clustering policy in Italy and in some of its regions, aimed at the definition of a coherent national and regional policy based on smart specialisation.

CONCRETE ACTIONS to implement Recommendation IV

At the European level**:**

- **Continue supporting European regions in elaborating and consolidating their smart specialisation plans** and to subsequently exploit synergies at EU level.
- **Update policies in a post-H2020 perspective** considering the inputs of new technology roadmaps as well as of the regional smart specialisation plans.

At national/regional levels:

- **Define place-based industrial policies based on smart specialisation considering at the same time the opportunities offered by European policies** with a view to synergies and complementarities, building on the activities of the RIS3 Platform for Industrial Modernisation.
- **Support trans-national/trans-regional cooperation for AMT uptake by SMEs**, based on the respective smart specialisation strategies of partners, thus identifying selected partners and technology groups, leveraging Article 70 CPR or INTERREG actions.

- **Take advantage of the "Seal of Excellence" label** to ensure alternative funding for strategic projects that are not financially supported at the European level due to lack of budget. Take advantage of the positive experiences already available in the EU.
- **Empower the role of clusters as partners in the process of policy definition** to identify and communicate industrial priorities as well as existing European support offers.

To clusters:

- **Create a better awareness of European policies among SMEs** and facilitate the design of a portfolio of funding instruments including European funding opportunities coherent with their specialisation.
- **Elaborate strategic research and innovation roadmaps outlying potential links with European policies** coherent with regional specialisations. Existing success cases, such as the recently created CFI and AFIL clusters in Italy, should be considered.
- **Actively engage in relevant European RIS3 initiatives**, such as the Smart Specialisation Platform for Industrial Modernisation and the Vanguard Initiative.
- **Contribute to political strategies in the area of trans-national/-regional cooperation** based on the specialisation of local industry and on the availability of specialised suppliers and service providers in other European regions, e.g. in the context of the Smart Specialisation Platform for Industrial Modernisation.

Annex A

Table A.1: Barriers and drivers in ICT-enabled intelligent manufacturing

	Barriers	Drivers
Environmental Context	• Expected shift of power and change of roles within the supply chain as it is digitalised • Difficulty in managing various nations' political, regulatory, judicial, tax and labour environments • Difficulty in evaluating investments in information systems, establishing performance metrics and making benefit-cost analysis	• Tax policies supporting innovation, for example, incentives for R&D, and tax benefits for "advanced manufacturing" • Promises in enhanced company performance by improved decision-making, reduced operating and admin costs and enhanced business processes • Give a customer greater control over the processing of an order; allow the customer to dynamically influence the way the order is produced, stored or transported
Organisational Context	• Difficulties in managing the expectations of non-technologically driven management • Difficulties with balancing the development of the strategic goals with pressures for commercial output • Difficulty in managing collaborative workflows, increased inter-firm rivalry due to a misalignment of motives and behaviours among allying partners • Challenging culture change management issues, resistance to change • Difficulty in finding skilled labour • Difficulty in developing innovative learning approaches and strategy to incentivise the development of competence	• Significance of intangible resources for business success has increased and may in some cases already be assessed as higher than the impact of tangible resources • Physical product, information systems and financial flows can be closely aligned with each other throughout the supply chain to improve supply chain visibility, to conduct experiments and what-if analyses, to improve the understanding of the real system and the possibility to improve communication • Adherence to best practice work patterns, organisational learning and effectiveness of employees
Technological Context	• Difficulty in demonstrating that an intelligent product environment can be deployed with industrial scale • Difficulty in accessing and retrieving data from partners and other information systems • Traditional six-sigma techniques show strong limitations in highly changeable production contexts	• Revenue growth fuelled by increased responsiveness occurring at lower costs using fewer assets, by reduced manufacturing cycle times, increased inventory turns, improved accuracy and timeliness of information • Improved ability to respond quickly and effectively to market demands, allows inventory to cycle to customers faster • Allow the evaluation of various manufacturability aspects during the design stage

Source: Own analysis (case studies & interviews)

Table A.2: Barriers and drivers in high performance manufacturing

	Barriers	Drivers
Environmental Context	• The additive manufacturing challenges relate to environment and energy, scale and cost of production and structural performance • Difficulty in developing a cost effective solution to additive manufacturing of non-metals and metals • Difficulty in estimating the required precision, without unnecessarily high accuracy of equipment used and, therefore, without inflated costs • Nano manufacturing generally lacking basic processes common to manufacturing-qualification	• Funder's focus on the systematic barriers to implementation rather than the technology itself • Developing cyber-enabled manufacturing systems, that is computation, communication and control approaches, will help in validating additive manufacturing and moving it to the factory floor • Adapted digital workflow promises advantages in the introduction of process documentation, aspects of quality control, cost minimisation and in the efficiency improvement • Promises in reduction of the pollutant emissions and the problems related to the workers' health
Organisational Context	• Managerial action needed with regard to advanced planning procedures, user involvement plans, communication channels, company labour policies and continuous training programmes • Lack of expert knowledge • Challenges in the conception and design of whole products and systems • Difficulty in managing information flow and system complexity of production cells that incorporate various producers' equipment	• Cloud computing paradigm can be utilised as a hosting platform for autonomous data mining and cognitive learning algorithms; these bring new service models in the manufacturing and service industries with advantages in ubiquitous accessibility, convenient scalability and mobility
Technological Context	• Selection of a robot for a specific industrial application is challenging • Robots do not adapt well to dynamic environments, do not offer rich human-robot interaction and are not simple for end-users to programme • The integration of micro-components into macro-scale products is non-trivial, conventionally posing difficult questions and compromises in the domains of packaging, interconnection and design • Difficulty in detecting, sizing and typing defects, need to improve the reliability of inspection and probability of detection • Complexity of high precision assembly process • Productivity of additive manufacturing process is still very low: must make products reliably and predictably, monitoring and closed loop control systems are needed • The lack of standards in additive manufacturing impedes its use for parts production, must ensure the consistency and quality	• In microelectronics, smaller feature sizes lead to higher frequency operation and lower power consumption • Promises of platforms tailored to a vast array of emerging applications: provides versatility, low costs, installation and operational flexibility, safety and reliable operation characteristics • New materials can add new functionalities: a great potential of various nano-particles as additives for enhanced product performance • Promises of opportunities to create products in ways which were previously considered impossible to manufacture • The integration of human operators into robot based manufacturing systems may increase productivity by combining the abilities of machines with those of humans • More intuitive ways to programme robots are developing

Source: Own analysis (case studies & interviews)

Table A.3: Barriers and drivers in sustainable manufacturing technologies

	Barriers	Drivers
Environmental Context	• The potential adverse human health effects of manufactured nano-material exposure are not yet fully understood and exposures in humans are mostly uncharacterised	• The role of innovation, importance of manufacturing scale and supply-chain development do affect the adoption of sustainable technologies

	• Need to identify the needs of manufactured nano-material companies in developing nano-protective environmental health and safety practices • Management need to balance business profit with environmental impacts and benefits, and is challenged by a low realisation of market benefits: difficult to convert technical opportunities into concrete benefits with quantifiable impact • Life cycle assessment methodologies not mature enough to be applied at the scale of entire product portfolios: neither product-level metrics nor facility-level metrics are sufficient for firm-wide cost-benefit analyses that affect multiple products and value-chain stages	• Local authorities can play an important role in developing sustainability enhancing policies as well as supporting novel networks of stakeholders • New materials are emerging from secondary sources or from waste products; provide positive environmental benefits with respect to ultimate disposability and raw material use • The Internet of Things paradigm promises to increase the visibility and awareness of energy consumption and financial inputs to manufacturing operations
Organisational Context	• General challenges with respect to employing sustainable manufacturing technologies relate to employee buy-in, competence and time • Difficulty in combining multiple expertise the sustainable manufacturing technologies typically require • Challenging to manage variety throughout the entire products life cycle; firms have to balance dual goals of reducing variation and promoting variation in their product configuration activities	• Efficiency considerations, market attention, and greening of innovation make company management to consider more carefully the specificities and interactions of various types of products and process innovations and their environmental implications • Current IT systems can support the collection of all the needed information to enable the manufacturer's design for disassembly and recycling analysis
Technological Context	• Difficulty in gaining all the information necessary to plan for the recycling evaluation; modifications often create trade-offs, improving some aspects but worsening others • Life cycle assessment methodologies are currently not mature enough to be applied at the scale of entire product portfolios • Continuous, process-like manufacturing places special requirements to the Six Sigma toolbox e.g. with respect to advanced control, dynamic simulation and dynamic optimisation • Difficulty in scaling up of bio-printing operations; challenges with respect to the mechanical strength and integrity in the manufactured constructs, lack of an effective design software	• Continuous manufacturing promises sustained operation with consistent product quality, reduced equipment size, high-volumetric productivity, streamlined process flow, low-process cycle times and reduced capital and operating cost • Improved power monitoring allows for the quantification of energy efficiency, the curbing of expensive peak power use and the control of the process stability • The unique advantage of nanotechnology is due to nanoscale physical and chemical properties that are quite different from those encountered in microscopic or macroscopic materials and devices

Source: Own analysis (case studies & interviews)

Annex B

Table B.1: Main drivers and barriers on the European AMT market

1.	The European AMT market is, in general, seen as very passive at the moment
2.	The European AMT market is not one unified market, but there are differences between countries and regions. Some leading areas (Germany) seems to be slowing down and others (Italy, UK, France) are showing some signs of awakening. Local or national activities and support also affect how the industry in the area is investing. For instance, the Basque Country has successfully supported AMT investment. There are, of course, good examples of companies which dare to invest also in other countries with high labour cost. For instance, Danish and Norwegian companies were mentioned in the interviews.
3.	Some AMT user industries are facing market concentration and intensification of competition from Asia. This is true especially in mass production of consumer goods, where the entry in the European market of Asian producers has destabilised the competition, raising dumping disputes between producers, and where relationships between competitors are strained and co-petition (cooperation between competitors) is not pursued. On the AMT market Chinese competitors have not been successful in Europe due to high quality requirements.
4.	Low competitiveness of the labour force and high cost of labour is affecting the entrepreneurial climate in some European countries. This also affects how entrepreneurs and managers see investment in AMT and investment in general.
5.	A central challenge is that few companies are prepared to make productivity leaps through investment in new advanced technology. Users are more willing to work further with already installed technology. The primary criterion for selection of a supplier is regularly the price, and not the novelty of the technical solution. Especially in publicly listed companies and companies operating in low-margin markets and relying on economics of scale, management is strongly risk-adverse when considering new investments in AMT. For them, return on investment (in the sense of payback time) is a fundamental consideration. At the same time, production stops, low production rates and high lead times due to non-robust technologies are regarded as unacceptable as they affect short-term profitability. Hence, innovation projects are typically only launched when the return on investment is significant and when they do not present high risks. In particular, it is very important not to invest in technologies whose advantage and robustness is not clearly proven, not to damage the company's reputation with regard to quality and reliability. In general, SME managers are particularly cautious before putting in production new technologies if they have not been exhaustively tested and engineered before.
6.	Lack of competence and knowhow to adopt and to use new technologies is also seen as a barrier to implementation of AMT in Europe. This concerns specifically the use of complex ICT-based systems with a high level of digitalisation (combined electronic and software elements), especially when the implementation of the system requires input from several suppliers. In case of high performance manufacturing systems, the situation can be reverse: due to new, user friendly technology the use is made even simpler than before.
7.	In order to manage innovation risk, user companies cooperate with innovation partners which develop, customise and industrialise the technology. User companies do not have the infrastructure capable of developing and introducing technology innovations alone, but it is necessary that the innovation partners develop the technology till TRL 9. Only at this stage, users buy innovative technology and introduce it into production lines. The user companies are very careful also in the selection of these partners, since it is crucial not to bring a technological risk in production and it is necessary that the relationship with supplier is very strong.
8.	Also the availability of reliable suppliers for the new technologies is important. Users have to rely on solid suppliers able to guarantee the supply of novel technologies to serve various production sites and the assistance in case of problems. This is a problem for SMEs whose product are not well known or are very innovative. Hence, there is a need for brokerage events.
9.	Well established companies have more references and more resources for R&D. As a consequence of this, they also get more subsidies from the EU. This affects the competition and puts SMEs in a less favourable position as suppliers of AMT. With their limited budgets they are either not able to offer or they need much more time for development and production of AMT system requested by the customer.
10.	Diffusion of AMT is also slowed down by complex structures in large globally operating companies. In global multinational companies, important decisions must meet the approval not only of top management in the headquarters, but also of the management of local companies and of various business units that are involved as future users of the innovation. Sometimes it might happen that different company areas have different priorities or different understanding/intents about new technologies. To find a common agreement may result a time-consuming process.

11. Organisational culture can also be a barrier significantly affecting investment in AMT. There are multiple reasons. The first one is of cultural type. In a company with a deep lean manufacturing culture and tradition employees at all levels are involved in development work and this is done by using a wide set of management/organisations instruments which are supported by paper documents as a carrier enabling information sharing and intra-organisational dialogue. Thus, digital tools are not immediately suited to lean manufacturing practices, at least in the conception of company culture. All employees do not have the competences required to appreciate and use digital tools.

Source: Own analysis (case studies & interviews)

Annex C

Table C.1: Specific drivers and barriers in case companies

Financial situation:
+ The ultimate goal for any investment is to improve or at least maintain the financial situation in a changing situation and this is what is expected from AMT as well.
- A weak financial situation and poor access to capital markets can be a barrier to AMT investment.
- Lack of public financial support for AMT investments at a national or EU level is also seen as a barrier.
Demand situation:
+ The demand situation can be improved through the customer value provided. AMT can be used to improve this value both in products and services.
+ Value to the customer is achieved through high quality products and services. ICT-enabled technology is part of the products and an enabler of services. Continuous availability for maintenance and training of operators are ICT-enabled services, which can affect how the customers invest in new technology.
- Limited demand or uncertainty about future demand is a barrier to investment. For instance, excessive concentration of sales on a few large customers introduces an element of risk in increasing productive capacity as the loss of a single customer can compromise the return on investment.
- The demand for products produced using AMT is not strong enough to guarantee the return on investment in the user organisation
Competitive situation:
+ Through the use of AMT companies can achieve unique product and service characteristics differentiating them from competition. In some cases AMT can provide a unique selling proposition for the company.
+ The use of AMT can also allow for more competitive pricing of products and services. In some cases AMT can provide both better product or services quality, and a lower price than the competition.
+ Introduction of AMT can also be a necessity in order to keep up with competition.
+ The use of AMT like sustainable technology can improve the image of the company. Being able to show customers that you are able to operate sustainably can convince the customer of your ability to provide high quality, sustainable products and services.
Know how, competence and skills:
+ AMT can provide data about production, products or services. This is a good opportunity for the technology provider and users to learn and to develop knowledge and competencies.
- Use of new technologies like Additive Manufacturing requires completely new knowledge of how to design and produce a product or service. Especially in small companies the time and money needed for this investment can be hard to find.
- In large companies the complex organisational situation, with decentralised units in charge of various products, can become a barrier for the adoption of new technologies. The complexity of the organisation affects internal communication and decision making.
- Organisational culture and knowhow in the company and in the value network does not support implementing high tech digital tools. For instance, lean manufacturing involving factory personnel in development can be a barrier to implementation of digital tools.
Process performance:
+ AMT can provide increased capacity compared with traditional means
+ Flexible automation can provide reductions in labour costs and improvement in labour productivity in heavy manufacturing industry
+ Cost reductions and improved productivity are central sales argument for AMT
+ AMT improve the flexibility of both manufacturing and R&D
+ The growing capacity of computers enables the development of increasingly flexible automation systems. This is a technical enabler for AMT now and in the future.
+ AMT improves the working environment in the factory. Sustainable technology can improve the situation both inside and outside the factory.
+ AMT can improve machine usability through improvements in maintenance
- AMT are not suitable for the type of production (manual assembly, one-of-a-kind), not mature enough or too expensive in comparison with existing technology
- The technology is too expensive or the effect on the manufacturing process is not enough to cover the extra cost of the investment
- Earlier failures to implement a specific technology can become a barrier even though technology develop and the situation changes

Customer requirements:
+ In small flexible companies like the AMT provider companies interviewed the customer requirement and fulfilment of these is at the core of their business model. AMT help these suppliers to provide solutions to these requirements through better performance of products, better quality of products and services, and through more price flexibility. - In mass producing user companies, increasing customer requirements are not the main drivers in adoption of innovative manufacturing technologies.
Legislative, regulation, political situation:
+ Regulation can be a market driver creating new markets for sustainable technology. This can also be a driver for investment in AMT. For instance, high requirements on technology can make investment in AMT profitable as it provides means to achieve these requirements. + Regulation can also push companies to use greener manufacturing technology - Old regulation can be a barrier for developing and adopting AMT. For instance, re-use of components is in some areas still hindered by regulatory issues. - There is *no* national *support for investing* in AMT - Applying for EU grants is *bureaucratic* and there is a low success rate for applications - Lack of information about new technology can in certain regions be a barrier to investment in AMT

Source: Own analysis (case studies & interviews)

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