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Advanced Technologies for Industry – Product Watch

Robotics for food processing and preparation

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Section 1

1. Introduction

Background

The Product Watch Reports have been developed in the framework of the 'Advanced Technologies for Industry' project and serve to identify and analyse 15 promising advanced technology (AT)-based products and their value chains, with an assessment of the strengths and weaknesses of the EU positioning.

Promising AT-based products can be defined as "*enabling products for the development of goods and services enhancing their overall commercial and social value; embedded by constituent parts that are based on AR/VR, Big Data & Analytics, Blockchain, Cloud, Artificial Intelligence, the Internet of Things (IoT), Mobility, Robotics, Security & Connectivity, Nanotechnology, Micro-nanoelectronics, Industrial Biotechnology, Advanced Materials and/or Photonics; and, but not limited to, produced by Advanced Manufacturing Technologies*".

1.1. Background of this report

The food sector faces a multitude of challenges out of which some originate from changes in the natural (depleting natural resources, climate change) and some from changes in the socio-economic (globalisation, increasing legislation, dietary trends) environment. Industrial robotics for food processing and preparation (food robotics), including collaborative robots for repetitive tasks in food preparation, may help tackling such challenges as they enable the flexibilisation and automation of food production processes. Thanks to their close links to advanced technological concepts like the Internet-of-Things, they may allow the food sector to take part in the transition towards and to harness the potential of the emerging industry 4.0 such as a better traceability and trackability of ingredients, processes and products[1]. Table 1 provides a non-exhaustive list of robot capabilities and their possible benefits to manufacturers.

Table 1: Robot capabilities and their possible benefits to food manufacturers

Industrial robot capabilities		Benefits
Decrease	Production cost	Reduce costs associated with manual labour and utility expenses
	Material waste	Increased efficiency allows for reduction of production material waste and less scrap from rejects
	Floor space	Compact systems with mounting versatility
	Production time	Higher speed and efficiency, fast re-configurability
Improve	Product quality	More efficient process control, high repeatability and accurate task execution
	Product uniformity	Errors caused by human error and fatigue eliminated
	Working environment	Existing labour upgraded, removes human from unfavourable conditions and tedious tasks
Increase	Production rates	Ability to produce 24/7 without disruptions
	Flexibility	Reconfigurable and easy to apply to a variety of tasks
	Safety compliance	Works in hazardous environments, made of hygienic materials
	Competitive advantage	Faster response to market demands, allows for product customisation and personalisation
	Efficiency	Optimised processes, increased yield (reduces production material waste, scrap from rejects)

Source: Bader and Rahimifard, 2018, 2020

[1] Bader and Rahimifard. (2018).

Table 1 illustrates that there are several potential benefits of food robotics. Processing activities that may especially benefit are:

- Activities that constitute bottlenecks to the whole production process (e.g. the filling of pie), which typically result from rigid processing equipment
- Processes taking place under hazardous and unfavourable conditions such as the handling of heavy objects or the use of dangerous tools like cutting devices
- Simple and repetitive processes such as placing ingredients in sandwiches or packaging, which are frequent in large scale food production
- Processes which require high overall variability and which e.g. may be caused by an increasing variety in the overall production portfolio

More precisely, the potential uses within the food industry for robotics could be:

- Material handling (including sorting, transporting, weighing or loading)
- Material processing (slaughtering, size reduction, separation)
- Assembly (foodstuff mixing, assembling or decoration of pre-prepared ingredients for food delivery)
- Packaging and palletising
- (Quality) Inspection[2]

These potential uses and the heterogeneity of food products imply that robots have to be designed specifically to customer needs and it is not possible to reach large scales such as is in the automotive industry.

The volume of the global food robotics market is estimated up to about €1.64 bn[3][4] and is expected to grow at a compound annual growth rate of about 12.6 % in the coming years[5]. Whereas Asia constitutes the largest market for industrial robots at large[6], the European area was the largest market for food robotics in 2016. Possible reasons for this are e.g. European food safety regulations, increasing labour costs, relatively quick high return on investment, rising investment for automation in the dairy sector, increasing demand for automation in the prepared food and meat processing industry[7]. The distribution of food robotics throughout the EU varies among Member States as Figure 1 illustrates.

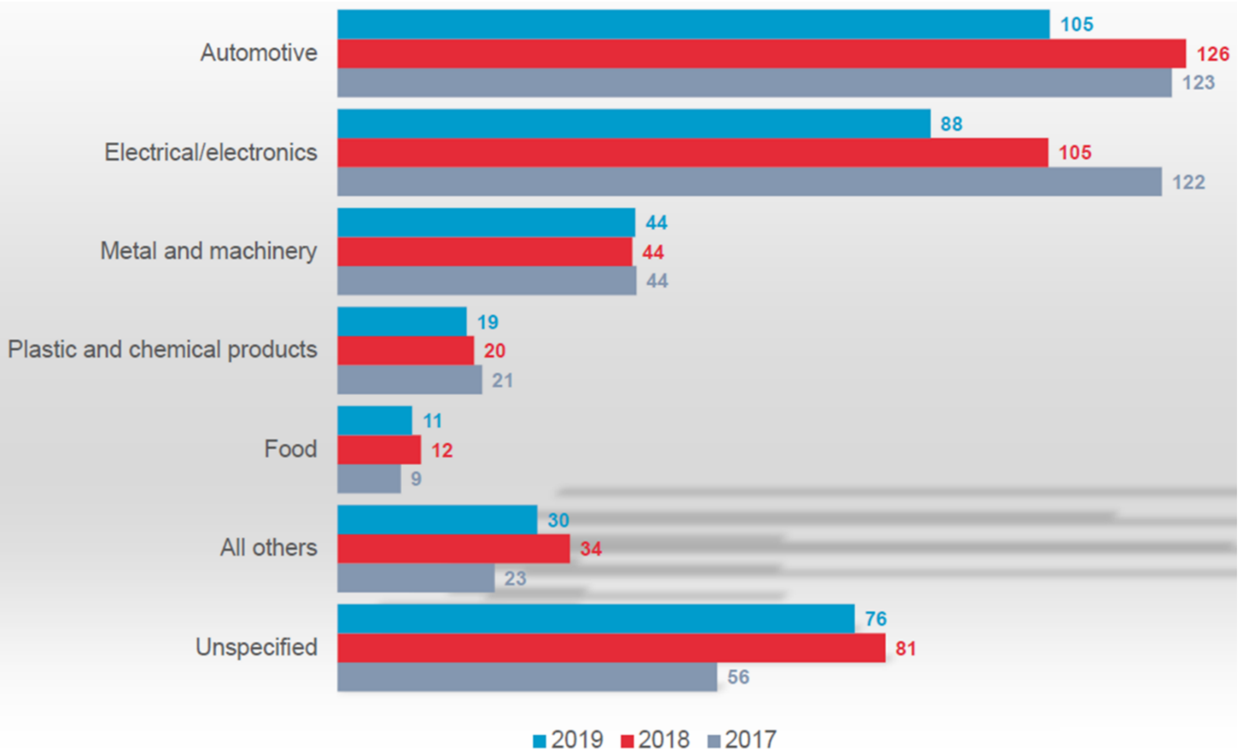
Figure 1: European robot stock in the food and drink industry (in 2017, in %)[8]

Source: FoodDrinkEurope, 2020

[2] Bader and Rahimifard. (2018).
[3] Based on current exchange rate February 2021, 1 EUR = 1.2091 USD. https://ec.europa.eu/info/funding-tenders/how-eu-funding-works/information-contractors-and-beneficiaries/exchange-rate-inforeuro_en
[4] Zion Market Research. (2020).
[5] Zion Market Research. (2020).
[6] International Federation of Robotics. (2020).
[7] Research and Markets. (2017).
[8] As of 1 February 2021, the UK is not part of the EU anymore.

Despite their apparent potential, up to now the uptake of industrial robots in food processing has been slow compared to other manufacturing technologies. According to the International Federation of Robotics[9], food and beverages only accounted for some 3 % of the global robot installations in the past as Figure 2 illustrates. What is more, robots used in food processing have typically not been developed for that purpose but have come as spillover from other application areas. Consequently available robot types are adapted to the requirements of the respective food processing step, e.g. impeccable hygiene and cleanability if raw foodstuff is to be processed.

Figure 2: Annual global industrial robot installations by customer industry (in 1 000 units)



Source: International Federation of Robotics, 2020

Alongside a range of socio-economic barriers (e.g. small margin of foodstuffs, small size of food firms), technical reasons for this slowness are stringent hygiene requirements and the physical specifics of foodstuffs which are listed in Table 2. As context conditions are more conducive regarding food logistics, e.g. handled materials typically have a regular shape and/or are rigid and sealed, robotisation in the food sector has chiefly focused on packing and palletising so far[10]. Conversely, although advantageous in handling applications, classic robots can neither cool nor cook foodstuffs in a continuous process like other types of (automated) machinery does. This may be one of the reasons why there is little use of food robots in the primary step of food production where raw inputs are being processed. Therefore, one should note that robotisation is no panacea applicable to all steps of food processing per se.

[9] International Federation of Robotics. (2020).
[10] Bader and Rahimifard. (2018).

Table 2: Characteristics of different foodstuffs and the challenge they pose to automation

Foodstuff characteristics	Effects on automation	Example
Naturally soft or fragile	Loss of grip probable, likely damaged under pressure	Tomatoes, berries, figs, cheeses, eggs
Slippery surfaces	Loss of grip by slippage	Cut-up fruits, peeled vegetables, meat and poultry
Non-rigid or semi-rigid	Likely damaged under pressure	Apricots, cheeses, pastries, meat and poultry
Irregular shapes and sizes	Likely affects surface grip	All-natural foodstuffs are irregular in shapes and sizes
Uneven surfaces	Systems will require visual systems for industrial robots to assess each individual item and use decision making to handle it	Avocados, meat and poultry

Source: Bader and Rahimifard, 2018, 2020

1.2. Objectives of this report

As the food industry faces an array of challenges such as changing diets, climate change, resource depletion, demographics and globalisation, food robotics could help mastering some of those, e.g. by increasing production efficiency, allowing for flexible changes in products or by assisting an ageing work force.

This report therefore aims to provide an overview of relevant stakeholders with an analytical and empirical base to see how AT based products can help EU industry to stay ahead of global competition. The objective is to map the EU food robotics industry and its interactions in the value chain, as well as to identify its strengths and weaknesses. Analyses are based on desk-research, the internal expertise of Fraunhofer ISI and on expert interviews.

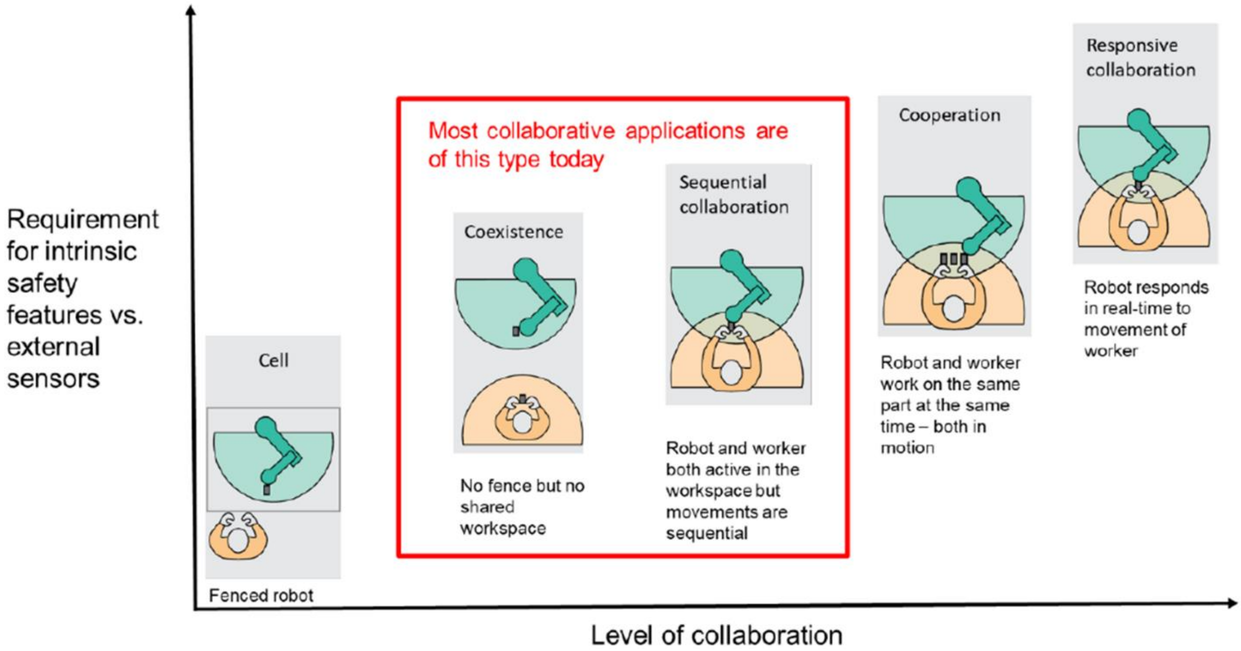
Section 2

2. Value chain analysis

The following chapter explores the value chain of food robotics including the key actors and the current state of play of cross-chain linkages.

Food robots are industrial robots which are used for food processing activities like sorting, handling and packing. They may either work without immediate human presence or alongside human workers with varying degrees of human-robot cooperation. Robots characterised by an advanced degree of collaboration capabilities are sometimes referred to as 'cobots'. Cobots typically feature a variety of characteristics that shall prevent human co-workers from being harmed in case of (involuntary) contact such as rounded contours, padding (with embedded sensors), lightweight materials, and force and speed sensors[11]. The International Federation for Robotics distinguishes five types of human-robot collaboration, which are depicted in Figure 3.

Figure 3: Types of human-industrial robot collaboration



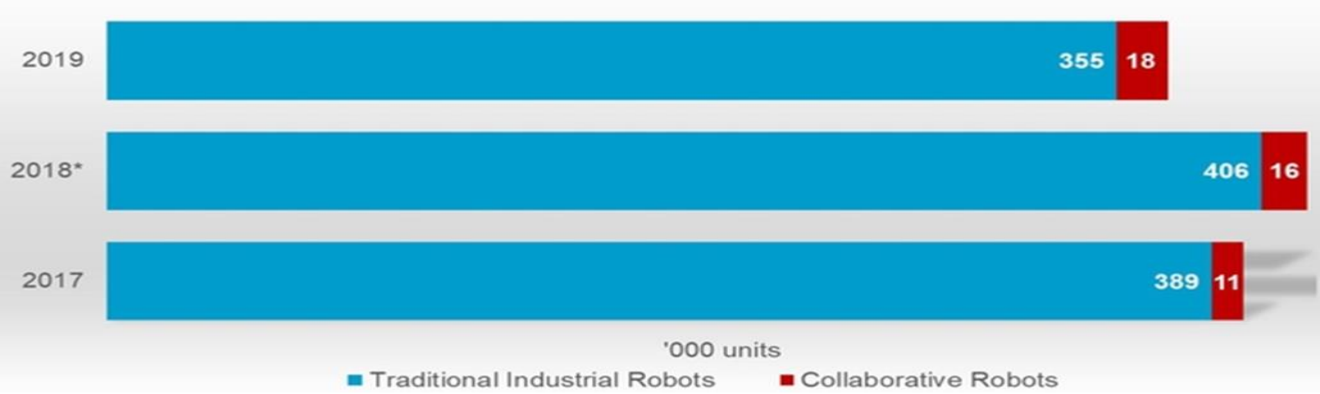
Source: International Federation of Robotics, 2018

Despite advantages like reduced floor-space requirements or the better dovetailing of human and robotic work steps, cobots come with a set of limitations such as low payloads, slower work speed or necessary ex-ante reconfiguration. What is more, applications which involve a high degree of timed human-robot cooperation are technically challenging still.

As Figure 4 implies, the general market for cobots currently remains in a nascent state. What is more, out of the installed capacity declared as cobots in this figure, up to 80% could also be classified as advanced industrial robots according to the continuum laid-out in Figure 3. Nevertheless, the range of cobot applications has increased and more and more companies start to supply them. Moreover, in contrast to the decreasing overall installation trend for traditional industrial robots in 2019, cobots have shown dynamic development.

[11] International Federation of Robotics. (2018).

Figure 4: Traditional industrial robots and cobots



**: revised*

Source: International Federation of Robotics, 2020

Theoretically, cobots can be used in different steps of the food supply chain in industrial and service settings such as food packaging and labelling[12], quality inspections, the spraying of bread rolls[13] or even to cook noodles and other dishes or serve food as service robots[14]. However, the added value of doing so seems questionable as traditional industrial robots remain preferable in cases where speed and absolute precision are key - and thus for the majority of procedures in food processing. In contrast, employing cobots makes particularly sense in cases where the freed up human workforce can concentrate on more fruitful activities that require sensory excellence.

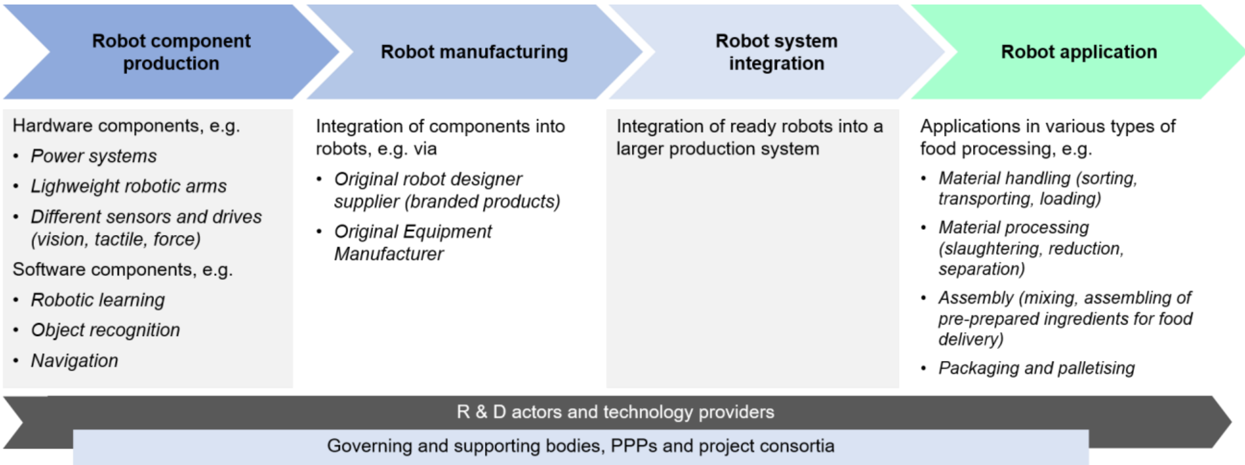
2.1 Value chain structure

Although robots enjoy widespread use in some sectors, particularly in the automotive and the electronics industry, the overall robot market is not yet fully developed[15]. As lined out above, cobots in particular remain a somewhat rare phenomenon. What is more, the industrial robot sector is quite complex in terms of potentially-eligible machine types as well as in size, technology and application areas of robots.

Given that robots that are used in food processing have typically originally not been developed for this application, Figure 5 depicts the generic robotics value chain, which comprises four core steps: robot component production, robot manufacturing, robot system integration and robot application. Depending on the specific robot type and application, different aspects of the chain are more or less important. For instance, for mobile service robots that transport specific goods within a specific building, IT (infrastructure) is much more important than for fixed and fenced robots in sorting applications. At the same token, the same robot company may act at different levels of the value chain, as becomes clear by the following chapter.

[12] Asia Pacific Food Industry. (2017).
[13] Universal Robots. (2016b).
[14] Ang. (2016).
Bruch. (2020).
Weiner. A. (2017). Taking Varying Paths As Food Robots Reach Viability. https://thespoon.tech/robot-or-cobot-companies-taking-varying-paths-as-food-robots-reach-viability/
[15] SPARC. (2013 & 2014).

Figure 5: Generic food robotics value chain



Adapted from: Forge and Blackman, 2010

Robot component production. The value chain starts with the production of individual components. These can be the hardware parts that make up a robot's physical set-up and functioning such as robotic arms, grips, power supply systems or sensors (e.g. vision). The other essential component type is software as it enables a robot to act and interact with its environment, e.g. by recognising objects, navigating through obstacles or by improving via 'learning'.

Robot manufacturing. In a second step, (pre-fabricated) robot components are assembled into robots. This can be done by Original Equipment Manufacturers which sell robots as white-label products or by producers that sell branded robots. Some manufacturers also engage in hardware production and system integration as well. Moreover, robot manufacturers are asked today to not only provide hardware but also to provide design features, software and applications in their products.

Robot System integration. In the third step of the chain, robots are integrated into the respective production system. Manufacturing and process industries in particular tend to require customised robots instead of finished stand-alone products. Depending on the case, integration can become more costly than the robot component, e.g. new buildings may need to be constructed that comply with a robot's requirements such as clean production rooms, strengthened floors or less air conditioning[16]. Conversely, integration may be less important in the case of cobots, which are typically easily programmable and flexible in terms of application.

2.2 Key actors in the value chain

As becomes clear from the previous chapter, the food robotics value chain comprises an array of different actors and services. Consequently, the main value creation does not necessarily need to be created via the provision of a robot itself. Robots accounted for 30 %, accessories (e.g. grippers, vision systems) for about 25 % and services (e.g. auxiliary hardware, software, installation) for about 45 % of the €39.7 bn[17] robot systems market value in 2017[18]. The supply chain for a robot is, at least for larger robot manufacturers, rather global, depending on the component, and usually each item is sourced by several suppliers.

In this section, major European and non-European actors are highlighted for each chain step in non-exhaustive lists. Some companies like Japanese Fanuc, Swedish-Swiss ABB or German KUKA are somewhat vertically integrated as they operate in several steps of the chain. Moreover, it should be kept in mind that companies other than integrators typically do not focus on food robotics as their prime market.

Robot component production. Some suppliers of robotic components provide standard hardware parts, i.e. components used in many applications like motors, batteries or actuators and some supply specialty components. Software components comprise a variety of different applications such as

[16] Forge and Blackman. (2010).
[17] Based on current exchange rate February 2021, 1 EUR = 1.2091 USD. https://ec.europa.eu/info/funding-tenders/how-eu-funding-works/information-contractors-and-beneficiaries/exchange-rate-inforeuro_en
[18] McKinsey & Company. (2019).

recognition, simulation and predictive maintenance. Table 3 provides a non-exhaustive list of robot component providers.

Table 3: Robot component manufacturers

Company	Headquarters	Related products	Website
ABB	Sweden Switzerland	Software	https://global.abb/group/en
Energid Technologies	United States of America	Software	https://www.energid.com/
Faulhaber	Germany	Hardware	https://www.faulhaber.com
Furhat Robotics	Sweden	Software	https://furhatrobotics.com/
H2O.ai	United States of America	Software	https://www.h2o.ai/
Neurala	United States of America	Software	https://www.neurala.com/
NVIDIA	United States of America	Hardware Software	https://developer.nvidia.com/
Pilz	Germany	Machine safety services Packaging robotic hardware	https://www.pilz.com/
Sick	Germany	Sensor technology for food and beverage production Sensors for cobots Packaging robotics	https://www.sick.com/de/de/

Source: Forge and Blackman, 2010; Markets and Markets, 2018; Mordor Intelligence, 2020. Verified Market Research, 2019

Robot manufacturing. Component integration can be done by Original Equipment Manufacturers who manufacture white label robots or by companies which design and supply branded products. Table 4 provides a non-exhaustive list of robot manufacturers.

Table 4: Robot manufacturers

Company	Headquarters	Related exemplary products	Website
ABB	Switzerland	Robotics for food picking, processing, palletising, packaging	https://global.abb/group/en
Autonox	Germany	Robotics of processing and packing foodstuffs	https://en.autonox24.com/
Bastian Solutions	United States of America	Robotics for food picking, processing, palletising, packaging	https://www.bastiansolutions.com/
Comau	Italy	Industry 4.0-enabled systems, machining for electric vehicles, robotised manufacturing systems	https://www.comau.com/en
Fanuc	Japan	Robotics, motorics, laser	https://www.fanuc.co.jp/eindex.html

Company	Headquarters	Related exemplary products	Website
Kawasaki Robotics	Japan	Robotics for food packaging, sterilising, picking	https://global.kawasaki.com/
KUKA	Germany	Robotics for food processing, palletising	https://www.kuka.com/de-de
Mayekawa	Japan	Robotics for deboning in meat processing	https://www.mayekawa.com/
Mitsubishi Electric	Japan	Food and beverage factory automation	https://www.mitsubishielectric.com/en/index.html
Rockwell Automation	United States of America	Process control systems, automation of bakery, brewing	https://www.rockwellautomation.com/de-de.html
Schubert	Germany	Food packaging systems	https://www.schubert.group/en/
Stäubli	Switzerland	Robotics for protein processing, baked goods, pastries	https://www.staubli.com/en-de/
Universal Robotics	Denmark	Cobots for packaging, machine tending	https://www.universal-robots.com/
Yaskawa Electric	Japan	Robots for food processing, picking, packaging, palletising	https://www.yaskawa.eu.com/

Source: Allied Market Research, 2017; Forge and Blackman, 2010; Grand View Research, 2017; Markets and Markets, 2020b; Research and Markets, 2017; Interviews

Cobots. Whereas a decade ago, there were rather few cobot suppliers, nowadays many large manufacturers of industrial robots have entered the cobot market. Table 5 provides a non-exhaustive list of cobot manufacturers.

Table 5: Cobot manufacturers

Company	Headquarters	Website
ABB	Sweden Switzerland	https://new.abb.com/
AUBO Robotics	United States of America	https://aubo-robotics.com/
Bosch[19]	Germany	https://www.bosch.com
Denso Robotics	Japan	https://www.densorobotics-europe.com/
Fanuc	Japan	https://www.fanuc.co.jp/eindex.html
KUKA	Germany	https://www.kuka.com/de-de
Precise Automation	United States of America	http://preciseautomation.com/
Rethink Robotics[20]	United States of America	https://www.rethinkrobotics.com/de/
Techman Robot	Taiwan	https://www.tm-robot.com/en/
Universal Robots	Denmark	https://www.universal-robots.com/
Yaskawa Electric	Japan	https://www.yaskawa.eu.com/

Source: Fortune Business Insights, 2019; Grand View Research, 2019; Markets and Markets, 2020a

[19] Based on KUKA technology.

[20] Acquired by German Hahn Group in 2018.

Robot System integration. Modern industrial robots are extremely versatile in terms of applications. Nonetheless, due to this versatility, tailoring and orchestrating an array of robots with respect to a specific production line requires expert knowledge, which typically lies with system integration companies. Moreover, as stated above, manufacturing and process industries tend to require customised robots instead of finished stand-alone products. Therefore, system integrators may play a major role in the food robotics value chain. Table 6 provides a non-exhaustive list of relevant system integration companies.

Table 6: Robot system integrators

Company	Headquarters	Website
ABB	Sweden Switzerland	https://new.abb.com/
Bastian Solutions	United States of America	https://www.bastiansolutions.com/
Bosch Rexroth	Germany	https://www.boschrexroth.com/en/xc/
Dynamic Automation & Robotics	United States of America	https://dynamicautomation.com/
Epic Systems	United States of America	https://www.epicsysinc.com/
Geku Automation	Germany	https://www.geku.de/
Genesis Systems	United States of America	https://www.genesis-systems.com/
JLS Automation	United States of America	https://www.jlsautomation.com/
KUKA	Germany	https://www.kuka.com/
Midwest Engineered Systems	United States of America	https://www.mwes.com/
Motion Controls Robotics	United States of America	https://motioncontrolsrobotics.com/
Motoman Robotics[21]	United States of America	
Phoenix Control Systems	United Kingdom	http://www.phoenixcontrol.co.uk/
Robot Worx	United States of America	https://www.robots.com/
SIERT	China	http://www.siert.net/
Simplimatic automation	United States of America	https://simplimatic.com/
Stelram	United Kingdom	http://www.stelram.co.uk/
Yaskawa Electric	Japan	https://www.yaskawa.eu.com/

Source: Adroit Market Research, 2019; Industry Research, 2020; Infinium Global Research, 2019; Research and Markets, 2019, 2020

Support actors. Under its Framework Programme 7, the EU funded about 130 robotics-based projects, which gathered some 500 organisations with roughly €536 m. Moreover, other robotics-related funding opportunities added another €170 m. In the subsequent programme, Horizon 2020, about €700 m were earmarked for robotics research and innovation. Moreover, the projects funded under Horizon 2020 cover a wide array of topics, including agro-food. The robotics work programmes under Horizon 2020 were closely linked to the public private partnership (PPP) SPARC, between the European Commission and the robotics stakeholder association euRobotics. SPARC aims to "facilitate the growth and empowerment of the robotics industry and value chain, from research through to production". SPARC gathers over 250 member organisations from research and industry as well as a budget of €2.8 bn.

[21] Merged with Yaskawa.

Another EU PPP is Factories of the Future, which is between the European Commission and the European Factories of the Future Research Association and which disposes of a budget of €1.15 bn[22]. It supports research on several priorities along the following domains:

- Advanced manufacturing processes
- Adaptive and smart manufacturing systems
- Digital, virtual and resource-efficient factories
- Collaborative and mobile enterprises
- Human-centred manufacturing
- Customer-focused manufacturing

In addition, there has also been support on the national level. For instance, the German government provided about €50 m between 2016 and 2021 to robotics research, whereas Sweden earmarked about €24.8 m[23].

2.3 Linkages along the value chain

Overall, there is evidence for intra-value-chain linkages. To start with, some companies are vertically integrated. That is, as becomes obvious from the above-presented tables, they cover various steps of the robotic value chain like component and system integration. Some companies may even produce specific components such as software themselves. In so doing, they link the different steps of the value chain. Particular cooperation takes place between robot manufacturers and robot system integrators, which are typically smaller companies compared to robot producers[24]. Indeed, some system integrators even state on their website that they are an authorised system integrator of a specific manufacturer. Depending on the specific case, system integrators may constitute a significant sale channel for robot manufacturers.

[22] EFFRA (European Factories of the Future Research Association).
[23] Based on current exchange rate February 2021, 1 EUR = 1.2091 USD. https://ec.europa.eu/info/funding-tenders/how-eu-funding-works/information-contractors-and-beneficiaries/exchange-rate-inforeuro_en
[24] SPARC. (2016).

Section 3

3. Analysis of EU competitive positioning

Since food robots form part of the portfolio of robotics provides, Figure 6 provides an overview of the key strengths, opportunities, challenges and risks for the industrial robotics chain value chain, with an emphasis on food and cobots where possible.

Figure 6: Strengths, opportunities, challenges and risks for the (food) robotics value chain

• Strong technological competences • Strong robotics industry • Important agro-food sector	**Strengths**	**Challenges**	• International competition • Consumer reality-perception dissonance • Rather weak business case for food robotics • Company/societal technophobia
• Technological progress enables more versatile and cheaper robots • Food as emerging target sector for robotics • Demand for automation in the food sector	**Oppor-tunities**	**Risks**	• Lacking standardisation and interoperability • Insufficient know-how availability • Unawareness and lacking competencies of SMEs • Limited potential for cobots in the food sector

Source: Fraunhofer ISI

3.1 Strengths

Strong technological competences. Europe features an array of renowned academic and research organisations, a strong research base as well as ample possibilities for technology transfer. According to SPARC, particular European strengths are variety of technologies like:

- cobots and ambient intelligence
- speech and haptics-based human-machine interface
- safety
- actuation (without gears), grippers and dextrous hands
- locomotion (without bipedal locomotion)
- materials science and engineering
- navigation and collision avoidance
- motion and task planning
- control of arms and vehicles
- learning
- modelling for control (kinematics and dynamics)
- biomimetics and bionics
- cybernetics[25]

Strong robotic industry. Robotics contribute to the success of many European large scale manufacturing industries. Moreover, European food manufacturers account for almost 50 % of the global food robot stock, with Germany and Italy having the largest share of robots among EU Member States[26]. Moreover, non-exhaustive actor lists under chapter 2.2 indicates that the EU is home to a range of leading robotics companies in all steps of the value chain. What is more, the EU features an especially-potent network of system integrators, which could help tapping into the potential food robotics market. Moreover, the process knowledge within the robotics sector is high, e.g. thanks to profound training and education systems.

Important agro-food sector. With a turnover of about €1.2 trillion and providing jobs for about 4.8 million people, the food sector constitutes the EU's largest manufacturing sector and a leading

[25] SPARC. (n.d.).
[26] ING Economics Department. (2019).

employer[27]. What is more, the EU is home to renowned multinational food companies such as French Danone, Belgian Anheuser-Busch InBev, Dutch-British Unilever, Italian Ferrero or Danish Arla Foods. In addition, there is a myriad of small to medium companies. Thus, there may be a significant domestic market for food robotics. There are many areas such as the sorting of chicken eggs or the slaughtering of animal, where the increased use of robotics could address societal demands like increased animal welfare.

3.2 Opportunities

Technological progress enables more versatile and cheaper robots. Since 1990 average robotics cost have declined by about 50 % and pricing could continue to improve in the future. At the same time, the variety among robot models has been increasing e.g. in terms of payload, precision, safety and mobility. Likewise, the advent of technologies like image recognition has opened up new application opportunities like the handling of delicate and diverse products. Moreover, the assembling, installing and maintaining of robots has become faster and cheaper thanks to improvements in relevant areas like computing power, software development and networking technologies.

Food and pharma emerging target sector for robotics. In the light of the uncertain future development of the automotive sector, which constitutes a prime market for industrial robotics, value chain actors may identify food processing as promising sales markets. This might lead them to better tailor their offer towards the needs of the myriad of SMEs that operate in the food sector. Moreover, in contrast to incumbent companies, emerging start-ups may directly address the food sector. Already today, there are about 30 000 robots in the EU food and drink industry, with robot sales having increased by 52 % between 2013 and 2017. If consumer demand for safe and sustainably sourced foods rises, food manufacturers need to supply greater amounts of produce at a high and consistent product quality. Thanks to their potential to efficiently process a large throughput at high quality, robots may profit from this demand. In addition, high synergies for robotics may be realised with the pharma industry, which poses rather similar and even more stricter quality demands for the robotics industry. Hence, the robots are rather similar for these different application areas and this increases the market for certain types of robots.

Demand for automation in the food sector. Robots become mainstream and the food and drink industry seems to be aware of the opportunities that lie with robotisation and automation. More and more food manufacturers may seek to increase the productivity and efficiency of their plants as the food sector is often price-driven. Likewise, some jobs in the food industry like in slaughtering must be considered unattractive due to the job profile as well as generally-low wages. Finally, societal demands towards the food sector rise, e.g. not to waste valuable foodstuffs and resources. As robotisation promises efficiency gains in various respects, developments as the former may lead food manufacturers to consider the increased use of robotics.

3.3 Risks

Lacking standardisation and interoperability. So far, there is limited standardisation and clear certification rules on the food robot markets. While there are many single rules or guiding lines for single components or parts, more integrated certification solutions are missing. There are initiatives to implement 'Best manufacturing practices', following the established 'Good Manufacturing Processes' standards in the pharmaceutical industry, however these activities are still in progress.

Missing standardisation and certification drives cost and decreases interoperability, e.g. as a robot line cannot be adapted to manufacture multiple product types. For instance a universal platform for robotics, a common programming platform or interfaces are still lacking. It seems reasonable to assume that this situation may hamper the uptake of robots by potential customers.

Insufficient know-how availability. Although more skilled labour is expected to be available in the future, employees with relevant robotic know-how could turn into a limiting factor for robotisation. Already today the necessary skills to install and operate robots tend to be scarce. In the light of an expected general increase in automation efforts, the lack of relevant know-how could even become more pronounced.

Unawareness and lacking competencies of SMEs. While today in particular the large food firms are important customers for food robotics, a significant part of the potential market is represented by SMEs. But in the past, robotisation was only of limited interest to SMEs, especially due to the high costs of robots and the comparatively limited and static application possibilities. Although this may change

[27] FoodDrinkEurope. (2020).

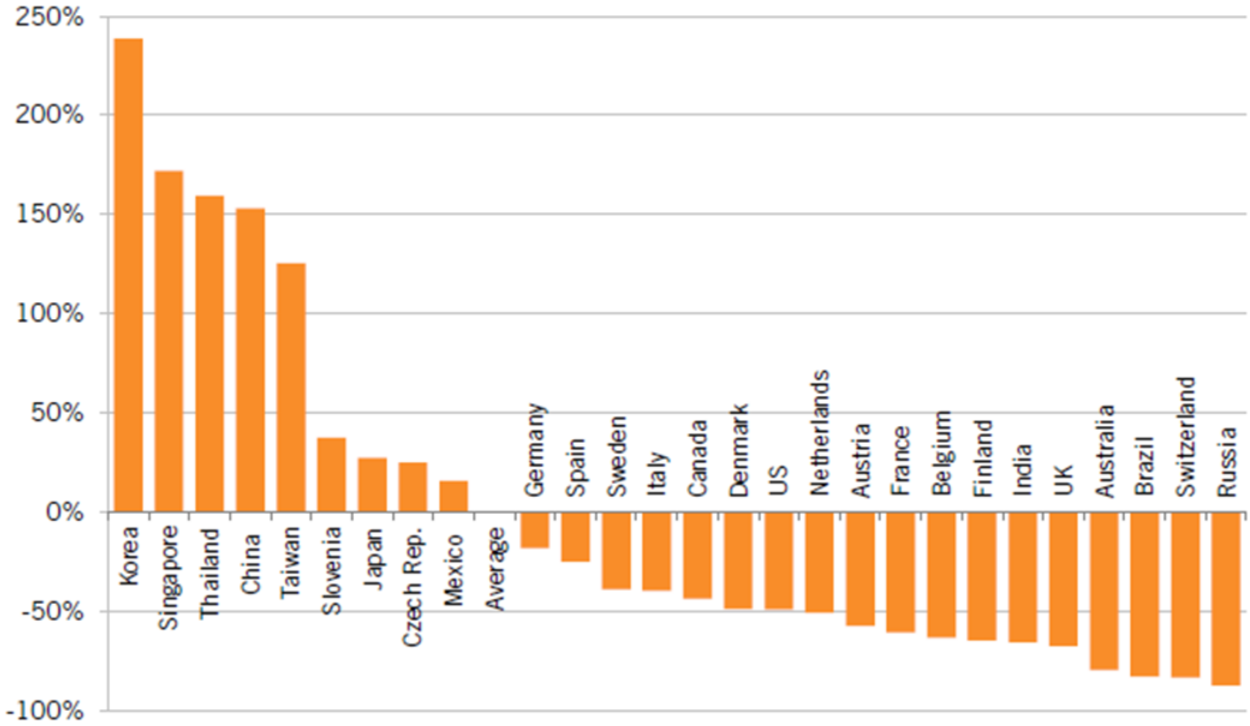
thanks to technological progress, SMEs may fail to notice it and thus miss novel opportunities to adopt food robotics. Moreover, effective robotisation requires a set of specific skills, which constitute a rare resource. Hence, especially SMEs, may face difficulties to find suitable workforce to handle robotics at acceptable wages. In particular, there is hardly specific education for food automation specialists. What is more, (perceived) high robotics costs, the scarcity of skilled workforce and a negative workforce-related perception of robotics are bigger adoption barriers for smaller than for larger companies.

Limited potential for cobots in the food sector. Modern food production constitutes a continuous process which requires high accuracy at high rates. Conversely, current cobot versions tend to be slower in their work than traditional industrial robots and feature lower payloads. Although their application range has increased in the past, their current potential regarding food sector applications remains limited, with highest potential in packaging and palletising.

3.4 Challenges

International competition. Robotics constitutes a competitive global market and the United States as well as Asia harbour a number of major players. What is more, Asia Pacific constitutes a fast growing market for food robotics, which provides domestic companies with a significant potential market base. For instance, in 2019, the share of newly installed industrial robots amounted to about 75 % of global supply[28]. Moreover, whereas the EU Framework Programme Horizon 2020 earmarked about €700 m for robotics-related projects over the period 2013-2020, China and Japan invested around €477.2 m[29] and €299.5 m[30] respectively in 2019 alone. Given the comparison between expected robot adoption rates as shown in Figure 7, EU Member States lag behind Asia Pacific.

Figure 7: Actual robot adoption rates as a share of expected robot adoption rate



Source: Atkinson, 2019

Consequently, if EU players do not manage to seize the opportunities that go along with this development, Europe may find it hard to defend a leading position. The more so, as notable parts of the robotics supply chain such as hardware component production have been outsourced to China in the past, which leaves the European robotics chain somewhat dependent. However, a big challenge for

[28] International Federation of Robotics. (2020).
[29] Based on current exchange rate February 2021, 1 EUR = 1.2091 USD. https://ec.europa.eu/info/funding-tenders/how-eu-funding-works/information-contractors-and-beneficiaries/exchange-rate-inforeuro_en
[30] Based on current exchange rate February 2021, 1 EUR = 126.2 JPY. https://ec.europa.eu/info/funding-tenders/how-eu-funding-works/information-contractors-and-beneficiaries/exchange-rate-inforeuro_en

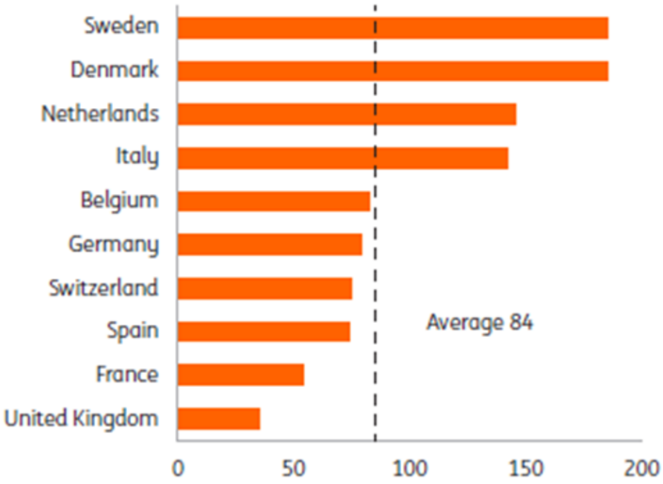
European actors is that the Asian markets are rather distinctive regarding needs and price sensitivity for food robotics than other markets.

Consumer reality-perception dissonance. The food sector does not seem to put much emphasis on communicating its technology use in food production. At the same time, at least in some countries, like Germany, people tend to cherish a nostalgic idea of food production. This situation may be risky, e.g. in that consumers may feel cheated on by the food sector if the question of food technology becomes publicly prominent.

Company/societal technophobia. Some members of society may fear to become substituted by robots. For example, although a 2017 Eurobarometer survey found a majority of Europeans to judge robots as something positive, about 70 % voiced the concern that "Robots steal peoples' jobs". These fears may translate into public pressure against further automation and robotics. Likewise some consumers may fear food to become less safe as a result of robotisation. Fuelled by public and social media hype cycles, companies willing to drive robotics might eventually give in or relocate.

Rather weak business case for food robotics. So far, robotic companies were less interested in SMEs as consumers, especially as they can pay less than large costumers and nonetheless require company specific solutions. However, about 99 % of food and drink companies are SMEs. What is more, in contrast to other industries, the food sector features costly additional technical requirements e.g. in terms of hygiene and food grade quality materials. Moreover, many foodstuffs are rather nation-specific which reduces the overall market size. Additionally, robotisation is assumed to provide larger benefit for nations, where wages are high so that robot amortisation rates are fast, which the higher rates of robot density in high-wage EU countries seem to corroborate (Figure 8).

Figure 8: Robot stock in the food and beverage industry per 10 000 employees



Source: ING Economics Department, 2019

In an overall level, for the very same reason the food sector with its partially low wages could remain of limited interest as a business case.

Section 4

4. Conclusion & Outlook

4.1 Conclusion

So far, the uptake of industrial robots in food processing has been slow compared to other manufacturing technologies, with the unique characteristics of the foodstuff and the food industry's limited access to relevant know how being important hurdles. Cobots have enjoyed even less adoption so far, which yet also applies to other sectors alike.

Nevertheless, Europe features a strong knowledge base and industrial infrastructure, which it can lever to further innovation. Moreover, it holds a leading position in a number of key technologies and markets and is home to a variety of notable players.

Various trends may facilitate a wider deployment of food robotics, like:

- Ongoing technological progress, which facilitates the integration of robots into a diverse range of work processes
- The general trend for sustainability, which could be addressed by efficient robotised production processes
- The awareness of food companies for the potential of robotics
- The need of robot manufacturers to capture new markets such as food processing

However, it seems advisable to keep in mind the specifics of the food sector, notably that it is populated by SMEs. In general, the robotisation of SMEs is expected to play a significant role for Europe's manufacturing and employment capacity. Nonetheless, whereas large manufacturing companies like car original equipment manufacturers are experienced in the application of robotics, there is still room in smaller scale and SME manufacturing. Yet, it may prove particularly challenging to automate small food sector companies for various reasons such as their lack of funds, lack of skilled staff, and thus lacking awareness of potential benefits. In addition, the specifics of certain foodstuffs combined with high requirements, e.g. in terms of hygiene, lowers the interest in food robotics as business case, especially for large incumbent robot manufacturers.

In line with the above paragraph, it has to be acknowledged that the increased use of robots and other automation technology is not an end in itself. That is to say that robotisation is likely to have different degrees of impact and benefit in different contexts. For instance, at least at the current state, cobots seem to bring little advantages for standard food processing operations. Although they allow for flexibility, require less floor-space and enable for a better dovetailing of human and robotic work, they still have drawbacks like lower speed. As food production is mostly a high-throughput continuous process, which requires accuracy at high speeds, the potential of cobots seems thus questionable. However, also industrial robots may be less advantageous in some contexts, for example in applications where wages are low or in continuous preparation processes such as cooking or freezing.

Finally, another key point is to adequately engage with employees and society. Some people may hold specific fears regarding the use of robotics and see robots as "Terminator-like machines destroying jobs"[31]. Although expert expectations with regard to such fears seem mixed or speculative, especially for higher degrees of robotic advancement, they should be taken seriously. If the robotics sector does not manage to credibly tend to prevalent socio-economic fears or feelings of uneasiness, the latter may lead to public backlash. What is more, people tend to be particularly sensitive when it comes to the use of technology in food production, holding inaccurate notions of how foodstuffs are being produced nowadays. This seems to increase the necessity for the robotics and the food sector to invest in trust and help reduce fears. One potential entry could be to demonstrate the benefits of robots to society.

[31] Atkinson, R. (2019).

4.2 Outlook

So far food processing has not been in the focus of robotics companies. Moreover, the adoption of robots has remained rather low in the food sector. In addition, robotisation has mainly taken place in packaging and palletising as opposed to start-of-line steps. However, technological progress together and with socio-economic trends may facilitate wider robot adoption in the future.

In general the EU robotics value chain seems well-equipped to enter further markets such as food processing. In order to exploit the dynamic landscape, Europe should:

- Develop progressive technology, ahead of the wave
- Exploit emergent robotics markets
- Engage and embrace disruptive robotics technologies and systems which redefine the economics of applications
- Instil increasing awareness in society of the potential for robotic systems[32]

Nevertheless, global competition is rising, especially from Asia which features notable government support and funding. In addition, significant activities in the upstream part of the value chain like hardware component production have been outsourced to China, which leaves Europe somewhat dependent on foreign supply. Likewise China features a dedicated robotisation policy. In addition to that, European robotics actors must credibly engage with society in order to find an agreement on how to combine the economic necessity of robotisation with wider societal wishes. Key policy issues for the food robotic industry relates to standardisation, guidelines and certifications. One issue raised by stakeholders is whether specific directive for food machinery may be needed, while until now it is subject to the overall Machinery Directive[33], which addresses some issues related to food.

4.3 Covid-19 – impact on food robotics

The impact of the Covid-19 pandemic on the European robotics sector at large seems blurry. On the one hand, the automotive sector which had already been a subject to transition prior to the pandemic outbreak, could demand less robotisation in the future. As the former constitutes one of the main demand sources for robotics, such developments may prove problematic for the robotics value chain. However, on the upside, the pandemic has stimulated growth in some of the supplied sectors such as pharmaceuticals, logistics or packaging. And the food sector grew considerably as well.

What is more, regarding the food sector Covid-19 had a particularly publicly visible impact on meat production, which might translate into future considerations about how to protect employee health by robotisation. Therefore, albeit possible turbulences in the short and middle run, the European (food) robotics value chain might essentially benefit from Covid-19 in the long run, especially if robotics manufacturers manage to increasingly orient towards supplying SMEs, of which the food sector is full of. Nonetheless, the full impacts of Covid-19 are not foreseeable yet.

[32] SPARC. (2013 & 2014).

[33] Machinery Directive 2006/42/ EC, https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2006:157:0024:0086:EN:PDF

Section 5

5. Annexes

5.1 List of interviewees

Interviewee	Position
Michael Fraede	Managing Director, robotics.consulting
Roland Ritter	Product Manager, Kuka
Dieter Rothenfusser	Portfolio Manager, Kuka
Helmut Schmid	Chairman, German robotics association
Andreas Wolf	Managing Director, robomotion

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The EU's industrial policy strategy promotes the creation of a competitive European industry. In order to properly support the implementation of policies and initiatives, a systematic monitoring of technological trends and reliable, up-to-date data on advanced technologies is needed. To this end, the *Advanced Technologies for Industry* (ATI) project has been set up. It provides policymakers, industry representatives and academia with:

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- Analytical reports such as on technological trends, sectoral insights and products;
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