Roadmap on Standardisation in Manufacturing

15 July 2010

Contributors

This document is the result of one of the activity conducted by the IMS2020 consortium (www.ims2020.net). Contributors to this document are:

- **Fabian Bauhoff**, FIR (DE)
- **Marc Brülhart**, Holcim (NL)
- **Katharina Bunse**, ETH Zurich (CH)
- **Cristiano Cagnin**, IPTS (ES)
- **Bartolomeo Cammarino**, POLIMI (IT)
- **Alessandro Cannata**, POLIMI (IT)
- **Emanuele Carpanzano**, CNR-ITIA (IT)
- **Jacopo Cassina**, POLIMI (IT)
- **Domenico Centrone**, POLIMI (IT)
- **Roberto Checcozzo**, COMAU (IT)
- **Maria Stella Chiacchio**, CNR-ITIA (IT)
- **Natalia Duque**, POLIMI (IT)
- **Frank Ernst**, Holcim(NL)
- **Kevin Fischer**, Rockwell Collins (USA)
- **Rosanna Fornasiero**, CNR-ITIA (NL)
- **Marco Garetti**, POLIMI (IT)
- **Thomas Hirsch**, FIR (DE)
- **Jon Agirre Ibarbia**, Fatronik (ES)
- **Robert G. Kiggans**, SCRA (USA)
- **Dimitris Kiritsis**, EPFL (CH)
- **Alexander Kleinert**, FIR (DE)
- **Totti Konnola**, IPTS (ES)
- **Thomas R. Kurfess**, CURF (DE)
- **Aristeidis Matsokis**, EPFL (CH)
- **Bjorn Moseng**, NTNU (NO)
- **Masaru Nakano**, Keyo University (JP)
- **Dirk Oedekoven**, FIR (DE)
- **Manuel Oliveira**, NTNU (NO)
- **Trond Østerås**, NTNU (NO)
- **Augusta Maria Paci**,CNR-ITIA (IT)
- **André Pirlet**, CEN (BEL)
- **Asbjørn Rolstadås**, NTNU (NO)
- **Fulvio Rusinà**, COMAU (IT)
- **Marco Taisch**, POLIMI (IT)
- **Sergio Terzi**, POLIMI (IT)
- **Jörg Trebels**, FIR (DE)
- **Marcello Urgo**, POLIMI (IT)
- **Matthias Vodicka**, ETH Zurich (CH)
- **Dong-Yol Yang**, KAIST (KR)

Acknowledgements

The consortium wish to thank the European Commission and, also, the Roadmapping Support Group listed below:

- Anci, Italy
- APS-Mechatronics, Germany
- Assoknowledge, Italy
- Barilla, Italy
- Base Protection, Italy
- BIBA (Bremer Institut für Produktion und Logistik GmbH), Germany
- BMW, Germany
- Bombardier, Switzerland
- Cambridge University, UK
- Cardiff University, UK
- CECIMO (European Committee for Cooperation of the Machine Tool Industries), EU
- Ceta Senai, Brazil
- Clariant, Switzerland
- Cranfield University, UK
- CSEM, Switzerland
- CSMT, Italy
- Daimler, Germany
- DIN, Germany
- Ecole Polytechnique Universitaire de Marseille, France
- FIDIA, Italy
- H3G SpA, Italy
- HEGAN, Spain
- Helsinki University of Technology, Finland
- Hilti, Liechtenstein
- Hong Kong University of Science and Technology, Hong Kong
- IBARMIA, Spain
- IBM, Italy
- ifak e.V. (Institut für Automation und Kommunikation), Germany
- Institute for Innovation and Development of University of Ljubljana (IRI UL), Slovenia
- Interlink Management Consultant, Australia
- ISVOR FIAT, Italy
- IT Partners Ltd, Bulgaria
- ITQ GmbH, Germany
- Jozef Stefan Institute, Slovenia
- KUHN Technology EOOD, Bulgaria
- KUHN Technology SRL, Romania
- Kühne+Nagel, Switzerland
- Kuleuven, Belgium
- Lappeenranta University of Technology, Finland
- LEIA Centro de Desarollo Tecnológico, Spain
- Loughborough University, UK

- Luleå University of Technology, Sweden
- Microelectronica, Romania
- MIT, US
- Nicolás Correa, Spain
- Norsk Industri, Norway
- Nottingham University, UK
- ONA Electroerosión, Spain
- Panství Bechyně a.s., Czech Republic
- Politecnico di Bari, Italy
- Prometeo , Italy
- Raufoss Technology & Industrial Management AS (RTIM), Norway
- Renault Consulting, Italy
- RMIT University, Australia
- SAP, Germany
- SCM Group , Italy
- SERCOBE, Spain
- Siemens, Germany
- Spiral Business Services Corp., Finland
- Stadler Stahlguss, Switzerland
- Swiss Association of Mechanical SME, Switzerland
- Tampere University of Technology, Finland
- Technical University of Berlin, Germany
- Tecnica, Italy
- Thales, France
- The Federation of Finnish Technology Industries (Techind), Finland
- Toolmakers cluster of Slovenia Zavod C-TCS Celje, Slovenia
- UCIMU, Italy
- UFRGS, Brazil
- Università di Bergamo, Italy
- University "Politehnica" of Bucarest, Romania
- VDI (The Association of German Engineers), Germany
- VDMA (Verband Deutscher Maschinen- und Anlagenbau - German Engineering Federation), Germany
- Wroclaw University of Technology
- WZL-RWTH Laboratory for Machine Tools and Production Engineering, Germany
- ZAYER, Spain
- ZENON, Greece

The views expressed in this publication are the sole responsibility of the author and do not necessarily reflect the views of the companies listed in this document.

Index

Tables

1 Introduction

The roadmaps developed in the IMS2020 project focus upon the identification of relevant manufacturing research topics and supporting actions which need to be fostered through international cooperation between 2011 and 2013. These are critical research topics and actions which, when implemented, will allow the achievement of the defined IMS2020 Vision and thus the shaping of Manufacturing systems by the year 2020 and beyond.

The IMS2020 Standards roadmap, which is described in this document, aims to support the achievement of the proposed research topics and thereby the achievement of the whole vision. Therefore it's necessary that the innovations in terms of new products or optimized processes arising from the proposed research topics quickly spread into practice. While the research topics mainly stimulate the innovations, they have to be supported by a suitable tool ensuring the efficient diffusion of these innovations into the market. Standardization is able to serve as such a tool.
Because of the strong relationship between innovation and diffusion into practice, early standardization activities should be already implemented in the innovation process. This approach would as well reduce the time lag between innovations and their macroeconomic impact. Furthermore, standardization can optimally fulfil its duty to enhance this diffusion if technology leaders in research and industry support the standardization process.
Allowing for these important facts, it is a reasonable approach to design a coherent standardization roadmap.

In the following, the methodological procedure applied to design the standardization roadmap is described. Afterwards the main standardization areas supporting the specific research actions are derived and compared to a rough state of the art overview. Based on this comparison the main standardisation actions to be initiated are named.

The purpose of this document is to identify the central standardization potentials and provide a good basis for the standardization work within upcoming projects related to the proposed research topics.

2 State of the Art

The "State-Of-The-Art" (SOTA) analysis on standards aimed at defining a detailed map of the IMS related activities, mapping the SOTA of the existing initiatives. To ensure a reasonable and successful execution of the mapping of standards activities, a multi-level approach was applied. Hereafter, the various steps and the results derived from the SOTA analysis are briefly described.

Collection of input
To achieve a wide and comprehensive reference map, researchers as well as industrials and standardization experts were contacted and contributed to the mapping activities. The WP leader set up the general framework and processes for successful, standardized and continuous planning and execution of the mapping activity.

In advance of the actual investigation activities, all contributors were asked to give their input regarding important subareas of their individual topics. Here the mapping of standards focused on all contextual aspects of IMS2020. Hence, dimensions for each key area were defined to divide them into smaller and more focused sub areas. To obtain a maximum grade of disjunctive clusters, the dimensions were defined as independent, but yet general, to allow the characterization of various research topics and their specific impacts (for details see www.ims2020.net).

Investigation activities

Based on the input from this first step, the investigation activities were performed. Since, the activities focused on international standards, CEN as an international standardization body and project partner supported the investigation process. In this context, CEN provided an access to its database1 and certain documents that helped to analyze the described standards regarding their connection with the various dimensions. Using the CEN materials as a basis for the investigation it was furthermore feasible to distinguish between international published standards and standards under development.

Aiming at the identification of future impact directions for standardisation and the need for standardisation activities within the mapping of the state-of-the-art procedure, a total of more than 1000 standards have been analyzed. The analyzed standards consist of about 67% of published standards and to about 33% of standards under development.

With a comprehensive literature review, altogether more than 200 standard-related documents were analyzed by the project team. Documents originating mainly in Europe but also from the other IMS regions, including Japan, Korea, Europe, and the United States were analyzed. A selection of documents published by companies, industrial associations and standardisation bodies was considered. With this investigation activity, a comprehensive collection of identified standards and standards under development in the European Union and within various industrial sectors emerged.

Result: Summary of standards

The final step was to summarize and align the results from the described investigation activities. To sum up the results in a reasonable way, a comprehensive database was developed that provides a clear vision of the investigated standards in a structured and clearly arranged way. The developed mapping database is separated into published standards and standards under development, each consisting of two parts.

1. The respective standards are characterized by source, geographical relevance, description, Citation in Official Journal (OJ) and related directives. Source contains the responsible Standardization Organization and the Technical Committee. Under the aspect of geographical relevance, the regions for which the single standard is relevant are mentioned. Besides, the exact title of the standard and a short description of the content and/or purpose of the standard, the columns “Citation in OJ” and “Directive” indicate whether the standard is referred to in a EU Directive.
2. In the second part, which is identical for both the mapping of published standards as well as standards under development, standards are characterized by means of the various dimensions.

[1] (http://www.cen.eu/CENORM/Sectors/TechnicalCommitteesWorkshops/CENTechnicalCommittees/)

This analysis has been performed separately for published standards and standards under development. The analysis shows that most of the 669 published standards, which were taken into account, are related to the topic “Sustainable Manufacturing”. About 83% of the standards affect at least one dimension of this topic. Whereas the areas “Key Technologies” and “Energy Efficient Manufacturing” show already a much lower level of consideration (respectively 45% and about 26%), there is just a minimal number of standards relating to issues of the topic “Education”. Analyzing the standards under development, it gets obvious that besides an increase of the proportion of standards affecting sustainable manufacturing, a decrease in standards relating to Key technologies is noticeable. Based on the analysis of the selected sample of standards, one can derive that there will be just minor changes of the shown distribution in the near future. To get a more detailed picture, the connection of the examined standards to the different dimensions sectioning the topics was also analysed. For this analysis, just the main dimensions were taken into account.

Regarding the topic “Sustainable Manufacturing”, it can be stated that the most important dimensions in terms of standardization are “Safety”, “Social Aspects”, “Environmental Aspects” and “Technical Performances”. Comparing the distribution of published standards with the one for standards under development, it becomes evident that the proportion of standards referring to “Social Aspects” decreases noticeably, while the other mentioned dimensions vary just by about 10 percentage points.

Concerning the topic “Energy Efficient Manufacturing”, the dimension most relevant for standardization is “Technology & Process Innovation”. Particularly the sub dimensions “Green Management” and “Construction of Buildings” are addressed by a high proportion of standards.

Deriving findings regarding the distribution of standards in the topic “Education” is hardly possible because of the low number of standards in this area. However it can be assumed that most standards in the area of education seem to address the dimension “Delivery Methods”.

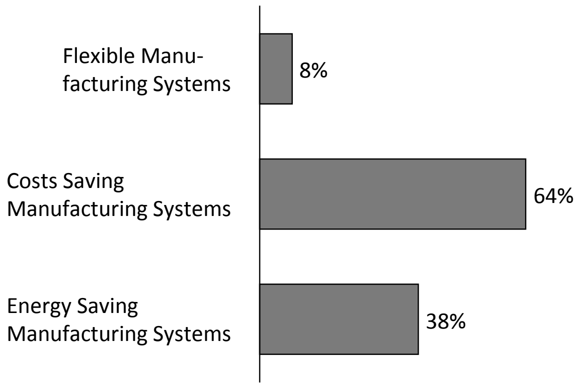

Figure 1: Affection of main dimensions constituting Key Technologies

Within the topic “Key Technologies”, just the main dimension “Flexible Manufacturing Systems” plays a minor role in terms of current standards. Referring to the standards under development, this aspect is of increasing relevance. Standards referring to the dimensions “Cost Saving Manufacturing Systems” and “Energy Saving Manufacturing Systems” are well represented (cp. Figure 1), particularly by the sub dimensions “High Performance Manufacturing” and respectively “Technologies for Energy Efficiency”.

Conclusions
Firstly, based on the current SOTA, the database serve to highlight general needs for standards. Secondly, the distribution of analyzed standards on the other four topics (Sustainable Manufacturing, Energy Efficient Manufacturing, Key Technologies and Education) is examined. Hence standardization is not a purpose of its own, it is an essential component of research activities in the fields of "Sustainable Manufacturing, Products and Services", "Energy Efficient Manufacturing" "Key Technologies" and "Innovation, Competence Development and Education". Due to this fact, standardization activities are embedded in the Research Topics (RT) of the above mentioned Key Areas as a "Specific Feature". Resulting from the described SOTA, in depth analyses and from the proposed research topics (see www.ims2020.net), additional analyses were conducted to derive the necessity of the development of new standards. Six standards-clusters were identified as mentioned below:

- Interface standards:
  This comprises standards for electronic information & data standards, communication & semantic standards as well as physical interface standards.
- Measurement standards:
  This includes standards for the measurement of process, production and manufacturing efficiency. Furthermore standards for the measurement of waste and emission detection are integrated.
- Process standards:
  Integrate standards for the design process as well as for manufacturing and business processes. Furthermore standards for closed loop management are added.
- Safety standards
- Product and component standards
- Material standards

These six standards-clusters are taken into consideration while elaborating the relevance of existing standards due to the needs of the other areas. The result of this analysis can be found at the beginning of the respective chapter, describing which clusters are already addressed by existing standards and leaving the opportunity to examine a gap analysis to identify future needs.

3 Methodology

3.1 Integration in general approach

As a result, the IMS2020 project delivers a roadmap which describes how to achieve a desirable vision of the year 2020. The IMS2020 Vision shows a realistic and desirable future for manufacturing which can be achieved if the identified Research Topics and their supporting actions are put in place through international collaboration. The main elements of IMS2020 vision can be summarised as follows:

1. *Rapid and adaptive user-centred manufacturing which leads to customised and 'eternal' life cycle solutions.*

2. *Highly flexible and self-organising value chains which enable for different ways of organising production systems, including related infrastructures, and reduces the time between engaging with end users and delivering a solution.*
3. *Sustainable manufacturing possible due to cultural change of individuals and corporations supported by the enforcement of rules and a proper regulatory framework co-designed between governments, industries and societies.*

The project results are delivered in two parts. According to the specified 3 IMS Areas of interest in the IMS2020 Vision, the first part has its main focus on the Key Area Topics (KATs) "Sustainable Manufacturing, Products and Services", "Energy Efficient Manufacturing" and "Key Technologies". Furthermore the so called research actions were put into place. They do not only cluster the research topics but consolidate and describe the thematic framework on an aggregated level as well. The IMS2020 research actions frame the future technology development within three important aspects of manufacturing:

- Economy with market and consumers' implications
- Environment with environmental issues
- Society with political and ethical implications.

In the IMS2020 roadmapping process, research topics have been elaborated and prioritised to focus fields to investigate or improve with technological development in the short term. In the mid term, research topics are grouped into research actions that should make an expected impact on three aspects of sustainability (Economy, Environment and Society).
In the figure below is reported the evolution path that from research topics supports the achievement of specific vision and objectives to go towards the IMS2020 vision that represent the final aim of new global manufacturing system.

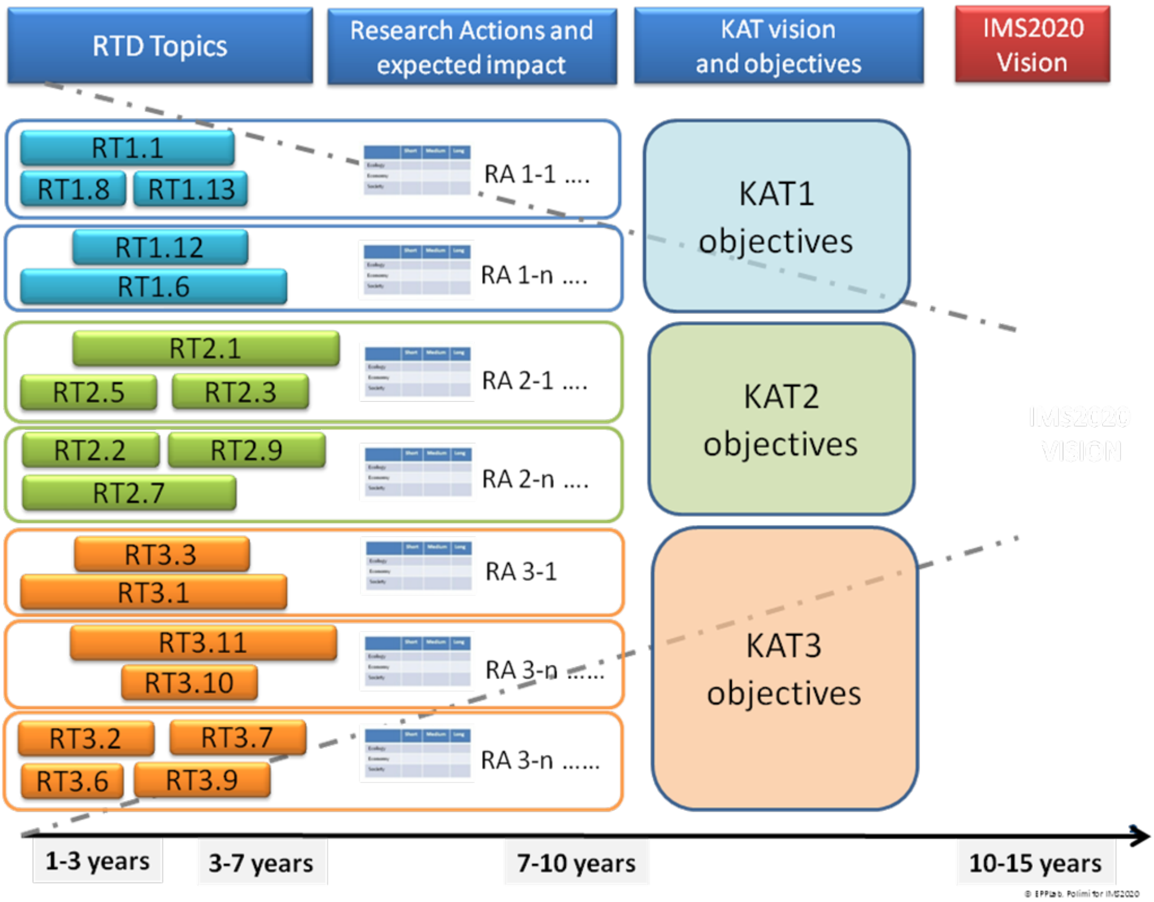

Figure 2: Research Topics and Research Actions toward the IMS2020 Vision

Following this point of view, the different structures have a specific role:

- The Research Topics are the bricks, "short" term (starting in 1-3 years, to be concluded in 3-7 years), focused actions to investigate or improve some research aspects;
- The Research Actions are middle term (7-10 years), wider, less focused. In a near future new RTs can be added to the research actions;
- The KATs contains specification of the vision objectives; long term, wide, strategic objectives to achieve the vision goals;
- The vision is the final aim, the wide, long term (10-15 years) and nice picture that provides in simple, strategic terms why all the efforts from the RTs on have to be done.

The IMS2020 roadmap addresses specifically cross sectional topics. The identified requirements of the "Standards" and "Innovation, Competences Development and Education" will be described in the upcoming second part of the deliverable. As they are relevant for all the other areas it is important to emphasize the contact points and to distinguish the different perspectives.

3.2 The Roadmap

The usefulness and value of standards supporting intelligent manufacturing of the future is undisputed. In order to design a standard roadmap fulfilling this supporting function to a maximum extent, the synchronization of the standard roadmap and the already existing roadmaps needed to be ensured. Therefore a special approach to define the standard roadmap was applied (cp. Figure 3):

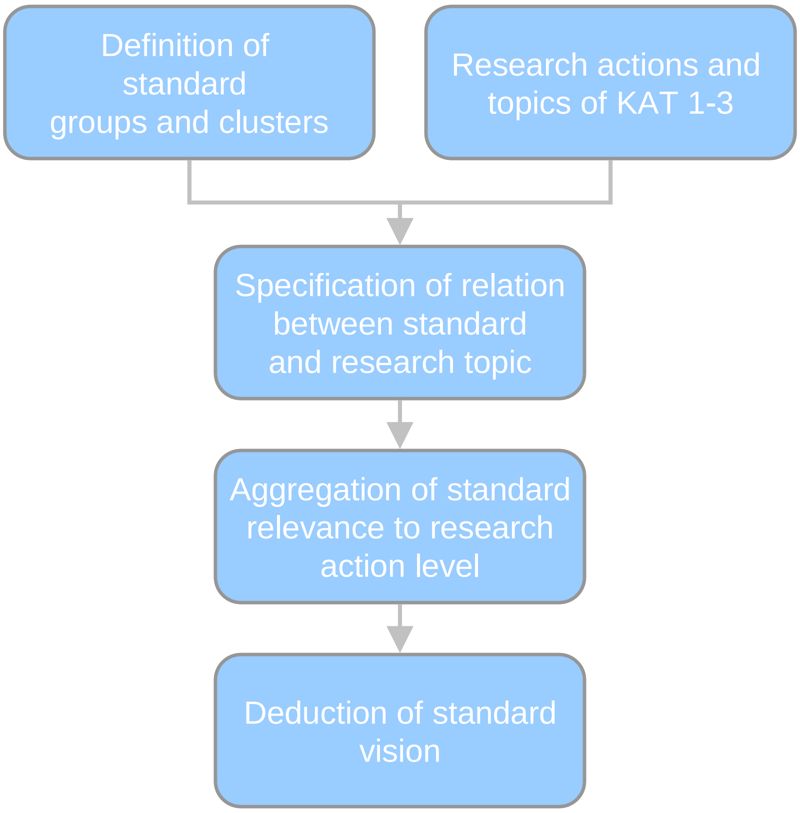

Figure 3: Approach for developing the IMS2020 standard roadmap

1. The various standards supporting intelligent manufacturing have been segmented into different clusters. Based on an analysis regarding existing standards as well as on standardisation requirements arising from the research topics the following standard clusters were defined:

- Interface standards
- Measurement standards
- Process standards
- Safety standards
- Product and component standards
- Material standards

2. The standard clusters were matched with the research topics resulting in a spreadsheet, which describes the relevance of the standard cluster for the specific research topics (cp. Figure 2). A “X” indicates that a standard category is relevant for the corresponding research topic.

IMS2020 Research Topics Relations with Standardization (KAT4)	Interface Standards			Measurement standards					Process standards						
	Electronic information & data standards (format)	Communication & semantic standards (content)	Physical interface standards	Measurement standardards for process efficiency	Measurement standardards for energy efficiency	Measurement standardards for manufacturing efficiency	Measurement standardards for waste detection	Measurement standardards for emission detection	Design process standards	Manufacturing process standards	Business Process standards	Closed loop management standards	**Safety standards**	**Product & component standards**	**Material Standards**
RA 1 Scarce Resources Management	0	1	0	0	0	0	1	0	0	0	0	2	0	2	2
RT1.11 Materials re-use optimization		x										x		x	x
RT1.16 Resource Recovery from Alternative Fuels and Raw Materials							x					x		x	x
RA 2 Technologies for Sustainability	2	3	0	1	1	1	2	2	0	1	2	1	0	1	1
RT1.01 Quality embedded manufacturing		x		x	x	x	x	x							
RT1.14 Additive forming processes for manufacturing							x	x		x	x				x
RT1.20 Sustainable Data Management	x	x									x				
RT1.24 Integrative Logistics Tools for Supply Chain Improvement	x	x										x		x	

Figure 4: Excel Sheet visualizing Standard Cluster – Research Topic relation

3. The research topic orientated relevance of standards was aggregated to research action level. This allows the definition of the standard clusters which are mainly driving the specific research topics.

4. Based on the derived main driving standard clusters the standard vision, which describes areas of future necessary standard developments, was defined. This vision is also synchronized with the research topics of the respective research action.

4 Standards Roadmap

4.1 Sustainable Manufacturing, Products and Services

4.1.1 Introduction

Sustainable development and sustainable manufacturing is, nowadays, after years of speculations, growing into importance. Concrete application of sustainability issues are ongoing, while the market and the consumers are more and more asking and taking care of eco and sustainable issues. At the same time, the regulation and standardization work that has been done in these years and is still currently under development is being applied and is under continuous development to fit the growing requests and requirements for sustainable measure and rating, which is start being a competitive advantage. Moreover, with the increase of price of resources and energy, it’s a key aspect manage correctly their shortage. All these issues are making sustainability a key aspect to be taken into consideration in business, business models and technological developments.

The sustainable manufacturing vision, is still far to be achieved, but has to be the basis of future researches and developments. Moreover, due to globalization, the sustainability issues have to be analyzed and developed not only at national or regional level, but guidelines and regulations have to be done at worldwide level.
For this reason, within the IMS2020 roadmap, sustainability has a great role, aiming at improving the sustainability of the technologies, the products and production systems as well as the businesses behind them.

According to this vision and this focus, the main areas of research and action identified are:

- Scarce Resources Management
- Technologies for Sustainability
- Sustainable Lifecycle of products and production systems
- Sustainable Product and Production
- Sustainable Businesses

The achievement of sustainable development and sustainable manufacturing vision also requires a wide standardization approach, capable to address all the standardization efforts of the five main research areas. In the following a standard vision has been defined for each research area, aiming at identifying which are the standardization needs covered, partially covered or not covered by the actual available standards. In this way it is possible to define which standardization action should be taken in terms of extension of existing standards or development of new ones.

4.1.2 Compendium of Relevant Standards

According to the six standard-clusters of *Interface standards, Measurement standards, Process standards, Safety standards, Product and component standards* and *Material standards*, the following tables give an overview which clusters are relevant for the research topics and which clusters are already addressed by existing standards.

The first table shows the correlation between clusters and defined research topics, the second serves as a caption. The white cells in the first table symbolize that the corresponding standard cluster is relevant for the respective research topic, while a grey cell indicates that the standard cluster is not seen as relevant for the research topic. The indices in the cells stand for currently existing standards which belong to the respective category and are related to the research topic. In this context, it has to be stated, that the intention of the following tables is not to provide an exhaustive overview of existing standards. In fact, the exercise is just meant and designed to serve the purpose of this document. Sources for the mapping of currently available standards were standard databases, search engines as well as European[2] and U.S. American[3] standardization bodies.

Having this restriction in mind, the empty white cells can be seen as standardization gaps which should be examined more intensively by upcoming projects dealing with the respective research topics. White cells with content indicate that there are already standards

[2] CEN – European Committee for Standardization
[3] Rachuri, S.: The landscape of Sustainability Standards, presentation at the „Sustainability Interest Group“

which should be further analysed and could serve as a basis for further development. While empty grey fields indicate no relevance for the topic, the grey fields with content imply that a standard is present in a cluster which is seen as not relevant for a topic. This could mean that the standard is not necessary, what definitely has to be validated in further investigations.

Thereby the results visualized in the following tables serve as a starting point to assess the standardization needs of each research action, indentify gaps and development issues. Finally they support the deduction of the main standardization needs and potentials summed up in the following standard visions. The specific conclusion at the end of this chapter will be based on this aggregation and conclude with the gap analysis.

IMS2020 Research Topics
Relations with Standardization (KAT4)

Legend:
(grey) = Standard category probably not relevant for reserach topic
(white) = Standard category probably relevant for reserach topic

IMS2020 Research Topics	Interface Standards			Measurement standards					Process standards						
	Electronic information & data standards (format)	Communication & semantic standards (content)	Physical interface standards	Measurement standardards for process efficiency	Measurement standardards for energy efficiency	Measurement standardards for manufacturing efficiency	Measurement standardards for waste detection	Measurement standardards for emission detection	Design process standards	Manufacturing process standards	Business Process standards	Closed loop management standards	**Safety standards**	**Product & component standards**	**Material Standards**
RT1.01 Quality embedded manufacturing															
RT1.02 Development of Green Controller for Machining					(12)										
RT1.03 Real-time Life Cycle Assessment and Cost	(10)														
RT1.04 Sustainability Labels		(9), (13)													
RT1.05 Sustainability Workshops															
RT1.06 Cost-Based Product Lifecycle Management (PLM)	(17)								(4)		(4)	(10)			
RT1.07 Remanufacturing for Sustainable Resource Management	(10)														
RT1.08 Predictive maintenance based on embedded information devices		(2), (15)													
RT1.09 Sustainable Packaging															
RT1.10 Optimization of Electronic Sustainability															
RT1.11 Materials re-use optimization		(10)													
RT1.12 Sustainable SMEs															
RT1.13 Maintenance Concept for Sustainability	(2), (15)														
RT1.14 Additive forming processes for manufacturing															
RT1.15 New workplaces for Aging and Disabled Workers															
RT1.16 Resource Recovery from Alternative Fuels and Raw Materials															
RT1.17 Eploiting Disruptive Innovation for Sustainability															
RT1.18 Integrated Service Supplier Development															
RT1.19 Product-Service Engineering															
RT1.20 Sustainable Data Management		(2), (14)									(1), (17)				
RT1.21 Sustainable Supply Chain Design	(10)														
RT1.22 Alignment of IT and Business Strategies		(3), (6),													
RT1.23 Multi-dimensional Inventory Management	(5)														
RT1.24 Integrative Logistics Tools for Supply Chain Improvement	(5)														
RT1.25 Management of Hazardous Substances in Manufacturing	(9)												(11)		
RT1.26 Lean Management for Service Industries															

Table 1: Correlation between standard clusters and research topics

Index	Standards
1	STEP standards: Product information modeling
2	PLM: PLCS: Product information modeling for maintenance
3	ISO 15926: defines a format for the representation of information about a process plant based on STEP standards
4	MIMOSA: aims to enable organisations to optimise the utilisation of their assets
5	EPCglobal standards: Information loop in PLM
6	SOAP: Information exchange standards
7	Closed-Loop Lifecycle Management (CL^2M): Closed-loop PLM Framework
8	Quantum Lifecycle Management (QLM): PLM extension
9	ISO 14000: Environmental management systems
10	LCA/LCI: PLM procedure
11	ISO 14031: Environmental performance evaluation
12	ENERGY-STAR: Energy standard on operation
13	ISO14001: Environmental management procedure
14	EN 16001: Environmental management system
15	ISO 13374: MOL maintenance standards
16	X3D: XML-enabled 3D standard to enable real-time communication of 3D data
17	PLCS: Product Life Cycle Support
18	ISO 15270: Plastics -- Guidelines for the recovery and recycling of plastics waste
19	ISO 30000: Ships and marine technology -- Ship recycling management systems -- Specifications for management systems for safe and environmentally sound ship recycling facilities

Table 2: Caption

4.1.3 Research Action 1 – Technologies for Sustainability

The overall goal of sustainable manufacturing is to obtain a holistic view of product cycles in the manufacturing industry and optimise the life-cycle of manufacturing systems, products and services. Methodologies and tools to support the manufacturing of products and production need to be increasingly life-cycle and service oriented, in addition to the requirements for quality, cost-effectiveness, safety and cleanliness.

The picture below illustrates the technical, economic, ecological and social implications of a sustainable product/process/service system.

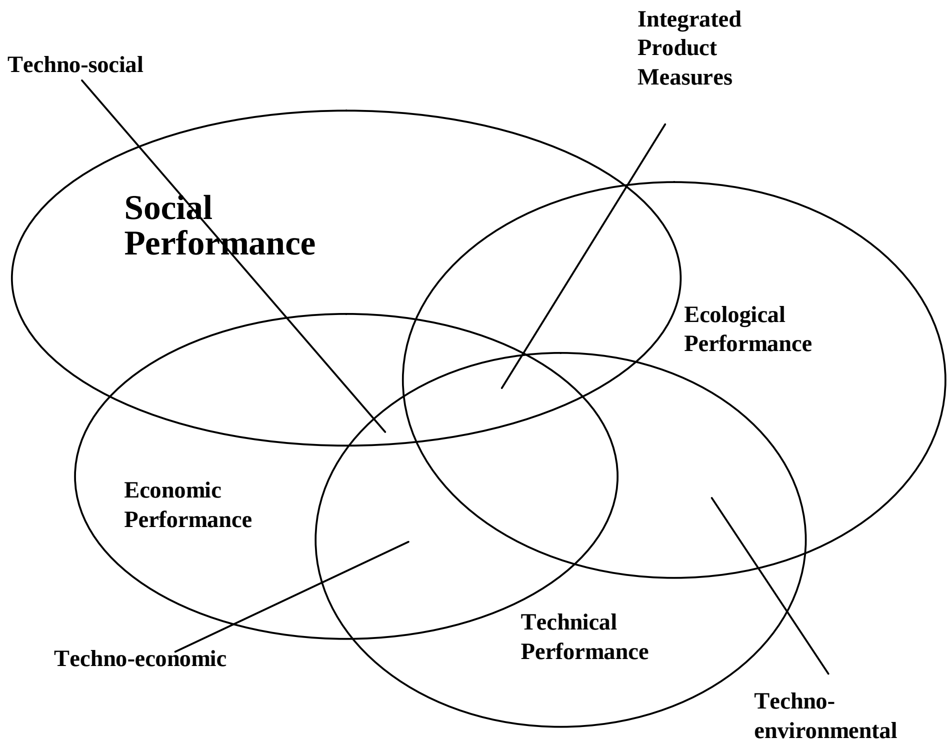

Figure 5: Technical, economic, ecological and social implications

With the sustainability vision in mind, technologies need to be developed that enable, support and improve the economic, ecological and social performance of product/process/service systems.

	Short	Medium	Long
Environment	++	+ +	++++
Economy	+	++	+++
Society	+	+ +	++++

Table 3: Impact of the Research Action "Technologies for Sustainability"

<u>Standard Vision:</u>

"Communication and semantic standards enable technologies to support sustainable manufacturing"

This research action embraces in an holistic way many aspects of the technological advancements wished to improve and manage the sustainability of product, production processes and services.
Within these areas many standards already exist, but actually are scarcely used; moreover since there are many standards covering bit and pieces of the whole, without synchronization between them, the interoperability that is needed to really do a step up in areas like, for example, data management or supply chain, is still missing.
Within this research action there is so a strong need for support to existing and ongoing standardization actions, so to improve and enlarge existing standards and relate them with the others such a way to create an efficient and interoperable network of standards that is able to cover all the required areas.
To achieve this aim the new potential offered by ontology and semantic web tools can be exploited; this process will enable standardization to widen its scopes and aims, being also open to future updates, improvements and developments.

4.1.4 Research Action 2 – Scarce Resources Management

Manufacturing is strictly dependent on continuous flows of materials and energy. Global consumption of engineering materials (i.e. hydrocarbon fuels; metals and polymers) amounts actually to 10 billion tonnes per year. Hydrocarbon fuels (such as oil and coal) accounts for a colossal 9 billion tonnes per years. Today they are used as the principal source of energy; in fact non-renewable carbon based fuels oil, gas and coal account for 86% of the total world energy consumption. Nevertheless those materials are not infinite. Enterprises aims not only at surviving, but also at growing on the market; the population and its consumptions are growing as well as, but that means evidently a further growth of consumption of energy and materials. This situation requires a new way of thinking: see the end of the “first life” of products not as a problem but as a resource.
Today a lot of reusing technologies have been investigated but there is a strong need of a reference model for material reuse optimization.
Recycling is the second feasible options: waste materials should return in supply chain and can be used as raw materials, source of energy or to replace no renewable natural resources (minerals and fossil fuels).
The following table shows the impact of this research action.

	Short	Medium	Long
Environment	++	+ ++	++++
Economy	+	++	+++
Society			+

Table 4: Impact of the Research Action “Scarce Resources Management”

Standard Vision:

“Closed loop approaches based on product-, component- & material standards preserve scarce resources”

To preserve scarce resources a global approach is needed; to optimize reuse, remanufacture and recycle components of a product (B2B or B2C) there is a need for knowledge and data on the products, their components and lifecycle usage. Actually some standards are able to trace parts of the lifecycle of the product, but not all the details of it. For a deeper discussion of product lifecycle standards, please check Research Action 3 in chapter 4.1.5.
Reuse and Recycle standards and regulations also exist, such as ISO 15270, ISO30000, parts of the ISO14000 family, the Waste Electrical and Electronic Equipment (WEEE) national or international regulations, but it doesn’t still exist a complete series of recycling standards and regulations that have also an international consensus. Moreover new ways of using lifecycle data to maximize the recycle and the reuse of parts and materials are needed.
The research topics under this research action will have also the aim of understanding deeply the existing standards and regulations, then to extend existing or/and develop new standards for data and procedures to optimize material re-use as well as resource recovery.

4.1.5 Research Action 3 – Sustainable Lifecycle of products and production systems

Sustainability of manufacturing is more and more affected by lifecycle considerations (Design, Production, Use, Retirement and EOL of products).
Sustainable manufacturing is not only “Green Machining” or “Environmental Benign Manufacturing”. Manufacturing must be sustainable not only in terms of sustaining a certain level of environmental parameters, but it must be also sustainable in terms of Performance and Quality of both products (including services) and processes and Safety of people (workers and other people affected in one or another way by manufacturing process or facilities and their products), but also of the related facilities and infrastructure. Maintenance of manufacturing facilities is important to sustain (i) the quality of processes and (ii) safety.

	Short	Medium	Long
Environment	++	+ +	++++
Economy	+	++	+++
Society	+	+ +	++++

Table 5: Impact of the Research Action “Sustainable Lifecycle of products and production systems”

Standard Vision:

“Electronic information & data standards facilitate the integration of Sustainable Lifecycle Production Systems”

Product information is generated during all the lifecycle phases. At the design stage, information can be distributed between several organisations and is generally composed of different types of documents such as 3D models, design documents or bill of materials. In the manufacturing process, parts and subassemblies can be produced by different manufacturers. When the product is sold to a customer, the usage phase begins and the product alternates between work phases and maintenance or repair phases. The product reaches then its EOL and the gathered information is used the EOL decision support.
The main PLM functions in the BOL, MOL and EOL phases are summarised in Table 6 below.

Lifecycle phase	PLM functions
BOL	Globally unique identifier for objects and the storage of object related quasi-static
	Access to previous MOL lifecycle information on product usage
	Access to previous EOL lifecycle information on recycled parts
	Product design improvements using MOL and EOL data
	New product design generation using MOL and EOL data
MOL	Object usage information capture
	Access to component relevant information from BOL
	Data analysis functions – DSS for predictive maintenance
	Capture maintenance events
EOL	Track and trace
	Access to component relevant information from BOL and MOL
	Data analysis functions – DSS for EOL management

Table 6: Summary of PLM functions

In terms of standards for the information loops of PLM, we can observe that the current STEP standards cover product development only. On the other hand, several standards cover partly the requirements of the information loops of PLM: PLCS and ISO 15926, MIMOSA, EPC global standards, etc.
In general, we can distinguish the related standards into product information modelling standards (e.g. ISO 10303 (STEP, PLCS), MIMOSA), information exchange standards (e.g. SOAP), product visualisation standards, E-business and value chain support standards and finally security standards.

We may summarise the most important among them as follows:

- **Product lifecycle support** (PLCS) is an application protocol of STEP (ISO 10303 AP 239). PLCS has been designed to support the maintenance of complex products such as aircrafts or ships in operational conditions.
- **MIMOSA OSA-EAI** (Open System Architecture for Enterprise Application Integration) aims to enable organisations to optimise the utilisation of their assets by filling the gaps between the different islands of information. MIMOSA specifications allow organisations to cost-effectively develop and maintain products.
- **ISO 15926** defines a format for the representation of information about a process plant based on STEP standards [Leal, 2005]. It does not only record the process plant as it exists at a given point of time but also represents how the plant changes after lifecycle activities such as maintenance.

Recently (2004-2008) the concept of **Closed-Loop Lifecycle Management (CL²M®)** was developed by the FP& IP and IMS project PROMISE (www.promise-plm.com) using the following standards framework and identified gaps:

PROMISE Architectural element	Recommended standards	Gaps to be filled
PEID	OGC SWE, EPCglobal standards (RFID)	None
Core PAC	UPnP	None
PMI	HTTP, SOAP, WWAI, XML, HTML, ID@URI, EPCglobal standards	Product Lifecycle event notification (only partly supported by EPCglobal standards: ALE and EPCIS
Middleware	J2EE OSGi, Web Services	None
PDKM	PLCS	Semantic management of item-level field data corresponding to the product

Table 7: Summary of the PROMISE standards framework and related gaps

This effort has been recently taken over by The QLM Consortium of The Open Group: http://www.opengroup.org/qlm/

Quantum Lifecycle Management (QLM) standards are necessary to support the natural progression and extension of Product Lifecycle Management (PLM). Their scope greatly exceeds product lifecycle management, exploiting common information exchange technologies to embrace other lifecycles including healthcare, supply chain and logistics, food, beverage, pharmaceutical pedigree and traceability, among many others. The quantum leap implied in the name is relevant because of the effect of harnessing the technologies and direction of the "Internet of Things", embracing the trillions of additional entities that will be introduced to the challenge of lifecycle management.

4.1.6 Research Action 4 – Sustainable Product and Production

A sustainable product and production system will contribute towards the modernisation of industry by improving the quality of product information and ease of access to information at the design, production, utilization and end of life stages.
Such a system will make possible to achieve a less resource intensive society and a more competitive industry because:

- Material re-cycling can be significantly improved when products "know" themselves what material they contain, who manufactured them and other knowledge that facilitates material re-use.
- More knowledge-intensive products make it possible to optimise utilisation of resources (especially energy) during the product lifecycle.
- Improved product traceability, which is important for discovering manufacturing errors and other quality-related issues, which helps increasing competitiveness.

- Traceability in logistics makes it possible to optimise stock utilisation, thus reducing material waste and transport costs.

	Short	Medium	Long
Environment	++	+ +	++++
Economy	+	++	+++
Society	+	+ +	++++

Table 8: Impact of the Research Action "Sustainable Product and Production"

Standard Vision:

"Sustainability in products and production requires standardization activities to a wide extent"

This Research Action is strictly related to the other actions, since product and production are the core elements of the same concept of sustainable manufacturing. For this reason, the achievement of a sustainable product and production requires a wide approach to standardization, addressing all the standardization needs and effort mentioned in the above and below sustainable actions.

In particular, **sustainable product and production is a matter of information** and STEP related standards (in particular PLCS) play a relevant role and call for a special effort. Product tracing and tracking are directly related to this issue and standardization efforts might be considered, as already mentioned in the Research Action 4.

But such a **research action is also a matter of methods and procedures**, some of them still existing. In particular, ISO 14000 and the LCA/LCI (Lifecycle Assessment and Inventory) normative constitute the right basement for the achievement of more sustainable products and productions processes.

Sustainability in products and production might be well communicated to all the possible stakeholders, customers at first. Ecolabels and eco-ticketing (already mentioned in LCA normative), as well as recognizable consortiums call for a special effort in standardization: standardization of communication procedures, but also standardization of organisation responsibility and social attention.

This way, a special attention to CSR (Corporate Social Responsibility) actions and its measurement might be paid. **Standardization efforts in accountability and performance measurement at organizational level** might be spent for achieving a sustainable product and production, starting from the existing effort (e.g. the Global Reporting Initiative GRI, and ISO 14031)

Finally, a special attention might be dedicated to the relationship existing among a more sustainable product and production process and the **energy consumption**. Energy efficiency in manufacturing is mainly addressed by next areas and its research actions but evidently this issue has a special link with sustainable manufacturing. Most parts of the matters addressed in the following pages might be considered also for Research Action 4.

4.1.7 Research Action 5 – Sustainable Businesses

Nowadays sustainability is a challenging key business imperative that calls for a new paradigm of thinking and acting.
Sustainability is a complex issue to manage due to the holistic nature of sustainability concept that embeds environmental, social and business aspects that are not independent of one other, but instead intertwine in tradeoffs. Enterprises need to manage all these conflicting aspects of sustainability in a integrate manner, focusing not only on environmental or social performances but also on sustainability of business: a shift to sustainability will only occur if it will not be costly and disadvantageous, but sound and attractive from economical point of view. There is a need to reach the so-called triple bottom line objectives: profitable growth, environmental friendliness, social responsibility. To achieve this aim, enterprises, especially in SME sector, need to develop:

- Business model that mediate between improving environmental performances and business competitiveness;
- Methodologies and tools that support managers in decision making and in innovation process with the aim to exploit enterprise potential for sustainability;
- New approaches, workplaces, working methodologies or special training for disabled and aging people.

Moreover, two aspects are changing and focusing the future business arena:
First of all, globalized market and networked supply chain require to act not only at enterprise level but also at value chain level in order to guarantee the sustainability of the business. A key feature of present production networks is the idea that supply chains compete, not single companies.
Moreover, today customers ask not only for products but also for complementary services. Consequently, producers have to advance and become solutions provider by integrating products and services into a high value offering.
These two points, at value chain level, require to optimize information flows and facilitate communication and interaction among all actors not only of the whole chain, but also including service providers and customers. To achieve this vision, globalized supply chains will need new methodologies and tools for supporting synchronized decisions across and beyond the supply chain, aiming at improving their sustainable (both economical and environmental) performances.
The expected impact of this Research Action is shown in the following table.

	Short	**Medium**	**Long**
Environment	++	+ +	++++
Economy	+	++	+++

Society	+	+ +	++++

Table 9: Impact of the Research Action “Sustainable Businesses”

Standard Vision:

“Interface paired with business process standards pave the way for sustainable businesses”

Sustainability in business means ensuring long-term business success while contributing toward economic and social development, a healthy environment and a stable society.

As part of their core principles, companies that want to be committed to sustainable business have to focus on a broad area that includes environmental protection, gender equity, working conditions, employee benefits, capacity development, community development and a set of transparent relationships between a company’s management, its board, its shareholders and other stakeholders.

The achievement of a sustainable business requires a supportive action of standardization, that provides both standards for information and data exchange (interface standards), and standards for business process automation.

As stated above, to guarantee the sustainability of the business a new way of thinking and acting is necessary since globalized market and networked supply chains require to act at value chain level, involving also customers and services providers. This new approach calls for a wide standardization activity capable of optimizing information flows among the various actors of the value chain and of defining a common language for facilitating communication and exchange of data and information. Typically each actor uses its proper language, so that there is a need of defining a standard format as a means to guarantee adaptability and interoperability among different applications. In fact, in a networked supply chain, relevant information can be distributed among several organisations and it is necessary to share them in an effective and efficient way to take synchronized decisions, aiming at improving sustainability of the entire value chain.

Another important aspect to reach sustainability in business is the automation of business processes both between enterprises and within the enterprise. In this way the entire supply chain increases its agility in responding to customer, market and strategic requirements. It is a task of electronic business integration to automate the information flow as much as possible in order to streamline operations. If, however, the information flow between an organization IT systems and those of its partners (particularly in the supply chain) is not also streamlined, then the overall agility of the business is still restricted. Therefore, many enterprises also strive to integrate their partner's IT systems with their own in order to more fully automate critical business processes such as sales, procurement, and research and development. The benefits of the increased agility resulting from business process automation are extensive: operational costs are decreased, inventories are reduced, customer satisfaction is increased, and products are brought to market faster. A wide set of new tools exist for facilitating the integration and automation of business processes. These include graphical process modelling tools, middleware technologies such as CORBA and

JMS, integration brokers, Business Process Management Systems (BPMS), and B2B servers.
The major problem consists in the investment required to each actor for integrating IT systems both inside their organization and along the value chain. Typically this is due to the different data format and proprietary interface used by each actor.
Today Web Services technology seems to be a good way to overcome this problem by replacing proprietary interfaces and data formats with low-cost, ubiquitously supported standards for interfaces and data that work as well across the firewall as within it. The first generation of Web Services technology, though, has largely focused on the messaging foundation supported by SOAP and WSDL. While this foundation is sufficient for some internal application integration needs, it is not sufficient to support the complete automation of critical business processes. This requires the ability to specify workflow, security requirements, transaction management, and other critical information related to the business process context. Such information is generally specified in a business process model. So there is a need to develop standards for business process models that enable processes to be modelled, deployed, executed and managed by the software of various vendors.

4.1.8 Conclusion

The Sustainability area is very wide, covering very different aspects, products, processes. Due to this manifold diversity, the difficulties of the evaluation of the real product impact and of a not-biased competition on sustainable issues, in next years there will be the requirement of lot of efforts in the standardization, regulation and legislation areas.
All the main standardization areas will be touched directly or indirectly; in fact a framework to measure and evaluate sustainability will need:

- *Measurement standards* to define how and what should be measured and how to compare different products and services offered,
- *Interface standards* to exchange data to evaluate product impact and integrate the sustainability information within the enterprises IT systems,
- *Process standards* to collect data about the real production, maintenance and recycling processes
- *Product Standards* to know and share real usage data knowing in details the real lifecycle of the products.

Finally sustainability, especially in its “societal” pillar, will also cover and need *Safety standards* that will be the basis for the development of sustainable business.

4.2 Energy Efficient Manufacturing

4.2.1 Introduction

Manufacturing is playing a core role when it comes to greenhouse gases (GHG) and final energy consumption. With about 33% of final energy consumption and 38% of direct and indirect CO2 emissions, the manufacturing industry has the biggest share in both. From the companies' point of view, the importance of energy efficient manufacturing has various reasons, for example customers changing their purchasing behaviour with regard to "green" products and services, rising energy prices, or emerging of new environmental regulations. Using the available energy more efficiently is a way to meet ever-rising energy needs and secure energy supplies.

The IMS2020 Key Area "Energy Efficient Manufacturing" aims for reducing the scarce resource depletion as well as the carbon footprint by considering innovative methods and technologies. Products and processes are no longer just subject to cost and quality. According to this vision there are four major areas for research and action.

- Energy Sources for Factories
- Efficient Production Processes
- Energy Utilization in Collaborative Frameworks
- Management and Control of Energy Consumption

In order to support these research actions, the development of standards plays an important role. For the research action "Energy Sources for Factories" both interface standards and measurement standards are the basis for a successful implementation and technology development. The research topics focus on becoming independent from external energy suppliers and to use the available energy in factories. This is for example achieved by adapted sourcing strategies which help to cope with rising energy prices, risk of unavailability and customers' environmental awareness. Measurement standards for process, energy and manufacturing efficiency help to make the improvement potential in factories and manufacturing processes transparent.

The research action "Efficient Production Processes" aims at reducing energy consumption while increasing the output of the manufacturing process. This means increasing the efficiency and productivity, for example by novel technological approaches in manufacturing equipment, which leads to reduction of specific energy consumption. The research topics are mainly supported by closed loop management standards as well as product and component standards. Products require characterisation about energy efficiency, which has to be standardized in order to coordinate improvement activities. Material standards do also play a role when it comes to improving the efficiency of the grinding process. Measurement standards for emission detection are needed to define the requirements for new approaches and concepts. For the research topics in this area, management standards and semantic standards play also a role and facilitate the development of suitable solutions.

The research action “Energy Utilization in Collaborative Frameworks” has the objective to develop frameworks and technologies that support the economically viable reuse of heat streams in another production process or industrial sector. Interface standards are a precondition for the recovery of energy and heat in collaborative frameworks. Moreover, especially in the field of recovery of wastes, whether in form of energy or material, standardized products, materials and processes are needed. Furthermore management and measurement standards support a holistic approach for waste streams and collaboration in networks.

The research topics in the research action “Management and Control of Energy Consumption” deal with new energy management systems which form a basis for deciding about energy efficiency improvement. As measurement and control systems are an integral part of the manufacturing systems, standardized measurement approaches are a prerequisite for energy consumption management and control. Moreover, measurement, communication and data standards will enable ICT to increase energy efficiency in the manufacturing processes.

4.2.2 Compendium of Relevant Standards (2)

According to the six standard-clusters of *Interface standards, Measurement standards, Process standards, Safety standards, Product and component standards* and *Material standards* the following tables give an overview which clusters are relevant for the research topics and which clusters are already addressed by existing standards.

The first table shows the correlation between clusters and defined research topics, the second serves as a caption. The white cells in the first table symbolize that the corresponding standard cluster is relevant for the respective research topic, while a grey cell indicates that the standard cluster is not seen as relevant for the research topic. The indices in the cells stand for currently existing standards which belong to the respective category and are related to the research topic. In this context, it has to be stated, that the intention of the following tables is not to provide an exhaustive overview of existing standards. In fact, the exercise is just meant and designed to serve the purpose of this document. Sources for the mapping of currently available standards were standard databases, search engines as well as European[4] and U.S. American[5] standardization bodies.

Having this restriction in mind, the empty white cells can be seen as standardization gaps which should be examined more intensively by upcoming projects dealing with the respective research topics. White cells with content indicate that there are already standards which should be further analysed and could serve as a basis for further development. While empty grey fields indicate no relevance for the topic, the grey fields with content imply that a standard is present in a cluster which is seen as not relevant for a topic. This could mean that the standard is not necessary, what definitely has to be validated in further investigations.

Thereby the results visualized in the following tables serve as a starting point to assess the standardization needs of each research action, indentify gaps and development issues.

[4] CEN – European Committee for Standardization

[5] Rachuri, S.: The landscape of Sustainability Standards, presentation at the „Sustainability Interest Group“

Finally they support the deduction of the main standardization needs and potentials summed up in the following standard visions. The specific conclusion at the end of this chapter will be based on this aggregation and conclude with the gap analysis.

IMS2020 Research Topics
Relations with Standardization (KAT4)

Legend:
= Standard category probably not relevant for reserach topic
= Standard category probably relevant for reserach topic

		Interface Standards			Measurement standards					Process standards						
		Electronic information & data standards (format)	Communication & semantic standards (content)	Physical interface standards	Measurement standards for process efficiency	Measurement standards for energy efficiency	Measurement standards for manufacturing efficiency	Measurement standardards for waste detection	Measurement standardards for emission detection	Design process standards	Manufacturing process standards	Business Process standards	Closed loop management standards	**Safety standards**	**Product & component standards**	**Material Standards**
RT2.01	Energy-aware Manufacturing Processes – Measurement and Control					(3)		?	(17)		(7)					
RT2.02	Integrating Energy Efficiency in Production Information Systems	(1)	(2)		(6) / (8)	(3)	(6)	?	?							
RT2.03	Using Energy Harvesting in Manufacturing Processes			(5)	(6)	(3)	(6)				(7)					?
RT2.04	Energy Autonomous Factory	(1)	(2)		(6)	(3) / (4)	(6)									
RT2.05	Intelligent Utilization of Waste Heat	N.A.	(2)			(3) / (4)		(4)					(9)			
RT2.06	Framework for Collaboration in the Alternative Fuel and Raw Material Market	(1)	(2)	(5)		(3)			?		?		(9)		?	
RT2.07	Technological Access to Wastes for Enhanced Utilization in Resource Intensive Industries	(1)	(2)	(5)	(6)	(3)		(4)	?				(9)			
RT2.08	Product Tags for Holistic Value Chain Improvement	(1)	(2)		(6)	(3)	(6)					(10)			...	
RT2.09	Emission Reduction Technologies								(11)				(9)		?	
RT2.10	Energy Efficient Particle Size Reduction										(12)				(12)	
RT2.11	Green Manufacturing for Future Vehicles	(1), (15)									?		?		(13)	(14)

Table 10: Correlation between standard clusters and research topics (2)

Index	Standards
1	Data exchange standards: IGES (Initial Graphics Exchange Specification-USA, SET (Standard D'Echange et de Transfert-France), VDA/FS (Verband der Automobilindustrie-Flächen-Schnittstelle-Germany) and STEP (Standard Exchange of Product Data)
	Standardised manufacturing management data: ISO 10303 AP-238, ISO 14649 (STEP-NC), ISO 13399, ISO 15331 (MANDATE), ASME B5.59-2
2	Data exchange standards: IGES (Initial Graphics Exchange Specification-USA, SET (Standard D'Echange et de Transfert-France), VDA/FS (Verband der Automobilindustrie-Flächen-Schnittstelle-Germany) and STEP (Standard Exchange of Product Data)
	Standardised manufacturing management data: ISO 10303 AP-238, ISO 14649 (STEP-NC), ISO 13399, ISO 15331 (MANDATE), ASME B5.59-2
	Document management -- Analysis, selection and implementation of electronic document management systems (EDMS) ISO/TR 22957:2009
	Industrial automation systems and integration -- Manufacturing software capability profiling for interoperability. ISO 16100-1:2009
	Information technology -- CDIF semantic metamodel -- Part 6: State/event models ISO/IEC 15476-6:2006
	Energy Management System Application Program Interface (EMS-API) - Part 1: Guidelines and general requirements (IEC 57/689/CDV) OEVE/OENORM EN 61970-1
	Energy management system application program interface (EMS-API) - Part 301: Common Information Model (CIM) base IEC 61970-301, CEI 61970-301
	Energy management system application program interface (EMS-API) - Part 301: Common Information Model (CIM) Base (IEC 61970-301:2003) DIN EN 61970-301 (2008-02).
	Electricity metering - Data exchange for meter reading, tariff and load control - Part 42: Physical layer services and procedures for connection-oriented asynchronous data exchange (IEC 62056-42:2002)
3	Environmental management systems -- Requirements with guidance for use ISO 14001:2004
	Energy management system -- Requirements with guidance for use ISO 50001 / DIN EN 16001
	ASTM E929 - 83(2009) Standard Test Method for Measuring Electrical Energy Requirements of Processing Equipment
4	Building environment design -- Guidelines to assess energy efficiency of new buildings ISO 23045:2008
	The MINERGIE®-Standard for Buildings (http://www.minergie.ch)
	Energy performance of buildings - Economic evaluation procedure for energy systems in buildings OENORM EN 15459
	Calculation methods for energy efficiency improvements by the application of integrated building automation systems OENORM EN 15232
	Solar energy - Vocabulary ISO/DIS 9488
	Heating systems in buildings - Method for calculation of system energy requirements and system efficiencies - Part 1: General OENORM EN 15316-1
	ASTM D5058 - 90(2007) Standard Test Methods for Compatibility of Screening Analysis of Waste
5	Industrial automation systems and integration -- Product data representation and exchange -- Part 1647: Application module: Assembly physical interface requirement ISO/TS 10303-1647:2006
	Industrial automation systems and integration -- Product data representation and exchange -- Part 1635: Application module: Assembly functional interface requirement ISO/TS 10303-1635:2006
6	Measurement management systems -- Requirements for measurement processes and measuring equipment. ISO 10012:2003
	Industrial automation systems and integration -- Product data representation and exchange -- ISO/TS 10303-1106:2008: Application module: Extended measure representation
	General requirements for the competence of testing and calibration laboratories: ISO/IEC 17025:2005
	Industrial-process measurement and control - Data structures and elements in process equipment catalogues - Partie 1: Measuring equipment with analogue and digital output (IEC 65B/546/CDV) IEC 61987-1
	ASTM D7204 - 07 Standard Practice for Sampling Waste Streams on Conveyors
7	Industrial automation systems and integration -- Product data representation and exchange -- Part 240: Application protocol: Process plans for machined products. ISO 10303-240:2005
	Industrial automation systems and integration -- Process specification language. ISO 18629
8	Information technology -- Measurement and rating of performance of computer-based software systems ISO/IEC 14756:1999
	Test code for machine tools -- Part 6: Determination of positioning accuracy on body and face diagonals (Diagonal displacement tests) ISO 230-6:2002
	NAMUR NA 110 Benefits, Design and Application of MES

Table 11: Caption

4.2.3 Research Action 1 – Energy Sources for Factories

Rising energy prices, risk of unavailability, but also the environmental awareness of customers push companies to re-evaluate their energy sourcing strategy. New strategies may include becoming independent from external power supplies on the bigger scale, but also using smaller scale energy potentials to power devices as sensors and controllers.

Today, companies receive their electricity from external and centralized energy suppliers, who produce electrical energy in power plants to distribute the energy to their customers. This bears two problems regarding energy efficiency. On the one hand, there are energy losses due to the distance between the plant and the companies. On the other hand, the centralized energy supply has to produce more energy than needed in order to cover peaks in demand, decreasing the efficiency of the system. Although centralized power supply generally has the advantage of economies of scale, there are specific situations, e.g. factories with limited, unsecure or long-distance access to energy, where on a smaller scale level energy demand and supply can be controlled to increase energy efficiency. With increased knowledge and data base about internal manufacturing processes, it is possible to control more effectively and thus increase the energy efficiency of the processes. By using energy potentials available in the environment, a “wireless” energy supply can be realized and sensors and controllers powered remotely, which contributes to the secondary energy savings.

	Short	Medium	Long
Environment	+	++	+++
Economy		+	++
Society		++	++

Table 12: Impact of the Research Action “Energy Sources for Factories”

The following two research topics deal with these issues and aim for providing solutions by research and development:

- **RT 2.04: Energy Autonomous Factory**
  In order to reduce energy consumption and to guarantee a reliable energy supply, technologies and frameworks have to be developed for production-sites, which enable self-dependent energy generation according to the actual on-site demand and facilitate the use of renewable energy sources.
- **RT 2.03: Using Energy Harvesting for Powering Electrical Sensors and Devices in Manufacturing Processes**
  Energy harvesting is a concept to transform surrounding energy (e.g. thermal, kinetic, waves) to electrical energy. By finding potentials and developing solutions for manufacturing, e.g. sensors’ and controllers’ energy storage devices can become smaller or even dispensable.

<u>Standard Vision:</u>

“Efficiency measurement standards enable the efficient use of companies' energy sources”

Standardization activities enable innovation for “energy autonomous factories”: In an early stage of this research activity, measurement standards have to be developed. Measurement standards for process and energy efficiency will help to make the improvement potential of factories transparent. Standardization of technologies may be necessary at a later stage of development for the “energy autonomous factory”. Technologies and frameworks for production-sites will be developed, which enable self-dependent energy generation according to the actual on-site demand and facilitate the use of renewable energy sources. At a time when the first energy autonomous factories are in operation, standards could be developed, requiring how to certify the factories/plants according to their percentage of “green” electricity use and according to their energy efficiency (similar to the ENERGY-STAR label for refrigerators, etc.). A standard could be possible for a “net-zero-energy-building/plant-culture”, where the training and education program of a company could be certified according to this standard. Moreover, standardization for technologies related to renewable energy sources and energy storage concepts are needed, especially if this technology is applied on a global level.

Standardization activities make benefits in the area of energy harvesting transparent: Energy harvesting is a concept to transform surrounding energy (e.g. thermal, kinetic, waves) to electrical energy. Standardization activities in this area may include standards for new technologies for sensors and controllers as well as energy storage devices. This topic has a need for standardization actions (e.g. considering parameters of the output of an energy harvesting device) especially focusing on physical interface standards. As new technologies have to be developed and new materials and approaches will be required, standards in this area may evolve. Special attention could also be given to the analysis of potentials of energy sources, as volume flow or velocity, mass or acceleration, potential or kinetic energy, but also thermal or electromagnetic sources, in order to concentrate on developments for energy harvesting at sources with a high recoverability. The measurement of the potential for energy recovery related to specific energy sources should be standardized in order to allow for benchmarks and best practice comparison. Similar to the area of “energy autonomous factories” efficiency measurement standards will be necessary in order to make energy saving potentials and achievements transparent. Also material standards and manufacturing process standards may be applicable and have to be further developed to foster energy harvesting.

4.2.4 Research Action 2 – Efficient Production Processes

Reducing energy consumption in the manufacturing processes is a key lever when aiming for CO2 reduction and increase of energy efficiency. Due to the losses in energy generation, transformation and transportation from the power plant to the end-consumer, each kW saved in consumption results in a much larger amount saved in energy “generation”. It has to be a strategic aim to reduce energy consumption on the long term whilst increasing the output of the manufacturing processes.
From an energy efficiency point of view, manufacturing processes can be improved in three different layers. The first layer is the technology of the existing manufacturing processes themselves. During technology development, energy efficiency has to be taken into account

as a priority objective besides of costs and quality. With this, the consumption itself can be further decreased. The second layer is the design of the process chains and the manufacturing systems, respectively. The planning and design of these systems includes a high potential for energy savings due to an improved configuration of process chains and manufacturing systems. The third layer considers the output streams from the manufacturing processes. There, technologies are required to decrease emissions and to filter pollution substances. Here, additional energy is required imposing indirect energy consumption on the manufacturing processes – decreasing the overall energy efficiency. Therefore, the issues of the three layers are represented in the following topics:

- **Energy Efficient Particle Size Reduction**
  New grinding concepts and technologies have to be defined (e.g. pre-treatments, flexible grinding systems) and demonstrated in order to increase the efficiency of grinding processes.
- **Green Manufacturing for Future Vehicles**
  Taking into account the interdependencies of product design and the manufacturing process, new possibilities of "green" car-manufacturing should be analyzed and new energy efficient production concepts developed.
- **Emission Reduction Technologies**
  Resource and energy intensive industries emit substantial amounts of green house gases and other polluting substances. Technologies to reduce these emissions have to be developed in a coordinated approach across sectors in order to gain benefits from implementing similar reduction and capture technologies.

	Short	Medium	Long
Environment	+	++	+++
Economy		++	++
Society	+	++	+++

Table 13: Impact of the Research Action "Efficient Production Processes"

Standard Vision:

"Development of closed loop management standards and product and component standards fosters the efficiency of production processes"

Standardization activities in the area of energy efficient particle size reduction may be necessary at a later stage of development. However, as the research and development is in an early level, no specific standardization activities can be related to this topic. In case of choosing an interdisciplinary and cross-industry approach, it may be beneficial to have a **specific characterization of the material which needs to be grinded**. So, similarities between materials may be found and research and development benefit from knowledge transfer in other areas of research.

Standardization activities in the area of “green” manufacturing of vehicles include a whole **bandwidth of processes and products**, as automotive supply chains are very complex. Standardization activity should contribute to the **assessment of the energy efficiency** of the manufacturing processes as a whole and not at single sites only. **Products require characterization** about energy efficiency, which has to be standardized in order to **coordinate improvement activities**. At a later stage, the whole life cycle has to be considered in order to strive for the **overall optimum** of energy efficiency. The improvements need to be undertaken bottom-up (improvements on single process basis) as well as top-down (coordinating the improvement activities to the significant areas). In order to coordinate these improvements **standardized guidelines** on how to include the findings from the different levels without limiting the value of information need to be defined. Energy efficiency potentials and approaches need to be identified in different companies and departments. A **standardized approach to detect potentials** and to **undertake improvements** would be beneficial and make the improvement process transparent.

Standardization activities for emission reduction technologies include a high potential of creating synergies in research and development by consolidating results from different sectors and industries. Best practices could be applied on a wider level. In order to do so, **characterization standards in form of semantic standards** need to be defined. Latter requires **clear definitions of the specific emissions and emission streams**, in order to define the requirements for new approaches and concepts. **Management standards** could help to lower the barriers of **knowledge transfer** from industry to industry. Another benefit could be the **increased awareness** of energy efficiency across employees. So, new opportunities for energy efficiency increase could be found.

4.2.5 Research Action 3 – Energy Utilization in Collaborative Frameworks

Today, energy is used in single factories for the own manufacturing processes. Dissipating energy in form of heat or by products is in many cases taken as waste output without potential of reusing it. However, this “waste” often includes a beneficial use or reuse in another production process or industrial sector. In the future, companies and industries need to be able to collaborate on a cross-sector basis in order to use energy and waste streams in a symbiotic way.

Such waste streams cannot always be used directly in another process, factory or industry. Often, a pre-treatment is required in order to make the “waste” reusable. Here, technology advancements have to be fostered in order to make the pre-treatment and the reuse both environmentally as well as economically viable. As almost all manufacturing processes emit heat in some way (representing the inefficiencies of the processes), the recovery and usage of waste-heat has to be focused on. Here, especially low temperature waste heat, which has a low temperature level but at the same time is available to a big amount in many forms throughout different sectors, needs to be considered. Further, the transparency of available “waste streams” at cross-sector and cross-industry level has to be increased. The following topics need to be focused in order to progress in this area of research:

- **Technological Access to Wastes for Enhanced Utilization**

Technological advances in pre-treatment and upgrade options are required in order to increase the ability to produce and use waste streams. Adaptation of the main existing processes needs to be demonstrated in a cross-industry approach.

- **Intelligent Utilization of Waste Heat**
  Factories in process industries are point sources of low and medium temperature waste heat, which remain widely unused. Cross-plant analysis of waste heat recovery potentials shows the significant sources. Possibilities of co-operations between plants need to be found. Optimized utilization of heat at various temperature levels can be identified.
- **Framework for Collaboration in the Alternative Fuel and Raw Material Market**
  Waste/by-products form energy-intensive industries can be used to replace raw material and fossil fuels in industrial processes. Methodologies and strategies for cross-industry and cross-sector collaboration have to be developed in order to enable increased utilization of waste.

	Short	Medium	Long
Environment	+	++	+++
Economy		++	+++
Society	+	++	+++

Table 14: Impact of the Research Action “Energy Utilization in Collaborative Frameworks”

Standard Vision:

“Interface standards are a precondition for the recovery of energy in collaborative frameworks”

Standardization action can increase the benefits of possible outcomes of these research topics significantly. Especially in the field of recovery of wastes, whether in form of energy or material, **requires standardized products and processes**. So, transparency can be increased and cooperation facilitated. The cooperation of recovering and reusing waste streams involves significant changes in the manufacturing processes. As it involves high investments and many risks (like dependency on supply chain partners, unknown costs, regulation activities) it becomes a strategic decision.

Generally, industry has to have a **reliable benchmark of their “waste” by-products**. This is important for a “waste” producing company, as it regularly needs to **comply with environmental regulation and waste treatment standards**. When there is cooperation with a buying company using the supplier’s waste as feedstock, the buyer has to be reliable; otherwise the stability of producer’s processes may be threatened. Between these two parties, it needs to be clarified by standards what kind of **product** will be supplied under what conditions. **Standards on material definitions (resources, energy)** are required in order to facilitate this process. Another aspect of standardized by-products is that they often need to be pre-treated in another process step. This **intermediate process requires standard** definitions in order to facilitate different parties to collaborate with each other. Further, also **standards on the installed processes** and their robustness would be helpful in order to evaluate the suppliers' and buyers' alternatives.

Furthermore, in order to support a holistic approach, companies should be able to **use management standards as guidelines** for the employees. One of the main aspects here would be the consideration of waste streams as useful by-products instead of just waste. Thinking in closed loops opens up new opportunities of using available resources and energy. Companies complying with this kind of **standards may be certified** in order to be able to find cooperation appropriate partners.

Also important standardization actions included in these research fields are related to the **interface standards. These enable building databases** with data on processes and products, which could be used by the single interested parties. The standardization would **increase the transparency** and transferability of data.

As globalisation is increasing, many companies act globally and implement best practices at their sites in different regions. In order to support companies in their effort to increase energy efficiency and environmental friendliness, the conditions from environmental regulation should be aligned. This may apply for example for waste treatment standards, which in one region may interfere with viable approaches of another region. Therefore, **environmental standards**, here on waste treatment and recovery, need to be comprehensively consolidated and **integrated on international level**.

4.2.6 Research Action 4 – Management and Control of Energy Consumption

The design of former manufacturing systems has been driven by the market, focusing on quality, fast delivery and low costs. Today, triggered through rising energy prices or environmental awareness of customers, energy efficiency is becoming increasingly important and the manufacturing systems have to be adapted, complemented and enhanced accordingly. In order to be aware of the energy consumption in the manufacturing processes, the measurement and control systems need to be integrated and become an integral part of the manufacturing system ("you cannot control what you cannot measure"). New Energy Management Systems will be the basis for deciding about and implementing energy efficiency improvement measures.

In order to develop new Energy Management Systems, the sensors and control devices require attention as well as the key performance indicators, the techno-human interfaces and new concepts of setting up a manufacturing system. With this, energy efficiency can become an integral part of the manufacturing systems and also be represented in the Information and Communication Technology Systems. The transparency of the energy consumed should be the final objective. With the aim to significantly increase energy efficiency, improvements have to be made with respect to the holistic picture, and not only locally. Based on standards, process changes at some tier of the supply chain need to be illustrated and communicated with all supply chain partners. Not only energy savings can be reached for the supply chain: due to the enhanced collaboration a positive effect on the productivity will result.

	Short	Medium	Long
Environment	+	++	+++
Economy	+	++	+++
Society	++	++	+++

Table 15: Impact of the Research Action "Management and Control of Energy Consumption"

The following three topics deal with the challenges to manage manufacturing process in energy efficient way:

- **RT 2.01: Energy-Aware Manufacturing Processes - Measurement & Control**
  An effective energy control system has to be developed, using the information of sensors and in-process measurement and a suitable energy efficiency performance measuring system. This control system focuses on concepts, which facilitate the evaluation, control and improvement of energy efficiency in manufacturing processes.
- **RT 2.02: Integrating Energy Efficiency in Production Information Systems**
  A novel framework that manages and optimizes energy efficiency with respect to production planning and control needs to be developed and implemented in enterprise control and information systems, such as Enterprise Resource Planning (ERP), Manufacturing Execution Systems (MES), and Distributed Control Systems (DCS).
- **RT 2.08: Product Tags for Holistic Value Chain improvements**
  Product related information about the in and outputs of manufacturing processes make the value chain transparent for its stakeholders. The transparency allows process improvements to be coordinated in order to increase the overall value chain performance (in terms of e.g. efficiency, costs, delivery time).

Standard Vision:

"Standardized measurement approaches are a prerequisite for energy consumption management and control"

Measurement standards are the basis for increasing energy efficiency in manufacturing processes: Standardisation activities can increase the benefits of possible outcomes of these research topics significantly. Especially important are standardization activities for energy efficiency performance measuring systems. In order to implement energy efficiency improvements and to measure and control "energy-aware" manufacturing processes companies need to be equipped with an efficient and effective energy management and control system. The standardization of effective (specific and quantitatively measureable) Energy Key Performance Indicators (KPIs) is needed. This standardization of measurement of energy efficiency is especially important because benchmarks are missing in this area. They will only be possible if the measurement is standardized – if possible internationally and across industry sectors. Concepts for evaluating these Energy KPIs have to be developed, followed by decision support, which control mechanisms and improvements measures have to be implemented on the basis of this information. Due to such concepts, factories will know their energy performance in real-time, facilitating more effective business decisions based on accurate and up-to-date information. Here management standards have to be developed. The environmental management standard ISO 14001 is already implemented in many companies, which are certified according to this standard. ISO has identified energy management as one of the top five areas requiring the development and promotion of International Standards. As a consequence the ISO is working on a new management standard for an effective energy management - probably launched end of 2010 (ISO 5001). Interviews conducted in the US evidence also the need for advances in this topic, namely related to the standardization of environmental performance metrics, energy efficiency KPIs and standardize supply chain performance measurement.

Summarising, the objective in this research area should be to provide the basis for a reference framework for energy measurement and control in manufacturing processes and facilitate its use and implementation in companies of various industries (e.g. for benchmarking and best practices). KPI-Standards in order to measure energy consumption have to be defined (specific and quantitatively measurable Energy-KPIs) to enable exchangeability and overall efficiency as well as benchmarking and best practice comparison. The new Standard EN 16001 (new European Standard on Energy management Systems) and the analogous upcoming International Standard ISO 50001 should also be taken into consideration when developing these standards.

Measurement, communication and data standards will enable Information and Communication Technology (ICT) to increase energy efficiency: A novel framework that manages and optimizes energy efficiency with respect to production planning and control needs to be developed and implemented in enterprise control and information systems, such as Enterprise Resource Planning (ERP), Manufacturing Execution Systems (MES), and Distributed Control Systems (DCS). Besides the already mentioned measurement standards, especially communication and data standards will be necessary to include energy efficiency as a relevant performance criterion in these systems. Moreover, CO_2-Emissions should be included as important criteria into strategic and operational decisions in companies. Therefore accounting models have to be enhanced by Energy- and CO_2-KPIs and new evaluation methods. These models should be applicable across industries. Apart from the theoretical framework development, in order to effectively create energy efficient production management systems, standardization action is needed to allow for different enterprise information systems to cooperate for optimizing energy efficiency. Finally, thanks to the adoption of a standardized approach, energy efficient certification for companies will be supported and facilitated. Several industrial players such as business software developers, industrial automation players and manufacturing companies (users) should be involved in the standardization activities.

Standardization activities provide the basis for supply chain transparency: Product related information about the in- and outputs of manufacturing processes make the value chain transparent for its stakeholders. The transparency allows for process improvements to be coordinated in order to increase the overall value chain performance (in terms of e.g. efficiency, costs, delivery time). Labels for eco-friendliness and eco-product are necessary which requires standardization. Consumers have to be educated for sustainability issues customers and labels could increase the awareness of customers. Especially companies in Japan and Korea expressed the need for these labels and the according standardization action. A defined and standardized environmental and energy performance measuring system (as described above) is again the prerequisite for a successful implementation of product tags for a holistic supply chain improvement. Establishing an information system with product related manufacturing data increases the ability to evaluate and improve the processes for a global optimum. Data standards, communication standards and semantic standards play an important role. The research focuses on the increase of transparency in the production process by providing the possibility to store and access product related manufacturing data which has to relate to direct manufacturing processes and to base on commonly agreed KPIs. Standardized approaches for measurement and evaluation regarding energy consumption (and possibly data such as costs, quality or lead time) and data semantics allow for comparable data. Due to the gained transparency, improvements can be planned and implemented in consideration of the overall value chain efficiency.

4.2.7 Conclusion

As shown in this chapter, there are several standards in the standards-clusters of *Interface standards, Measurement standards, Process standards* that support the research topics in the four research actions of “Energy Efficient Manufacturing”. For some of the research topics, *Product and component standards* and *Material standards* also play an important role.

In the area of *Interface standards*, several manufacturing data standards and communications models exist. Is has to be evaluated within the research projects if these standards are suitable for the development of e.g. the “Energy Autonomous Factory” or “Intelligent Utilization of Waste Streams”. Where necessary, the existing standards might be enhanced or new standards developed serving the specific needs of the proposed research actions. In the more technology focused research topics, like “Using Energy Harvesting in Manufacturing Processes” and the research topics dealing with Alternative Fuels and Raw Material (AFR) physical interface standards may also play an important role. New physical interface standards might be developed within the research activities proposed in this area.

Measurement standards play an important role in most of the research activities proposed in the area of Energy Efficient Manufacturing. Especially in the area of “Energy Aware Manufacturing Processes – Measurement and Control” and “Integrating Energy Efficiency into Production Management Systems” adapted measurement standards form the basis for successful implementation. There are already some management standards that also deal with measuring environmental relevant data in the manufacturing process, like the ISO 14001. As the ISO already identified energy management as one of the top five areas requiring the development and promotion of International Standards, the ISO is working on a new standard for an effective energy management - probably launched end of 2010 (ISO 50001). It has to be seen if this standard will cover the measurement standard needs shown in these subchapters or if they need to be enhanced and revised later on. Measurement standards exist for technological data of specific equipment and specific processes. In the area of measurement of emission and waste detection, it has to be analyzed further within future research projects if existing standards fulfill the requirements given by the research topics and actions. Measurement standards for emission detection are needed to define the requirements for new approaches and concepts.

Manufacturing process standards and closed loop management standards are found to be important in the area of *Process standards* research topics. For research topics dealing with AFR and collaboration in industry networks life cycle assessment is required and more focused closed loop management standards. Some standards already exist, e.g. a standard for the definition of cumulated energy demand terms. It has to be analyzed if these standards satisfy the specific needs of the research topics or if new standards should be developed. For collaboration in networks, supply chains and cross-industry borders, these standards play an important role for the communication and the success of the collaboration.

Product and component standards and *Material standards* are required for the more technology-focused research topics, but also for the research topics dealing with collaboration cross-industry and with holistic optimization of product and process characteristics throughout the whole supply chain. Here more energy-specific product and material data has to be standardized and integrated in existing standards frameworks.

4.3

Key Technologies

4.3.1 Introduction

In the manufacturing sector the main technological driver has been the productivity growth while reducing costs. In the next decade, with global markets and networking manufacturing communities, state-of-the-art technologies will continue playing that key role because this time manufactures will demand value-adding, competitive and sustainable manufacturing systems and processes along their entire lifecycle, so that appropriate enabling technologies will be required for that ambitious goal. Indeed, technologies such as e.g. intelligent cognitive elements, adaptive systems, diagnostic features and multi-disciplinary simulations will establish the basis for allowing system builders to deliver to customers customised configurable systems at reduced costs and minimised lead-times, and in turn, will allow the users of said systems to embed value into their manufactured final products along highly efficient production processes.

Within this vision, the IMS2020 Key Area "Key Technologies for Manufacturing" aims at developing the technologies for allowing system builders to produce value-adding systems at minimised costs and environmental impacts and for allowing the users of said systems to produce value-adding customised products with increasingly shorter delivery times and of high technological content. In particular, four areas are proposed for that research:

- Flexible Manufacturing Systems
- Cost-Saving Manufacturing Systems
- Energy-Saving Manufacturing Systems
- Key Technologies embedded in manufactured products

In addition, and related to those four areas, a vision has been included about the standardisation needs along the life cycle of Manufacturing Systems for aspects such as design, assembly, maintenance, safety etc. This analysis will lead to identifying for the different areas and for the involved topics the aspects that are duly covered by standards as well as the aspects that are just slightly covered or not covered at all, what will allow to define the standardisation needs in the field of Flexible, Cost-Saving and Energy-Saving Manufacturing Systems.

4.3.2 Compendium of Relevant Standards (3)

According to the six standard-clusters of *Interface standards*, *Measurement standards*, *Process standards*, *Safety standards*, *Product and component standards* and *Material standards*, the following tables give an overview of which clusters are relevant for the research topics and which clusters are already addressed by existing standards.

The first table shows the correlation between clusters and defined research topics, the second serves as a caption. The white cells in the first table symbolize that the corresponding standard cluster is relevant for the respective research topic, while a grey cell indicates that the standard cluster is not seen as relevant for the research topic. The indices in the cells stand for currently existing standards which belong to the respective category and are related to the research topic. In this context, it has to be stated, that the intention of the following tables is not to provide an exhaustive overview of existing standards. In fact, the exercise is just meant and designed to serve the purpose of this document. Sources for the mapping of currently available standards were standard databases, search engines as well as European[6] and U.S. American[7] standardization bodies.

Having this restriction in mind, the empty white cells can be seen as standardization gaps which should be examined more intensively by upcoming projects dealing with the respective research topics. White cells with content indicate that there are already standards which should be further analysed and could serve as a basis for further development. While empty grey fields indicate no relevance for the topic, the grey fields with content imply that a standard is present in a cluster which is seen as not relevant for a topic. This could mean that the standard is not necessary, what definitely has to be validated in further investigations.

Thereby the results visualized in the following tables serve as a starting point to assess the standardization needs of each research action, indentify gaps and development issues. Finally they support the deduction of the main standardization needs and potentials summed up in the following standard visions. The specific conclusion at the end of this chapter will be based on this aggregation and conclude with the gap analysis.

[6] CEN – European Committee for Standardization

[7] Rachuri, S.: The landscape of Sustainability Standards, presentation at the „Sustainability Interest Group“

IMS2020 Research Topics Relations with Standardization (KAT4)	Interface Standards			Measurement standards					Process standards						
Legend: = Standard category probably not relevant for reserach topic; = Standard category probably relevant for reserach topic	Electronic information & data standards (format)	Communication & semantic standards (content)	Physical interface standards	Measurement standardards for process efficiency	Measurement standardards for energy efficiency	Measurement standardards for manufacturing efficiency	Measurement standardards for waste detection	Measurement standardards for emission detection	Design process standards	Manufacturing process standards	Business Process standards	Closed loop management standards	**Safety standards**	**Product & component standards**	**Material Standards**
RT3.01 Modular Assembly /Disassembly Production Systems	(1)		(2)/N.A.									?		(3)/N.A	
RT3.02 Control for Adaptability				(4)										(5)/N.A	
RT3.03 Mutable Production Systems	(1)	(6)	(2)/N.A.									?		(3)/N.A	
RT3.04 Lower Labour and Energy Cost Performance				(4)	(4)	(4)	(4)/N.A.	(4)/N.A.		(7)			(8)		
RT3.05 Interoperable Products and Production data exchange	(1)	(6)													
RT3.06 Build-to-Order - New Production Planning and Control Models for Complex Individualized Products	(1)	(6)								(7)					
RT3.07 Efficient Use of Raw Materials										(7)					
RT3.08 Model Based Engineering and Sustainability	(1)	(6)							(9)	(7)		?			
RT3.09 Cooperative & Mobile Manufacturing Systems	(1)	(6)	(10)	(11)									(12)	N.A.	
RT3.10 High Performance (High Precision, High Speed, Zero Defect)	(1)	(6)								(7)				N.A.	
RT3.11 Model-based Manufacturing	(1)	(6)								(7)	(13)	?			
RT3.12 Mechanical MicroMachining Enhancement						(4)								N.A.	
RT3.13 High Resolution Total Supply Chain Management	(1)	(6)									(13)				
RT3.14 High Accuracy Modelling	(1)	(6)									(13)				
RT3.15 Semantic Business Processes	(1)	(6)									(13)				
RT3.16 Professional Virtual Collaboration Platforms for Regional Cluster Optimization											(13)				
RT3.17 Engineering Asset Management											(13)	?			
RT3.18 Semantic Based Engineering	(1)	(6)							(9)		(13)				
RT3.19 Forthcoming "Brown Fields" Re-Engineering	(1)	(6)	(2)/N.A.						(9)	(7)	(13)	?			
RT3.20 Advanced Automation for Demanding Process Conditions				(4)											
RT3.21 Business concept B2C-communities	(1)	(6)									(13)				
RT3.22 Knowledge Embedded Products														N.A.	
RT3.23 Dealing with unpredictability											(14)				

Table 16: Correlation between standard clusters and research topics (3)

Index	Standards
1	Data exchange standards: IGES (Initial Graphics Exchange Specification-USA, SET (Standard D'Echange et de Transfert-France), VDA/FS (Verband der Automobilindustrie-Flächen-Schnittstelle-Germany) and STEP (Standard Exchange of Product Data)
	Standardised manufacturing management data: ISO 10303 AP-238, ISO 14649 (STEP-NC), ISO 13399, ISO 15331 (MANDATE), ASME B5.59-2
	BPML – Business Process Modelling Language
	IPC-2570 series – Shop Floor Communications (PDX) IPC-2507x
2	Manipulating industrial robots - Mechanical interfaces - Part 1: Plates (ISO 9409-1:2004)
	Manipulating industrial robots - Mechanical interfaces - Part 2: Shafts (ISO 9409-2:2002
3	Industrial automation systems and integration - Product data representation and exchange - Part 210: Application protocol: Electronic assembly, interconnection, and packaging design (ISO 10303-210:2001).
4	Measurement management systems -- Requirements for measurement processes and measuring equipment. ISO 10012:2003
	Industrial automation systems and integration -- Product data representation and exchange -- ISO/TS 10303-1106:2008: Application module: Extended measure representation
	General requirements for the competence of testing and calibration laboratories: ISO/IEC 17025:2005
5	Ergonomic design of control centres -- Part 5: Displays and controls ISO 11064-5:2008
6	Industrial automation systems and integration -- Manufacturing software capability profiling for interoperability. ISO 16100-1:2009
	Information technology -- CDIF semantic metamodel -- Part 6: State/event models ISO/IEC 15476-6:2006
	APECMA 2000M – International Specification for Material Management Integrated Data Processing for Military Equipment
7	Industrial automation systems and integration -- Product data representation and exchange -- Part 240: Application protocol: Process plans for machined products. ISO 10303-240:2005
	Industrial automation systems and integration -- Process specification language. ISO 18629
8	Safety of machinery - Positioning of protective equipment with respect to the approach speeds of parts of the human body (ISO/DIS 13855:2008)
	Hydraulic fluid power - General rules and safety requirements for systems and their components (ISO/DIS 4413:2008)
	Safety of machinery - Permanent means of access to machinery - (ISO 14122-1)
	Safety of machinery - Basic concepts, general principles for design (ISO 12100-1:2003/FDAM 1:2009)
	Safety of machinery - Integrated manufacturing systems - Basic requirements - Amendment 1 (ISO 11161:2007/DAM 1:2008)
	Safety of machinery - General principles for design, risk assessment and risk reduction (ISO/DIS 12100:2009)
9	Industrial automation systems and integration -- Product data representation and exchange -- Part 221: Application protocol: Functional data and their schematic representation for process plants. ISO 10303-221:2007
10	Manipulating industrial robots -- Mechanical interfaces. ISO 9409-1:2004
11	Manipulating industrial robots -- Performance criteria and related test methods. ISO 9283:1998
	Manipulating industrial robots -- Informative guide on test equipment and metrology methods of operation for robot performance evaluation in accordance with ISO 9283. ISO/TR 13309:1995
12	Robots for industrial environments -- Safety requirements -- Part 1: Robot. ISO 10218-1:2006
13	Enterprise integration -- Framework for enterprise modelling. ISO 19439:2006
14	Risk management -- Risk assessment techniques. ISO/IEC 31010:2009

Table 17: Caption

4.3.3 Research Action 1 – Flexible Manufacturing Systems

In the sustainability perspective, manufacturing industries need to be able to adapt quickly to market challenges and to take advantage from market changes. Flexible production systems may mitigate the effect of demand uncertainties. Compared to dedicated systems, flexible systems require new investment costs. Companies need new knowledge for the creation of new products and processes and the improvement of existing products and processes of new global manufacturing systems.

The end users in the manufacturing value chain are demanding to their providers customised products with increasingly shorter delivery times, in line with the so-called “mass customization” and “build-to-order” manufacturing paradigms, so that for facing this technological challenge, the manufacturing companies need machines and manufacturing systems that are productive and reliable and that at the same time are highly flexible and adaptative both in terms of volume and variants of the manufactured products.

To achieve this vision, the manufacturing sector needs a multi-disciplinary approach for conceiving and manufacturing flexible and adaptive manufacturing systems by covering the different stages of their life-cycle, from design and assembly to use and end-of-life. More precisely, these technologies are required for integrating new knowledge for new or improved products and processes needed for industrial innovation. The following technologies refer to new architectures and components:

New architectures include:

- Comprehensive models integrating products + services, processes and business models for allowing engineering of customised manufacturing systems
- New concepts for interfacing, assembling and disassembling mechatronic components with ease for adapting manufacturing systems to varying demands in volume and product type
- New concepts for flexible manufacturing plants based on dynamic communities of mobile robots, machines and human workers, capable of reacting to demand fluctuations in an agile manner
- New business models aimed at improving the efficiency of operating production plants in terms of re-use of machine components and re-programming of control systems in easily adaptable plants

New components include:

- Miniaturised, compact and modular mechatronic devices integrating simulated models and process control systems for building flexible systems that fulfil varying product and process requirements
- Innovative technologies for developing miniaturised machine components with embedded sensors and actuators
- Innovative manufacturing processes based on additive forming technologies as a means for enabling short lead time to markets of customised machines

This new generation of technologies for manufacturing systems will impact in a decisive manner their production lead time, that will be reduced above 30%, their reconfiguration time, that will be reduced above 50%, and their productivity that will be adjusted 100% to the specific needs of the different customers.

This research action focuses on the following specific domains oriented to provide solutions for economy, environment and society, in short, medium and long term:

- To develop semantic knowledge models that integrate machine products and services and associated business models along the life cycle of manufacturing system products, as well as tools and methodologies for analysing and modelling the value added in the manufacturing value chain and along the entire lifecycle of the production system(economy, short term)
- To develop advanced tools for modelling adaptive system configurations that are based on adaptronic modules with embedded intelligence and with standardised plug-and-play interfaces (economy and society, mid-term)
- To develop additive manufacturing processes and integrate them into agile and responsive manufacturing environments for machine and component builders (economy and environment, mid term)
- To develop knowledge-based and self-learning control systems that are based on multi-layer controls capable of managing dynamic and easily adaptive networks of machines, robotic members and human workers (economy, Environment and society, mid-long term)
- To develop methodologies and tools for managing the re-use of the modular and adaptronic components within easily reconfigurable machines and easily adaptive production plants (economy, environment and society, mid-long term)

	Short	Medium	Long
Environment		+	+++
Economy	+	++	+++
Society		+	++

Table 18: Impact of the Research Action "Flexible Manufacturing Systems"

Standard Vision:

"Standardized data and processes allow high level flexibility in manufacturing systems"

Standardised data allow high level flexibility in manufacturing systems:
Flexible Manufacturing Systems consist of resource elements of different types such as CNC machine tools, auxiliary devices, material handling devices etc. Each of these resources has its specific role within the system, so that there is a need of having the information associated to them in a standard format as a means for assuring the adaptability of the system when implementing new resources and components. If besides this standardisation process covers also the methodologies and tools of the stakeholders that are involved in the Manufacturing Value Chain, it will allow stakeholders to represent and share the information about those resources and thus to establish information links among

them, which will lead to adapting the manufacturing systems to market variations in a flexible and efficient manner.

Within this view, there is a need for extending information standardisation related to flexible manufacturing in three main areas:

i) Standardised modelling representation of manufacturing resources and systems,
ii) Standardised modelling of the service dimension associated to flexible manufacturing systems,
iii) Model driven information sharing across the life cycle of the manufacturing systems: design, use and reuse.

Finally, it is remarkable to note that an efficient way for tackling this standardisation process will be to build on existing information model standards and to extend them in the three areas that have been mentioned above.

Standardised processes allow high level flexibility in manufacturing systems:
Standardised manufacturing processes are usually associated to high-volume, repetitive and low-flexible manufacturing systems. Anyway, the fact of having standardised some of the manufacturing processes in the manufacturing value chain becomes a complementary means for achieving a high level of flexibility in state-of-the-art manufacturing systems. As reference, standardised processes allow implementing common components for different product variants as well as reducing the need for purchasing new equipment, what leads to reducing the cost and the delivery time when developing customised products. Another benefit associated to standardising manufacturing processes is that it will ease applying best practices throughout the different operations of the manufacturing company and will ease the process of training of the employees and besides will improve their security.

Within this view, there is a need for applying standardisation to manufacturing processes mainly in the areas of assembly and disassembly processes, which will build on developing standardised mechanical, hydraulic and software interfaces capable of assuring plug and play connectivity when applying new resources in the manufacturing system.

4.3.4 Research Action 2 – Cost-Saving Manufacturing Systems

Present manufacturing systems are characterised by sophisticated processes. To be competitive, a new approach is required which allows to reduce systems' downtime, to maximise efficiency and to minimise lifecycle costs. In the current industrial environment, companies need to reconsider their production systems and processes within a life-cycle view, aiming at conceiving, designing, producing and using cost-effective, value-adding and sustainable manufacturing systems as basis for minimising total life-cycle costs associated to manufacturing systems.

To achieve this vision, the manufacturing sector needs a multi-disciplinary approach for conceiving new concepts for manufacturing systems that fulfil users needs while reducing total life-cycle costs. More precisely, both physical and organizational processes must be able to achieve new performances to quickly respond to technical and cost constraints due to environmental, economic and societal issues.

The following technologies are required for enabling cost-reduction changes in manufacturing systems facing that overall need of efficiency. The following technologies refer to a sustainable production and innovative solutions for value chain management.

Sustainable production includes:

- Innovative methods and technologies for increasing the efficiency of work force that is actively involved in the manufacturing process, and also the effectiveness and safety of manufacturing processes and peoples' activities
- Technologies for more efficient and productive manufacturing systems for maintaining highest standards in the event of changing operating conditions: "zero-defect" manufacturing
- Semantic systems for supporting collaborative engineering for value-adding and cost-effective manufacturing systems
- Production Planning and Control approaches based on high resolution models for allowing companies to plan production processes in a cost-effective manner
- Advanced ICT Tools for allowing companies to predict the risk and opportunity potential associated to developing new products, services and manufacturing processes

The innovative ICT solutions for value chain management include:

- Innovative tools for allowing planning, management and optimisation of production and logistic resources within companies and within manufacturing networks
- Control mechanisms of decentralised production for allowing companies of the manufacturing value chain to adapt their production and capacity management in a cost-efficient manner
- New production planning and control approaches for coordinating the production activities and for assuring good process reliability, short delivery times and low production costs
- Virtual manufacturing environments for integrating knowledge into the manufacturing value chain in an explicit manner
- Tools, standards and innovative co-operation models for efficient inter-organizational workflows among companies along the manufacturing value chain

This new generation of technologies will impact in a decisive manner their life-cycle production costs, which will be reduced above 10% as well as in the costs associated to logistic costs, which will be reduced above 20%. In addition, these technologies will lead to shorter lead times of material and information and improved service levels and added value for the end users in a customer-oriented manner.

This research action, which will be oriented to providing solutions for economy, environment and society at short, medium and long term, will focus on the following specific domains:

- To conceive and develop cognitive systems and ICT tools for condition monitoring, diagnostics and prognostics as means for building intelligent, self-optimising and cost-effective machines with "zero-defect" manufacturing (economy and society, mid-term)

- To develop methodologies and ICT tools for allowing high resolution planning and forecasting of Production, Planning and Control processes within complex networks of companies and multiple stakeholders (economy and society, mid-term)
- To develop organizational concepts, processes and methods for the collaborative planning, management and optimisation of production and logistic resources, (economy and society, mid-term)
- To develop digital factory models with real time animations for assuring concurrent and distributed engineering activities within networks of companies and research institutions (economy and society, mid-term)
- To develop ICT tools for creating value within globally networked operations including global supply chain management, product-service linkage and management of distributed manufacturing assets (virtual factories), securing of information and knowledge exchange and process synchronization. (economy and society, mid-long term)
- To develop ICT tools for enhancing the accessibility and sharing of the information generated in the virtual manufacturing environment as a means for integrate that information within design and life cycle analysis for holistic approaches. (economy and society, long-term)
- To develop methods and ICT Tools for assessing risks and improve the predictability associated to new products, services and manufacturing processes and thus avoid future expensive corrections and production re-orientations (economy and society, short-mid term).

	Short	Medium	Long
Environment	++	+++	+++
Economy	+++	+++	+++
Society	+	++	+++

Table 19: Impact of the Research Action "Cost-Saving Manufacturing Systems"

"Interface and process standards open up cost saving potential in manufacturing systems"

Standardisation of processes will enable lifecycle costs minimisation: (design process standards, manufacturing process standards, business process standards, closed loop management standards).

In the beginning of the life cycle, the costs for collaborative design and manufacturing will be reduced by the use of design process and manufacturing process standards. Collaborative design will be more efficient through compliance of the different parts of design models, reusability of existing parts of design models, good knowledge of the information that already exists, etc. In the manufacturing process, standards will enable flexibility which

includes leanness in multi-site production, multi-customisation according to customer requirements, etc.
Business process standards and closed loop management standards will affect positively all aspects of the lifecycle using the information produced during the lifecycle in order to improve provided services, new generations of products and lead time, generate new services, reduce production cost and finally increase customer satisfaction.

Examples of such applied standards in specific domains are:

- ISO-15926 which standardises the lifecycle activities and processes of production facilities. Its aim is to provide data integration for these activities and processes. Although it focuses in the oil and petrochemical industry, its concepts are generic and may be extended to cover other domains.
- ISO-13374 which defines the different functions of a condition monitoring system. This standard focuses in the Middle of Life (MOL) in order to support a system which monitors the condition of the product according to certain criteria. The functionality of the condition monitoring system is defined as six “function” blocks: Advisory Generation, Prognostics Assessment, Health Assessment, State Detection, Data Manipulation, Data Acquisition. Also general inputs and outputs of these blocks are defined. Thus, the this system may be applied in a wide range of products to improve the maintenance services provided and to use the information generated in MOL to improve future generations of the products.

Standardisation of interfaces will enable lifecycle costs minimisation: (electronic information & data standards (format), communication & semantic standards (content), physical interface standards).
Electronic information & data standards (format) will reduce costs in collaboration among different information systems during the entire lifecycle. It will enable access to previously non-accessible data and will make all new developed work (design models, information models, etc.) reusable. Costs for re-developing already developed “parts” of models will be eliminated.
Communication & semantic standards (content) will enable data to know what it is. It will provide the basis for data and information exploitation in order to generate knowledge for improving new generations of products, services etc. Costs for putting the information pieces together will be reduced and/or the knowledge generated will pass to a higher level.
Physical interface standards may be used in all aspects of lifecycle to aid enterprises to implement new technologies, techniques, etc. at a lower cost (i.e. training personnel of different departments, countries, working culture etc.). Moreover, such standards may be used to aid non-experts to see and use information which previously was not reachable.

Examples of such applied standards are:

- ISO-10303 (STEP) which mainly is used to exchange data between CAD, Computer-aided manufacturing, Computer-aided engineering, Product Data Management (PDM)/ Enterprise Data Management (EDM) systems.
- MIMOSA OSA-CBM (Open Standard Architecture for Condition-Based Maintenance) is an implementation of the ISO-13374. MIMOSA OSA-CBM defines interface methods for the functionality blocks defined by the ISO-13374 and adds data structures to them.

4.3.5 Research Action 3 – Energy saving Manufacturing Systems

Taking into account the high environmental impact associated to current manufacturing systems and related processes along their whole life-cycle, both builders and users of manufacturing systems demand innovative solutions (manufacturing systems + services + processes) with reduced consumption of energy and material resources. This enables to assure a competitive position and a sustainable development of the manufacturing sector, that needs solutions ensuring quality rates of manufacturing systems while reducing energy and material resources. This target means introducing new parameters for energy efficiency and raw-material efficiency. A paradigm shift will be necessary in the current design approaches of manufacturing processes towards new conceptual approaches that relate specific energy and materials savings to manufacturing..

To achieve this vision, the manufacturing sector will need a multi-disciplinary approach for managing the environmental impact associated to the life-cycle of manufacturing systems. The efficiency of energy and raw materials needs to be correlated to the involved processes and products that have to be highly improved. More precisely, the following technologies will be required for facing that overall need that will refer to both efficient manufacturing processes and manufacturing systems.

Efficient manufacturing systems will include:

- Innovative manufacturing equipment for increased raw material efficiency and “zero defect” parts through new manufacturing methods, use of detailed modelling and simulation tools and the integration of monitoring and control techniques in the design process
- New intelligent automation and control systems for ensuring stability of manufacturing processes as a means for improving the energy efficiency of manufacturing systems

Efficient manufacturing processes will include:

- Innovative manufacturing processes including near-net or finishing techniques that will minimize material stocks and scrapes as a means for achieving “zero waste” manufacturing processes
- The use of innovative materials with pertinent machinability and tribology characteristics for achieving efficient cutting processes. In addition, environmentally-friendly structural materials with the pertinent damping, stiffness and recyclability characteristics for reducing the material content of current material intensive machine structures

This new generation of technologies will impact in a decisive manner in the life-cycle environment associated to manufacturing systems, that will be reduced above 20%, especially because of the energy consumption reduction, as well as in the consumption of raw materials, that will be reduced above 10%. The increased process stability technologies will lead to working places with less acoustic contamination and safer working conditions. In addition, constant product quality and decreased energy cost will contribute to strengthening the competitive position of manufacturing companies.

This research action, which will be oriented to providing solutions for economy, environment and society at short, medium and long term, will focus on the following specific domains:

- To conceive and develop innovative concepts for manufacturing systems where their associated functionalities of accuracy, productivity and reliability are achieved with the minimum possible of involved material resources (economy, environment and society, short term)
- To develop innovative control and monitoring algorithms and systems for enhancing on-line the stability of manufacturing processes in an autonomous and intelligent manner (economy, environment and society, short term)
- To conceive innovative manufacturing processes aimed at minimizing the consumption of raw materials as well as of consumables such as lubricants, refrigerants etc. (economy, environment and society, short-mid term)

To research on simplified life-cycle assessments methods for enabling users and builders of manufacturing systems to integrate environmental-friendly materials both in the cutting processes as well as in the structural components (economy, environment and society, short term).

	Short	Medium	Long
Environment	++	+++	+++
Economy	++	+++	
Society	++		

Table 20: Impact of the Research Action "Energy saving Manufacturing Systems"

Standard Vision:

"Energy saving in manufacturing systems grounds on standardized interfaces"

Process stability is a key to energy efficient production. In the process industry this may be achieved either by stable input material and advanced process control. Especially when input materials are sourced from a material chain (reuse-recycle-recovery networks), the respective properties have to be assessed reliably and communicated to assure the efficiency of the subsequent process. This is a critical interface issue making a network of suppliers/user efficient or not. Standardization in measurement of material properties and their reporting and communication will support collaborations. This includes standards for sampling (procedures, statistics), analysis, and data exchange. This is valid in a similar way for discrete manufacturing. Reusing and recycling material reduces the resource intensity and respective standardization in handling input material to ensure product quality.

Besides the input material, the processing itself impacts on the overall energy and resource efficiency of a manufacturing unit. Especially when using fluctuating input materials from alternative resources such as reused/recycled materials, process control is demanding. The trend towards ever larger systems increases these challenges. Standardization of automation and control for large systems will mitigate these challenges. This includes electronic information, data and communication standards as well as security standards for remote (by internet) monitoring and data exchange.
Introducing "zero-waste" and "zero-defect" manufacturing technologies is a step towards reduction of resource intensity. These technologies require well defined processing material properties and mathematical modelling for process optimization. Standards in this optimization procedure that include energy and resource efficiency indicators will support their success and multiplicability across industries. These measures to reduce energy and resource intensity of manufacturing processes may be effective if their impact is monitored continuously.
Standardization may support this monitoring and benchmarking of processes by respective measurement and reporting procedures. This is related to process, energy and resource efficiency.

4.3.6 Research Action 4 – Key Technologies Embedded in the Products

In current global markets, the manufacturing industry needs to pass from providing technologically advanced products to providing total solutions, i.e. products + services + processes, as a means for increasing the value that customers perceive when using said technological products. Within this view, manufacturers will have to focus on solution thinking and besides will have to integrate their potential customers in the development process of those innovative solutions as a means for generating new business opportunities and for creating more value for their customers.

To achieve this vision, the manufacturing sector will need innovative concepts of intelligent products and customised services for allowing customers obtaining the maximum value. In this respect, innovative customer-oriented services and new knowledge will be required for having it embedded into this new generation of total solutions. More precisely, the following technologies will be required for facing this overall need, which will refer to value-adding products and solutions as well as to customer-oriented manufacturing processes.

Value-adding products and solutions will include:

- Smart materials, sensors and RFID technologies for developing products with embedded knowledge and innovative customer-oriented functionalities
- Value-adding information, services and functionalities such as educating customers for obtaining the maximum added value from those intelligent products

Customer-oriented manufacturing processes will include:

- Innovative tools and standards for allowing companies to build up business communities that will integrate customers with their requirements
- Innovative methods for assuring active participation of customers in such communities

This new generation of products and services will have a decisive impact in a decisive manner in the added-value associated to products and services, especially because of the integration of customer requirements into the development process of those products and services. In addition, this concept will increase the added-value in the life-cycle of such products and services, will reduce manufacturing costs above 20% and will create new markets for new types of products and solutions.

(What will be done to fulfil those needs?)
This research action, which will be oriented to providing solutions for economy, ecology and society at short, medium and long term, as shown in Figure 2, will focus on the following specific domains:

- To develop mechatronic systems with embedded knowledge and customer-oriented information that in turn will be embedded into innovative services and business models (economy society and ecology, short-mid term)
- To embed intelligent functionalities such as self-learning capabilities and self-repairing capabilities within knowledge-embedded products (economy and society, mid-long term)
- To develop tools for supervising the efficient operation of communities that include customers and their requirements (economy and society, long term)
- To develop guidelines and methods and tools for meeting and transferring customers requirements to different business communities (economy society and ecology, long term).

	Short	Medium	Long
Environment	+	+	++
Economy	++	+++	+++
Society	++	++	+++

Table 21: Impact of the Research Action "Key Technologies Embedded in the Products"

Standard Vision:

"Communication standards provide a basis for innovative Community-concepts and enable knowledge embedded production-processes"

Standardization activities provide a basis for innovative B2C-community concepts: In order to establish B2C-communities as an innovative business concept the development of certain standards in different areas is mandatory. We described hereafter which standardization activities stimulate the design-, installation- and operation-phase of a B2C-community. The design and installation process of B2C-communities is quite skill-intensive and binds a huge amount of company-internal resources. In this context, primarily small and medium-sized enterprises would benefit from business process standards defining the different steps that have to be taken in order to initiate a successful B2C-community. Complementing the business process standards which should provide a detailed guideline for the initiation phase, the development of measurement standards for process efficiency is necessary. They could lead to a cycle time reduction in the operation phase of the community and thus help to minimize costs. In this context the motivation for building up B2C-Communities would increase on the company side. The integration of the customers´ into the development of new products - respectively services- pictures one main objective of B2C-communities. Against this background, electronic information and data standards are needed which empower companies to collect and to analyse the customers´ necessities. In this context, these standards provide a precondition for an appropriate answer to the customers´ requirements. Another critical success factor regarding B2C-communities is the interaction between the company and the participants of the community on the customer side. In this case the company is in charge of identifying effective communication channels which help to bind the established clientele and which motivate new customers to participate in the community. Communication, respectively semantic, standards which support the identification of certain communication channels and thus lead to a high number of community participants have to be developed.

Standardization activities enable knowledge embedded production-processes: The development of detailed communication and semantic standards would not only provide a basis for the establishment of B2C-Communities but also for communicating innovative knowledge embedded products to the market place. In this context, standards would help potential consumers to understand the benefits of new intelligent functionalities and thus would stimulate the roll-out process of innovative products. Apart from communicative aspects, innovative knowledge embedded products have to be compatible to existing components. Therefore standardization activities which aim to a fitting accuracy of new products and existing components are in charge. Such product and component standards would lead to a stimulation of the diffusion process of new products as well.

4.3.7 Conclusion

Standardisation actions will become a key support for achieving the goals that the different Research Actions are aiming at. Indeed, standardising resource elements such as data, processes, interfaces and communications will allow improving the interoperability among the methodologies and tools of the different stakeholders that are involved in the Manufacturing Value Chain, and additionally will allow improving the interoperability among the different elements, components and mechatronic systems that are involved in the Manufacturing Systems.

Within this view, and after having analysed the standards that are currently available and also having integrated that study with the needs and benefits that are associated to standardisation actions, some standardisation gaps that have not been duly covered yet in the field of Key Technologies for Manufacturing have been identified:

i) Information as well as modelling representation of manufacturing systems and processes does not cover either their service dimension or the lifecycle approach.
ii) The elements, components and manufacturing resources themselves that are involved in the Manufacturing Systems are not standardised on the whole, unlike for

the case of their interfaces and communication systems, that are in general well covered.

Concerning the point (ii), the fact that the interfaces and communication means are on the whole duly standardised facilitates the communication and interoperability between components and manufacturing resources. Anyway, as the resources themselves are not generally standardised, this aspect limits aspects such as exchangeability among manufacturing resources and limits also the conception of new concepts and architectures for the manufacturing sector such as, for example, cooperative and mobile manufacturing systems, as mentioned in RT3.09.

For these reasons, this Key Technologies chapter has provided a comprehensive list of not covered aspect for each individual Research Topic as cornerstone for achieving the visions that have been stated for each of the four Research Actions:

- standardised data and processes for achieving flexible manufacturing systems
- standardised interfaces and lifecycle activities for achieving cost-saving and energy-saving manufacturing systems
- standardised communication for achieving knowledge-embedded production processes

5 General Conclusion

Within the IMS2020 project roadmaps for the key areas *sustainable manufacturing*, *energy efficient manufacturing* and *key technologies* were developed, that focus on the identification of relevant manufacturing research topics and supporting research actions. Whereas these research topics mainly stimulate the innovations, they have to be supported by standards ensuring the efficient diffusion of innovations into the market.
The above introduced IMS2020 Standards roadmap aims to support the achievement of the proposed research topics and thereby the achievement of the whole IMS2020 vision. Therefore the purpose of this document was to identify the main standardization potentials and provide a basis for the standardization work within upcoming projects, related to the proposed research topics.
In order to design a standard roadmap, the synchronization of the standard roadmap and the already existing roadmaps (see www.ims2020.net) needed to be ensured. Resulting from a SOTA in depth analysis and from the proposed research topics additional analyses were conducted to derive the necessity of the development of new standards. Therefore the various standards supporting intelligent manufacturing have been segmented into different clusters. Six standards clusters were taken into consideration while elaborating the relevance of existing standards due to the needs of the other areas. These standard clusters were matched with the research topics resulting in a spreadsheet, which described the relevance of the standard cluster for the specific research topics. The research topic orientated relevance of standards was aggregated to research action level. Based on the derived main driving standard clusters the standard vision, which describes areas of future necessary standard developments, was defined. This vision is synchronized with the research topics of the respective research action.

The analysis matched existing standards and standards that need to be developed to support the various research topics respectively research actions. As an important result the analysis reflects a high demand of standardization activities that have to be initiated in order to implement the holistic IMS2020 vision. Against this background each area leader attaches importance to measurement, interface, process and product standards. In addition, “Energy Efficient manufacturing” accentuates the impact of material standards as well. Since there exists a whole range of standards at different political levels (National, European and International) the identification of deficits regarding standards is quite challenging. Thus the analysis demonstrates only results which have been validated within the specific area.

The future development in “Sustainable manufacturing” area will require activities in each standardization field. One important aspect highlighted in the analysis is the implementation of new interface standards which support the integration of sustainability information within the enterprise IT systems. Besides safety standards will be mandatory for the design of sustainable businesses.

The “Energy efficient manufacturing” area attached importance to interface, measurement, process as well as product and material standards. In this context the analysis has shown that the ISO already works on the development of new standards regarding energy management. But it has to be checked if these standards will cover all requirements of management and measurement processes relevant for future manufacturing systems. Another important outcome of the analysis is the identification of a standardization lack concerning product and component as well as material standards. Here activities have to be implemented focussing the standardization of energy-specific product and material data.

In the “Key technologies” area it was detected that more effort has to be invested in the standardization of elements, components and manufacturing resources which are involved in manufacturing systems. Furthermore the standardization of data and processes relevant for achieving flexible manufacturing systems was regarded as an important sphere of activity.

Although the specific standard analysis focuses specific research items the standardization of data was defined as an overall field of action. Furthermore the analysis pointed out standardization deficits in various fields of research. In this context it can be stated that standardization activities are no accessory parts for the conversion of future manufacturing systems. They are a fundamental pillar for the implementation of the IMS2020 vision. This roadmap provides a theoretical basis for initiating development activities in the field of standardization. Due to this fact the annex includes a proven description how to transfer the identified needs for standardization into practice.

Contacts

Project Coordinator:
Prof. Marco Taisch
Professor of Operations and
Supply Chain Management,
Phone: +39 (02) 2399-4815

Email: **marco.taisch@polimi.it**

Project Manager:
Dr. Ing. Jacopo Cassina
Department of Management,
Economics and Industrial Engineering
Phone: +39 (02) 2399-3951

Email: jacopo.cassina@polimi.it