Deliverable 1.1

Market Segmentation for CPS Technology

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1 Glossary

Platform – Unless otherwise stated in the context of Platforms4CPS this is a hub for the integration or distribution of technology. It should have measures in place for persistence and support.

CPS – A Cyber-Physical System has the goal of modifying and interaction with the real world. It represents the control processes in digital space that affect the physical environment through actuators, particularly in an industrial context. There is an emphasis on aggregate or decentralised systems of systems. When two CPSs are interconnected, the one with higher coordination capability subsumes the other and they become one CPS.

IIoT - Industrial internet of things, is the communication means by which physical resources such as sensors, actuators and devices are connected via the internet. This is with respect to an industrial context, where real-time constraints, safety and security usually have a significant role.

Note: ISO-IEC definition of IoT is “An infrastructure of interconnected objects, people, systems and information resources together with intelligent services to allow them to process information of the physical and the virtual world and react.” They have an associated mind-map to encompass a wider understanding.
2 Introduction

Cyber-Physical Systems are involved directly and indirectly in a large part of modern day society. A majority of the products we buy as consumers have been produced by these, our mobility to work, to other towns and countries is facilitated by them, lives are saved by them and they even manage their power sources. These are systems whose goals are to modify the physical environment in ways that are beneficial to us. It distinguishes the critical goal of Cyber-Physical System (CPS) technology from other technology classes. This study has been produced as part of a coordination and support action for the European Commission in the field of Cyber-Physical Systems. It provides a market survey of the technologies across four particularly significant sectors, being Transportation, Manufacturing, Healthcare and Energy.

For a CPS to act on the physical environment requires mechanical devices (actuators) such as motors, wheels or at higher levels complete systems like container ships; to control these actions require processing; to optimise the effects requires sensing of the physical and increasingly digital environments. Communication infrastructure is needed to transmit system information internally and also eternally as required; finally energy sources are required to power these systems. An overview of the elementary building blocks for a CPS is shown in Figure 1.

Making desired changes to the environment is the goal of CPSs with roots lying in embedded systems ranging from electric razors up to aircraft, however through external coordination/cooperation a CPS extends to include examples such as managing transportation of goods and smart cities. This means, as alluded, that actuators can take on more abstract forms, where coordination of systems (like aircraft) achieve higher goals (such as air traffic control). This higher state of CPS is a goal for advancing this technology class. This distinction is important to note here, that in literature CPS can be existing systems, or technology used to achieve a higher state of CPS capability. To achieve the intelligent higher CPS state tight integration is needed at all levels and a call for a new ‘systems science’ [5].

Estimates of the CPS market size are difficult because CPSs are used in so many domains and its definition requires more homogenisation and use across industry. However, as an example, in the rail sector alone products from Europe were estimated at €40 Billion. An IDC report on behalf of the European Commission estimated overall €1.5 trillion in revenue for 2015. Considering R&D investment, an interesting report was produced for the European Commission in 2016, including the top 11 industry sectors with highest investment (Figure 2) and Volkswagen (Germany) being the leading single organisation worldwide. Across these sectors, Cyber-Physical Systems have high visibility, either contributing directly to or being supported by them.
The Internet of Things (IoT) is essentially the drive towards improving communication technology within systems for global connectivity. It is contributing significantly to increasing the capabilities of CPS and many other technology classes such as Big Data and AI. It also plays a role in many areas unrelated to CPS such as business services and purely virtual systems. However, as for CPS, what constitutes IoT remains fragmented with overlap occurring between these two domains. As a result, but also because industrial IoT (IIoT) is one of the biggest enablers for CPS at the moment, it has particular relevance in the upcoming market survey sections.

Predictions of the IoT market size for 2022 vary with Cisco estimating $14.4 trillion and AS Newswire predicting $1.0 trillion. However it is worth noting that the Cisco analysis considered secondary impacts on money saved such as for time-to-market ($3T), improving supply chain and logistics ($2.7T), cost reduction strategies ($2.5T) and increasing employee productivity ($2.5T). About 50% of IoT activity has been indicated to be taking place in manufacturing, transportation, smart cities and consumer markets.

This document presents foremost a market survey, where the current status of CPS technology is divided and considered across the domains of Transportation (in particular automotive, rail, aerospace, maritime and logistics), Manufacturing, Health (Hospital, Home and Fitness) and Energy (focusing on renewables, storage, distribution and efficiency). The final section before the Conclusion begins an action for the CPS Community, considering types of customers for particular technologies. This is what is referred to specifically as Market Segmentation. While many enterprises do this internally for products, it is a new step for such information in the public domain, particularly with CPS technology typically being acquired by businesses than individual consumers. As a last note, cross cutting factors between the four domains will be treated in a later document (Demand side needs for future platforms). This will include aspects such as co-engineering, dependability, sustainability, human factors, scalability and migration from legacy systems.
References

3 Transportation CPS & IIoT Market

3.1 Automotive Market

EU Automotive Market
The EU is among the world’s biggest producers of motor vehicles, and the sector represents one of the largest private investors in research and development (R&D) within Europe. The sector provides jobs for 12 million people and accounts for 4% of the EU’s GDP. Manufacturing accounts for 3 million jobs, sales and maintenance for 4.3 million, and transport for 4.8 million. The automotive industry also has an important multiplier effect in the economy as it generates jobs in upstream industries such as steel, chemicals, and textiles, as well as downstream industries such as ICT, repair, and mobility services.

Traffic Management Market
Traffic management represents a highly complex cyber physical system of systems coming under increasing demands for additional capacity, greater safety, and lower costs while meeting strict environmental regulations. At the same time, the global car fleet is predicted to double from currently 800 million vehicles to over 1.6 billion vehicles by 2030. Without integration of information and flow control systems, severe congestion will be a major concern for mobility with long commutes and dramatic implications for road haulage of freight, leading to logistical problems of late deliveries within highly complex scheduled systems.

Markets and Markets predicts that the global traffic management market is expected to grow from USD 4.12 Billion in 2015 to USD 17.64 Billion by 2020, at a Compound Annual Growth Rate (CAGR) of 33.8%. This is being driven by environmental concerns, rapid urbanisation and population explosion, and also by the demand for real-time information. The opportunities are in the management of both traffic and pedestrians considering LED signals, traffic light controllers, CCTV, loop detection and automatic number plate recognition systems. There is also a growing market in car parking and toll management. The car detection market is gaining high traction due to the increasing need for countries and cities to understand traffic management issues. Moreover, the increasing demand for real-time information both from traffic controllers and from users is increasing demand for introduction of new solutions and services.
Car-to-Car and Car-to-Infrastructure Communications Market for Traffic Management

Embedded intelligence, mobile phone, car-to-car and car-to-infrastructure communication technologies are offering the opportunity for increased awareness, more efficient mobility, and automated driver safety systems. The industry has been working for 10-15 years already on car-to-infrastructure and car-to-car communications. The technology, which is quite mature, is expected to enhance safety and efficiency and to reduce emissions via enabling a better traffic flow. Even if only a few cars are equipped with the technology in an incremental roll-out, e.g. 2-3%, their modified behaviour will have a large impact on general traffic flow. The industry view is that communication between cars and infrastructure is the future, but there is a need for experience from applications. A critical issue is the quality of the standard. This needs to work in all the member states and also worldwide, covering Europe, America, Japan, and China. A study by Frost and Sullivan (See Fig. 2) identified that for vehicle-to-vehicle and vehicle-to-infrastructure communications countries with significant private ownership of road infrastructure are more likely to invest in cooperative systems infrastructure. These countries are highlighted in Fig. 2 with red boxes.

![Fig. 2 European Opportunities for Car-to-Infrastructure Communications](image)

In terms of standardisation good progress has been made by the European Car-2-Car consortium in developing a standard for short-range communications, and similar work is ongoing in the US on IEEE 802.11 protocols, e.g. WAVE. Not only is it necessary to agree on a standard it is also important that any infrastructure implementation is future-proofed to allow for future likely innovations. This is challenging as electronics typically become obsolescent in 18 months and a car in 10 years. An infrastructure investment needs to last 30 years or more, and in order to maintain the system’s built-in functionality, remote monitoring is also required. There are a number of barriers to adoption, including the difficulty of integrating with legacy equipment, justifying the need for investment to governments, and the slow and bureaucratic decision making process of governments.

Connected Car Market - Infotainment

Driven by the Internet of Things the “Connected Car” is seen as a major business opportunity. BI Intelligence, predicts that there will be 94 million connected cars being shipped in 2021, and that 82% of all cars shipped in that year will be connected. This would represent a compound annual growth rate of 35% from 21 million connected cars in 2016. BI Intelligence expects 381 million
connected cars to be on the road by 2020, up from 36 million in 2015. Furthermore, BI Intelligence forecasts that connected cars will generate $8.1 trillion between 2015 and 2020.

![Estimated Global Connected Car Entertainment Market Potential](image)

*Fig. 3 Predicted Growth in Car Connectivity (Source BI Intelligence)*

The number of connected cars is rapidly increasing (See Fig. 3). Currently, automakers are connecting their vehicles in two ways called an “embedded connection” or a “tethered connection”. Embedded connection cars use a built-in antenna and chipset, while tethered connections use hardware to allow drivers to connect to their cars via their smartphones. The ability to integrate Apps into cars is becoming commonplace in today’s vehicles. Google Maps and other navigation tools are replacing built-in GPS systems in many cars. Music Apps replace the need for a traditional radio or music player and other Apps are being used by drivers as helpful aids, for instance Apps to find the cheapest fuel in the area. A key advantage for automotive manufacturers is that Internet connectivity in vehicles allows car companies to release software updates in real time, which is extremely important during a recall. Secondly, automotive companies can use data from the car to analyse its performance and obtain valuable data on how drivers use their cars. Finally, once connectivity is provided automakers can find even more ways to cross-sell their products and services to customers.

![Global OEM Leading Connectivity and Self-Driving Cars](image)

*Fig. 4 Leaders in Car Connectivity (Source KPMG)*
According to BI Intelligence European car manufacturers are leaders in this field. As shown in Fig. 4, BMW is considered to be the leading company in the area according to a KPMG survey of 200 automotive executives with Daimler, General Motors, Toyota, and Tesla also being near the top of the list.

Although the car companies are providing the connection interface in the car it is other companies that provide data services that are driving this change. For instance the telecommunications company AT&T added 2.7 million connected cars in the U.S. in the first three quarters of 2015. Major players such as Microsoft, Apple, Pandora, Sprint, Google, etc., all see the opportunity for getting their platforms onto connected cars. A Google survey found that 30% of U.S. smartphone users get "anxious" when they do not have their smartphone on them, and 68% check their smartphones within 15 minutes after waking up in the morning. The connected car is seen as a way of allowing people to stay connected more frequently and remove this anxiety. However, texting and phone use is also a leading distraction that results in accidents. Many governments are cracking down on phone use while driving and the connected car is seen as a way of providing a hands free option letting drivers keep their hands on the wheel and their eyes on the road even as they communicate with others.

Consumers are also interested in being increasingly connected. Approximately 62% of U.S. consumers were aware of the term "connected car" in a recent AT&T and Ericsson survey. Google Trends shows the term "connected car" is trending more highly every month. As a result, estimates say in-car infotainment centers will generate $15 billion in sales in 2021, up from $7 billion in 2016.

**Autonomous Car Market**

**Levels of driving automation [NHTSA]**

The move to greater automation with driver-assist functionality and eventually driverless vehicles is very much the current Zeitgeist, and the whole industry is trying to move in this direction. Currently the level of automation is considered to be at Level 2 with features such as cruise control and lane centring as shown in Fig. 5. Moving to the future the next two stages which are already happening are limited self-driving automation (Level 3) and Full Self-Driving Automation (Level 4).
In order to provide autonomy there is a need to supply sensors (radar, LIDAR, cameras) to detect obstacles and other traffic, and to combine this with GPS information to give very accurate positioning. The approaches being used by a number leading cars in the field are shown in Fig. 6. The main obstacle for introduction of fully autonomous vehicles is the availability of reliable software, hardware and supporting infrastructure.

As the level of autonomy increases the necessary technology to support this increases. Along with this so does the cost of the car which is another barrier to the technology. In order to provide Level 3 Autonomy which is the next big step currently the additional cost is estimated to be around $2200 in terms of sensors technologies alone as shown in Fig. 7.
The predicted markets for software and hardware are shown in Fig. 8. In the analysis performed by Lux Research a key conclusion was that the software industry would be the main benefactor in a move to autonomy. Lux Research predicts that the market for self-driving cars will be $87 Billion by 2030 (however in their prediction no cars are expected to be fully autonomous to Level 4 by this date). The prediction is that 92% of vehicles will have simple Level 2 driver assist features such as adaptive cruise control, lane departure warning and collision avoidance braking. Level 3 cars using high resolution maps are expected to gain an 8% share of the market.

Autonomous driving is seen as an important technology to make road traffic more secure and more efficient. The majority of the work is currently concentrated on technical solutions, e.g. processor architectures, sensor technologies, and data processing algorithms. The key challenge here is to make the technologies cheap enough for mass usage. The systems used on the Google Car, for instance, to make it fully autonomous currently cost $150,000. More of a concern, however, is how will autonomous vehicles actually behave when mixed with more traditional vehicles, especially under fault conditions. Designers will not be able to anticipate all possible eventualities and put in place necessary and sufficient mitigations as the scope of the system is effectively unbounded and the number of eventualities is very large. As a consequence, there is a need for intensive real-time monitoring of the performance of the systems to spot potential issues arising before they develop into accidents. This leads to other potential barriers such as the loss of driver’s privacy.
Predictions such as that shown in Fig. 9 indicate that the introduction of autonomous cars will happen in phases as the technology develops and users develop trust. The uptake of fully autonomous cars is only just beginning and is likely to be slow up until the 2020s. BCG surveyed 1,500 U.S. drivers as well as interviewing executives of some leading car making companies. The study revealed that around 55% of the respondents would like to buy a fully autonomous car within 5 years, while about 44% would consider to do so within a 10-year time. About 20% would pay an extra $5,000 for highway and urban autopilot features. The attractions for potential customers are the ability to perform self-driving in itself, increased safety and resulting lower insurance and fuel costs. BCG predicts that self-driving cars with highway and traffic jam autopilot modes are most likely to be adopted first with urban autopilot mode cars being adopted by 2022, with large scale uptake of fully driverless cars no earlier than 2025. By this time, the global market will be worth around $42 billion. Japan and Western Europe are predicted to be the fastest adopters of intelligent self-driving cars, followed by the U.S. and China.
Not all cars will be fully autonomous in the future and looking at the global market there will be a mix of vehicles on the road with Advanced Driver Assist Systems (ADAS), partial autonomy and full autonomy. The predicted market for these three types of vehicle is shown in Fig. 10. This leads to a global market prediction of $42 Billion in 2025 and $77 Billion market in 2035.

These figures are supported by studies from BI Intelligence (see Fig. 11) which divides autonomous functionality into different categories up to 2020. Step one will be stop and go autopilot, which allows cars to drive themselves in traffic jams by analysing the lane ahead of them. Step two is the remote valet assistant which provides the ability to summon a car in a small space (such as a parking garage) through a smartphone, smartwatch, or key fob. Step three is highway autopilot with lane changing, which includes blind spot technology to shift lanes. Step four is cars that require a driver behind the wheel, but have an option for the driver to push a button to let the car drive itself. Step five will be totally driverless vehicles that do not require a driver behind the wheel, or even a steering wheel at all. BI Intelligence expects these cars to be on the market after 2020.

Fig. 11 Growth in Autonomous Features (Source BI Intelligence)

Projected sales of automated vehicles 2015 - 2035

Automated vehicles
Projected global unit sales (m)

Source: Exane BNP Paribas estimates

Fig. 12 Market Prediction for Autonomous Cars (Source BNP Paribas)

BNP Paribas also predicts a change in the sales of cars with the area of highly autonomous cars being dominant by 2035 with fewer fully autonomous cars. This is predicted based on the rapid
advancement of technology and investment from automakers, such as Daimler, GM, BMW and Volkswagen.

![Autonomous Vehicle Sales by Region](image)

**Fig. 13 Predicted Autonomous Vehicle Sales by Region**

The predicted sales by region provided by Navigant Research indicate that the future market will be dominated by the Asia Pacific region with roughly equal numbers of cars being sold in Europe and North America. Worldwide the total number of autonomous car sales was considered to be about 95 million.

Lux Research has also provided a world-wide market analysis with more optimistic figures. This identified that the uptake of autonomous cars will be led by the United States and Europe but China will rapidly grow and claim a 35% share of the 120 million cars expected to be sold in 2030. The revenues from this are expected to be $24 Billion against a $21 Billion US market and a $20 Billion European market. The biggest opportunities for companies are in the software sector as this will be a differentiator and also key to safety. This is expected to grow from $0.5 Billion today to $10 Billion in 2020 and $25 Billion in 2030. Here it is expected that Google and IBM will be major players.
Car Sharing and Mobility Integrator Markets

Car ownership is predicted to decrease in the future with more and more people using mobility solutions and services. This presents a market opportunity for Mobility Integrators and many new players are entering the market as shown in Fig. 14. As an example Uber has revolutionised the taxi industry. Uber, was founded in 2009 and operates worldwide with an estimated worth of $62.5 billion. The company is active in development of autonomous cars (although with some bad publicity from accidents). The biggest expense for Uber is in paying drivers so the use of self-driving cars would be a major saving for the company. According to the German publication “Manager Magazin” Uber has ordered at least 100,000 Mercedes S-Class cars from Daimler’s Mercedes Benz. The reason for the deal with Daimler is that it is a leader in advanced driver assist technologies, including products such as the Distronic Plus. A challenge for Daimler is whether it would be able to meet Uber’s order specifications by 2020. Liability is also an issue and if the cars do not perform according to specification or, even worse, are involved in serious accidents, Daimler would have to deal with lawsuits. For Uber, the decision to partner with a major company such Daimler has benefits but there are also potential pitfalls as it would make it difficult for the company to change to Google, Tesla or another company that may leap ahead of the competition with respect to autonomous cars.

Notably this move towards providing mobility services is also being explored by motor manufacturers themselves. GM has bought a $500 million stake in Lyft a rival to Uber in the US and also bought Cruise Automation for $1 billion which has key self-driving technology.

The provision of mobility services and “ride-sharing” is a natural fit for self-driving cars. Ride-sharing has taken off in urban areas where personal vehicle ownership is not a high priority. Many consumers in these markets prefer efficient and safe services that can be delivered on demand rather than owning their own cars. This removes the hassle of driving which may not be possible if combined with social drinking. Also by not being the owner of the vehicle the responsibility for maintaining and insuring the car is taken away. Notably the CEO of Tesla, Elon Musk, has also highlighted plans to implement car sharing for their vehicles which would allow Tesla owners to earn money by lending out their cars.

References

3.2 Rail Market

The European rail infrastructure, a highly complex system of systems as shown in Fig. 1, is facing increasing congestion due to unprecedented numbers of passengers requiring innovative ways to increase capacity on existing infrastructure (faster scheduling of passengers through stations and shorter stopping times at stations) and demanding levels of punctuality never before seen with more people and improved journey times. The commercial drivers in the industry are for 24/7 operation, high availability, low cost, safety, increased capacity for both passengers and freight, recovery from disturbance, and low carbon emissions. There is also a drive to attract more customers, and to achieve this, there is a need to improve customer satisfaction and customer service. Customers are becoming more sophisticated and will demand a door-to-door service from public transport in the future. Here, the management, control, and sociological aspects need to be considered in unison.

The overall rail sector in the EU, including the rail operators and infrastructure managers, employs approximately 1.8 million people with an estimated 817,000 dependent individuals. The European rail supply industry employs nearly 400,000 people and is a top exporter, accounting for nearly half of the world market for rail products with a market share of 84% in Europe and a total production value of €40 billion (2010). The rolling stock and locomotives market is the most important market...
employing 160,000 people, but there are also large markets for rail infrastructure (around 50,000 employees) and a smaller market for signalling and electrification. The world rolling stock industry market is dominated by three major players which are (partly) based in Europe: Bombardier (Canada/Germany), Alstom (France), and Siemens (Germany).

The interoperability regulations and the 2011 Transport White Paper [1] require that the European railway system behaves as a single system of systems. Within the EU, the Commission requires a level playing field without barriers to competition, and already trains operate across the European continent. The 2011 Transport White Paper also requires that in the future, the majority of medium-to long-distance journeys (freight and passengers) are to be by rail. This is driven by congestion costs (1.5% of EU GDP) and the need for greatly reduced transport emissions.

This is challenging as the rail network has stiff competition from other modes of transport, and in order for the railway to be the preferred transport mode, the industry must offer a guaranteed door-to-door or factory-to-point-of-sale service 24/7. Currently, capacity is severely restricted due to controlling train movement through a system of blocks. The use of moving blocks would improve this, and autonomous train-to-train communications and new infrastructure components could increase capacity by more than 100% and have an asset value of billions. To achieve this, there is a drive for automatic train control and automated maintenance to increase capacity and reduce costs to the point where rail operations do not require subsidy from the government.

The industry aims for a more resilient infrastructure, and some of this resilience can be obtained by better systems to route traffic in an optimal manner responding to an incident. Via a central coordination system, operators and managers should have a better overview of the whole system rather than the more localised view of the individual control centres or signal boxes. Key improvements expected from using CPS are increased capacity through improved planning and operation by optimising the timetables at peak periods to maximise traffic flow, and reduced emissions by optimised driving to reduce stopping and starting. Additionally, technology may provide the planning necessary to allow hybrid rail vehicles to just run the combustion engine when outside of stations and urban areas, reducing noise and urban pollution.

**Rail Automation**

Existing railway control centres communicate with the individual railway sections that are controlled by signalling interlocks utilising information from track circuits or axle counter methods of train detection. Control centres act as higher-level systems that plan traffic routes and respond to delays and incidents. Each control centre covers a regional area, and therefore the intercommunication between control centres is vital.

![Fig. 2 ERTMS Level 3](image)

To address this ERTMS aims to gradually replace the different national train control and command systems across Europe to create a seamless European railway system. Instead of lineside signals, a
computer in the driver's cab controls the speed and movement of the train, whilst taking account of other trains on the railway (See Fig. 2). Bringing the control system inside the train will allow more autonomous operation, so that drivers can always run at the optimum safe speed helping more trains run faster and recover from delays quicker. Each train will run at an appropriate safe speed, allowing more trains onto the tracks. This will increase passenger and freight capacity, reliability, reduce maintenance costs, improve punctuality and lead to safer trains and greater competitiveness for the supply market. By moving more people and freight onto trains and reducing delays there is also an expected reduction in pollution.

ERTMS has two basic components, the ETCS, the European Train Control System, which is an Automatic Train Protection system (ATP) to replace the existing national ATP-systems, and GSM-R, a radio system for providing voice and data communication between the track and the train. This uses standard GSM but on a reserved rail frequency. It should be noted that ERTMS is not a new concept and it has been successful outside Europe in countries such as China, India, Taiwan, South Korea and Saudi Arabia. The ERTMS/ETCS is split into a number of application “levels” which range from track to train communications (Level 1) to continuous communications between the train and the radio block centre (Level 2). Level 3 will further increase ERTMS potential by introducing a “moving block” technology to increase capacity.

- ERTMS level 1 is used as an add-on to conventional lineside signals and train detectors. Communication between balises and the train ensures that it automatically brakes if exceeding maximum allowed speed.
- ERTMS level 2 does not use lineside signals (reducing maintenance costs by their removal). The movement authority is communicated directly from a Radio Block Centre (RBC) to the on-board unit using GSM-R. Balises are used to transmit “fix messages” such as location, gradient, speed limit, etc.
- ERTMS Level 3 allows introduction of “moving block” technology. Removal of fixed blocks (sections of tracks where two trains cannot run at the same time) increases capacity greatly. The train itself becomes a “moving block” communicating accurate position data.

The introduction of the European Railway Traffic Management System (ERTMS) will provide a much more centralised traffic management system that will remove many of the operational problems of running trains between countries. The system is being trialled currently at different levels in different countries, with full roll out expected by 2024.
Global Infrastructure Markets – Track and Rolling Stock

In Fig. 3 the projected global investment in global infrastructure investment for the period 2005-2030 is shown as predicted by Frost and Sullivan. This covers investment in water, power, road, rail, air and ports around the world. Notably transport investment will account for 19% of the $41 trillion to be spent on infrastructure.

In recent years investment in rail infrastructure has been affected by the global recession. However, as shown in Fig. 4 both passenger and rail freight traffic has recovered across the world since 2008. The movement of freight dominates in the US, Europe and China. Notably this is an area which has been slow to recover in Europe due to competition from road haulage. China and India are the fastest growing markets and in both cases this is being driven by an increase in both freight and passenger traffic.
Currently, in terms of business, the global high speed rail market presents the biggest opportunity in the rail market as shown in Fig 5. This shows a breakdown of the high speed rail market by region. While the opportunities in Europe are strong, the Middle East and North America are the most attractive areas for global OEMs.

Another key area experiencing growth is the Urban Rail market. Within Europe considering deliveries of rolling stock Italy and Denmark will be key opportunities in coming years as shown in Fig. 6.
Railway Management System Market

The other key area that is growing rapidly is in the rail management system market. According to a study by Markets and Markets, the railway management system market size is expected to grow from USD 29.27 Billion in 2016 to USD 57.88 Billion by 2021, at a Compound Annual Growth Rate (CAGR) of 14.6% during the period 2016–2021. The major drivers for upsurge in demand for railway management systems & solutions and services include an increasing demand for improved services in railways, government initiatives, and the emergence of Internet of Things (IoT).

High demographic growth and hyper-urbanisation are the major drivers for the market. The railway management system ecosystem includes technology vendors, such as Alstom SA (Saint-Ouen, France), Cisco systems, Inc. (San Jose, U.S.), General Electric (Connecticut, U.S.), ABB Ltd. (Zurich, Switzerland), IBM Corporation (New York, U.S.), Hitachi limited (Tokyo, Japan), Bombardier, Inc. (Quebec, Canada), Huawei Technologies Co. Ltd. (Shenzhen, China), Indra Sistemas SA (Alcobendas, Spain), Siemens AG (Munich, Germany), Alcatel-Lucent (Paris, France), and Ansaldo STS (Genoa, Italy), which provide numerous IT and non-IT components required for railway management systems & solutions, as well as, assessment, consulting, system integration, and support services to the railway management system platform.

The railway management system market can be divided into the following segments:

- **Rail Operation Management System**
  - Facility management solution
  - Revenue management solution
  - Ticketing management solution
  - Workforce management solution
  - Rail automation management solution

- **Rail Traffic Management System**
  - Intelligent signalling solution
  - Real-time train planning and route scheduling solution
  - Centralised traffic control solution
  - Traffic analytics

- **Rail Asset Management System**
  - Train information solution
  - Track monitoring solution
  - Asset performance analytics

- **Rail Control System**
  - Positive train control solution
  - Communication-based train control solution
  - Integrated control system

- **Rail Maintenance Management System**
- Vehicle maintenance scheduling solution
- Predictive analytics for maintenance management solution

Of these different subsectors the **Rail Traffic Management System is expected to hold the largest market share in the railway management system market.** Rail traffic management involves signalling, traffic control, routing, and train scheduling. The system offers a flexible solution to increase the network capacity & time efficiency, regulate flow of traffic, reduce the risk of operational delays, and improve disaster management over the network. The growth of the rail traffic management system is also attributed to the need for advanced transportation infrastructure.

**The Managed Services market is expected to grow at the highest CAGR over the next few years.** Managed services support the implementation of railway management systems & solutions, across trains and stations.

**Notably Europe is expected to hold the largest market share in the railway management system market.** Europe is most likely to benefit from technological advancements, with predicted high usage of IoT and data analytics platforms, across various rail management operations. The planned investment to improve urban transport and traffic infrastructures in France, Germany, Italy, and the U.K. are expected to drive the European railway transportation market. The roll out of the European Rail Traffic Management System (ERTMS) is expected to drive the overall European market.

Regional, long-distance and freight rail services will also be more automated in the future. The expectation is that 40% of the rail operations for industry, mining and freight will be semi-automated within the next four years. The urban transport market is predicted to grow at 3% overall between 2014 and 2020 and within this market, the share of fully-automated operation is expected to increase from around 30% today to around 70%.

The Internet of Things is also being exploited in a number of areas, e.g. for gathering maintenance data to improve the availability of vehicles and infrastructure through predictive maintenance, create faster throughput in transport systems, provide better resource management and to provide greater passenger comfort and convenience, through intelligent ticket and passenger information systems. Maintenance is a key cost for rail networks and the use of predictive maintenance with data analytics is a major growth area. Here joint ventures are being formed, e.g. Siemens with Renfe in Spain, to use data analysis to monitor trains giving 99.98% availability.

**Competition**

Although Europe has very strong OEMs in the rail sector there is growing competition, particularly from China. At a global level the merger of the two Chinese suppliers CNR and CSR is a concern with both Chinese suppliers already operating in the international markets. The Chinese government is investing huge amounts of money in the railway sector.

At a European level research activities into new technologies have been highly fragmented. As a consequence the European Commission, together with the European railway industry has established the Shift2Rail joint undertaking that focuses on holistic rail solutions and covers all areas of railway research activities under one roof. The objectives of the JU are to double the capacity of Europe's rail system and increase reliability and punctuality of operations by 50%, while at the same time reducing life-cycle costs by 50%. The results and feasibility of the Shift2Rail targets need to be shown and verified in technology demonstrators. Standardisation is also being pursued to provide common rules in an international and European context and to establish them as the accepted guideline for rail technology. A priority for the industry is the Fourth Railway Package.
3.3 Aerospace Market

![Major Air Traffic Routes](image)

The European aerospace industry is a world leader in the production of civil and military aircraft, helicopters, drones, aero-engines, and equipment, exporting them all over the world. It also provides support services, such as maintenance and training. Aerospace within the EU provides more than 500,000 jobs and generated a turnover of €140 billion in 2013. Employment in the aerospace sector is particularly significant in the United Kingdom, France, Germany, Italy, Spain, Poland, and Sweden. A sizeable share of value added is spent on research and development (R&D) within Europe.

In the aerospace sector, air passenger volume is predicted to double air traffic density over the next two decades in an already congested airspace. On key routes and large airports within Europe, there are over 50 million passengers a year, and on the majority of other routes, there are 10-50 million passengers. Air traffic is increasing, and the number of aircraft is expected to double by 2020. As a global aviation industry, the biggest and most important challenge is to continue to safely accommodate ever-increasing air traffic in support of global economic growth and prosperity, whilst...
protecting the environment. Movement of increasing numbers of passengers requires a complex system of systems across the world that integrates airport operations, baggage handling, and air traffic control to maximise flow. Air traffic control systems by themselves integrate numerous functionalities that enable semi-automated operations in the en-route airspace. Tools and methods that partially automate some of what is manually performed by air traffic controllers today is currently an active area of research. At the same time, the need for unprecedented high levels of aircraft availability is driving the use of sophisticated information and communication technologies for predictive health monitoring, integrated with worldwide maintenance and logistics systems to ensure that aircraft are always fit to fly.

**Air Traffic Management Market**

![SESAR Air Traffic Control System](Source SESAR)

Air traffic management is a major topic, especially in Europe where separate systems are being integrated via SESAR into a new more efficient system which will guarantee time of arrival. The challenges here are not only technological, but also legislative/political and need to be tackled at a European (and even world-wide) level. Already air space is congested, and better coordination of aircraft will allow for increases in capacity and real-time deconfliction of flight paths. The expectation is that new technology will provide a better integrated end-to-end passenger journey experience and reduced emissions. Improved air traffic control will reduce costs and delays, and better integration of systems offers the opportunity to optimise gate-to-gate transits without on-the-ground delays or stacking before approach (with consequent reductions in emissions).

At a global level the Air Traffic Management (ATM) market is projected to grow from USD 50.01 Billion in 2016 to USD 97.30 Billion by 2022, at a CAGR of 11.73%. This will be driven by an increasing demand for safe and reliable air traffic operations, increasing airspace congestion, development of new airport infrastructure, and modernisation of existing airports. The air traffic management market in India, China, and Japan is expected to witness significant growth by 2022.

**Global Aerospace and Defence Market**

According to Deloitte Global in its *2015 Global aerospace and defense sector financial performance study* the revenue growth in the aerospace and defence market has declined from 3.2 percent in 2013, to 1.9 percent growth in 2014, and to minus 0.5 percent in 2015. Despite this the global aerospace and defence industry was expected to return to growth in 2016 with total sector revenues estimated to grow at 3.0 percent, according to the Deloitte Touche Tohmatsu Limited (Deloitte Global) Consumer & Industrial Products Industry group’s 2016 Global aerospace and defense sector outlook. The commercial aerospace subsector is expected to continue its decade-long trend of above-average growth rates, driven by growth in passenger travel demand and an accelerated equipment replacement cycle.

The military market is being driven by increasing defence spending in the US, United Kingdom, France, Japan, and several Middle Eastern countries. This has been driven by heightened national
security threats with governments equipping their armed forces with modern weapons, platforms and next-generation technologies, including cyber, intelligence gathering, defence electronics, and precision strike capabilities.

The expectation is that the global industry will begin stronger growth in 2017 following multiple years of subdued growth. There will growth in travel demand driven by wealth creation in Asia and the Middle East which will impact the commercial aerospace sector. It is expected that sector revenues will likely grow by about 2.0 percent in 2017.

**Commercial Aerospace Market**

The commercial aircraft market is expected to grow steadily to 2035 as shown in Fig. 3. Stable global gross domestic product (GDP) growth, relatively lower commodity prices including crude oil, and strong passenger travel demand, especially in the Middle East and Asia Pacific regions, is expected to drive the commercial aerospace sub-sector growth. Despite an expected increase of 96 additional large commercial aircraft being produced in 2017, continued pricing pressure and product mix changes by airline operators will likely result in only a marginal increase of 0.3 percent in commercial aerospace sub-sector revenues.

**Military Aerospace Market**

Fig. 4 Military Aircraft Market
The military aircraft market revenues are likely to grow at 3.2 percent in 2017 due to increased spending in the US after multiple years of decline in defence budgets. Future growth is expected to be driven by the new US administration’s increased focus on strengthening the US military. Rising global tensions have led to increasing demand for defence and military products in the Middle East, Eastern Europe, North Korea, and the East and South China Seas. This is in turn has resulted in increased defence spending globally, especially in the United Arab Emirates (UAE), Saudi Arabia, South Korea, Japan, India, China, Russia.

**Aircraft Systems Market**

The markets for aircraft systems can be divided into a number of key subsystems:

- The aircraft flight control system market is projected to grow from USD 11.85 Billion in 2016 to USD 16.59 Billion by 2021, at a CAGR of 6.97%.
- The more electric aircraft market is projected to grow from USD 7.68 Billion in 2016 to USD 10.94 Billion by 2021, at a CAGR of 7.33%. The key advantage of adopting More Electric Technologies is to provide optimised aircraft performance, and reduce operating & maintenance cost. China, India, Brazil, and Russia are key countries expected to increase demand for more electric aircraft.
- The environmental control systems market is estimated to grow from USD 3.27 Billion in 2016 to USD 4.22 Billion by 2022, at a CAGR of 4.34%. This will be driven by technological advancements in environmental control systems and growth in air traffic.
- The aircraft electrical systems market is projected to grow from USD 17.04 Billion in 2016 to USD 24.79 Billion by 2022, at a CAGR of 6.45%. Increasing demand for more electric aircraft, fuel-efficient aircraft, and unmanned aerial vehicles are the key factors driving the aircraft electrical systems market. The aircraft electrical systems markets in India, China, and Japan are expected to witness significant growth during the forecast period.
- The electronic flight instrument system market is expected to grow from USD 867.9 Million in 2016 to USD 1,139.6 Million by 2021, at a CAGR of 5.60%. Key drivers are the increasing need for lightweight systems with more functionalities and better accuracy, enhanced safety and situational awareness with electronic flight instrumentation systems, and automation of flight controls.
- The aircraft health monitoring systems market is estimated at USD 3.43 Billion in 2016, and is projected to reach USD 4.71 Billion by 2021, at a CAGR of 6.53%. This will be driven by increases in situational awareness to drive operations, cost effective maintenance, and increase in asset utilisation, and the need to analyse an increasing volume of data.
- The airborne telemetry market is projected to grow from USD 7.08 Billion in 2016 to USD 8.52 Billion by 2021, at a CAGR of 3.78% during the forecast period. This will be driven by the growing use of software defined radio technology, emergence of modern electronic warfare and network-centric warfare systems, and the increased use of wireless and cloud computing technologies.
- The inflight entertainment market is projected to grow from an estimated USD 3.18 Billion in 2016 to USD 6.91 Billion by 2022, at a CAGR of 13.80% during the forecast period. This is driven by the need to enhance the passenger experience, new technology development, and the opportunity to make ancillary revenue for airlines.

**Unmanned Aerial Vehicle Market**

In the military domain it is already commonplace to operate autonomous vehicles in controlled military airspaces. The sector is thus a leader in terms of implementation of autonomous vehicles. The commercial use of drones is also expanding for surveillance and monitoring in a number of domains such as search and rescue, policing and also for agriculture. Here there is currently a limit on the size of drones for safety reasons that can be operated without a pilot. Future programmes such
as ASTRAEA in the UK are looking at the technological, legislative, and political challenges of how unmanned aerial vehicles can also be integrated with the civilian ATM network.

According to Markets and Markets ("Global Aerospace Robotics Market Analysis & Trends - Industry Forecast to 2025") the global aerospace robotics market is expected to grow at a CAGR of around 17.7% over the next decade to reach approximately $7.9 billion by 2025. Presently there is a huge amount of research and development in the area of Aerospace Robotics with increasing demand for collaborative robots.

The UAV (Unmanned Aerial Vehicle) market is estimated to be USD 13.22 Billion in 2016 and is projected to reach USD 28.27 Billion by 2022, at a CAGR of 13.51% as shown in Fig. 5. Key factors fuelling the growth of the market include increasing demand for UAVs for commercial applications, advancements in technologies of drone payloads, and increasing defence budgets of emerging economies. The drone software market is estimated to be USD 2.85 Billion in 2016 and is projected to reach USD 12.33 Billion by 2022, at a CAGR of 27.63% from 2016 to 2022. Factors such as growing investments and the increasing use of drones in commercial and military applications are expected to drive the growth of the market in the near future. The drone services market is estimated to be USD 705.3 Million in 2016 and is projected to reach USD 18,022.7 Million by 2022, at a CAGR of 71.62% between 2016 and 2022. One of the major factors expected to drive the growth of the drone services market is the increasing demand for monitoring and inspection services across various industries.

Smart Airports and Passenger Handling Markets

The ground handling and support software market is projected to grow from USD 2.49 Billion in 2016 to USD 3.25 Billion by 2022, at a CAGR of 4.56%. The smart airports market is projected to grow from USD 11.31 Billion in 2016 to USD 14.87 Billion by 2021, at a CAGR of 5.64%. This will be driven by increasing passenger traffic, the need for check-in services upgrades, baggage handling services and improved security systems. In addition, the need to provide real-time information to passengers is further expected to drive the smart airports market.

References

Other Markets and Markets References

- Air Traffic Management Market by Domain (ATC, ATFM, AIM), End-Use (Communication, Navigation, Surveillance, Automation & Simulation), Investment Type (Greenfield, Brownfield), Airport Class (A,B,C,D), System & Region - Global Forecast to 2022
- Unmanned Aerial Vehicle (UAV) Market, by Application, Class (Mini, Micro, Nano, Tactical, MALE, HALE, UCAV), SubSystem (GCS, Data Link, Software), Energy Source, Material Type, Payload and Region - Global Forecast to 2022
- Drone Software Market by Architecture (Open Source, Closed Source), Offering (App-Based Software, Desktop Software), Application (Control & Data Capture, Image Processing, Analytics), Platform, and Region - Global Forecast to 2022
- Drone Services Market by Industry (Infrastructure, Agriculture, Entertainment, Logistics), Application (Aerial Photography & Remote Sensing, Data Acquisition & Analytics), Type of Drone, Duration of Service, and Region - Global Forecast to 2022
- Ground Handling Software Market by Application (Land, Terminal, Air), Software (Passenger Boarding & Departure Control, Baggage Management, Flight Information Display), Airport Class (A, B, C), Investment Type, and Region - Global Forecast to 2022
- Smart Airports Market by Technology (Communication, Security, Cargo & Baggage Handling, Traffic Control, Endpoint Devices), Landside, Airside, Terminal Side, Application, Region - Global Forecast to 2021
- Aircraft Flight Control System Market by Type (Primary, Secondary), Application (Commercial, Business, Military), Platform (Fixed, Rotary), Aircraft Type (NBA, WBA, VLA, RTA), Technology (Fly-by-Wire, Hydro-Mechanical) and Region - Global Forecast to 2021
- More Electric Aircraft Market by Technology (Power Electronics, Thermal Management, Energy Storage & Others), Application (Power Generation, Passenger Comfort, Air Pressurisation & Others) Platform (Fixed Wing, Rotary Wing), and Region - Global Forecast to 2021
- Environmental Control Systems Market by End User (Commercial, Defense), Platform (Rotary, Fixed), System (Air Supply & Management, Thermal Management & Control, Cabin Pressure & Control), Component, and Region - Global Forecast to 2022
- Aircraft Electrical Systems Market by Technology (Power Generation, Conversion, Distribution, Energy Storage), Component (IDG, VFG, APU, TRU, GCU, Power Electronics, Power Distribution Systems), Application, Platform, & Region - Global Forecast to 2022
- Aircraft Health Monitoring System (AHMS) Market by IVHM Technology (Prognostic, Diagnostic, CBM & Adaptive Control), Sub-System (Aero-Propulsion, Aircraft Structure, Avionics and Ancillary System), Fit, Type & Region - Global Forecast to 2021
- Airborne Telemetry Market by Application, Technology (Wired, Wireless), Platform, Component (Receiver, Transmitter, Antenna), Sensor (GPS, Load Cell, Torque, Weather Prediction) And Region - Global Forecast to 2021
- Inflight Entertainment (IFE) Market by Fit (Linefit, Retrofit), Aircraft Type (NBA, WBA, VLA, Business Jets), Product Type (IFE Hardware, IFE Connectivity & Communication, IFE Content), Region - Global Forecast to 2022
- Electronic Flight Instrument System (EFIS) Market by Application (Flight, Engine Monitoring, Navigation), Sub-system (Display, Communication & Navigation, Flight Management), Fit (ADS-B, EVS), Platform (Fixed, Rotary) and Region - Global Forecast to 2021
3.4 Maritime Market

Over 90% of world trade is carried by ships, making them pivotal in the world economy. It is the most economical and the least environmentally damaging form of transport. Without ships, the transport of raw materials and the import/export of affordable food and manufactured goods would not happen. The growth in seaborne trade has averaged 4% per annum since the 1970s. The estimated number of active seafarers in maritime EU Member States in 2010 is 254,119 (143,967 officers and 110,152 ratings). It is estimated that 4.78 million people are employed in maritime-related activities in ports and logistics that support the movement of goods.

By far the most efficient mode of transport for the movement of goods, the shipping sector is expected to grow by 150-250% over the next 30 years. European shipbuilders are world market leaders by turnover. In particular Europe produces nearly all the high-value cruise ships in the world, around 50% of all equipment suppliers’ products are exported outside Europe, and almost 100% of the dredging technology and know-how is European. From a fleet management perspective, around 40% of the world merchant fleet is controlled by European companies, and approximately 25% are flying the European EEA flag. Of the top 5 world ports, 3 are European, and the European oil & gas service industry is also a world technology leader, exporting 70% of products.

The European maritime industry is spearheading environmentally friendly technologies. For example, European equipment suppliers have provided on-board total waste management systems ahead of future environmental regulations. In the industry, world-wide ship management systems are being linked with ship fouling efficiency metrics and navigation systems to optimise performance to reduce shipping costs, fuel consumption, and emissions. This is being addressed through the introduction of ICT technologies and algorithms to optimise shipping movements and port operations. There is also a big push to improve safety across all types of shipping due to high-profile accidents. Here the use of more automation is predicted with roadmaps being announced for autonomous ships as shown in Fig. 1. This indicates that increasing levels of autonomy will be introduced to reduce crew levels. Firstly remotely piloted vessels will be adopted in a 10 year timescale in coastal waters, leading to remote piloting of vessels in the oceans by 2030, with a long term goal of fully autonomous vessels by 2035.
Cruise and Container Shipping Markets

Europe is a key producer and operator of cruise ships as can be seen in Fig. 2. The increasing size of passenger ships and their operation in remote and inhospitable locations, e.g. Baltic waters, is leading to concerns about safety. Here there are calls for improved safety systems and more automated control. At the same time emissions have become a major issue at the local port level and also at an international level with legislation, e.g. IMO Tier III, driving for increased monitoring of emissions.

In the container ship market the introduction of emissions monitoring has led to new operational approaches such as “slow steaming” for products that are not time-critical. The major container ship operators are shown in Fig. 3. It can be seen that APM-Maersk is a dominant company in the sector. Logistically, there are complex interactions in the movements of containers around the world to ensure that shipping and handling costs are minimised, with tight linkage into the appropriate rail or road haulage networks to move the goods onwards as quickly and efficiently as possible. The commercial requirements are for high performance, fuel cost reduction, reliability, safety, lower capital expenditure, and lower operating expenses (maintenance). Efficient operations, fleet management, and the logistics of moving containers and goods is a key driver in the industry. Although management systems exist there is currently a fairly low level of use of ICT and little connection between systems.
**E-Maritime and Integrated Bridge Systems Markets**

The industry believes that the introduction of new ICT technologies for maritime traffic management will be key for safer and more secure operations. There is great interest in optimised shipping operations and voyage optimisation, condition-based maintenance, cost reduction, and emissions reduction. The drivers are for reduced maintenance, enhanced asset life, reduction in crewing levels through increased automation and fleet optimisation via shore-based decisions. Key enablers in the industry are the introduction of VSAT systems that provide connectivity to ships and much greater data rates for data transfer. Presently, however, there is not a clear view of what data should be transferred and how this should be used.

There is also a drive for a more integrated transport chain. To reduce congestion in ports and port fairways, port traffic guidance systems need to be at the same time cost efficient and easily deployable. Synergies with existing systems should be ensured, with the aim of integrating the use of port traffic guidance tools by all relevant authorities and ensuring the full interoperability between ICT systems, which monitor vessels, freight and port services.

Actions such as Waterborne and e-Maritime are helping drive technologies here. The introduction of data exchange standards would be a major move forward, allowing currently installed systems to become interoperable. The increasing use of ICT within the industry and the new internet-savvy crew and operators offer great potential for improvements in efficiency.

In the area of safety-improved navigation systems, traffic management algorithms for busy sea ways and ports will improve safety, and looking to the future, there will be a gradual reduction of crew levels leading to fully autonomous ships once regulatory authorities are convinced that this is safe.

![Fig. 4 Integrated Bridge Systems Market by Platform - Global Forecast to 2021](image-url)

As shown in Fig. 4 the worldwide Integrated Bridge Systems (IBS) market is estimated to be valued at USD 5.08 Billion in 2016 and is projected to reach USD 5.60 Billion by 2021, at a CAGR of 1.97%. This market is driven by the increasing trend in world trade by sea, increasing maritime navigation safety resulting in a reduction in the number of accidents, and growing maritime tourism. The marine bridge electronics industry has a total market value of around US$3.2 billion according to one of the leading equipment manufacturers Navico. The market value considered predicted sales in marine bridge electronics for commercial shipping, workboats of various types, fishing vessels, and recreational boats. This includes all navigation equipment, as well as GMDSS (the global maritime distress and safety system) radios, autopilots, speed logs, and echo sounders, but not satellite
communications equipment. It also does not include the servicing of equipment which would increase this global market value significantly. The top 10 suppliers of vessel bridge equipment, including radar, ecdis, autopilots, voyage data recorders, safety communications, echo sounders, etc., generate around US$2.5 billion of these sales.

Navico is the second largest supplier of marine bridge electronics, behind Furuno Electric Co but ahead of Japan Radio Co (JRC). Garmin is considered the fourth largest in marine electronics annual sales, highlighting the fact that this market includes recreational vessels. Sam Electronics, which was acquired by Wärtsilä last year, was the fifth largest. The next five largest are Transas, Flir Systems’ Raymarine, Raytheon Anschütz, Sperry Marine and Tokyo Keiki. Some of other well-known companies in the sector are Kongsberg Maritime, Kelvin Hughes, and Humminbird.

Owners are looking for more functionality from bridge systems, such as track control, advanced voyage planning, an integrated autopilot, data telematics and vessel management systems. The importance of bridge systems is thus changing although radar and ecdis are considered to be critical for safe navigation and collision avoidance.

**Shipbuilding Countries World Market Share**

Although European companies are strong in terms of ship operations and supplying systems Europe is less strong when it comes to ship building. The maritime industry has very good system integration engineers as ships are highly complex systems. The fact that ships are regularly sold to other ship owners makes investment in on-board technology such as monitoring more difficult, as installation of expensive equipment may be lost within a few years to a new operator. As a consequence, the suppliers of equipment are now building in monitoring for their own equipment which is used internally. The ship owners are then offered the option of purchasing monitoring and management services by the suppliers, e.g. in power-by-the-hour contracts in the case of Rolls-Royce.

![Shipbuilding market share](source: KOSHIPA)

The ship building industry is dominated by Asian countries. As can been seen in Fig. 5 Japan was historically dominant in the sector with a change from European shipbuilding in the 1980s and 1990s to an increase in building vessels in South Korea and China in 2005.
There are three main types of shipyard. Those building exclusively merchant marine vessels, those building both marine and offshore units and those that build exclusively for the offshore sector. In Fig. 6a it can be seen that there was a rise in shipbuilding between 2005 and 2009 but this reduced as a consequence of the recession in 2008. The current levels of shipbuilding are back to the levels of a decade ago. Looking at the number of orders received by shipyards worldwide for ships larger than 20,000 tonnes it can be seen in Fig. 6b that orders reduced dramatically in 2009 due to the recession. (Note that the data in this graph for 2016 is only for the first half of the year). The current order levels reflect the situation in 2005 before the recession.

### Fig. 7 Current European Position in Shipbuilding

The current position of European companies has fallen in recent years. The industry is now dominated by China, South Korea and Japan, with China being the world’s foremost shipbuilder. Denmark, Italy, Croatia and Poland are no longer in the world’s top ten manufacturers as can be seen in Fig. 7. Despite this Europe is still strong in the ship automation sector.
Military Ship Market

The military ship building market has also been affected by defence cuts. There is likely to be an increase in building of destroyers and auxiliary ships. An overall market size of $838.2 Billion is foreseen over the next decade as shown in Fig. 8.

Autonomous Surface Vessels and Submarines

In both the military and civilian sectors in order to reduce the costs of performing surveillance and monitoring tasks there is great interest in smaller autonomous platforms. These are far cheaper to operate than ships which currently require a crew. Monitoring of the oceans is seen as a major opportunity in the future. As systems become more interconnected it will be possible to combine mixtures of autonomous underwater, surface, and aerial drones to monitor accidents at sea, pollution spills, ocean acidification, wildlife, and also the relationship between the oceans and climate change.

This is an area that is still in its infancy, but already fairly large-scale deployments are being trialled. Much of the technology push here is on the development of vehicles that can operate for long periods as this is a prerequisite for cost-effective deployment. It is interesting to note that monitoring of the oceans is seen as a new commercial opportunity and this is supported by Google’s interest in being a central player in this area.

Fig. 8 Military Ship Building Market

Fig. 9 Waveglider from Liquid Robotics
Examples of vehicles are the Waveglider from Liquid Robotics (recently bought by Boeing). These vehicles can operate remotely for very long periods of around a year without the need for maintenance.

The unmanned surface vehicle (USV) market is projected to grow from USD 437.57 Million in 2016 to USD 861.37 Million by 2021, at a CAGR of 14.51%. This is being driven by an increased demand for Intelligence Surveillance and Reconnaissance, water quality monitoring, maritime security and threats, ocean data collection and mapping. Various manufacturers are getting increasingly interested in USVs and government organisations and private agencies have been investing a lot in the manufacture and development of advanced and efficient USVs.

At the same time there is also interest in underwater autonomous vehicles. The Unmanned underwater vehicle (UUV) market is projected to grow from USD 2.29 Billion in 2015 to USD 4.00 Billion by 2020, at a CAGR of 11.90%. This is being driven by the needs of the deep water offshore oil and gas production industry, by the needs for protecting against maritime security and threats, and the need for ocean data and mapping. Government organisations and private agencies have been investing in the manufacture and development of UUVs.

References

References Markets and Markets
- Unmanned Surface Vehicle (USV) Market by Application (Defense, Scientific Research, Commercial, Miscellaneous), Size (Small, Medium, Large, Extra Large), Propulsion System, Modes of Operation, Payload & Geography - Global Forecast to 2021
3.5 Logistics

Logistics is a global business, and Europe has some of the largest logistics companies in the world with highly developed and efficient delivery networks. Logistics contributes nearly 14% to the European GDP (900 billion Euros) and has a significant impact on the service sectors it supports. Within warehouses the market for logistics robots currently accounts for 9% of the total sales of professional service robot systems. This is expected to grow in the future, driven by the increasing cost of labour and higher demands for efficiency.

The consumer marketplace is becoming increasingly volatile, fragmented, and dynamic, being dominated by extreme service-level requirements, multi-tier distribution networks, and a myriad of high- and low-volume stock keeping units. Order-to-delivery excellence is now a key requirement for demand management that drives new business models and collaborative transport management. Customers expect on-time delivery with an eco-conscious approach, driving supply chain sustainability initiatives to reduce fuel consumption and lower emissions. Information provided by modern ICT systems is available at all levels of the supply chain, offering unprecedented opportunities for optimisation. Successful supply chains are complex and rely on accurately forecasting market demand, formalising vendor-managed inventory consignment, reducing stock levels, and focusing on buying/manufacturing inventory only when it is needed.

The challenges in this sector are that transport volumes keep growing globally, but the sizes of individual shipments are not increasing, and indeed there is a move towards shipments of smaller loads. Customer service expectations are high with demands for fast and efficient on-time delivery. In order to execute transport tasks efficiently, transport service networks play a vital role. These networks are dedicated, e.g. to parcel, express or less-than-truckload-shipments and related logistic services. Analysis and optimisation of their structure can provide great benefits in terms of efficiency and also fuel cost and emission reductions. More efficient operation of nodes (depots, hubs,
terminals) provides greater throughput and lower latency. To support this, operators are increasingly turning to simulation models to achieve robust solutions that improve their efficiency, reduce handling costs, and increase the performance of their terminal operations. A key challenge is to link between material-flow simulation and arriving and departing traffic. The task of delivery in urban areas increasingly is leading to congestion, and ways of bundling deliveries at local hubs to reduce the numbers of vehicles making deliveries are being sought.

Worldwide distribution systems have been in place for many years, however, the industry is facing new challenges in the shift from large individual shipment sizes to shipments of smaller loads. The transport volumes are thus growing rapidly, introducing challenges in cost, emission reduction, and increased congestion on roads and in cities.

Data and knowledge are becoming key competitive criteria, with tracking of items through the logistics chain the norm and companies competing to provide efficient and cheaper services. A problem with increased interconnectivity in logistics systems of systems is that it exposes them to external risks, such as natural disasters and organised crime. Security and flexibility to reconfigure are thus key prerequisites and concerns. Congestion is a growing problem, and there is a need for incentive schemes that produce a more balanced use of the vehicle, facilities and traffic infrastructures. The key aim here is to drive demand and reduce traffic bottlenecks. Schemes that allow bundling of deliveries from different companies would have a significant impact, and there is a need to move more transport to off-peak hours. At a system level, there is a need to understand how much centralised planning is needed versus the use of decentralised self-organised flexible delivery. Currently, there is a drive towards tighter time limits on delivery. This makes it more difficult to implement energy-minimal logistics to reduce emissions.

The use of autonomous vehicles in the logistics domain is already an established concept, with autonomous picking machines being commonly used in large warehouses. There is a drive towards more distributed autonomy for these vehicles to provide greater flexibility in operations, and this, coupled with the use of smart communication technologies in intelligent bins, is leading to greater efficiencies.

Moving out of the warehouse, the industry is beginning to think about automated delivery systems. An example of this is Amazon Prime Air which is a drone concept for delivering small packages to customers within 30 minutes. This is still many years away from deployment and needs to gain certification acceptance from the FAA before it can be reality, however, again it shows synergies with the move towards autonomous aircraft operations.

The industrial Logistics Automation space alone is projected to be worth $30 billion by 2020. Technologies such as machine vision, motion sensors, navigation algorithms and artificial intelligence are enabling robots to perform increasingly sophisticated, mobile and delicate knowledge-based work. This widens their use to an array of products and services. The manufacturing of items is incomplete without the material handling and distribution channels that bring the objects to their intended users. The many economic advantages to speedy and error-free distribution, such as operating with low-inventory and being responsive to customer demands, is a significant growth area for robotics and automation. This is continually reducing the costs for businesses and consumers. According to the US Department of Commerce, 2015 marked the sixth year in a row that e-commerce sales have grown near or above 15%. The typical e-commerce retailer can no longer compete on price and the new competitive advantage is “fulfilment”. The economic advantages of speedy, cost-effective, and error-free distribution are a significant growth area for Robotics & Automation.
Logistics Market Value

The Logistics market value is projected to be worth $33.6 billion by 2022 at a CAGR of 10.4% (Source: Knowledge Sourcing Intelligence LLP). This includes automation for transporting goods, heavy lifting, warehouse distribution and in the area of Automatic Guided Vehicles (AGV) that facilitate efficient material handling, most commonly the automatic movement of pallets. These are particularly used in warehouses with extremely narrow aisles and very high storage racks and also those that handle dangerous chemicals. There is also a big market in sorter, picking, and conveying systems in factories and distribution centres. These are used in many industries such as electronics, medical & pharmaceutical, food & beverage, transport & warehousing. The material handling systems improve production efficiency and distribution control by reducing lead time, improving delivery accuracy, eliminating receiving inspection, supporting EDI (electronic data interchange), and managing goods.

In ARC’s global Warehouse Automation & Control Market Research Study the explosive growth in e-commerce and the ways in which it is affecting fulfillment are highlighted. These will be leading factors contributing to the growth of the WAC market. The shift in retail from brick and mortar to e-commerce is creating demand for warehouse automation to support modern shopping and fulfillment practices. Companies are now investing in warehouse automation to survive, not just to grow. These systems need to handle high volumes of small, multi-line-item orders. The demands of e-commerce are also driving WAC investment up the supply chain to wholesalers and manufacturers. It is also stimulating warehouse automation investment by parcel carriers and other logistics service providers.

At the same time automation is being used to obtain operational efficiencies in high labour cost regions such as Western Europe, the US, and Japan. The return on investment for WAC projects is also being supported by the additional software intelligence that can be included. Adaptability has also become more important to fulfillment operations due to increased order variability. Shorter lead times and the heterogeneous nature of today’s items, orders, and loads are placing a different set of pressures on warehouse operations. These customer requirements are increasing demand for flexible warehouse automation. Here warehouses are employing shuttle systems that are adaptable to various items and loads, and that are also easily scalable to changing volumes. Many WCS can also interpret data and facilitate processes with a greater level of sophistication. Agility is becoming increasingly important to fulfillment operations. WCS have visibility to the operations across a facility. This makes it possible to adapt operations to changing circumstances, constraints, and priorities.

References

Manufacturing, with its about 20 industrial sectors, is the backbone of the European economy – producing 80% of Europe’s exports, accounting for 80% of private RTDI expenditures, and providing more than 30 million jobs with additional 70 million in related sectors. Thus, the manufacturing sector plays a pivotal role in fostering economic growth and social welfare across Europe, and it has the potential to provide innovative solutions for the grand societal challenges. But – enforced by the financial and economic crisis – European Industry’s share of added value has decreased tremendously during the last two decades. Against this backdrop, the European Commission launched several initiatives such as e.g. the European Technology Platform “ManuFuture”, the contractual Public-Private Partnership “Factories of the Future” and – more recently – the “Digitising European Industry” initiative in order to ensure Europe’s mid- to long-term competitiveness with implications for overall welfare. Digital technologies in general and CPS in particular play an increasing role in that context.

4.1 CPS – Industry 4.0 / Smart Factory – Internet of Things

CPS are subject to discussion in the manufacturing community, especially in the automation sector, for years. The “Industrie 4.0” discussions in the German community give a good example for the trajectory from embedded systems to CPS to smart manufacturing and Internet of Things, Data and services from a national perspective. Starting from a CPS Agenda with outlines for a new research domain [1], concrete recommendations for implementing a strategic initiative on “Industrie 4.0” have been derived [2], which in then end resulted in the foundation of the national Plattform Industrie 4.0 [3]. In other countries, similar initiatives have been launched (see figures/maps below for some examples). Today, discussions on “Industrie 4.0” can be seen as a real global phenomenon [4, 5].

All over the world, Industrie 4.0 related concepts and activities can be identified, each tailored to specific perspectives and the focuses of particular countries. The so-called INBENZHAP study [5] identified four focuses within the global fields of action (Fig. 2):

- Activities in the United States are characterised by two fundamental directions of strategic action: On the business side, implementation of intelligent technologies is driven by pragmatic advantages and value for the customer. The focus is mainly on the realisation of new products and services, innovative business models and promises of benefits for the customer. Already existing technologies are only selectively used in production, e.g. for improving quality control.
- The focus of Japan and South Korea is on establishing strong local corporations in mechanical engineering and electronics in the new business segment of “networked manufacturing systems”. A primary goal is averting looming productivity losses caused by rapid and pronounced demographic changes. Public support programmes – such as the one to construct at least 10000 smart factories in South Korea – allow conglomerates to achieve

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3 The term “Industrie 4.0” denotes the transformation of “traditional” industries by the Internet of Things, Data and Services.
their planned economies of scale through comprehensive implementation of their technologies.

- In China, speed is crucial. Technologies available to the market are pragmatically implemented where they provide obvious benefits. However, the country’s low average automation level prevents large-scale comprehensive implementation. Catching up to global competitors in key technologies of advanced manufacturing is part of a national strategy. The overarching goal of all Chinese activities is maintaining the global leadership role in manufacturing and associated jobs, and raising the standard of living to the level of other industrialised countries.

- The focus of European initiatives (see Fig. 3) is on the implementation of strategic concepts, balancing the opportunities of digitalisation in industrial value creation with the needs of a human-centric world of employment. Industrie 4.0 is seen as a socio-technological challenge. In many fields, the overarching goal is reclaiming industrial competitiveness – especially as a manufacturing location – as well as the creation (or preservation) of sustainable jobs to counteract the effects of the financial and economic crisis.

The transformation of the economy being brought about by Industrie 4.0 means that, in the future, business processes such as supply, manufacturing, maintenance, delivery and customer service will all be connected via the Internet. At its core, Industrie 4.0 involves the technical integration of Cyber-Physical Systems (CPS) in the realms of production and logistics (see figures below). Smart machines, warehousing systems and production resources are capable of independently exchanging information, triggering actions and autonomously controlling each other. This makes it possible to achieve a fundamental improvement in industrial processes: rigid value chains are being transformed into highly flexible value networks.
Accordingly, analysts such as e.g. the Experton group put the concept of Industry 4.0 in the broader context of the Internet of Things [6]. In their surveys they found out, that the market for Industry 4.0 (I4.0) and “Internet of Things (IoT)” is still at its emerging stage.

4.2 Market Potential, Impact and Segmentation

As the market for CPS-based Industry 4.0 (I4.0) and Internet of Things (IoT) is still at its emerging stage, it’s difficult to find proper forecasts and the existing market studies vary widely in their market expectations. For example, Statista provides an overview on expected global revenues by connected devices [7] (Fig. 7). However, nothing is said about the specific scope of this prognosis.
Different figures are provided by i-scoop for the IIoT market and its global impact [8] (Figure 10). IIoT in this context comprises beside smart manufacturing also smart energy and smart transportation segments amongst others.

Bosch is expecting in one of its white papers [9] approximately 14 billion connected devices worldwide by the end of year 2022, starting with more than 2 billion connected devices by the end of 2013. They assume that the highest amount of IoT connected devices will be concentrated in four industries in 2022 – intelligent buildings, automotive, healthcare, and utilities. According to these assumptions, the manufacturing sector will require a relatively low number of connected devices. But the potential effect of device management and IoT solutions in this sector are seen as comparably high.

A German study on potential increase in added value for Germany (2025) sees the biggest impact of Industry 4.0 in the manufacturing sector, with the automotive and ICT sectors in lower-ranking positions [10].

Figure 10: Size and market impact of the Industrial Internet of Things.

Figure 11: Potential market impact (value added) of Industry 4.0 by 2025 (Germany).
Another German study from 2016 empirically analysed the current state of Industry 4.0 implementation and published a respective market survey [11]. Based on two different databases⁴, this report distinguished between:

- 8 main manufacturing industry sectors such as vehicle manufacturing, mechanical engineering/manufacturing etc. plus other sectors (Figure 12), and
- 10 main categories for Industry 4.0 application scenarios (Figure 13)

Top 3 industry sectors, where first Industry 4.0 solutions are already realised, are the manufacturing sector (mechanical engineering) with 28% of all use cases in both surveys, the ICT sector (electronics, electronic equipment, devices, etc. with 26%/ 14 %), and the automotive sector (car manufacturing with 16% / 17%). These results correspond to the findings of the foreseen market impact per sector (cf. Figure 10).

The analysed application categories partly correspond to the I4.0 application scenarios, which have been published by the German I4.0 platform as specific aspects of the research roadmap [12].

The majority of use cases could be assigned to assistance systems (40% in both surveys), in particular to operator support assistance systems for automation solutions (34% / 35%). A second focus could be identified in the field of value based services (21% / 19%).

Accordingly, the categorisation exercise shows – for both surveys based on two different databases – a clear focus on assistance systems in the vehicle manufacturing, mechanical engineering, electronics and metalworking industry sectors (red area in Figure 14). A second focus is on value-based services in the vehicle manufacturing and mechanical engineering sectors. Based on the example of value-based services (see also [13]), a customer profiling approach is presented in Chapter 7 “Market Segmentation for Technologies” of this report.

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⁴ The report is based on 203 uses cases published from the Platform Industrie 4.0 in the context of the German IT Summit 2015 as well as on 187 use cases from the “innovation register Industrie 4.0 / IoT” of the Pierre Audoin Consultants (March 2016).
4.3 Technologies and some technology providers

As the “Industrie 4.0” approach is still a visionary concept, far from being broadly implemented in real industrial environment, several enabling technologies are still at a very early development and deployment stage. Gartner recently published a hype cycle referring to the management of operational technology (OT) in digital businesses, providing an overview of technologies and concepts emerging when looking to the “blurring of physical and virtual boundaries” in industry [14].

The Gartner hype cycle reveals a couple of enabling technologies at a maturing level, covering aspects like system understanding as well as communication requirements. However, remarkable is the very low maturity level of cyber physical systems (CPS), which foresees CPS with more than 10

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5 Gartner defines operational technology as “hardware and software that detect or cause a change through the direct monitoring and/or control of physical devices, processes and events in the enterprise”.
years to mainstream adoption. Following technologies are mentioned in the study as prerequisite for implementing CPS:

- distributed computing,
- interconnected information systems and
- prescriptive analytic techniques
- real-time interaction over high-speed networks

At Gartner’s “peak of inflated expectations” following technologies are mentioned with 5 - 10 years to mainstream adoption:

- Embedded Software and Systems Security: the technology based on an integrated hardware and software security concept is driven by microchip manufacturers. The built-in security is a feature required by cyber physical systems, which are highly interconnected.
- Event Stream Processing: streaming analytics to enable distributed decision-making is another enabler for fully autonomous CPS, which can “decide” in a certain scope on their actions. The combination of distributed and central computing and storage capacities

Regarding specific providers of I4.0/IoT technologies, the Experton Group published an “Industry 4.0/IoT Vendor Benchmark 2017” [15]. This report identified on the one hand many partial I4.0/IoT solutions and on the other hand – caused by the fragmented solutions space – a high need of consulting on the user side. It seems to be evident, that the market is evolving fast and the success of single-purpose solution vendors is limited compared to full-service providers in the domain. Nevertheless, customers currently ask for domain specific solutions (such as logistics, manufacturing or customer services), which can be covered by tailored solutions. A wave of consolidation is expected right now with the effect that some of the IoT platforms will disappear in a very short time (“the market is evolving in time lapse speed compared to other markets”). Thus, the structure of identified leaders in the I4.0/IoT Vendor Benchmark report are just a snapshot in a very dynamically developing market landscape. As can be seen also in the (founding) members structure of e.g. the Plattform Industrie 4.0 or the Industrial Internet Consortium [16], big players from the ICT sector such as IBM, INTEL, SAP, Telekom, Microsoft or ATOS compete and cooperate with “traditional” industry companies such as Bosch, General Electric, Siemens etc. but also with smaller engineering and manufacturing companies such as e.g. Beckhoff or Trumpf (AXOOM) for realising the I4.0/IoT vision.

4.4 Trends, competitiveness drivers and future scenarios

I4.0 and IIoT are still visionary concepts, but with first successfully implemented partial solutions. A common report of Plattform Industrie 4.0 and Industrie du Futur lists some further implementation scenarios affected by the key trends of digitizing manufacturing and platform economy [17]. Digitalisation impacts different aspects which Plattform Industrie 4.0 structured in the three interdependent strategic, value chain and system layers (Figure 16). The Alliance Industrie du Futur has identified following six drivers for future competitiveness, which can be related to the three layers and specific activities of the Plattform Industrie 4.0 (Figure 17):

- Connected devices and IIoT
- Advanced production technologies
- New human-machine collaboration approaches
- Driven and optimised lines and factories
- Integrated customer supplier relation
- New social and business models

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6 Gartner’s definition of CPS “CPS blend physical/mechanical automation with algorithmic knowledge to be self-adaptive and automatically reconfigurable. CPS are the core for the vision of smart manufacturing and Industry 4.0. CPS offers the migration path from industrial Internet of Things (IoT) and virtualization of IT and OT into a business-driven environment.”
Strategic layer: This layer addresses the business model of a company and the interaction of companies in a business ecosystem. Examples, how digitalization impacts this layer can be found especially in B2C, e.g. Amazon, Spotify Music, or Uber. But in B2B also such examples are emerging like pay per use models for power used instead of paying for a physical drive.

Value chain layer: This layer addresses the value creation processes within a company as well as the value chains across different companies. This layer is impacted by digitalisation since years. Typical examples are building virtual prototypes instead of physical ones, supporting an operator onsite via remote service instead of travelling to the site, or executing online software updates instead of manual installation.

System layer: This layer addresses the technical systems including the required and used technologies. This layer is also impacted by digitalisation since years, where products are augmented digitally for different stakeholder along their entire lifecycle. Typical examples are remote monitoring and control functions supported by telecommunication services offering wide area connectivity, the provision of online documentation for users and sales, or the provision of a “digital twin” for engineering and operation.

Figure 16: Conceptual Cornerstones of Industry 4.0.

Figure 17: Competitiveness Drivers related to I4.0 conceptual cornerstones.
4.5 Business Expectations and Roadblocks

Regarding the 4.0 adopters perspectives, a recent study – conducted with companies from Germany, China, Japan, South Korea, Great Britain and the USA – reveals the expectations regarding 4.0 in manufacturing as well as steps required for successful adoption of 4.0 technologies [4]. The results of the survey show that many countries share a very similar understanding of Industrie 4.0, despite differences in their specific focus. The experts from all of the countries in the study primarily associated Industrie 4.0 with networking and digitalisation (Figure 18).

The survey also reveals differences in the business expectations across countries. While the focus in Germany, South Korea and UK lies on production optimisation, the US and Japanese companies put more focus on business models, and in the US in particular on better customer service. Chinese companies expect to enhance their product and service portfolio by means of Industry 4.0. Furthermore, the survey investigates interoperability and common standards as the key roadblock for 4.0 implementation (Figure 19). Connectivity and related issues like interoperability require a strong set of standards to enable companies to profit from nonproprietary solutions. The adoption of 4.0 solutions will depend on international standards and their adoption. As there are more than 100 standardisation organisations worldwide, the risk of local standards is high (Figure 20). This implies the risk of technological lock-in and a barrier for open, flexible and successful ecosystems.
References


[16] www.iiconsortium.org

5  Healthcare CPS & IIoT Technology

Within the health domain, there are major pushes for data analysis and aggregation (Big Data), and interoperability (communication) for devices (IoT), but limited work on the cumulative control over such connected devices (CPS). While this is true to an extent in other domains, it is particularly evident in this domain, where there is a distinct lack of CPS dedicated platforms.

According to COCIR [2], the European medical technology market is estimated to make up 31% of the world market. It is the second largest medical technology market after the US (40%). This highly innovative industry (R&D investments up to 12% of revenues) consists of 80% of SMEs.

A global perspective for healthcare – hence a global segmentation from a « market » viewpoint – could be misleading, as the distribution of healthcare expenditure in general (including products and services, prevention – including insurance – and therapy, etc.) is highly dependent on the healthcare system (including customer behaviour), hence very much country dependent.

In the past years, the debate about the US healthcare system triggered a number of market analyses [3], which probably would apply only to European countries with similar healthcare systems and demographic features, but not to Europe as a whole. Also, the different regulation authorities in the US and in Europe do have an impact on medical innovation and healthcare market.

Looking at Europe, according to Eurostat [4], healthcare expenditure by country ranges from 6% of GDP (Romania, Poland, Luxembourg, …) to 11% of GDP (Sweden, France, Germany, The Netherlands). Relative to population size and in Euro terms, current healthcare expenditure ranges from 5k€ (Sweden, Luxembourg) to less than 1k€ for 9 countries (including Bulgaria and Romania, with less than 500 € per inhabitant). Considering price level differences, the ratio between the highest and lowest levels of healthcare expenditure per inhabitant is still 5 (Luxembourg) to 1 (Romania).

The share of long-term care (including both the health and social components of long-term care) in current healthcare expenditure is also quite different across European countries : In six EU Member States — Cyprus, Croatia, Romania, Greece, Slovakia and Bulgaria — long-term care accounted for less than 3.0% of current healthcare expenditure. At the other end of the scale, this share is more than 30% in Sweden, the Netherlands, and Finland.

Long-term care expenditure exceeds 1.5k€ per inhabitant in the Netherlands and Sweden. The disparities between countries are huge – even adjusting for price differences, it is more that 1 to 1000.

In spite of such differences making difficult a comprehensive quantified market perspective, this study still shows common features:

- Curative care and rehabilitative care services account for more than half of current healthcare expenditure in a majority of EU Member States
- Medical goods (including drugs) account for around one quarter of total current healthcare expenditure
- In most EU Member States, hospitals are the main provider of healthcare in expenditure terms
Demographic evolutions is also heterogeneous across European countries [5]. However, population ageing is a long-term trend which began several decades ago in Europe. The share of the population aged 65 years and over is increasing in every country. Enabling « home care » for the elderly is generally viewed as a means to improve patient comfort, and possibly reduce costs (though this could be controversial, depending on family environment and healthcare system organisation), at least for some types of diseases.

Major and chronic diseases (MCDs) are defined as diseases affecting at least 50 per 100 000 people – together they cause 87% of deaths in Europe.

MCDs market segmentation (i.e. of consumers) is relevant for medical technologies market, as well as research priorities :

- cardiovascular diseases (atherosclerosis, stroke)
- cancer
- neurodegenerative disorders (vascular dementia, Dementia, Parkinson’s, Huntington's disease, Creutzfeld-Jakob's)
- epilepsy
- mental disorders (depression/schizophrenia)
- autistic spectrum disorders
- musculoskeletal diseases
- metabolic diseases (metabolic syndrome, obesity, diabetes, hyperlipidaemia/hypercholesterolaemia)
- asthma / chronic obstructive pulmonary disease (COPD)
- hypertension
- kidney (renal) diseases
- visual impairment
- hearing disorders

Relevant to the market segmentation is the marketing push for « healthy living », consumers being increasingly engaged in their health – typically monitoring their activity, adapting their eating and sleeping habits – indirectly contributing to MCD prevention. To what extent the technologies from this « fitness » segment could directly benefit to traditional healthcare segments (e.g., by cutting down the costs of some sensors, or by pushing interoperability standards) is an open question.

One major marketing trend, supported by big data techno push, is personalised medicine [6], whereby medical decisions, practices, interventions and/or products are tailored to the individual patient based on their predicted response or risk of disease. Pharmaceuticals industry is investing in this approach, especially for personalised treatment of cancer. Extension of the approach to other diseases (cardiovascular, hypertension, metabolic diseases) could be supported by a new generation of medical CPS/IoT sensors.
In our analysis of the needs for CPS research, IIoT technologies and associated platforms in Health sector:

- We focus on **products rather than services**. We keep in mind that while services account for 75% of healthcare expenses, their organisation is very dependent on healthcare funding system, which is itself very much country dependent. However, since the same medical devices can be used in a variety of healthcare systems, hence a segmentation of products is more generic.

- We do not take into account the **pharmaceutical industry**. Though drugs represent a large part of research investment in healthcare, we do not see a direct term impact of CPS principles and IIoT technologies on this market. Conversely, better prevention, better diagnostics, and personalised medicine, supported by CPS and IIoT, could help reducing drug usage.

- We recognise the central role of **hospitals** in any healthcare system. This is true not only in European countries, but also in foreign countries, e.g. China, where the upgrade of equipment hospitals, e.g. imaging systems offer significant opportunities for European providers.

We divide the healthcare field using the healthcare cycle (Figure 22) as follows:

- **« Fitness »** including devices and systems for healthy living, including healthcare monitoring and possible direct contribution to diseases prevention

- **« Hospital Care »** including devices and systems for prevention, diagnosis and treatment provided by a (public or private) large healthcare infrastructure, including mainly traditional hospitals but more generally sustainable structures coordinating the cooperation of healthcare professionals

- **« Home Care »** including not only devices and systems at home for treatment and monitoring, but also personal equipment such as prosthesis or other implanted devices

For each of the major MCD, one segment may be dominant, and the shift of expenses from one segment to another might be a stake for improved efficiency of healthcare, for which CPS and IIoT solutions could be key.

Transverse to these segments, taking healthcare systems as a whole, we consider and agree with Energetics findings [1] that:

- Today’s medical device architectures lack interoperability. The typical device employs proprietary systems and relies on trained professionals to operate the device and interpret system output, which frequently requires to be connected to a patient at one time (e.g., in
an operating room), in which case clinicians must monitor all devices independently, clinicians frequently consult others present to interpret the readings. This is an error prone process and it can be affected by stress, fatigue, and other human factors.

- Today’s verification and validation (V&V) efforts are driven by system-life-cycle development activities that rely primarily on methods of post-hoc inspection and testing; these approaches, although adequate for a thermometer or pressure measuring device, are not appropriate for the diverse and complex interactions between different components in the medical devices of the future. Many of those devices have time constraints and/or constraints that rely on analysis of input signals coming from the patient.

Furthermore, from a technology viewpoint:
- Regarding Hardware: Current device architectures are highly proprietary, not interoperable. Embedded systems are, for the most part, open-loop. Closed-loop systems tend to be implantable devices. Examples of such devices include implantable cardioverter defibrillators (ICDs) or cochlear prosthetics. In current devices any network communication is largely for the purpose of diagnostic output. Both complex instruction set computer (CISC) and reduced instruction set computer (RISC) architectures are commonly used. Multicore and system-on-a-chip (SoC) architectures and flexible reconfigurable architectures, such as field programmable gate arrays (FPGAs), are becoming more common in device designs.

- Regarding Software: Current software development methods range from older methods such as structured programming to object-oriented programming paradigms where objects are instantiated at run-time. Formal methods-based design and analysis that have flourished in computer science are not widely used. To demonstrate that a device will perform as intended the techniques used should be Human resource-intensive. Use of static-analysis tools on implemented code is limited. Development platforms do not facilitate integration of hardware, software, and human factors in design, development, and manufacturing.

From a system engineering perspective:
- Research approaches are needed that can provide assurance for the correctness of the operation of embedded real time systems with networking and control capabilities.

- New software engineering techniques are needed that integrate computational and communication designs together with patient models. Software development methods must scale across the device industry’s entire problem.

Medical devices are increasingly moving towards to cyber-physical and closed-loop, meaning prior feedback is taken into consideration when assessing an incoming signal. Most medical devices are currently open-loop [1] and as such there is a significant need to advance control mechanisms related to sensing and the large gap between signals and symbolic representations.

The means for traceability along the product lifecycle is significantly important to advance. At the engineering level there are many constraints including the environment, control, communications, timing, computation. With connectedness of verification and validation, information from early stage tools should be exchanged with later design tools to increase the effectiveness [1]. Subsequently, when products are in operation, feedback on verification and validation should be a continuous process: competitiveness of Medtech will increasingly need to “use analytics to prove the effectiveness and efficiency of its products and actions” [8].
Before proceeding to look individually at sections of the healthcare cycle, we wrap up this part by emphasising that a significant demand for technology from the healthcare market remains to be addressed. Ernst & Young note[9] that approximately 9 million people in the US could benefit from physical medicine and rehabilitation services and industry professionals estimate only half of these cases are sufficiently treated due to a lack of rehabilitation resources.

References
Smart System Technologies for Manufacturing, Power Grid and Utilities, Buildings and Infrastructure, Transportation and Mobility, and Healthcare, March 9, 2012, Prepared by ENERGETICS INCORPORATED on behalf of the National Institute for Standards and Technology (NIST).
[7]  Casper Garos (Philips Senior Director Innovation) Technical meeting preparing the round table on the electronics industry, October 2016

5.1 Hospital Care

Market Size
According to the Organisation for Economic Co-operation and Development (OECD), hospitals worldwide absorb 30 to 40% of all healthcare spending; for example, about one-third of U.S. healthcare is provided by hospitals, 35% in France, 42% in Australia and Korea, 44% in Turkey and the Czech Republic and 45% in Denmark, while nearly half of healthcare in Japan is provided by hospitals.[5] However, this being said, whilst “Digital Healthcare” is used widely, “Digital Hospital” appears very infrequently currently. This may be an interesting opportunity for Europe.

The Global Hospital Supplies market has been estimated to be USD 30 billion in 2016 and it is projected to reach USD 51.9 billion by 2021 at a CAGR of 11.5% during the forecast period from 2016 to 2021. Hospital medical equipment and supplies refer to various devices, tools, instruments and medical consumables that are used in hospitals and healthcare establishments. Hospital equipment and materials market is increasing at a substantial rate past few years. [6]

Leaders in the field

Some of the largest major competitors in this field include [1]:

**General Electric (GE) Healthcare** is valued as a $17 billion unit of the GE Company. Having its headquarters in the UK it employs over 46,000 people across more than 100 countries. Medical products include: digital x-ray, ultrasound, nuclear medicine, positron emission tomography,
computed tomography, magnetic resonance imaging, surgical navigation and interventional imaging systems, and clinical IT.

**Hitachi Medical Corp.** has headquarters in Japan and over 10,000 employees manufacturing integrated medical systems. Their business covers the range of medical equipment and medical information systems, including: diagnostic imaging systems including Magnetic Resonance Imaging (MRI) systems, diagnostic ultrasound systems, X-ray Computed Tomography (CT) systems, and X-ray systems.

**Siemens Healthcare (SH)** also valued at around $17 billion has headquarters in Germany and over 45,000 employees. It is one of the largest suppliers of healthcare equipment in the world. Their range of products cover imaging systems for diagnosis and therapy equipment for treatment, electro-medicine and hearing instruments, fluoroscopy, angiography, ultrasound, nuclear medicine, computed tomography, magnetic resonance imaging, radiography, molecular imaging, patient monitoring systems, clinical IT, and mammography. They also provide solutions to optimise workflow and increase efficiency in hospitals, clinics and doctors' offices.

**Philips Healthcare** is value at about $9 billion with their headquarters split between the Netherlands and the US. Comprised of 33,000 employees, Philips Healthcare provide equipment including: diagnostic imaging, general X-ray, ultrasound, nuclear medicine, computed tomography, magnetic resonance imaging, cardiac and monitoring systems, clinical IT, radiation therapy planning, molecular imaging and next-generation PET as well as single photon emission computed tomography (SPECT) systems. There are also advanced IT technology and services to support the equipment.

In terms of innovation leadership through partnerships, the French company **DOSISoft** [8] is a strong competitor in radiotherapy. Formed from a partnership between Gustave Roussy and Institut Curie (two major cancer treatment centers), in just under 10 years they have become the leader in France and second in Europe. Their software solutions specialised in radiotherapy and molecular imaging, with experience including multimodality registration, volume segmentation, beam set-up, dose calculation, tumor response follow-up, are used by more than 160 hospitals in 18 countries. In 2016 they opened a subsidiary in the US.

**Trends**

Healthcare is one of the most innovative sectors. Across the hospital care market advances in technology can take place in a variety of ways [1]:

Merging of technologies can occur between different providers. For instance **Boston Scientific** (BS) was working with Philips Healthcare and Siemens Medical Solutions to integrate its iLab® Ultrasound Imaging System with the Philips Allura™ Xper and the Siemens AXIOM™ Artis and Artis™ zee interventional X-ray systems. Physicians are able to generate a 360-degree view inside the heart and coronary vessels with this Intravascular Ultrasound technology, significantly more accurate than with only angiography. The iLab System is thus able to be installed in cardiac catheterisation laboratory or radiology suites in conjunction with these X-ray systems to be used in the physician’s procedures.

Examples of new technology includes a feasibility study launched by **Edwards Lifesciences Corp** in Europe. The system is called Project Odyssey and is a novel approach for minimally invasive aortic valve surgery. It will enable “surgeons to rapidly deploy a heart valve that offers excellent
hemodynamics and proven durability which will not require the usual sutured approach, providing a faster operation with smaller incisions and shorter patient time on cardiopulmonary bypass.

Another comes from the organisation Medtronic, developing a device for patients with paroxysmal atrial fibrillation. This problem exhibits an irregular quivering of the upper chambers of the heart that starts and stops on its own. Their device called the Arctic Front® Cardiac CryoAblation Catheter System, uses cryoablation (freezing) to ablate heart tissue between the pulmonary veins and the left atrium. This is to stop the arrhythmia at the source. Their device has been submitted to the FDA for Pre-Market Approval.

McKinsey & Company [4] highlighted some important trends to encourage. As for industry in general, implementing full traceability of a product remains elusive – this extends from the device to the stages of the patient’s health journey and requires an effective connected health strategy. With the mobile becoming a dominant source of internet traffic, business and consumer value propositions (market segmentation) needs to be reassessed with adapted structuring for the new basis of competition. For given health scenarios, knowledge of the context is critical and winning market strategies will a more intimate discernment of customers. They say “the entire business model should be boldly reimagined” and that “bold aspiration” is needed for deploying digital/mobile technologies to avoid simply reinforcing the status quo.

The ITEA project Modolution plans to create a form of “automatic data format harmonisation” this will enable interoperability through independence of the data source. This will contribute to their intended “Smart Patient Environments” intended for use by both the medical staff and patients. This is illustrated in Figure 23.

Road Blocks

Doctors and nurses tend to be more careful with the uptake of new technologies than employees from other domains but also unable to make changes in cases with a high work load given related higher risks. Methods to achieve trust sooner and also increased support of daily tasks during training will be needed to overcome resistances where burnout or technology overload is occurring. Medisas indicated possible ways to overcome this including [7]: Use multiple communication channels for new technologies to a hospital as staff are often distributed across several locations – also success stories from elsewhere help; find “evangelists” strongly motivated by the new solution.
such as driven by a desire to improve current processes or with an acute problem to resolve; “make problems personal” by developing an understanding of the pain points at particular hospitals; set expectations in a clear phased approach with attainable targets; incorporate feedback from key users during deployment through meetings and other channels – but you need to be proactive here as often physicians are not in the habit of providing this.

With respect to technology roadblocks, CPS specific Platforms in healthcare are very few / non-existent. Building blocks and shared engineering tools would benefit SMEs wishing to enhance the capabilities of their devices without starting from scratch. The main general drive in hospital care has a focus on communications and data management, challenges here including the need for real-time data provision requiring customised high-performance computing platforms with run-time libraries for IoT enabled devices[3]; a proliferation of common data element models [2] which is counterproductive to achieving stronger interoperability of healthcare data; a seamless transition from the legacy system and setup to an IoT-based configuration is a major challenge[3], i.e migration needs to ensure backward compatibility and flexibility in the integration of existing devices; finally in an environment where many caregivers perform their duties with many patients, careful identification among them is a necessity.

5.2 Home Care
This sector deals predominantly with treatment/management of ailments or rehabilitation from the home to enable patient independence. It can be referred to as ‘Ambient Assisted Living’ and usually encompasses both sensors and actuators connected to the home and/or the person.

Market Size
The Home Health Care market at USD 244.4 billion in 2015 is predicted to reach a value of USD 517.2 billion by 2025 [8]. It can be divided into Services, Diagnostics, Mobility Assistance and Therapeutics with CPS being chiefly related to the latter two with associated services. Conversely IoT has highest usage in Diagnostics but offering general utility across the market.

Therapeutics itself can be significantly subdivided further. For instance, the cardiovascular market can be divided into ten primary fields, with the three largest being [1]: (1) Cardiac rhythm management, which consists of pacemakers, implantable cardioverter defibrillators (ICDs), and

References
cardiac resynchronisation therapy; (2) Interventional cardiology devices, which consists of PTCA balloons, coronary stents, cardiac catheters, coronary guidewires, arteriotomy closure devices, and intravascular ultrasound systems (IVUS); and (3) Peripheral vascular devices, which includes peripheral vascular stents, PTA balloons, aortic stent grafts, synthetic surgical grafts, embolic protection devices, inferior vena cava filters, and peripheral guidewires.

**Leaders in the field**

Here we take some snapshots across the market as there appears to have been no global studies yet specifically on CPS technology for Home Care. Related to rehabilitation equipment and supplies market (including wheelchairs), it has been indicated [1] to be highly fragmented with significant competition. In the US, providers of such products are primarily locally or regionally focused, with Invacare and Patterson Medical being among the few exceptions.

Considering the pacemaker market, it was valued at $4.9 billion in 2015[9], with the US being about half of this. Leading equipment suppliers in this field are: Medtronic is the market leader with 50 percent US market share; St. Jude Medical (now merged with Abbot) has 28 percent US share; Boston Scientific (BS) with 18 percent US share. All these companies are headquartered in the US. European based companies include Biotronik SE & Co. KG in Germany and in Italy there is Medico and the Sorin Group. The three initial companies are also the leaders in the Implantable Cardioverter Defibrillator (ICD) market.

In terms of innovation leadership by public-private ventures, the European (French) company CARMAT [10] is a leader of heart prosthesis. Heart prothesis is a typical example of complex, safety critical, embedded biomedical cyber-physical system. It combines several technical challenges in terms of smart system integration, reliable command and control software. It also shows the complexity and typical timeline for the test and validation of such systems - even questioning established processes, in Europe as well as in the US. Based on several inventions by Prof. Alain Carpentier, the first prototype was tested on animals in 1989. A first phase of clinical trials on 4 patients was authorised in 2013. A second phase on 20 to 25 patients should start in 2017. Initiated thanks to private funds (Airbus Group) in 1990, the company also got support from public (regional and national) funding, and now benefits from more than €30 M of private funding, complemented by a national loan to achieve validation ("CE" label). This highlights the relevance of Public/Private partnership for such ambitious CPS development.

**Trends**

Related to Hypertension, there is a growing worldwide prevalence and a need for alternative treatments for patients that do not respond well to drug therapy [1]. Investigations into several non-drug treatments including nerve ablation and electrical stimulation are being conducted by BS.

Some new cardiovascular technology areas being focused on by Medtronic, Inc. on include new implantable heart rhythm devices, replacement heart valves that do not require major surgery, pacemakers designed to work safely in MRI scanners, and defibrillators that reduce the number of unnecessary shocks.

Advances in wireless cardiac monitoring devices are being led for instance by CardioMEMS. The clinical trials of their wireless heart failure sensor have been successful. This monitoring device can be implanted in the patient using a simple catheter-based technique. After this patients can perform wireless measurements of their pulmonary artery pressure from home with data immediately transmitted to a secure database CardioMEMS Champion website available for review by the a physician or nurse – where problems are detected solutions can be provided, such as adjustments in medication, without requiring a hospital visit.
Bioelectronics is another trending technology [2]. In response to particular diseases, miniature devices are implanted in the body in order to provide stimulus to specific nerves. These modulate disease pathways to ensure required signals are delivered at the right time.

The ITEA project Medolution [3] will be advancing Medical Image Analytics and plan to include contextual data for analysis of large image data sets. A platform will be developed to support algorithms in this field. Additionally they will be developing an extensible UI architecture supporting personalised development of user interface (UI) in the health domain. This is because standardised UIs are often not feasible. It was also noted that in current health care systems being developed, there was still significant benefits of big data analytics that have not yet been tapped into, including patterns and associations identified from access healthcare processes and patient health records. This will contribute significantly to supporting evidence-based clinical practice and reduction of hospital readmissions.

It is estimated that in 2017, 50% of smart phone and tables users will have mobile health apps, with only 0.5% regulated. [4] Establishing the fine line to determine when regulation is required is increasingly a need. In terms of improved connectedness, a Deloitte report [6] considered benefits for health providers and patients as in Figure 24 below. With tests showing a 60 percent reduction in paper work with up to 30 percent more patient facing time, It was also found that A&E abd hospital bed usage was reduced by over 50 percent.

Figure 24: mHealth contribution to Health provider and patient [6].
Road Blocks

The development and use of new materials is often a roadblock transverse across domains. For Home Care, smart skin is such an example. This technology [7] consists of prosthetic devices with the capability of sensing and providing feedback to the system. They change their characteristics based on the environment and context of the patient and their movements. A number of challenges need to be addressed related to safety and managing the artificial-biological interactions.

Another challenge transverse across domains is UI development. In health care this contributes significantly to devices not being accepted and returned by clients. Model-driven engineering (MDE) practices could offer significant benefits here in terms of error reduction and reuse, however it is as yet used very little in current e-Health/m-Health applications [3]. Open platforms in conjunction with MDE would further support entry into new health care sectors, such as the pacemaker market [1], where high R&D costs can mean entry into them has significant barriers to overcome.

Related to Decision Support Systems (DSS) products [3], there is limited diagnosis support (mostly drug dosage or interaction) and usually off the shelf have quite significant differences to a particular hospital’s medical protocols, procedures and management system which can require significant time for an organisation to adapt a DSS to their requirements. There is a need to advance standardisation in this field and improve functionality enabling real-time decision support, using multiple data stream and incorporating sophisticated imaging data.

In relation to “connectedness”, there is a need to advance capability for continuous monitoring especially for patients with chronic problems requiring long-term supervision [5]. There is also a need, given the recent proliferation of home care applications through mobile and wireless technology, to boost regulation [4] providing sufficient safety for the user and maintaining trust.

References

5.3 Fitness

Fitness and Wellness wearable devices [1] are designed to sense and track data points such as body temperature, workout time, distance covered and heart rate. Most of these are worn on the wrist, but there are also a number of clip-ons, chest bands, leg bands, smart garments and ear-worn devices on the market. Numerous software applications are included with these, from very basic measuring and mapping of running routes to more advanced offerings, such as coaching, analysis and daily recommendations for optimising one’s fitness and wellness.

Wearable products are noninvasive and is a domain that covers both consumer and patient applications. While sold as fitness devices the avoid some of the heavy regulation that medical devices see. Examples include hearing aids and sensors that monitor heart rate, blood pressure and glucose. There is also a drive towards greater shared data collection from these devices for “lifestyle medical” cloud software services.

**Market Size**

The wearable technology market estimated worth USD 15.74 billion in 2015, will rise to USD 51.60 Billion in 2022 according to Markets and Markets [2]. Wearables can be divided into three categories based on the part of the body on which they are worn [1]:

- Wearables for the head comprise a reasonably mature segment; headphones alone are worth about $10 billion per year, and Bluetooth headphones account for about 55% of that total. Other devices in the category include virtual reality (VR) and augmented-reality (AR) headsets.
- Wearables for the body include smart T-shirts, body cameras, high-visibility jackets, socks, shoes, bras and chest straps. Sportswear companies are highly active in this segment and are working on connecting fitness- and wellness-tracking devices with health-related software ecosystems.
- Wrist wearables is a segment that has experienced massive growth, partly thanks to Apple, which shipped nearly 12 million Apple Watches in 2015, according to IDC, despite launching only in April of that year. Apple’s entry in the premium watch segment has even spurred some luxury watchmakers to create their own smartwatches. Another notable maker of wrist wearables is Fitbit, which sold close to $2 billion worth of fitness bands and other products in 2015.

**Leaders in the field**

In the first quarter of 2016, the top-selling wearables brands [1] were Fitbit (with 4.8 million units shipped), Xiaomi (3.7 million) and Apple (1.5 million), according to market measurement firm International Data Corporation (IDC).

Gartner forecasts that total wearable units shipped will grow at a CAGR of 17.9% between 2015 and 2017, with the wrist-worn wearables segment growing the fastest, at a CAGR of 30%. According to market-measurement firm IDC, in the first quarter of 2016, the top wearables brands were [1]:

- Fitbit, with 4.8 million units shipped.
- Xiaomi, with 3.7 million units shipped.
- Apple, with 1.5 million units shipped.
- Garmin, with 0.9 million units shipped.
- Samsung and BBK, which each shipped 0.7 million units.
Figure 25: Company focuses across wearable market segments. [1]

Trends

A convergence in some areas of fitness and medical technologies – for instance the identification of new diseases and disorders can be found and treated when analysing data collected by many people monitoring their fitness.

There are two major trends underpinning the continued growth of the wearables market[1]. First, the emergence of “wearables 2.0” will shift the category from stand-alone devices to lifestyle-enhancing systems tying together multiple connected devices and cloud services. Second, the clothing and sportswear categories are likely to see a jump in wearables offerings, with mass-market brands such as Google, Levi’s and Nike launching new products.

Innovation and change are rife in the wearables market. A large number of startups—fueled by access to cheap components, 3D printing and willing crowdfunders—have emerged, and some have been further funded or acquired by venture capital firms or corporate buyers. [1]

Wearables are naturally converging with the IoT, and a number of companies have focused on creating software ecosystems for wellness and personal healthcare monitoring. Sportswear companies and IT giants such as Google and Apple are also developing software that connects devices. [1]
A wearable tech partnership that has recently borne fruit is Project Jacquard, which Google and Levi’s launched in 2015 to develop products that use conductive textiles and machine learning to interpret motions. In May 2016, the two companies unveiled a connected jacket designed for urban cyclists. The jacket has smartphone-connected functionality that allows users to control their music and answer calls using technology embedded in the jacket’s sleeve. [1]

Since 2013, Adidas, Under Armour and Asics have spent a combined $1 billion acquiring companies that develop fitness and health software applications. Nike dropped its fitness-tracking-band division in 2014, but has since developed the Nike+ fitness-tracking software application, which is featured on the Apple Watch. Underscoring the importance of software applications to the sportswear market, in January 2016, Under Armour partnered with IBM Watson to ensure that UA Record software users receive notifications that help them optimise their daily fitness, wellness and sleep rhythms. [1]

Nike will release its HyperAdapt 1.0 self-lacing shoe in the fourth quarter of 2016, initially only to users of the Nike+ app. It will be the first mass-produced self-lacing shoe and will rely on a mixture of mechanical and electronic engineering for its functionality, enabling the wearer to get just the right fit and tightness as the shoe “adapts” to the wearer’s foot. The price and release date have not yet been announced. [1]

In January, New Balance announced that it was launching a Digital Sport division to develop wearable, embedded and analytic technology. The company also revealed that it was partnering with Intel on developing a sports watch for runners. [1]

The wearables market is merging and overlapping with other markets, such as medical devices with key points being[1]:
- Larger companies appear to be developing wearables with a more strategic approach; the collaboration between Levi’s and Google is one example of this. In the past, a number of companies launched items such as smart shirts, bras or socks, but these efforts seemed to be mainly for PR value.
- Fitness is becoming synonymous with wellness and personal health. The trend is being driven by the sportswear giants and by IT companies such as Google and Apple, which are developing wellness data clouds that allow people to measure, track and analyse more of their daily activities.

Two major trends underpinning the continued growth of the wearables market can be noted [1]:
- The emergence of “wearables 2.0” will shift the category from stand-alone devices to lifestyle-enhancing systems tying together multiple connected devices and cloud services. Brands such as Under Armour are currently leading the way in offering bundles of connected products and services.
- Wristwear has dominated product launches and driven market growth so far, but the clothing and sportswear categories look set to expand in terms of wearables offerings. In May 2016, Google and Levi’s launched their first product collaboration, a smart jacket, and products scheduled to launch later in 2016 include Nike’s self-lacing shoes.

Road Blocks

Augmented Reality (AR) applications have clearly defined industrial and business-to-business use cases. But hardware and software prices are likely to remain too high to ensure mass consumer uptake in the immediate future, and it is still unknown if even industry will be willing to invest in AR at current prices. [1]

A number of clothing brands have produced apparel with built-in technology. However, the longevity and appeal of some of these garments has been limited, in some cases apparently due to opportunistic marketing and a lack of strategic foresight. [1]
References

6  Energy CPS & IIoT Market

6.1  Renewables

The global investment in renewable energy is at a record level, despite the plunge in fossil fuel prices, the strength of the US dollar, the continued weakness of the European economy and further declines in per unit costs of wind and solar photovoltaics (PV). For six years in a row the renewables sector has outpaced the fossil fuels sector for investment in power capacity additions. Wind and solar PV account for about 77% of new installations, with hydropower representing most of the remainder. Notably the world now adds more renewable power capacity annually than capacity from fossil fuels. The renewable capacity in place in 2015 was enough to supply an estimated 23.7% of global electricity, with hydropower accounting for 16.6% of this.

![Figure 1 Worldwide Breakdown of Renewable Power Source Additions in 2015 [1]](image)

This increase in the use of renewable power sources has also resulted in an increase in employment in the sector with an estimated 8.1 million jobs (direct and indirect). The largest numbers of new jobs were in the areas of Solar PV and biofuels. Large-scale hydropower accounts for 1.3 million direct jobs. On a world-wide level leading employers in the sector are China, Brazil, the United States and India.
Table 1 Top 5 Countries Considering Net Capacity Additions for Different Renewable Sources in 2015 [1]

Considering the addition of key renewable technologies the top 5 countries in each sector are shown in Table 1. Overall an estimated 147 gigawatts (GW) of renewable power capacity was added in 2015 which was the largest annual increase ever. These increases were against a number of negative factors including falling global prices for fossil fuels, ongoing fossil fuel subsidies and other challenges facing renewables, including the integration of rising shares of renewable generation, policy and political instability, regulatory barriers and fiscal constraints.

Wind Power

Figure 3 Increases in Wind Power Capacity 2005 to 2015

The use of wind power has been steadily increasing over the past 10 years as shown in Figure 3. In the period 2005 to 2015 the capacity increased from 59 Gigawatts to 433 Gigawatts, i.e. by more than 700%. In 2015 there was another record increase with more than 63 GW added. This is a 22% increase from the 2014 market. It is notable that more than half of the world’s wind power capacity was added in the last five years. There are commercial installations of wind turbine technology in more than 80 countries with 26 countries having more than 1 GW in operation. Wind power is the
leading source of new power generating capacity in Europe and the United States. Wind supplied more new power generation worldwide than any other technology in 2015.

China alone accounted for nearly half of global additions, but new markets are also opening across Africa, Asia, Latin America and the Middle East. Guatemala, Jordan and Serbia all installed their first large-scale wind plants in 2015, and Samoa also added its first project. At the end of 2015, the leading countries for total wind power capacity per inhabitant were Denmark, Sweden, Germany, Ireland and Spain.

**2030 Market Forecast**

The European Union set a legally binding target in 2014 that by 2030 at least 27% of final power should be generated by renewable energy. Wind energy is expected to account for 21% of this. EWEA’s [1] has predicted a number of scenarios for the future of Wind Turbines as shown in Figure 5. Considering the Central Scenario 320 GW of wind energy capacity is expected to be installed in the EU in 2030. This is divided into 254 GW of onshore wind power and 66 GW of offshore wind power. This is double the capacity installed in 2014 and an increase of two thirds from the expected capacity installed in 2020 (192 GW). It is expected that wind energy will produce 778 TWh of electricity which is 24.4% of the EU’s electricity demand. As a result of this the wind energy industry is expected to provide over 334,000 direct and indirect jobs in the EU with wind energy installations in 2030 being
worth €474 bn. The 96,000 wind turbines installed on land and offshore will cut emissions of CO2 by 436 million tonnes.

The Low Scenario foresees 251 GW of wind energy installations which is 22% lower than in the Central Scenario providing 19% of the EU’s electricity demand in 2030. This would create 307,000 jobs in the wind energy sector, €367 bn worth of investments and a reduction of 339 Million tonnes of CO2 emissions from the 76,000 wind turbines installed. In the High Scenario 392 GW of capacity is expected to be installed. This is 23% higher than in the Central Scenario and would meet 31% of the EU’s electricity demand. As a consequence 366,000 jobs would be generated, as well as €591 bn of investments. The 114,000 wind turbines installed would reduce CO2 emissions by 554 Million tonnes.

![Figure 6 Expected European Installations to 2030](image)

Already wind power has a major role in a number of countries, including Denmark (42% of demand in 2015), Germany (more than 60% in four states) and Uruguay (15.5%). To meet rising demand, new factories are being opened up or are under construction around the world.
Wind power was the leading source of new power generating capacity in Europe and the United States in 2015, and the second largest in China. Non-OECD countries were responsible for the majority of installations, led by China. New markets are also emerging across Africa, Asia and Latin America. Corporations and other private entities continued to invest in wind energy for reliable and low-cost power, while many large investors were also drawn by stable returns. The offshore sector had a strong year with an estimated 3.4 GW connected to grids, mostly in Europe, for a world total exceeding 12 GW.

The Wind Turbine market can be broken down into the manufacture of the turbines themselves and the electrical parts. In terms of value, the wind turbine composite market was valued by Markets and Markets at USD 7.15 Billion in 2015, and is projected to reach USD 12.17 Billion by 2021, at a CAGR of 9.28% between 2016 and 2021. Wind turbine composites are utilised in the manufacturing of wind turbine parts such as blades and nacelles making lightweight components with superior properties with low maintenance and long product life. The use of carbon fibre is expected to grow at a fast rate driven by the trend for larger blade sizes at a CAGR of 9.2% from 2014 to 2019. In 2014, the market was dominated by the Asia-Pacific region, which had more than 54% of the total installed blades in the world. The region is projected to remain the most attractive market through to 2019. South America, the Middle East and Africa are also predicted to have promising growth rates.

The microgrid market was valued at 16.58 Billion USD in 2015 and is expected by Markets and Markets to reach USD 38.99 Billion by 2022, at a CAGR of 12.45%. Many countries are focusing on innovations, and expansions are being carried out through rural electrification projects, which would help increase the demand for microgrid systems in the coming years. To be efficient and remove gearbox losses there is interest in direct drive (gearless) wind turbines. These use a low-speed generator that eliminates the need for a gearbox from the turbine’s drive train. These turbines are lighter than conventional turbines and have significantly lower maintenance costs. The preferred direct drive wind turbine generator is based on a permanent magnet type generator, as it is lighter in weight and possesses high reliability for offshore applications. The global small wind power market is estimated to reach USD 1.89 Billion by 2019, with a projected CAGR of 19.5%.
Solar PV

Photovoltaic (PV) systems are used to convert sunlight into electricity. They are safe, reliable, have low operating costs, and are easy to install. A successful PV installation provides power for over 20 years with no fuel costs and less maintenance. When compared to diesel generation, PV is a cost-competitive option, especially where electricity and diesel prices are often high. Although PV technology is an appropriate choice for many applications, high capital costs, poor installation and maintenance practices have been the limiting factors in the overall deployment of photovoltaics.

Despite this the solar PV market increased by 25% in 2014 to 50 GW, lifting the global total to 227 GW. The annual market in 2015 was nearly 10 times the world’s cumulative solar PV capacity of a decade earlier. China, Japan and the United States account for the majority of capacity added, but there are emerging markets on all continents. Uptake is being driven by the increasing cost-competitiveness of solar PV. 22 countries had enough capacity by 2015 to meet more than 1% of their electricity demand. Some countries have far higher uptake such as Italy 7.8%, Greece 6.5% and Germany 6.4%. Notably in China there is now 100% electrification which has been achieved with significant use of off-grid solar PV.

A challenge for the industry is that the prices of panels have reduced significantly as more panels have been mass produced. This has been particularly affected by Chinese manufacturers in recent
years. The markets have strengthened due to the rise of new markets and strong global demand. Most top-tier companies recovered in 2015. Notably record-low bids for large-scale solar PV project tenders were made in Latin America, the Middle East and India. Distributed rooftop solar PV is still more expensive than large-scale projects but this is also reducing in cost.

![Graph showing predicted PV panel costs to 2030](image)

**Figure 10. Predicted PV Panel Costs to 2030 [3]**

The predictions of PV costs are shown in Figure 10. This highlights that the PV panel costs will halve over the next 15 years.

**Future Market 2030**

According to the International Renewable Energy Agency (IRENA), solar PV could account for 13% of global power generation by 2030 due to dramatic capacity expansion from the current 227 GW to 1,760-2,500 MW by 2030. Recent cost reductions for solar power are expected to continue into the future, with up to a 59% cut in costs possible in the next ten years. As a result average annual capacity additions are expected to more than double in the next 14 years. Notably in 2015 solar PV accounted for 20% of total new capacity additions and solar installations have increased from 40GW to 227 GW in the last two years.

The regional industry group SolarPower (formerly EPIA) expects PV installations to exceed 60GW in 2016. The association forecasts grid-connected capacity to reach 516GW by the end of 2019 and 716GW by 2020. Here China is expected to install 87GW of new capacity by 2020 and reach 130 GW by 2020. This will far exceed installations in the United States (+59 GW to 85 GW), India (+52GW to 57 GW) and Japan (+29 GW to 63 GW).

Markets and Markets [4] highlight that incentives and funding provided by the government towards the adoption of solar energy is driving growth with big increases in China and Japan being expected. This is mainly attributed to the initiatives taken by the government, the key market players being located in the region. There will be growth in both the building-mounted and ground mounted PV panels.

The global photovoltaic market is expected to grow at a CAGR of 18.30% between 2014 and 2020 and the overall market is estimated to be worth $89.52 billion in 2013 to $345.59 billion by 2020. In terms of application, the utility application accounted for the largest market size in 2013 at 57% and
this is expected to continue and grow with the highest CAGR. This is expected to be driven by the growing usage of photovoltaics in power plants, military applications, space & defence and industrial projects.

The major players in global photovoltaics market are Kaneka Corporation (Japan), Kyocera Corporation (Japan), Mitsubishi Electric Corporation (Japan), Panasonic Corporation (Japan), Sharp Corporation (Japan), JA solar Co. Ltd (China), Jinko Solar (China), ReneSola Co. Ltd (China), Suntech Power Holdings Co. Ltd (China), Trina Solar (China), Yingli Green (China), and Canadian Solar (Canada) among others.

In terms of technologies the market can be divided into organic photovoltaic and inorganic photovoltaic, crystalline silicon PV cells, thin film PV cells and also the associated components for modules, tracker, and optics.

References


6.2 Storage, Distribution and Efficiency

Production of electricity is dominated by fossil fuels, but renewable sources of energy are increasingly used to generate electricity. In 2010, electricity was generated from 24% natural gas, 10% renewables, 45% coal, 20% nuclear, and 1% oil and other liquids. Electricity demand is expected to increase 23% by 2035 due to higher demand of electricity-consuming products (electronics, cars) among other factors. Cyber-physical systems can help to meet this demand by helping the electric grid become more efficient and successfully integrate the increasing renewable sources of electricity into the grid. However, the increased operation of renewable energy and its distribution create further challenges to the energy sector. These challenges address the volatile and more seasonal availability of energy, thus concepts for storage, distribution and efficient use of energy in peak load times are required.

Figure 27 shows that the stability of the power grid depends on various actors working in concert to maintain a balance between electricity supply and demand. Traditionally, electricity assets are categorized based on their function; i.e., generation, transmission, or distribution. Storage systems differ in that they have the ability to balance supply and demand across the segments that comprise the value chain. The new control points offered by storage systems enable operators to selectively respond to fluctuations in grid inputs and outputs. Such functionality is essential to realising the vision of “smart cities” where producers and consumers are equally informed and equipped to respond to market dynamics in real time.

Figure 27: Energy storage across the power sector.

Market Size

According to the Global Energy Storage Market Overview, the US has the largest market for energy storage with an installed storage capacity exceeding 357 MW by end of 2014 and with projected additional 220 MW to be installed in 2015 alone [3]. Some US States have the world leading energy storage incentive programs, (most notably California) which has adopted a 1,325MW target by 2020. By 2019 the energy storage market is forecast to reach 861MW annually and be valued at $1.5 billion.

Leaders in the field

On a global level, Japanese giants Toshiba and Panasonic are vying with South Korean conglomerates Samsung and LG for leadership in the fast-growing battery energy storage market for power generated from renewable sources such as solar and wind. Other contenders in energy storage such as Nissan’s AESC, Mitsubishi’s joint venture partner GS Yuasa and Chinese maker BYD, are concentrating on the market for battery-powered electric vehicles. Also Siemens is striving for a global leadership in the area of energy storage [6, 7]. Together with AES Corporation, Siemens founded Fluence, a company for energy storage technologies and services. This company offers the energy storage platforms Advancion from AES and Siestorage from Siemens, and also develops new technologies. Siestorage is a modular system that combines high-performance lithium-ion batteries with the power electronics needed for connection to the grid. The system can store, and subsequently release, up to 500 kilowatt hours with a capacity of one megawatt. Other traditional short-term storage solutions include capacitors, flywheel storage systems and compressed-air storage.
Companies such as **ABB, Bosch, Tesla** and others are very active in various US energy storage market segments (Figure 28).

![Figure 28: Overview of companies which are active in the US energy storage market.](image)

**Trends**

Facing the increasing proportion of largely unpredictable renewable resource injected in the energy network, two trends emerge:

- Focus on increasing distributed storage capacities,
- Adaptation of the business processes to volatile energy supply.

Regarding the **future storage of energy**, an open question is how much energy storage will be needed in order to ensure grid stability as more and more electricity is generated from renewable sources. The International Renewable Energy Agency (IRENA) has estimated the world would need 150 GW of battery storage by 2030 if it is to meet the desired target of 45 per cent of power generated from renewable sources [3]. For Germany, estimates covering the next four to six years vary from as little as 3 gigawatts (GW) to as much as 30 GW [4]. A study conducted by Fraunhofer predicts that the country will need 13 to 50 GW of energy storage by 2030 [5]. These figures vary so greatly because of the complex and differing assumptions that underlie such studies. Despite these differing assumptions regarding future energy storage capacity needs, it’s widely recognised that the energy storage market in general is rapidly growing and pushed by global trends such as the following [3]:

- **Electric Vehicles (EVs) time has come** – subsidies for EV’s in China, and a rapidly growing global market is fuelling a massive scaling up of battery technology
- **Cheaper storage** – these economies of scale are leading to rapid decreases in the cost of battery technology with spin off benefits for other applications.
- **Micro-grids becoming economic** – as grid infrastructure costs climb, and areas that do not have grid access are electrified, micro grids supported by distributed energy generation and energy storage are becoming the rational economic choice.
- **Changed pricing regimes** – an additional major driver is increasing fixed and demand charges in some areas driving behind-the-meter installations. The impact of renewables and storage on long term business models, and the narrowing number of customers from which to get a return on an existing asset and investment base has seen a reaction of increased fixed charges and introduction of demand charges. Charges and financing structures will remain volatile for some years as new models evolve to deal with distributed energy networks – with storage as a core part.

Regarding the **rearrangement of industrial processes** to volatile energy supply, the industry sector faces manifold challenges at multiple levels. Several CPS concepts can be observed to make industry equipment, plants and processes more intelligent and more flexible regarding volatile markets. Some examples are:

- On machine level: autonomous decisions to change production state (stand-by, low consumption, turn-off). For example, energy efficiency systems like Festo’s E²M modul may be used to implement those concepts [8].
- On building level: concepts like active electric power management so that heating, ventilation & air conditioning (HVAC) equipment can be turned off temporarily to save energy.
- On factory level: concepts to efficiently manage energy and resource consumption. These processes are often not automated, but will be in future. Combinations of different autonomous CPS-systems of the various hierarchical levels will take more and more control. Platforms for the orchestration of demand, supply and generation of energy on a “prosumer level” will become more important.

**Road Blocks**

A grand challenge for CPS is the design and deployment of an energy system infrastructure that is able to provide blackout-free electricity generation and distribution, in addition to other properties. To be blackout free and eliminating power surges, the infrastructure must be flexible, allowing heterogeneous participants to consume energy from and supply energy to the grid. The energy system infrastructure must also be secure and impervious to accidental or intentional disruptions or manipulations.

Technical challenges arise with the increase of distributed sources of power generation. Incorporating power generated from distributed resources into the grid requires new controls as well as complex balancing schemes. For example, power generated from wind is growing rapidly, yet it supplies an irregular stream of electricity. This type of source, along with other distributed sources, causes an additional stress on the current grid.

**Energy storage effectiveness**

Energy storage technologies are currently not effective enough to support a higher penetration of renewable sources and there is only an ill-defined hierarchy for integrating the sources into the grid. Coordination of and interaction between varying distributed resources will pose many new challenges.

**System management**

One of the challenges of applying CPS engineering and technology to the electric grid and other utilities is integrating these technologies into the existing infrastructure. Improvements and changes are being applied to the existing power grid system, which must transition into the smart grid of the future. There will need to be changes in how the system is managed as power generation comes from more distributed that need to be continually integrated into the existing infrastructure.
One of the technical challenges that face the smart grid is how to better store excess energy. Instead of the current model of utility companies providing electricity on demand for consumers in a downhill, one-way fashion, the smart grid must be able to handle increased generation from renewable sources as well as directly from customers or electric vehicles. The grid must be able to flexibly respond to changes in supply and demand.

In systems as complex and networked as the smart grid and other utilities, there are measurement problems and challenges in various areas that continue to emerge as CPS and other technologies are integrated.

Data capture, transmission, and retention methods that are reliable and effective must be developed. If there is a delay or disruption of the delivery of data from sensors or actuators, this can present multiple challenges to control systems that will rely on real-time data. Data transmission is reliable but not entirely trustworthy, as it is still affected by problems such as memory overflow, network overload, and slow processing speed, all of which can cause possible vulnerabilities. There must be methods to ensure that data cannot be corrupted or manipulated through a cyber-attack. Current data management methods work well for small amounts of data but fail or become ineffective for larger data sets that will come from distribution automation and customer information. Other challenges in data management include data identification, validation, updating, time-tagging, and consistency across databases.

**System engineering**

Although there are currently large-scale simulation test beds for the power grid, these will not suffice as more CPS technologies are integrated. Tomorrow’s test beds should be broadly accessible and encompass aspects that extend beyond the grid, including communication and computing layers and the fuel supply chain. Including the ability to integrate adaptation, control, and other intelligent elements into the test beds for utilities can help achieve outcomes such as the following:

- Fine-grained optimisation of efficient energy generation, storage, transmission, and use
- Multi-regional or multi-national coordination, pricing, and control of power supply and demand
- Just enough generation and use of energy
- Definition and management of energy needs, costs, and emissions

Development and use of predictive tools can help increase the efficiency and reliability of the power industry as well as that of other industries. Current practices are only reactive because action can only be taken after a problem occurs, such as an outage caused by severe weather conditions. Developing anticipatory control will make the grid smarter and better able to deal with imminent problems. Advances beyond the current information technology, real-time access to data from wired and wireless devices, and a coordination network that can realise impacts of future events are necessary to enable predictive control for the grid.

Tools that could predict and coordinate power needs and costs based on weather, time and day of the week, energy future costs, or other criteria in a highly distributed system are not yet available. In order to help increase performance while ensuring robustness, tools need to be developed that can help quantify the boundary of acceptable operating conditions. Tools such as these could increase the efficiency and capacity of the grid while ensuring secure operation. In the water sector, there is a lack of performance metrics and tools that can successfully evaluate the operation and control systems. These metrics and tools should be able to identify critical cyber and physical components and systems as well as the effects of increased interconnectivity.

It will be a challenge to develop and establish a modelling framework that is sufficiently accurate; not too complex; and that captures interdependencies between the grid, technologies, and systems.
Data collection will be useful when developing and verifying models, but the data will constantly be changing as the system status changes. There is a need to develop other models, theories, and tools that consider the continuous and discrete aspects of the energy supply system, including the integration between the cyber and physical components. As more components are integrated into the system, the numbers and types of interactions increase and the components have various types of safety and security verification. Verification and validation of these interactions will be a challenge, especially as the automation, connectivity, and accessibility of control processes increase.

When the system is in an abnormal condition, operators in utility plants are overwhelmed by the number of alarms. Operators must make decisions about how to react within very little time. As the smart grid is developed, there must be a method developed that can evaluate, prioritise, and respond to the alarms to reduce confusion. Currently, there is no diagnostic software than can provide operators suggested courses of action for abnormal conditions. Software needs to be developed that is user friendly and can detect the causes of technical problems and provide effective actions to operators.

Software applications, including programs, algorithms, calculations, and data analysis, are essential to the successful operation of the smart grid. This software must be able to handle increasingly complex problems as CPS technologies and applications are integrated into the grid. Other types of software should be developed to be adaptive and able to alter objectives based on changing conditions. Also, there needs to be more situational awareness displays and analysis tools.

Security
As technologies and systems are incorporated as part of the modernisation of the grid, security remains a paramount concern in terms of lowering the vulnerability of the smart grid and water sector systems. Any disruptions to these sectors affect other sectors, making their secure operation a necessity. The energy sector is networked and complex, with increasing interactions between generation, transmission, and distribution processes, resulting in numerous access points. Control systems should have integrated protection, detection, and response mechanisms to be able to survive natural disasters, human error, and cyber-attack without loss of function. Privacy of various stakeholder data will need to be protected as the grid becomes more interconnected.

Increased connectivity within the system allows for better interoperability and communication, yet security risks increase as more entities are provided access.

Business and policy challenges
Since there are many different stakeholders in the smart grid, there are numerous business and policy challenges that arise. Different states will have their own policies on regulating and implementing smart grid technologies, including advanced metering. Some states are considering passing legislation that gives the customer the option to opt out of the installation of smart meters in their residence. Standards are developed based on the consensus of multiple stakeholders. While this is effective, it is taking a considerable amount of time. Other challenges to consumers providing power to the grid include the legal and policy implications as to who is responsibility for maintaining, operating, and repairing the necessary equipment.

Business roadblocks
A crucial roadblock for broadly implementing energy saving and efficiency technologies in industry is seen in (relatively) low energy prices or very low proportion of energy costs compared to the overall production costs. Except e.g. for heavy industry, in many manufacturing industries the energy costs are marginal costs compared e.g. to material costs. Thus, resource saving and efficiency technologies (saving precious material) or zero-defect and high-speed production technologies are much more attractive for industry investments compared to energy saving technologies.
References

7 Market Segmentation for Technologies

This report has so far provided a market survey of CPS technology and its landscape, by splitting up the market into fields of technology application denominated as Market Sectors. It has identified trends and characteristics at the global level. This Chapter introduces a complementary perspective - splitting the market customers for particular technologies into groups with common attributes and denominated Market Segments. It represents an initial investigation into an area where public shared knowledge is sparse, but is believed will bring value to the CPS community through contributions towards expanding such a knowledge base. Identifying segments is frequently an important factor for tailoring technology to meet needs that will be desirable for the most relevant customers. This technique enables an analysis of customer profitability and where to compete, it also can show hurdles to be solved and reveal customers previously unrecognised.

As an example of segmentation, drone technology is likely to be purchased for different reasons by customers with civil and defence backgrounds. For rescue services: the civil side is likely to have applications such as in zones difficult to reach (mountains, high radiation, etc); the defence side of course has a key focus in conflict zones amongst others. Integration of drones with the rest of the transport infrastructure also has differences: in the civil sector, high visibility of a drone is needed as causalities are not acceptable, also individual data privacy is considered important; for defence often location secrecy is required and a degree of collateral may be considered acceptable, data privacy is more at organisation level. Additional segmentation comes into play for instance if the civil/defence customer is based in the EU or US and for their size (for instance an SME, LE or government).

There generally is one of two types of customer bases considered for market segmentation, custom from businesses or the much more common segmentation of end consumers (usually groups of individuals).

The Business-to-Business (B2B) segmentation is particularly relevant when considering selling technologies. This means splitting up your client base into groups of organisations based on key differences. Examples of these include Business Demographics (e.g. Age, Size), Operating Variables (e.g. how products are used or technologies implemented), Purchasing approach (e.g. purchasing policy, structure of purchase department), Personal Characteristics (e.g. Socioeconomics, personality of a purchasing team).

The Business-to-(End)Consumer (B2C) is the most common market segmentation generally investigated, although this form is less relevant when considering technologies contributing to CPS. Characteristics used often include geography (e.g. Cities, Countries, Regions), demography (e.g. Age, Sex, Occupation, Income, Education, Religion), psychography (e.g. Lifestyle, Personality, Hobbies, Product, Knowledge) and Socio-economy (e.g. Rich/Poor, Rural/Urban, Literate/Illiterate).

This different client base means business-to-business differs from B2C in ways such as [2]:

- Markets have a more complex decision-making unit
- Buyers are more ‘rational
- Products are often more complex
- Target audiences are smaller than consumer target audiences – i.e. personal relationships are more important in B2B markets
- Buyers are longer-term buyers
- Markets drive innovation less than consumer markets
- Markets have fewer behavioural and needs-based segments
When segments have been defined, assessing their quality is usually a next step. Criteria for this include being measurable, sustainable, accessible, useful and stable [1]:

- **Measurability** is the extent to which segments can be measured and assessed for market potential.
- **Substantiality** concerns whether a particular segment is sufficiently large to justify marketing activity. Each organisation in a market will have a view about what size a segment must be to be regarded as viable. In some circumstances, organisations will invest in currently small segments but which they believe will grow in the future.
- **Accessibility** refers to whether a marketing program can be developed cost-effectively and reaches the targeted segment.
- **Usefulness** relates to the extent to which the segments provide obvious benefits and clarity to the organisation. For example, if the segmentation approach facilitates the relationship with targeted customers or makes appropriate use of sales and marketing resources, the usability might be regarded as good.
- **Stability** is the extent to which a segment is stable in the short, medium or long term. In a changing marketing environment, assessing stability helps organisations judge the segment’s viability over time.

Restructuring a sales model in such a way takes time and effort, but can enable a significant degree of added competitiveness on the market and increased sales. The degree of segmentation adopted by a B2B enterprise can range significantly. For instance [3], a European directory company developed its segmentation by looking at invoiced revenue from customers. They only needed a few characteristics to explain buying behaviours and layered this with total customers’ advertising spending – resulting in the capacity to sort customers by development potential and make their solutions more attractive for each segment. At the other side of the scale, the company Infor, who provide software solutions to mostly small businesses, identified customer characteristics (micro-verticals) in the range of 2000 where they believed they had a competitive edge. This is partly due to small businesses providing a wide customer base, but also because Infor addresses diverse domains including breweries, hospitals and agriculture. The segmentation approach subsequently enabled them to identify standard functionalities, providing building blocks with which to efficiently create tailored solutions for customer segments.

In the following sections, a selection of B2B technologies is provided as examples for the first public release of this document. The groupings mainly considered will be by region (EU vs US), application (civil vs defence) and size of organisation (SME vs large industry). A database is envisioned where the examples will be made available for extension by the community. Extensions may include more technologies being considered or more segments (where China has already been proposed). We commence the sections by considering the common differences between the segments of focus before proceeding to look at technology examples.

**References**

[1] Market Segmentation Success: Making It Happen!, Sally Dibb(PhD) & Lyndon Simkin(PhD), Published 2013 by Routledge, New York, USA.
7.1 Comparing and Contrasting Business Customer Characteristics

Before looking at some specific technology examples, The following features combined provide a profiling of some businesses, that is, segments of the market where the customer is an enterprise.

Table 1: General defining characteristics of six B2B Segments.

<table>
<thead>
<tr>
<th>Small-to-Medium Enterprise</th>
<th>Large Enterprise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Usually have a smaller decision making panel for purchasing technology, so decision making process is shorter and with less unknown variables.</td>
<td>Often LEs state product reliability as a key purchasing factor, but a recent survey derived that service and support had the prime importance[3].</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Selling in Europe</th>
<th>Selling in the United States</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buyers generally expect to meet face to face [2].</td>
<td>-Buyers are tending more towards online purchasing, with engagement analytics used to understand buyer’s particular problems.</td>
</tr>
<tr>
<td>-Influenced more by seeing metrics than visions of what a technology may enable [4].</td>
<td>-Only one main language support required for a technology, so platforms can access the whole market. However there can still be significant differences across regions including laws.</td>
</tr>
<tr>
<td>-Working at national level and achieving leadership, before moving to another country can be a useful growth strategy.[5]</td>
<td></td>
</tr>
<tr>
<td>-European companies tend to have stronger business models for regional differences.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Selling to the Civil Sector</th>
<th>Selling to the Defence Sector</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Demand side: Consolidated or fragmented, public and private.</td>
<td>- Demand side: Consolidated, public</td>
</tr>
<tr>
<td>- supply side: blurred for civil security;</td>
<td>- supply side: clearly demarcated interaction between demand and supply: well-structured and centralised</td>
</tr>
<tr>
<td>- interaction between demand and supply: decentralised and locally structured;</td>
<td>- with respect to technology and product development: longer term technology roadmaps and cost and risk sharing drive innovation for defence.</td>
</tr>
<tr>
<td></td>
<td>- Given contracts are for large sums, SME entry most likely as sub-contractor for an LE.</td>
</tr>
<tr>
<td></td>
<td>- Quality/standards often more stringent.</td>
</tr>
<tr>
<td></td>
<td>- Challenging to enter from the civil side such as due to procedural and secrecy aspects.</td>
</tr>
</tbody>
</table>

References related to above table
[2] How to Sell in Europe Versus the US, Graham Curme, Sept. 2016,
Notes:
The demand side is clearly defined: the end-users of military products and services are almost entirely made up by national Ministries of Defence (MoDs). This concentration on the demand side is to a large extent reflected on the supply side as well. Lead systems integrators, platform producers and producers of weapon systems are mainly large companies, primarily “national champions”, specialised on defence production. These so-called ‘prime’ contractors subcontract specialised systems producers, for example in electronics, and producers of complete sub-systems or major components. Often, these ‘tier 1’ contractors are also risk sharing partners. Although only few of these prime and tier 1 companies produce exclusively for the defence market, they are very much aware of their status as defence companies and are fully organized to the particular characteristics of the military market. The clear and focused structure on both the demand and the supply side leads to the well regulated and close interaction between the two sides. Established, long term relationships are important. This situation constitutes a significant barrier for new entrants to the defence market.

From a technological point of view, the defence sector is characterised by a long term and integrated approach, often caught under the term “capability based planning”. The various MoDs across Europe set clear military requirements for the longer term. Military equipment typically has a life of several decades. In many cases, the defence industry is involved in defining the technical specifications for equipment that are derived from these requirements. The demand side is prepared to share risks in technology and platform development. Although the influx of ‘civil’ technology has increased over the past decades and will continue to do so, the defence technological base is still quite clearly defined. Again, this forms a barrier for new markets entrants, in particular innovative SMEs.

7.2 Manufacturing Examples

As described in Chapter 4, the “Industrie 4.0” approach is still a visionary concept, far from being broadly implemented in real industrial environment. However, several examples and use cases in the industrial environment can be found [1, 2]. This section presents some examples of Industrie 4.0 related CPS technologies with the characteristics of potential clients across the segments SME vs. LE and EU vs. US.

Intelligent automation components

Intelligent automation equipment incorporates in physical automation devices (hardware) the intelligence provided by the “cyber” sphere (software, learning algorithms, etc.) in “CPS components” or sometimes also called “IoT devices”. One of many examples for such a “CPS component” is the first app-controlled valve for factory automation from Festo [3]. At the field level of smart factories, these intelligent automation components and systems are at the core of the Industrie 4.0 approach. According to the Industrie 4.0 vision, they enable decentral, autonomous decision making, based on aggregated information coming from sensors which are integrated in the intelligent devices, and with direct impact to the physical processes. In future intelligent automation equipment, hardware functions are adaptable by software configurations (e.g. updated via internet), which results in a higher flexibility of use. Use cases for these intelligent components and systems are e.g. specific condition monitoring or assistance systems for predictive defect detection / maintenance, energy management, etc.

The table below identifies segment characteristics with respect to intelligent automation components.

<table>
<thead>
<tr>
<th>Small-to-Medium Enterprise</th>
<th>Large Enterprise</th>
</tr>
</thead>
<tbody>
<tr>
<td>SMEs, particularly from the IT sphere, are very active as specialised vendors and consultants Also, SMEs in the engineering business (e.g. for special purpose machines) are very open for the new opportunities of intelligent automation components For SMEs in the production business, there is high need of consulting on the user side due to many partial I4.0/IoT solutions and the fragmented solutions space [4]. Resistance due to lack of interoperability / common standards and unclear “added value for money”</td>
<td>Large enterprises are active on the vendor side as well as on the user side. For large industry enterprises, it’s easier to demand and enforce interoperability standards and to benefit from the opportunities which are provided by intelligent automation equipment (e.g. optimising large production lines and supply chains)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Selling in Europe</th>
<th>Selling in the United States</th>
</tr>
</thead>
<tbody>
<tr>
<td>As in European manufacturing industry a focus is on production optimisations [5], there will be generally a higher demand for technologies and services which contribute to optimising production processes. For buyers, face-to-face contacts and personal consulting still plays an important role</td>
<td>As in US companies the focus is more on new business models and on better customer services [5], the selling story has to highlight more the customer value rather than technical details Buyers are tending more towards online purchasing and less face-to-face contacts and personal consulting</td>
</tr>
</tbody>
</table>

Figure 29: Intelligent automation components market segmentation of clients.
Cloud-based IoT platforms and operating systems

Cloud-based IoT platforms and operating systems such as e.g. the AXOOM IoT Platform\(^8\) or the open, cloud-based IoT operating system MindSphere from Siemens \(^7\) help to orchestrate intelligent automation devices and to realise customer value (value added for equipment and factory operators). In future, new value based services such as e.g. predictive analytics/maintenance, supply chain optimisation, etc. can be provided with the help of such digital platforms \(^8\).

The table below identifies segment characteristics with respect cloud-based IoT platforms and operating systems.

<table>
<thead>
<tr>
<th>Small-to-Medium Enterprise</th>
<th>Large Enterprise</th>
</tr>
</thead>
<tbody>
<tr>
<td>SMEs as specialised equipment or service provider could use the opportunities of such</td>
<td>Large enterprises are active as vendors and service providers as well as users of these platforms</td>
</tr>
<tr>
<td>platforms to offer their expertise to a broader customer base</td>
<td>Integration, compatibility and connectivity of the platform/operating system in the huge IT</td>
</tr>
<tr>
<td>SMEs as potential users of such platforms rely on “easy-to-use” and low cost investments</td>
<td>ecosystem of the enterprise (manifold software solutions) hast to be ensured</td>
</tr>
<tr>
<td>SMEs as buyers/users are more reluctant due to concerns regarding security and data</td>
<td></td>
</tr>
<tr>
<td>ownership is needed at all levels</td>
<td></td>
</tr>
<tr>
<td>Training and education is needed at all levels</td>
<td></td>
</tr>
<tr>
<td>Large enterprises are active as vendors and service providers as well as users of these</td>
<td></td>
</tr>
<tr>
<td>platforms</td>
<td></td>
</tr>
<tr>
<td>Integration, compatibility and connectivity of the platform/operating system in the huge IT</td>
<td></td>
</tr>
<tr>
<td>ecosystem of the enterprise (manifold software solutions) hast to be ensured</td>
<td></td>
</tr>
<tr>
<td>Selling in Europe</td>
<td>Selling in the United States</td>
</tr>
<tr>
<td>Concerns regarding security, privacy and data ownership play an important role</td>
<td>Opportunities of data analytics, etc. to create new value for customers play an important role</td>
</tr>
<tr>
<td>Focus is more on increasing manufacturing performance</td>
<td>Focus is more on business model innovation in the field of internet services and multimedia</td>
</tr>
<tr>
<td>Background in Europe is more the engineering expertise and the domain knowledge in the</td>
<td>Background in US is more in the ICT and internet economy rather than in the field of production</td>
</tr>
<tr>
<td>field of production rather than a broad ICT expertise =&gt; “Industrie 4.0”</td>
<td>and engineering excellence =&gt; “Industrial Internet of Things”</td>
</tr>
</tbody>
</table>

Figure 30: Cloud-based IoT platforms and operating systems market segmentation of clients.

References:

\(^8\) AXOOM has been founded by the machine tool manufacturer TRUMPF in 2015.
7.3 Transport Examples

**Autonomous Car Technology**

The key driver for autonomous functionality in cars is enhanced safety. There is also potential for a reduction in emissions through better coordination of traffic via connected cars. Public trust in the technology is currently a major barrier to uptake. The market is driven by the traditional large car manufacturers but there is some disruption from new companies such as Tesla. For SMEs the opportunities are in providing electronic components, e.g. Lidar and other sensors, and also in software and supporting toolsets for software development/certification.

The table below identifies segment characteristics with respect to autonomous driving technology.

<table>
<thead>
<tr>
<th>Small-to-Medium Enterprise</th>
<th>Large Enterprise</th>
</tr>
</thead>
<tbody>
<tr>
<td>The automotive sector relies on an extensive supply chain of SMEs. Standards exist for automotive integration such as AUTOSAR [1] and also for safety-critical certification, ISO 26262 [2], but new standards and certification methods need to be developed to support autonomous cars.</td>
<td>Large enterprise is concerned with the integration of technologies to allow autonomous driving. As certification is performed at the system level they are responsible for liability. There is a particular interest in safety-critical software.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Selling in Europe</th>
<th>Selling in the United States</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regulation is needed in Europe to allow cars to operate on member states’ roads. This requires harmonisation and guidance on liability. For communication standards ITS-G5 [3] is being promoted.</td>
<td>Several US states have sanctioned the use of autonomous vehicles on roads and there is a more open attitude to operation. Liability has been highlighted by some high profile accidents. The DSRC [4] communication standard is being promoted in the US.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Selling to the Civil Sector</th>
<th>Selling to the Defence Sector</th>
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</thead>
<tbody>
<tr>
<td>A key challenge is gaining public confidence in the technology. There is a need to develop trust in the new technology. There is also a need to address the ethical issues.</td>
<td>Autonomous ground vehicles have been developed for military applications. The US defence sector is closed to European vendors unless there is a sizeable US based subsidiary of a large company.</td>
</tr>
</tbody>
</table>

Figure 31: Autonomous car technology market segmentation of clients.

References

Unmanned Air Vehicle Technology

The military domain leads the uptake of unmanned air vehicles, however, they are restricted to operation in controlled military airspace. The commercial use of drones for surveillance and monitoring in search and rescue, policing and agriculture presents opportunities for SMEs. Here there is currently a limit on the size of drones for safety reasons that can be operated without a pilot. With respect to technology there are opportunities for both platform control systems and on-board sensor payloads.

The table below identifies segment characteristics with respect to UAV technology.

<table>
<thead>
<tr>
<th>Small-to-Medium Enterprise</th>
<th>Large Enterprise</th>
</tr>
</thead>
<tbody>
<tr>
<td>In the smaller UAV sector SMEs have a very active role in both providing low cost platforms and also in integrating a variety of sensor, communications and camera payload technologies.</td>
<td>Large companies are less likely to enter the smaller UAV market as they cannot compete with the low cost UAVs developed by SMEs. The larger UAV market, where certification is required, is an area where they have a major advantage.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Selling in Europe</th>
<th>Selling in the United States</th>
</tr>
</thead>
<tbody>
<tr>
<td>Certification for smaller UAVs is not an issue, however, in operations there is a need to consider overfly rules for privacy [1], etc. For larger UAVs there is a need to address certification for operation in civilian air space.</td>
<td>There are similar opportunities to the EU, however, there is stiff competition from large military companies, e.g. Lockheed-Martin [2], Boeing, etc. and latest developments are covered by security. Some communications systems use reserved frequencies.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Selling to the Civil Sector</th>
<th>Selling to the Defence Sector</th>
</tr>
</thead>
<tbody>
<tr>
<td>For smaller UAVs there are many opportunities in surveillance, policing and agriculture. Future programmes such as ASTRAEA [3] in the UK are looking at the technological, legislative, and political challenges of how larger unmanned aerial vehicles can also be integrated with the civilian ATM network. Similar activities are being performed across Europe at a national level.</td>
<td>This is already a very well-developed market in defence. This is dominated by the large companies as the platforms tend to be larger carrying sophisticated sensor payloads as well as armaments.</td>
</tr>
</tbody>
</table>

Figure 32: UAV technology market segmentation of clients.

References

7.4 Health Care Examples

This section presents some examples of CPS technology for Health Care with the characteristics of clients across the segments SME, LE; EU, US; Civil, Defence. These are technology specific characteristics in addition to the general characteristics at the start of the chapter.

**Active Implantable technology**

Customers may include vendors of pacemakers and insulin pumps (mostly civil sector), and prosthetics. Key technology drivers include energy sources, programmer usage (software updates), resistance to external electric/magnetic fields including compatability with medical check procedures (e.g. Magnetic Resonance Imaging) and biocompatible materials. Furthermore, secure (and privacy respecting) interfacing to external networks for data or status exchange, possibly via an on-body hub have increasing relevance. For internal devices, non-invasive device identification, remote monitoring and device longevity are additional key drivers.

The table below identifies segment characteristics with respect to implanted technology.

<table>
<thead>
<tr>
<th>Small-to-Medium Enterprise</th>
<th>Large Enterprise</th>
</tr>
</thead>
<tbody>
<tr>
<td>These clients make up the majority of the market. Fragmented with few common standards for technology interchange.</td>
<td>Remote monitoring and data analysis techniques (big data) are particular focus for implantable technology.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Selling in Europe</th>
<th>Selling in the United States</th>
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<tbody>
<tr>
<td>Largely public sector. Certification is shorter than the US, but less easy to get buyers.</td>
<td>Standards are more device specific: <a href="https://www.iso.org/committee/53122/x/catalogue/">https://www.iso.org/committee/53122/x/catalogue/</a></td>
</tr>
<tr>
<td>Selling to the Civil Sector</td>
<td>Selling to the Defence Sector</td>
</tr>
<tr>
<td>No technology specific differences identified.</td>
<td>No technology specific differences identified. However there are additional uses, such as boosting human capability including managing stress levels.</td>
</tr>
</tbody>
</table>

Figure 33: Implanted technology market segmentation of clients.

**Medical Imaging technology**

According to the FDA, "medical imaging refers to several different technologies that are used to view the human body in order to diagnose, monitor, or treat medical conditions. Each type of technology gives different information about the area of the body being studied or treated, related to possible disease, injury, or the effectiveness of medical treatment."[2] Technology fields include Ultrasound,
MRI (Magnetic Resonance Imaging) and Medical X-ray Imaging. The technology includes actuators to emit a directed beam which is captured by sensors – significant image processing and analysis techniques can then be applied.

The table below identifies segment characteristics with respect to medical imaging technology.

<table>
<thead>
<tr>
<th>Small-to-Medium Enterprise</th>
<th>Large Enterprise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Are usually not the end vendor but supplier of components for complete systems, however miniaturisation is opening this up. Technology is fragmented with few common standards for technology interchange. There can be some small system vendors, however in that case they are in general focusing in on technical fields (eg. A part of the X-Ray market, or ultra sound ...)</td>
<td>The main vendors of complete systems are large enterprise. [3] The main difference between the “majors” and the Smaller enterprises is that the offer of the majors is able to address the full spectrum of technologies (MRI, Ultrasound, X-rays ...), while the small companies focus on one specialty.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Selling in Europe</th>
<th>Selling in the United States</th>
</tr>
</thead>
<tbody>
<tr>
<td>Largely public sector. Certification is shorter than the US, but less easy to get buyers.</td>
<td>Largely private sector. Certification is longer than the EU, but easier to get buyers. U.S. suppliers are particularly dominant. [4]</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Selling to the Civil Sector</th>
<th>Selling to the Defence Sector</th>
</tr>
</thead>
<tbody>
<tr>
<td>No technology specific differences identified.</td>
<td>No technology specific differences identified.</td>
</tr>
</tbody>
</table>

Figure 34: Medical imaging technology market segmentation of clients.

References


7.5 Energy Examples

This section presents some examples of CPS technology for Energy with the characteristics of clients across the segments SME, LE; EU, US; Civil, Defence. These are technology specific characteristics in addition to the general characteristics at the start of the chapter.

Electric Battery Technology

The cost of Electric Battery Technology has remained significantly high for decades, but with the advent of mobile phone, electric vehicles and storage capacity for renewables, prices are dropping. This increased demand also sees research investigating new or updated approaches including gold nanowire batteries, solid state lithium-ion, fuel cell for phones and drones, graphene car batteries, laser-made micro super capacitors.

The table below identifies segment characteristics with respect to electric battery technology [2].

<table>
<thead>
<tr>
<th>Small-to-Medium Enterprise</th>
<th>Large Enterprise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Restricted to small batteries as traditionally costs have been too high, but access to this market appears set to change with costs coming down.</td>
<td>Tesla in particular is leading the field in battery technology research and having an impact at reducing costs.</td>
</tr>
<tr>
<td>Selling in Europe</td>
<td>Selling in the United States</td>
</tr>
<tr>
<td>Internal combustion engines are seen to be phased out in some places as early as 2025. This means</td>
<td>Regardless of pollution policies, generous subsidies are being granted for advancing battery technology.</td>
</tr>
<tr>
<td>Selling to the Civil Sector</td>
<td>Selling to the Defence Sector</td>
</tr>
<tr>
<td>No particular customer characteristics identified.</td>
<td>No particular customer characteristics identified.</td>
</tr>
</tbody>
</table>

Figure 35: Example1 technology market segmentation of clients.

Energy Saving / Efficiency Technologies in industrial environment

Regarding the future challenges of the energy sector, there is a need to implement more intelligent and transparent industrial equipment, buildings and processes. Industry will face to react on volatile energy prices from the supply side, as well as saving opportunities by shifting consumption. As there are manifold general energy saving technologies to improve energy efficiency in industrial environment [1], in particular CPS-related technologies can help to achieve more flexibility in energy consumption on different levels of factories.

The table below identifies segment characteristics with respect to CPS-related energy saving / efficiency technologies in industrial environment.

<table>
<thead>
<tr>
<th>Small-to-Medium Enterprise</th>
<th>Large Enterprise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transparency and autonomy interesting for smaller system scope like dedicated production equipment or specific building functions like lighting. Low price and medium gains will be</td>
<td>More complex environment for the application of autonomous systems due to the expected size of the production environment. Standardised solutions are required to increase</td>
</tr>
</tbody>
</table>
Interesting for SME in specific.

Interoperability with legacy systems.

<table>
<thead>
<tr>
<th>Selling in Europe</th>
<th>Selling in the United States</th>
</tr>
</thead>
<tbody>
<tr>
<td>As drivers there are (especially for Germany) plans for increasing the amount of energy from renewables by governments, as well as regulations (e.g. ISO 50001) which becomes mandatory in some European regions. Thus, increasing energy prices will lead to higher demand for energy saving and efficiency technologies and services.</td>
<td>Energy saving and efficiency plays in traditional US manufacturing industries a marginal role, particularly if energy costs have a low compared to the overall production costs.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Selling to the Civil Sector</th>
<th>Selling to the Defence Sector</th>
</tr>
</thead>
<tbody>
<tr>
<td>Civil sector is driven by cost optimisations by efficiency gains, as well as the requirement for stable operation. Further reimbursement of locally generated energy becomes interesting for some kinds of systems.</td>
<td>No information available.</td>
</tr>
</tbody>
</table>

Figure 36: Energy Saving / Efficiency Technologies in industrial environment market segmentation of clients.

References

7.6 Segmentation Next Stages

The above technology examples should be extended by the community to provide increased public awareness about the profiles representing particular customer segments. This includes further refinement of characteristics of the segments presented and adding other relevant customer segments not yet considered. Also the inter-relations between segments should be considered such as shown in Figure 37 – for instance technology likely has different regional requirements, but the behaviour of SMEs can also be influenced by region [1]. The EU has greater emphasis on revenue than growth (because funding at mid-stage is difficult), but also with more autonomy and less equity dilution. This results in some different technology needs when contrasted with the US.

Advancing the segmentation descriptions will enable vendors of CPS technology to have a greater market penetration through increased ability to refine how they address their existing client base, but also see where they might successfully extend to new client segments.

In the following, a market segmentation approach for manufacturing is illustrated based on the example of value-based services (VBS) [2]. The VBS application scenario is based on the innovation hypothesis that in the future delivered products will be connected to a service platform, data from the usage of the product by the customer will be fed to the service platform, and based on the usage data a service provider can offer data-driven value-added services to the customer (Figure 38). Thus, the market segmentation approach distinguishes between the different roles of the involved stakeholder, their specific tasks and different types of stakeholders / organisations (Figure 39).
Other examples will be made available online for update by the CPS community.

**References**


8 Conclusion

Significant advances have forecast to take place across CPS domains. The resulting demands will need significant advances in actuation, sensing, processing, communication and energy management. Coupling of these to create CPS technology with increased capability and associated complexity will require particular attention to safety, security, performance, usability and interactions between these for acceptance in society and a sustainable economy. With respect to current R&D expenditure, China currently leads significantly on R&D investment for many CPS-related technologies. All CPS-related domains are seeing a strong shift towards global connectivity represented by the Internet of Things technology class. Such a communication backbone is bringing great benefits to the CPS domain, with standardised interfaces and associated technology greatly facilitating the sensing capability of Cyber-Physical Systems. This will also support significantly higher CPS functions of cooperation and coordination between systems and with people. It is evident in this study there is a need for increased clarity of the interface between these and some framework enhancing IoT->CPS and CPS->IoT technology exchanges. This and bridging between other technology classes such as AI and Big Data will be needed to meet the demand for high capability and safe actuation to effect changes in the real world.

In the Automotive Sector, use of cars expected to double by 2030 (1.6 billion), this will have significant implications for traffic management, autonomous driving, car sharing, networking among cars and infrastructure. It is expected in just over three years 82% of all cars will be connected with the Internet. The rail sector will also see significant increases in autonomy and capacity for goods and passengers, particularly as a result of demands to reduce emissions. The railway management market as a case in point is expected to double in the next few years.

As for other transport sectors, the Aerospace sector is expected to see aircraft double in the next couple of years. Currently there is a significant effort to integrate European airspace such as in the SESAR programme. On the defence side many countries are increasing acquisitions of equipment in relation to heightened risks to national security. Across commercial and defence domains, the unmanned aerial vehicle market is growing rapidly, expected to have doubled from 2016 to 2022. The shipping sector is the most efficient for goods transport and leads other sectors in terms of environmentally friendly technologies. Over the next 30 years the growth of the market may grow to more than triple its current size. Unmanned surface vehicle technology is expanding at a significant pace, predicted to double between 2016 and 2021. Logistics for the management of supplying goods, contributes across all aforementioned domains currently representing nearly 14% of European GDP.

The Manufacturing Domain produces 80% of European exports and as such has a pivotal role in maintaining European competitiveness. Out of all the domains, manufacturing contains the highest concentration and diversity of large scale cyber-physical systems. Of the fields considered it is also likely to be the hardest hit during an economic downturn. These factors mean this domain has an especially high demand to expand the understanding of environmental changes. Whether in relation to industrial control plants, along the supply chain or of the market status, incorporating IoT technology is seen as the most significant enabler for efficient and robust production. This technology class contributes one of the most major roles in current funding programmes like Industry 4.0 to launch the next industrial revolution, but it is still early days for this migration to the needed infrastructure.

The Health Domain also sees a drive towards greater connectivity, but the current chief motivating factor is for Big Data analysis to extract patterns enabling doctors and nurses to better treat diseases. Nevertheless latent benefits are likely to be seen in the future where systems ranging from insulin
diffusion pumps, medical imaging and smart hospitals can take advantage of the pioneered infrastructure. However, this relates to another technology class. More specifically for CPS technologies the domain is made up of 80% SMEs and currently significantly fragmented. There is a need for platforms to help integrate and distribute medical CPS technologies, including hardware, software and system engineering practices. The geographical market segmentation is also diverse across Europe with significant differences to the US. Across European countries long-term expenditure has as much as a thousand-fold difference. More particularly for Hospital Care, the global supplies market is expected to almost double from USD 30 billion to USD 51.9 billion by 2021. Uptake of new technologies in particular requires methods to gain trust sooner and also workload support during transitions. The Home Care market, divided across Services, Diagnostics, Mobility Assistance and Therapeutics is forecast to grow from USD 244.4 billion in 2015 to USD 517.2 billion by 2025. Increased regulation is needed to maintain safety given the proliferation of home care application and attention paid to user interfaces which contribute significantly to product returns (including more generally in the health sector). For the Fitness Sector, or technology to stay healthy, the wearable market alone is predicted to more than triple from 2015 to 2022 reaching USD 51.60 Billion. Some promising technologies remain out of reach here currently due to high costs of hardware/software. While there is significant opportunity here with increasing percentages of populations taking responsibility for their fitness, strategic foresight is needed from the CPS domain for durable applications.

Within the Energy Domain, there was a focus on renewables, storage, efficiency and distribution. Generally the renewables sector has been ahead of fossil fuels for the last six years with respect to investment in new storage capacity. Solar PV and Wind have accounted for 77% of this capacity with hydropower being most of the remainder. In 2015 almost a quarter of energy generated came from renewable sources. More than half the world’s wind energy was added in the last five years, with China accounting for almost half. The wind turbine market specifically is expected to increase more than 50% between 2015 and 2021. The associated microgrid is likely to double between 2015 and 2022 reaching USD 38.99 Billion. Related to the solar PV market, this technology is very low maintenance and durable with costs shown to reduce by half over the coming 15 years. The global market here will almost quadruple between 2014 and 2020 up to USD 345.59 billion. Renewable energy is volatile which requires significant advances in management of storage, distribution and efficient technology. As an example, to address this in Germany a large consortium has gathered around the programme Kopernikus to develop energy supply networks, storage of energy overcapacity, adjusting industrial processes for volatile energy supply and general orchestration of industry in this sector. There are numerous market disrupters including electric vehicles, cheaper storage, micro-grids becoming economically viable and changed pricing regimes.

Finally, this report has created a baseline for the CPS Community to develop a publically available market segmentation of the CPS domains. Such profiling of customers groups helps technology providers to identify particular modification that make their product significantly more appealing to particular groups at not necessarily much added cost. In addition to the market survey, it provides additional information with which industry and in particular SMEs can use to judge the viability of branching products into new markets and strategies in terms of purchases, workforce/facility expansion and product promotion.