Headline nr.	Headline title	CL1: New data-driven services and business models	CL2: Data-based improved products	CL3: Closed-loop manufacturing	CL4: Cyberized plant/ Plug & Produce"	CL5: Next step production efficiency	CL6: Digital Ergonomics
4	Material and resource efficiency in manufacturing					CPS	
7	Zero-defect manufacturing – quality assurance – self-learning systems				CPS		
9	Safe and ergonomic work environments						CPS
10	Supporting the human in the workplace – Manufacturing training/re-skilling						CPS
12	Reconfigurable cells, self-reconfigurable cells through smart sensors/devices				CPS		
14	Novel production management tools for a responsive CPS-based production	CPS				CPS	
17	Multiple Source (Big) Data Mining and Real Time Analysis		CPS		CPS		
18	Cyber-Physical Factories		CPS		CPS		
19	Digitisation of the Supply Chain – Manage complex customer-driven value networks			CPS			
20	Collaborative, dynamic and resilient customer-driven production networks		CPS				
22	Manufacturing as a Service (MaaS) – Servitisation of autonomous and reconfigurable production systems	CPS			CPS	CPS	
24	User Centric Product and Production Equipment Engineering		CPS				
28	European Circular Economy Open Platform			CPS			
29	Business Models for the Digital Service Factory	CPS					

ID 04	Headline: Material and resource efficiency in manufacturing	Rank

Addressed challenges in terms of impact (along the dimension of challenges of FoF roadmap: economic, environmental, social, future products) and the link with the technologies that are addressed in this research headline

- Efforts to develop sustainable manufacturing systems must consider issues at all relevant levels (product, process, system and the value chain.
- All the sustainability features/means must be taken into account (i.e. not only energy consumption, but also CO2 emissions, pollutants, wastes, scraps, etc.) to design eco-friendly factories.

Specific technological (or non-technological) enablers or solutions that need to be addressed by the research or innovation activities

- Re- and demanufacturing: Radical increase in the range in products that can be part of a circular economy through smart and adaptive remanufacturing systems, such as joining and additive manufacturing technologies for repair and upgrading
- Technology and services for demanufacturing: Example: applying existing knowledge and capability in Automated Aircraft Assembly, Drilling and Digital manufacturing to the tasks involved in disassembly of end of service aircraft structures.
- …

Expected impact (more quantified and bullet list style)

- The ultimate objective is to take into account sustainability issues at all levels of smart manufacturing systems, reducing energy use, CO2 emissions, pollutants, scraps and waste of resources, among others.

Notes / Comments

ID 07	Headline: Zero-defect manufacturing – quality assurance – self-learning systems	Rank

Addressed challenges in terms of impact (along the dimension of challenges of FoF roadmap: economic, environmental, social, future products) and the link with the technologies that are addressed in this research headline

Thanks to real time data flows and intelligent controllers, in the future, predictive and preventive maintenance will be present on the factory floor. It will even be possible to run fully automated Artificial Production Intelligence systems in order to decrease down time machine failures.

- Integrated approach to quality, safety, maintenance, lead time and productivity
- …

Specific technological (or non-technological) enablers or solutions that need to be addressed by the research or innovation activities

- Data mining through advanced sensing and integrated approach regarding material tracking through the manufacturing chain, HMI and MMI
- To develop analytics tools, that combine raw data from heterogeneous sources into meaningful information or predictions—and presents information on easy-to-use interfaces (such as dashboards or mobile Apps) enabling users to monitor, automate response actions or remotely control equipment or systems.
- …

Expected impact (more quantified and bullet list style)

- Condition based maintenance and quality control
- De-risking production installations
- Increased productivity on continuous manufacturing process change: 20% faster changing time on machines and resources.
- Increased efficiency on preventive maintenance: 90% identification of errors, malfunctions or damaged parts thanks to predictive self-learning systems.
- …

Notes / Comments

ID 09	Headline: Safe and ergonomic work environments	Rank

Addressed challenges in terms of impact (along the dimension of challenges of FoF roadmap: economic, environmental, social, future products) and the link with the technologies that are addressed in this research headline

- Establish a production process within which machines empower humans to better use their experience and improve working processes, merging human capabilities such as recognition and fine motor skills with machine intrinsic endurance, power and replicability.
- …

Specific technological (or non-technological) enablers or solutions that need to be addressed by the research or innovation activities

- Design and development of novel methodologies for the detection of persons by robots, mobile machines and industrial vehicles within this context are proposed by means of cognitive perception, merging multiple sensors data and intelligent reasoning
- Design of novel interaction concepts for humans to predict, perceive and understand the actions and movements of robots, mobile machines and industrial vehicles within the shared workspace to improve safety and smooth work processes.
- …

Expected impact (more quantified and bullet list style)

- Increase the use of knowledge and involvement of senior employees.
- Improve well-being, human engagement and productivity in an increasingly automated context
- …

Notes / Comments

ID 10	Headline: Supporting the human in the workplace – Manufacturing training/re-skilling	Rank

Addressed challenges in terms of impact (along the dimension of challenges of FoF roadmap: economic, environmental, social, future products) and the link with the technologies that are addressed in this research headline

- In the future, visual models of the production systems will allow employees to enlarge their feeling, comprehension and sense making
- Employees will be able to interact with the models, to receive concrete feedback, to store their personals experience and their stories
- …

Specific technological (or non-technological) enablers or solutions that need to be addressed by the research or innovation activities

- To design prediction tools for Human-in-the-loop (HiL), Human-in-the-mesh (HiM)of cyberphysical production systems (CPPS) and Smart Manufacturing Working
- HiL and HiM modelling and simulation to support the participative design of organization, tasks, roles and responsibilities describe stationary and dynamic, regular and exceptional working conditions, including Smart and remote Working
- …

Expected impact (more quantified and bullet list style)

- Foster the take-up and effectiveness of CPS
- Increase work productivity and effectiveness
- Attract novel societal groups to manufacturing, reduce traffic and social cost for commuting
- Improve worker competences engagement and performances

Notes / Comments

ID 12	Headline: Reconfigurable cells, self-reconfigurable cells through smart sensors/devices	Rank

Addressed challenges in terms of impact (along the dimension of challenges of FoF roadmap: economic, environmental, social, future products) and the link with the technologies that are addressed in this research headline

- Manufacturing of custom-made parts on demand
- Use of flexible, reliable and reconfigurable resources
- Create production systems that are easily upgradable and into which new technologies and new functions can be readily integrated
- …

Specific technological (or non-technological) enablers or solutions that need to be addressed by the research or innovation activities

- Development of a customer driven IoT-based factory with new self-learning and self-optimization systems
- New organisational models development to describe the behaviour of the system and the knowledge of the plant
- Data and data derived knowledge based self-learning and self-optimisation
- …

Expected impact (more quantified and bullet list style)

- Increased productivity on continuous manufacturing process change: 20% faster changing time on machines and resources.
- Reduction of programming of new manufacturing processes, through virtual commissioning AND self-learning systems down of 20%.
- Integrate specific technology already present on the shopfloor (e.g. automated lines, robots, power management, etc.)
- Migrating overall production structure towards self-learning and self optimisation

Notes / Comments

ID 14	Headline: Novel production management tools for a responsive CPS-based production	Rank

Addressed challenges in terms of impact (along the dimension of challenges of FoF roadmap: economic, environmental, social, future products) and the link with the technologies that are addressed in this research headline

- It is important that production is supported by an innovative production management approach that supports responsiveness of the production plant, in terms of highly customized products, at the same time exploiting the intelligent digital integration. It is expected that the technological advancements, such as smart technologies, smart connectivity and decentralized intelligence, could support the development of innovative production management techniques together with the possibility to have a high level of "reconfigurability" of production systems

Specific technological (or non-technological) enablers or solutions that need to be addressed by the research or innovation activities

- Development of a new production management paradigm to be applied in a responsive CPS-based production system.
- This includes the development of innovative tools, methods and models for production management, which can support the plant self-adaptation capability with respect to production mix and volumes and manage multiple production steps, limiting costs, lead time variability and increasing machine utilization
- ….

Expected impact (more quantified and bullet list style)

- Strong improvement in firms' responsiveness
- High level of "reconfigurability" of production systems
- Reduction of variables such as: (i) lead time, (ii) lead time variability (iii) and inventory.
- Acquisition of the ability to adapt the production mix to the continuously changing market demand
- …

Notes / Comments

ID 17	Headline: Multiple Source (Big) Data Mining and Real Time Analysis	Rank

Addressed challenges in terms of impact (along the dimension of challenges of FoF roadmap: economic, environmental, social, future products) and the link with the technologies that are addressed in this research headline

- Use machine data for various objectives within and for the different factory levels (machine, shop floor and supply chain)
- Data mining and real time analytics are the basement for novel supply chain approaches for innovative products and collaborative and mobile enterprises. Connected objects, assets and enterprises in the supply networks provides a new type of collaboration, permitting collaborative demand and supply planning, traceability, and execution.

Specific technological (or non-technological) enablers or solutions that need to be addressed by the research or innovation activities

- Improve ways of gathering valuable machine data
- Provide decision makers with tools for forecasting and monitoring benefits and risks
- New scale of magnitude of complexity arises from this landscape to ensure that data are available, protected and reserved
- Data architectures matching industrial needs, provision of the right information, to the right person at the right time to avoid wrong decisions
- …

Expected impact (more quantified and bullet list style)

- Demonstrate real time analytics along the whole Lifecycle and value chain, quantify benefits to the industrial sector, demonstrate how to make profit out of data
- Solving transmission data bottlenecks in the industrial sector
- Tools to quantify benefits in the implementation of (big) data mining and Real-Time analysis

Notes / Comments

ID 18	Headline: Cyber-Physical Factories	Rank

Addressed challenges in terms of impact (along the dimension of challenges of FoF roadmap: economic, environmental, social, future products) and the link with the technologies that are addressed in this research headline

- Solutions for complex, expensive and geographically distributed factories
- Specific focus on interoperability solutions
- To embrace internet technologies in manufacturing will enable the paradigm shift
- Need of new machines natively embedding connectivity capabilities

Specific technological (or non-technological) enablers or solutions that need to be addressed by the research or innovation activities

- Evaluation of “monolithic” architecture towards modern IT systems
- Demonstration of new connected or IoT compliant machines
- Integration of connected compliant machines with legacy production lines
- To provide high-level services for the holistic factory control
- …

Expected impact (more quantified and bullet list style)

- 20% saving in the integration of connected machines within an existing line
- Convincing demonstration of cyberisation of legacy machines/lines
- Deployment of factory apps with a ROI shorter than 1 year
- Inclusion of factory personnel into the loop
- …

Notes / Comments

ID 19	Headline: Digitisation of the Supply Chain – Manage complex customer-driven value networks	Rank

Addressed challenges in terms of impact (along the dimension of challenges of FoF roadmap: economic, environmental, social, future products) and the link with the technologies that are addressed in this research headline

- Manage complex customer-driven value networks
- Smart Logistics
- Improve visibility across the value network
- …

Specific technological (or non-technological) enablers or solutions that need to be addressed by the research or innovation activities

- Digitalisation of complex supply networks considering the whole eco-system (sub-contractors, suppliers, partners, etc.)
- Integration of CPS and the IoT (advanced analytics, cloud-computing, big data)
- To leverage the data made available (through the implementation of CPS and IoT)
- To use cloud-enabled and virtualised production networks
- …

Expected impact (more quantified and bullet list style)

- Increased supply network visibility
- Increased supply network flexibility
- Improved quality of products and services
- Reduced time to market
- …

Notes / Comments

ID 20	Headline: Collaborative, dynamic and resilient customer-driven production networks	Rank

Addressed challenges in terms of impact (along the dimension of challenges of FoF roadmap: economic, environmental, social, future products) and the link with the technologies that are addressed in this research headline

- New models on how companies can plan and operate supply chain
- Continuous request of customization and innovative products and services with reduced lead time
- Wider diversification of products
- …

Specific technological (or non-technological) enablers or solutions that need to be addressed by the research or innovation activities

- Sharing of data/information coming from all the actors in the supply chain
- Support continuous monitoring and control of all the production phases
- Security and confidentiality of data shared along the supply chain
- Open innovation adopted through the value chain, with the inclusion of customers/end users
- …

Expected impact (more quantified and bullet list style)

- Reduction of production costs
- Reduction of lead time
- Reduction of time to market
- Increased customer satisfaction
- …

Notes / Comments

ID 22	Headline: Manufacturing as a Service (MaaS) – Servitisation of autonomous and reconfigurable production systems	Rank

Addressed challenges in terms of impact (along the dimension of challenges of FoF roadmap: economic, environmental, social, future products) and the link with the technologies that are addressed in this research headline

- Customer driven production dynamics requiring high product configuration flexibility, minimum lot size and fast order delivery time
- Fast time to market at global level
- Multiple stakeholder participation to the design, engineering and distribution process
- …

Specific technological (or non-technological) enablers or solutions that need to be addressed by the research or innovation activities

- Use of cloud services and IoT technologies
- Autonomous reconfiguration and planning systems able to provide the optimal and viable configuration of exiting production assets
- Aggregation of information from the cloud to support evolving status of production process and monitoring assets and products
- …

Expected impact (more quantified and bullet list style)

- Significant improvement of performance
- Production and Distribution Costs reduction
- Time to market gain
- Increased flexibility of product variants and elasticity of production capacity
- …

Notes / Comments

ID 24	Headline: User Centric Product and Production Equipment Engineering	Rank

Addressed challenges in terms of impact (along the dimension of challenges of FoF roadmap: economic, environmental, social, future products) and the link with the technologies that are addressed in this research headline

- Open and collaborative IT tools (including PLM systems) to information and knowledge coming from inside and outside the companies, therefore enabling open innovation and product cocreation with customer engagement.
- …

Specific technological (or non-technological) enablers or solutions that need to be addressed by the research or innovation activities

- Inclusion of data/information from CPS and PLM solutions to enable designers to study personalised solutions and better focus on the market
- Visualization of design solution for user by exploiting novel tools such as Virtual and Augmented reality.
- Correlation of design requirements with simulation, testing and usage data, demonstrating factbased design
- …

Expected impact (more quantified and bullet list style)

- Higher degree of personalization of products
- Increase of market shares
- Customer satisfaction
- Decrease of design and engineering costs of at least 15%

Notes / Comments

ID 28	Headline: European Circular Economy Open Platform	Rank

Addressed challenges in terms of impact (along the dimension of challenges of FoF roadmap: economic, environmental, social, future products) and the link with the technologies that are addressed in this research headline

- Developing the European Circular Economy Open Platform
- Review of current IoT and Cloud Computing architectures implementation
- To create a specific Circular Economy IT Platform, i.e. an extension of a PLM platform by adding de- and re-manufacturing services
- …

Specific technological (or non-technological) enablers or solutions that need to be addressed by the research or innovation activities

- Platforms to consider product-service combinations for new products design
- Large open source communities of developers to work on top of open and standard platforms
- Stimulate innovation and spirit of entrepreneurship
- Circular Economy extends STEEP sustainability by introducing new technologies and services for de- and re-manufacturing
- …

Expected impact (more quantified and bullet list style)

- Optimised de- and re-manufacturing processes
- Shorter time-to-market for Circular products
- Improved knowledge circulation along the whole product lifecycle and beyond
- Innovation ecosystems for Circular Economy stakeholders
- …

Notes / Comments

ID 29	Headline: Business Models for the Digital Service Factory	Rank

Addressed challenges in terms of impact (along the dimension of challenges of FoF roadmap: economic, environmental, social, future products) and the link with the technologies that are addressed in this research headline

- To associate new technology with economic models for the future Digital Service Factory
- Methods for shaping suitable business models
- Use information as the main driver for the competitiveness of companies
- …

Specific technological (or non-technological) enablers or solutions that need to be addressed by the research or innovation activities

- New ICT technologies for smart and digital Product Service Systems
- Advanced platforms and tools for a better alignment between target customers and personalized offerings
- To reduce the cost and increase the effectiveness of Product Service Systems provision
- These new tools have to provide dashboard with customisable KPIs for quantifying the service performances and calculating the ROI of the services
- …

Expected impact (more quantified and bullet list style)

- New business models for the further digitisation of factories
- New business models for the further digitisation of the Supply Chain
- New models for reduction of Time to Market for digital product service systems
- Increase Value Added perceived by the users
- …

Notes / Comments

NEW	Headline:	Rank

Addressed challenges in terms of impact (along the dimension of challenges of FoF roadmap: economic, environmental, social, future products) and the link with the technologies that are addressed in this research headline

Specific technological (or non-technological) enablers or solutions that need to be addressed by the research or innovation activities

Expected impact (more quantified and bullet list style)

Notes / Comments