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17 Partners from 9 European Countries Towards Innovative Eco-Factories

This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no. 285363.

The Eco-Factory

Solutions for Experts and Decision Makers

Solutions from the European Union funded Research Project EMC2-Factory



The Eco-Factory

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Motivation

According to the International Energy Agency the manufacturing sector worldwide accounts for approximately 37% of primary energy consumption in most developed countries. It is the largest energy consumer and CO₂ emitter. Against this background, the EMC2-Factory project consortium has developed solutions to plan and to operate eco-efficient factories. The tools and methods support decision

makers and experts in their efforts to run production efficiently at all levels of a factory, taking into account the holistic perspective. This integrated view prevents problems being shifted from production to technical building services and vice versa. The intention of this brochure is to give experts and practitioners an overview of solutions that have been carefully selected from the project results.



“We are committed to properly addressing environmental and climate change through an efficient use of energy and resources and the development and implementation of technical innovations.”

Amit Eytan, CRF, Project Coordinator and member of EFFRA



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Title: EMC2-Factory –
Eco Manufactured Transportation Means from Clean
and Competitive Factory

Consortium: 17 partners from 9 European countries

Funding Frame: FP7

Duration: 3 years

Budget: €12.5 million

Funding: €7.5 million



SOLUTIONS

~~PROBLEMS~~



Holistic Thinking for the Eco-Factory of the Future

Eco- Factory of the Future

“European manufacturing needs to undergo a transformation towards a solution- and business-oriented approach that understands sustainability as a driver for innovation.”

*Prof. Marco Taisch and Prof. Christoph Herrmann,
heads of EMC2-Factory university research and members of EFFRA*

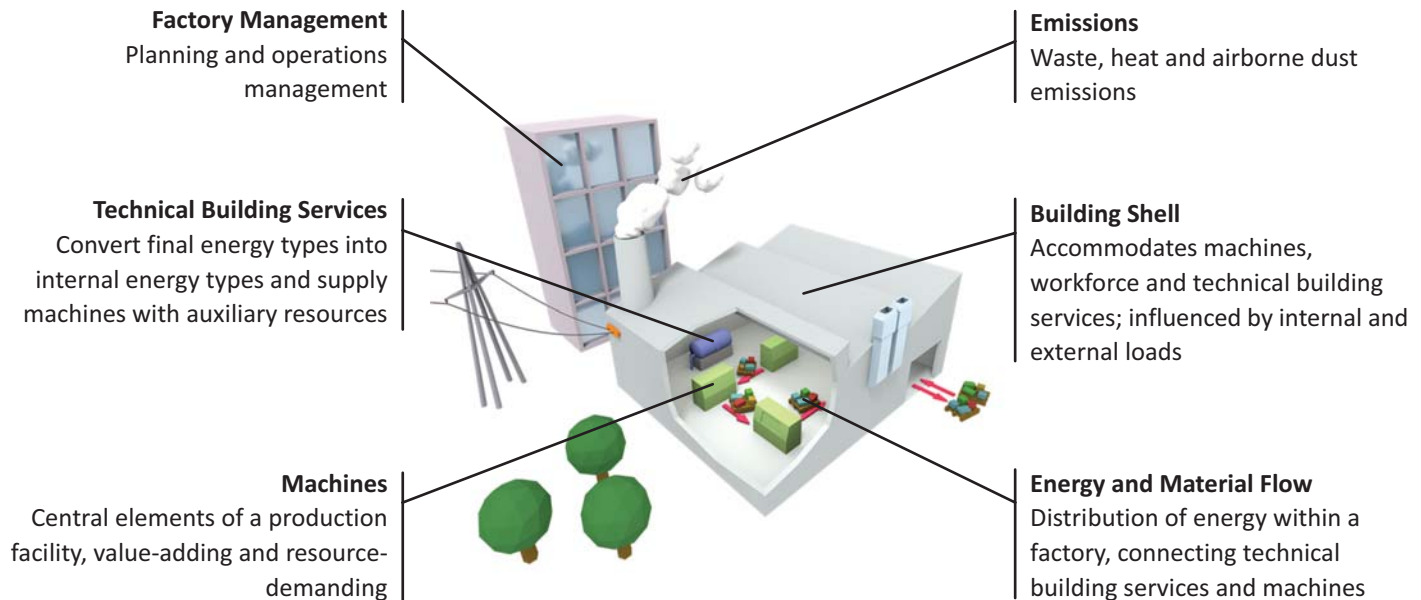
Holistic Thinking for the Eco-Factory of the Future

What is holistic factory thinking? An integrated paradigm that considers not only the dominant production assets such as machines, but also all those elements too often disregarded in a factory environment. These include factory management, technical building services

and the building shell as well as the energy, auxiliary resources and material, product and emission flows interconnecting all these elements. The holistic factory view supports manufacturing experts in their everyday job by providing an integrated perspective as a fundamental information

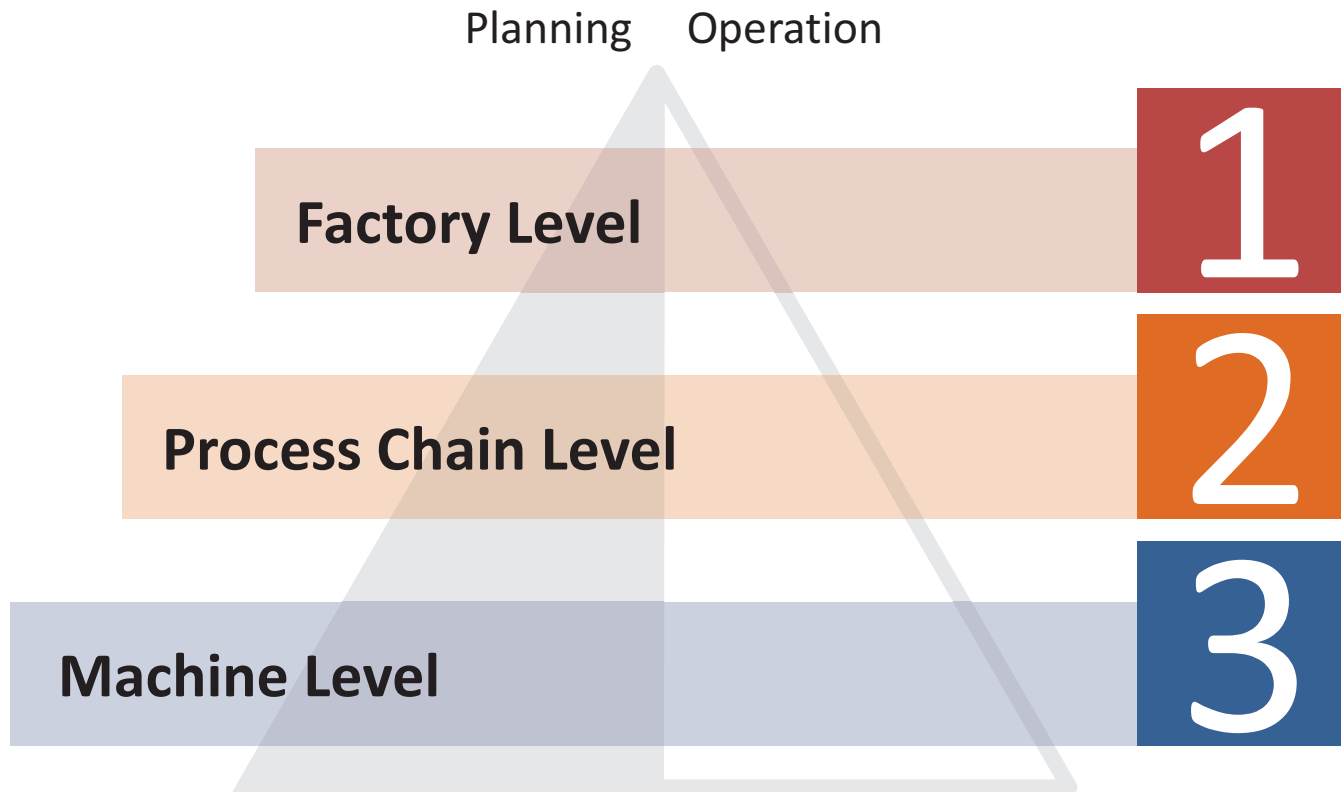
basis for decision making, in order to be able to transform conventional manufacturing systems into genuine eco-factories that meet the needs of future European manufacturing.

Holistic Factory View



Until now, researchers and experts in industrial practice typically utilize isolated approaches to gain ecological improvements. However, as can be seen in the holistic factory view, the factory is a complex control system with dynamic interdependencies between different subsystems and internal and external influencing variables. While isolated considerations of these subsystems are available, an integrated perspective considering all material and energy flows with their existing coherences and interdependencies, which lead to constraints but also opportunities, seems to be lacking so far. One of the main reasons for this is the multidisciplinary nature of the problem.

All innovative solutions developed in the EMC2-Factory research project are integrated into the Eco-Factory of the Future Framework. For easier readability the overview of a complex factory system is broken down into a hierarchical dimension and an activity dimension. This is represented by the six-section pyramid structure. The hierarchical structure is subdivided into the aggregated **Factory Level**, the intermediate **Process Chain Level** and the granular **Machine Level**. The hierarchical dimension represents the level of detail and the breadth of focus on the technical system. Moreover, the three levels are divided into two fields – Planning and Operation activities.



Eco-Factory of the Future Framework

On the following pages each of the three levels is illustrated in detail. There is a special emphasis on the stakeholders involved in the specific planning and operation activities. The solutions presented in the upcoming compilation are meant to be applicable to both greenfield (new) and brownfield (existing) activities to promote and enable Europe's ambitions for Factories of the Future.

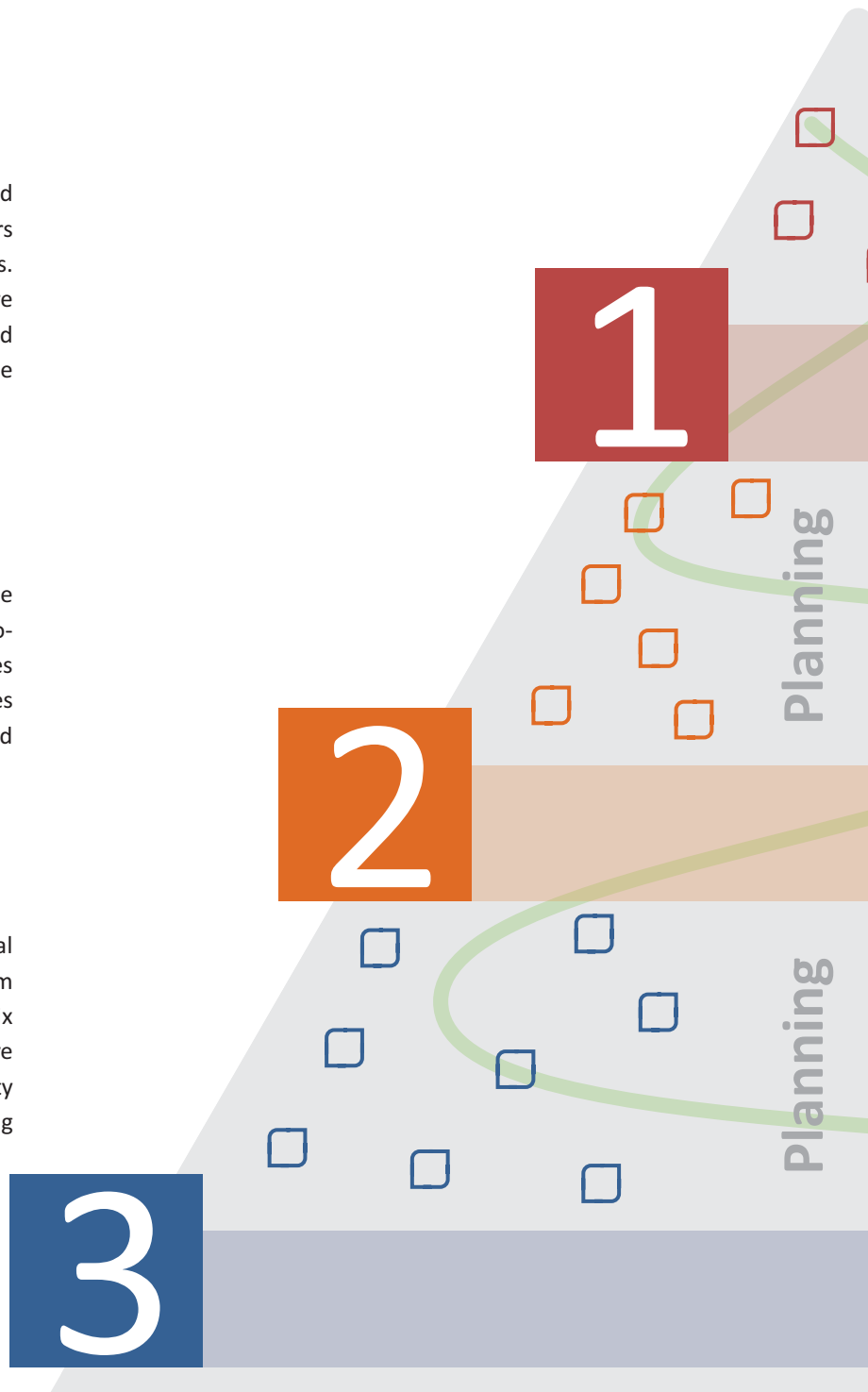
Solutions



Solutions mean methods and tools developed in the EMC2-Factory project that aim to cope with a given problem by providing technical or organisational measures for problem solving. The solutions are presented in boxes coloured in the same way as the levels of application and carry a tag marking the proposed activity phase.

Problem Solving Path

Each factory is different and, hence, demands individual solutions. This idea is represented by the green problem solving path linking individual solutions among all six sections of the pyramid. According to a holistic perspective it is essential to take all hierarchical levels and all activity phases into consideration to enable large scale leveraging effects.



Eco-Factory of the Future



Factory Level

Factory Level

An Eco-Factory is thriving economically, producing high quality goods and in harmony with the eco-system, all at the same time. Harmonising means producing goods at the highest efficiency levels while using fewer inputs to create the same high quality outputs. That means environmentally impacting resources should be replaced by renewable or closed loop resources, while at the same time clean and socially attractive working and living environments are provided.

Operation

Process Chain Level

Process Chain Level

High quality products require well engineered, efficient Eco-Process Chains that utilise the technical building services of a factory system in as harmonised way as possible. Well-balanced utilisation and smart operation of process chains enable factories to comply with the principles of lean and green manufacturing, meaning that they are productive and have low carbon emissions at the same time.

Operation

Machine Level

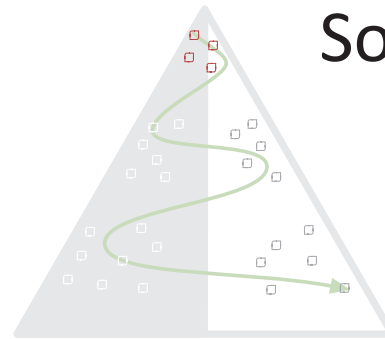
Machine Level

The Eco-Machine is the smallest eco-compatible unit of a factory. Eco-Machines are energy efficient, have low resource demands and are highly productive at the same time. Smart engineering allows loads to be adjusted and provides low energy- and resource-consuming modes by reducing idle time and utilising the latest and most productive manufacturing technology. Eco-Machines enable linked Eco-Process Chains that are harmonised with their environment to create a true Eco-Factory of the future.



1

Factory Level



Solutions

Planning

Life Cycle Evaluation (LCE) Tool

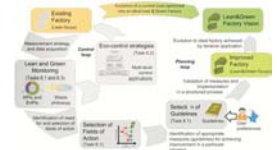
The LCE tool evaluates the impact of physical flows that occur during all life cycle phases and for all system elements. By means of a holistic comparison of factory configurations, alternatives can already be evaluated from environmental (Life Cycle Assessment) and economic (Life Cycle Costing) perspectives in an early planning phase.



Planning and Operation

Lean and Green Framework

for holistic factory optimisation. While continuous improvement towards the ideal factory is realised through planning, an already achieved state is maintained by the way of controlling.

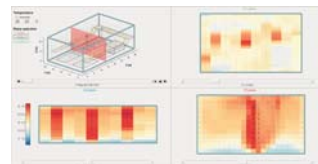


SIEMENS

Operation

3D Indoor Climate and Emission Monitoring

By merging measurements from a wireless sensor network with a 3D indoor climate model, temperatures and air flows are visualised in real-time. This leads to more efficient design and operation of technical building services.



TNO

Actors and Stakeholders at the Factory Level

Solutions presented at this level are meant to support stakeholders with a broad perspective on the manufacturing system, considering not only the process of value creation but also the surrounding and enabling sub-systems of a factory. This includes **managers** and **engineers of technical building services, facility management, production management** as well as **factory management** with all related planning and operation disciplines.

Factory Level

1

Planning

Green Data Monitoring System

GreenDMS (Data Monitoring System) is a smart metering system able to associate production data and energy consumption. The concept constitutes a reliable tool to identify optimisation opportunities.



POLITECNICO
DI MILANO

Planning

Body Welding Process Simulation

Process simulation tool for the evaluation of energy consumption during an early concept stage of body welding manufacturing systems.

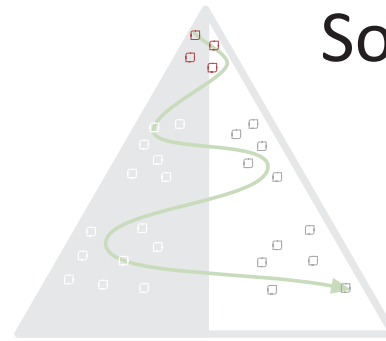


Planning Activities

The harmonisation of all factory elements is of the highest ecological and economic importance and interest. To enable engineers and managers to plan such activities in new green-field and existing brownfield factories, holistic methods and tools must be provided. Only by making the proper data available effective utilisation for predictive decision support becomes possible.

Operation Activities

During operation activities the proper capturing of data to evaluate the current situation is essential. Only on the basis of solid feedback data, operation activities can be controlled effectively. Well-planned factory systems can only be eco-efficient if they are also well operated. Simple tools that support daily business decisions are the most vital step towards an Eco-Factory.



Solutions

1

Factory Level

Planning

Production Planning and Scheduling

Software for quickly generating a set of production planning solutions considering multiple objectives – e.g. energy use in addition to economic goals – and evaluating the corresponding trade-offs.

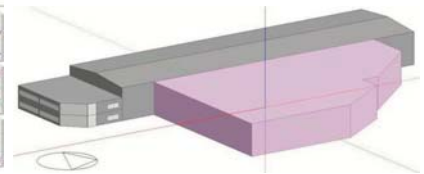
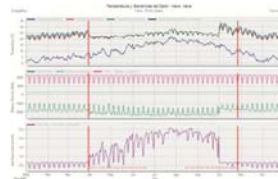


SIEMENS

Operation

Strategy for Environmental Assessment and Optimisation of Aeronautic Manufacturing Plants

The simulation of plant energy consumption and carbon footprint calculation will enable the optimisation of the plant and the definition of a strategy for the growth of the company.



Planning

Planning

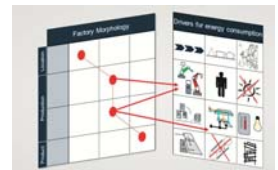
Eco-Factory Holistic Perspective

Systemic and flexible framework for modelling and assessing manufacturing systems at all levels and along multiple dimensions, including energy and resource efficiency, environmental impacts and costs.



Green Factory Planning

Collaborative factory planning guide to dissolve barriers between multidisciplinary experts and green factory elements.

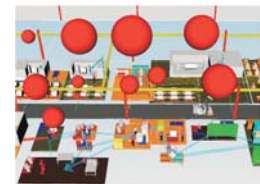


SIEMENS

Planning

Green Layout Guide

Visualisation of environmental data with layout layers for a collaborative planning workshop integrating several disciplines, supporting tools and planning methods.

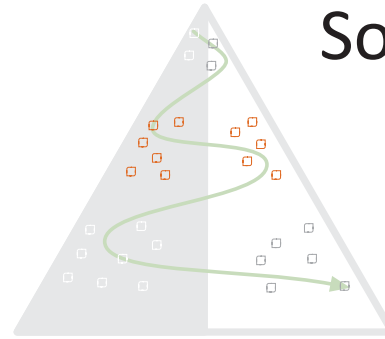


SIEMENS



2

Process Chain Level



Solutions

Operation

Rapid Simulation Tool

With this tool the energy and media load profiles of production lines can be quickly evaluated. Based on this, it is possible to define production line control strategies (e.g. one-piece vs. batch) with easy and intuitive simulation support.



Operation

Eco-Sustainable Process Archetypes for Body Welding

New eco-sustainable process archetypes for body in white manufacturing facilities in the greenfield and brownfield context have been developed. Measures cover the implementation of strategies for process active time reduction through material reduction, joining parameters and process optimization.



Operation

Dynamic Energy Value Stream Monitoring

Quick changes in production planning and process parameters can be applied and benchmarked dynamically with lean and green KPIs through real-time energy metering concepts.



Actors and Stakeholders at the Process Chain Level

Process chains represent the arteries of a factory. **Production planners** design them around the product to achieve the best possible quality at the lowest possible resource input. **Industrial engineers** and **technical experts** operate the process chains at highest utilisation rates and with the lowest possible waste emission. The **engineers in technical building services** and **logistics engineering** are the vital links to the factory.

Process Chain Level

2

Operation

Feasibility of Friction Stir Welding as Assembly Technology

The goal is to analyse the possibility of replacing manual riveting tasks by friction stir welding (FSW) technology, which would reduce the global environmental impact while assuring the requirements of the product.



Operation

Model Predictive Eco-Control Strategies

Model Predictive Control (MPC) techniques are used to manage control problems characterised by constraints both on control actions and on process variables by optimising the energy performance index and process variable trajectories.



Planning Activities

Production planners, facility planners and building service planners need predictive tools that estimate the complex interdependencies between all entities of the individual domains. Virtual design and layout tools help to prevent over-engineering and unforeseen situations in later operation and maintenance activities.

Operation Activities

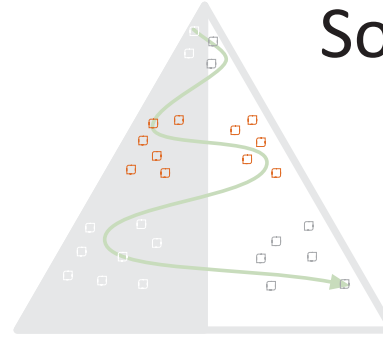
The main concern of operation activities is to maintain the pulse of the process chains. Quality issues and throughput dominate daily decisions. New holistic methods and tools allow engineers and technicians to seamlessly extend their daily decisions to include the eco-dimension without diverting the focus from other prominent priorities such as throughput, cost or quality.



2

Process Chain Level

Solutions



Operation

Intelligent Machine Monitoring for Compressed Air

There is a need for decentralized smart monitoring and control of compressed air supply on machine level. The compressed air saving module fulfills this requirement by functions, such as leakage detection and reduction during stand-by as well as monitoring of pressure and flow rate.



FESTO

Operation

Green Fit

New methodology to increase environmental sustainability of manufacturing plants through energy consumption assessment and application of a wide set of improving actions at machine, process chain and factory level. Advanced control strategies for standby and sleeping status management of machining systems for highly optimized energy use.



Operation

New Minimum Quantity

Lubrication Titanium Machining Technology

New process definition in order to reduce the large amount of coolant used in the machining of titanium parts based on minimum quantity lubrication (MQL) technology.



ACITURRI tecnalia Inspiring Business

CEVAL POLITECNICO DI MILANO IITA Istituto di Tecnologie Industriali e Automazione

2

Planning

Guideline for Actuation Technology

A comprehensive study for factory planners to re-engineer production control systems. It helps finding energy efficiency weak spots as well as it gives advice for improvements and implementation under cost considerations.



FESTO

Operation

Energy Profile for Manufacturing Execution Systems

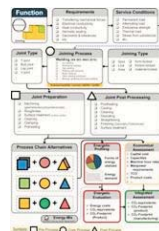
Changes in production variants cause changes in machine, station and production line efficiency. In order to build a green factory, an accurate energy profile collected by manufacturing execution systems (MES) is a vital information component. The flexible and scalable system energy profile based on the OPC UA interface is used.

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Planning

Overall Process Chain Design

Methodology for process chain development to achieve an optimal overall solution in terms of energy and economics, not just for single processes within the chain.



SIEMENS

Solutions

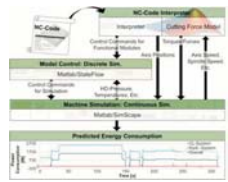
3

Machine Level

Planning

Energy Simulator for Machine Tools

Software-based solutions which can evaluate the energy consumption and energy efficiency of production machines on the basis of a simulation approach.

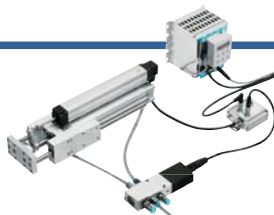


Operation

Energy Efficient Control Strategies for Drive Systems

Complex handling applications aim at high productivity and reduced costs in planning and operation phases. To reduce energy consumption during run and idle phases of actuators, software algorithms and new hardware are utilised to enable efficient operation of automation equipment.

FESTO



Operation

Wireless and Passive Surface Acoustic Wave Sensors

For a highly dynamic monitoring of the critical parts of machines, surface acoustic wave (SAW) sensors open up new possibilities offering clear benefits to the machine owners (increased life time and yield, reduction of maintenance operations).



Operation

Consulting for Green Production Processes

Business innovation opportunity in industrial energy efficiency consultancy. Application of eco-solutions in a wide range of industrial contexts, starting from high level of expertise as production system integrator.



Machine Level

3

Actors and Stakeholders at the Machine Level

The machine is the smallest but most important entity of a factory system. A wide variety of stakeholders is involved. A large group of actors, such as **procurement managers**, **industrial engineers**, **maintainers** and **production managers** require an optimal information basis to obtain support in their daily business around the shop floor. If the machine is also a product, even more stakeholders such as **research engineers** and **developers** as well as **after-sales staff** come into play.

Planning

Green Control Processor

Detailed information on energy efficiency is covered under 'Control System'. This information is still available but not used. The green control processor makes it possible to benefit from on-line production data and use it to verify machine efficiency, generate efficiency alerts and give information about required maintenance activities.



aiut

Operation

Decision-Making Tool

The decision-making tool enables the user to evaluate the energy and resource consumption of a production machine in a quick and easy way. It is capable of mapping different machine configurations as well as different production framework conditions.



Planning Activities

Machines are complex entities with many mechanical and electrical components that need to be designed thoughtfully and controlled properly to achieve an Eco-Machine. Only selecting the right combination of components enables efficient resource utilisation and high-quality production of goods. Procurement needs to be able to define suitable requirements concerning economical and ecological performance indicators.

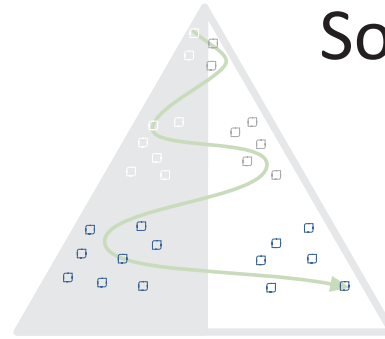
Operation Activities

Eco-Machines need smart sensors to obtain feedback on current performance and smart controls to perform energy- and resource-efficient operation on an automated basis or to provide suitable decision support for operation and maintenance staff. Automated waste detection supports shutdown or hibernation modes to enable low-energy demand while maintaining a quick recovery to production mode.

Solutions

3

Machine Level



Operation

Leakage Detection for Pneumatic Drives

In rough production environments leakages may occur, e.g. in tubing of clamping devices in body-welding applications. With cost-efficient flow sensors and software plug-ins, the valve terminal constantly monitors and quickly detects emerging leakages – system performance is guaranteed.



FESTO

Planning

Energy Machine Modelling

Advanced simulation tools enable full modelling of machines and components to optimize energy efficiency and environmental sustainability.



Operation

Welding Line Weight Reduction

Innovative solutions for downsizing welding tooling to enable weight reduction of manufacturing lines. Energy optimization is starting from the welding gun and spreading across the whole process chain: welding robots, support systems, power supply up to factory facilities.



Operation

Machine Control Policies for Energy Saving

Machine functional modules keep consuming energy when the machine is not involved in part processing. To increase energy efficiency, a software algorithm is used to switch the machine to a low energy-consuming state when production is not critical, and switch it on again when the part flow has to be resumed.



Operation

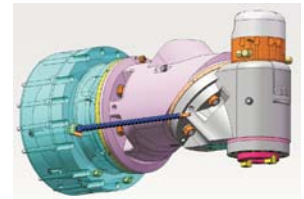
EcoMode in CNCs

New control strategies will reduce the energy consumption during all machine operations. These strategies will make it possible to customise an EcoMode in the CNC that includes the most appropriate operational level of secondary elements for each machine operation, the automatic switch-off of the machine, etc.



Integration of Green Tool-Cooling Technologies in Machines

The new designs of machine tools will integrate green tool-cooling technologies, such as minimum quantity lubrication (MQL) through the cutting tool in the new generation of machine tools. The long life cycle of machine tools will assure the high ecological impact of these solutions.



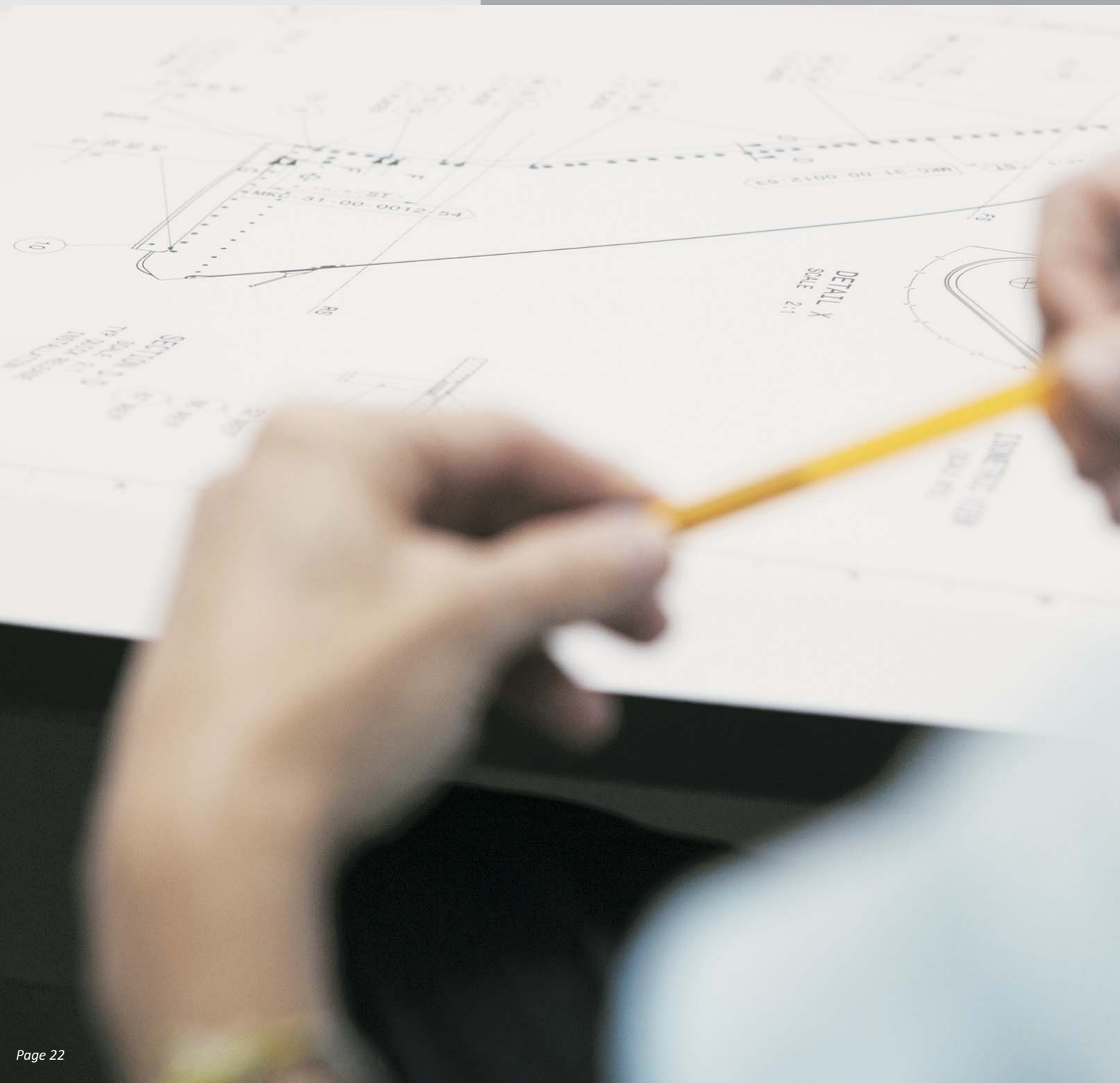
Planning

Supported Technology Decision for Actuator Systems

An actuation task can be realised with different technologies (pneumatics, hydraulics, electrical drive systems). A holistic approach supports machine designers in decision-making concerning a specific application. Both technical and total cost of ownership (TCO) aspects are taken into account.



Planning



Aero Pilot

Aciturri Metallic Parts S.L.U., Spain
Metallic Components for Airframes

“Aciturri designs, develops and manufactures advanced aircraft structural components to achieve a more suitable and sustainable mobility of passengers and freight.”

F. Rodriguez, General Director of Business Development, Aciturri Metallic Parts

Aero Pilot

Aciturri Metallic Parts S.L.U., Spain

Aciturri Aeronáutica, established in 1977, is a Spanish industrial group specialised in the design, manufacturing and assembly of high-tech aerostructures (both in metal and composite) and the production of engine components for the aeronautical sector. Aciturri is a Tier 1 supplier for aerostructures for Airbus Operations, Airbus Military and Embraer and has been

participating as risk and revenue sharing partner in their new development programmes since 2002. Aciturri Aeronáutica integrates four enterprises, each one with specific capabilities in engineering and/or manufacturing. Among them, Aciturri Metallic Parts is the company dedicated to the production and assembly of metallic components and sets.

It was the first company of the group and has gathered extensive metallic production experience and know-how of different manufacturing technologies acquired during the last 37 years.

Starting Position of the Project

Significant reduction of both recurring and non-recurring production costs has become mandatory for all industrial players within the aeronautical sector in order to achieve the very demanding sector goals of the strategic research and innovation agenda for 2020 and 2050. According to this, Aciturri has identified a set of operations for specific case-problems, with an expected major impact on both cost drivers and a clear opportunity to be extended to other major programmes that are currently under serial production, and a significant expected rate increase within the next five years. On the one hand, the work focused on optimal cutting parameters calculation in order to gain efficiency in the current industrialisation process. Furthermore, the industrialisation process also has been analysed from the factory planning point of view through project-developed simulation tools.

On the other hand, recurring production costs have been examined through the characterisation of machining associated wastes and the analysis of minimum quantity lubrication (MQL). For the latter, cutting tool integrity and life together with process-associated new risks and parts quality have been considered in order to assure the validity of the process.

Products:

Titanium Components

Medium and large profiles for the internal structure of A380 belly fairing.

Fittings for the C295 engines supporting structure.

Aluminum Components

Frames and fittings for the vertical tailplane and S19 internal structure of the A350 XWB.

“Our vocation is to deliver top-class complex structures produced with the most advanced and sustainable technologies.”

A. Fernández, General Director of Strategy, Aciturri

Complex Metallic Aerostructure Parts Process Chain

- Case: Machining of structural elements requiring very strict tolerances.
- Challenges at the factory level: Integrating environmentally friendly process technologies with novel control systems through multi-objective simulation.
- Challenge at the process chain level: Increasing effectiveness in aspects such as fluid or coolant reduction.
- Challenge at the machine level: Increasing cutting tool life, energy consumption reduction, external vibrations.



“In 2020 Aciturri will produce structural components with minimum energy, lubrication and cutting tool wastes and maximum residues recovery.”

E. Porras, Head of Innovation, Aciturri Metallic Parts

Aero Pilot



Challenges Addressed at the Factory Level

The pilot at factory level is being developed at the Aciturri Metallic Parts new production plant at Ayuelas Site, where the latest generation 5-axis machining centres have been installed and the industrialisation of new products is in progress. In order to optimise industrialisation, the pilot case has included the calculation of stable diagrams for the critical tools used in the machining of 7075 aluminium parts. The work performed identified the unstable machining regions where chatter could appear.

Additionally, for some cases, the cutting depth was increased by up to 40% and the spindle speed by up to 11%. Furthermore, given the foreseen enlargement of the plant equipment within the next two years, the green factory planning method developed by EMC2-Factory is being tested in the aerospace pilot to ensure the optimal future factory layout.

Process Chain Level

The project focuses on the reduction of the huge amount of emulsion used in the manufacturing of aero structure titanium profiles. The pilot has been implemented using an external MQL (minimum quantity lubricant) system provided by CORREA, allowing for the testing of the feasibility of the process, with promising results.

Planning

1

Strategy for Environmental Assessment and Optimisation of Aeronautic Manufacturing Plants

The main factory and machine wastes have been monitored and data delivered for the plant energy simulation.

Operation

2

New Minimum Quantity Lubrication Titanium Machining Technology

Reduction of general waste from machining operations of 90%.

Aciturri Plant in 2020: A Vision

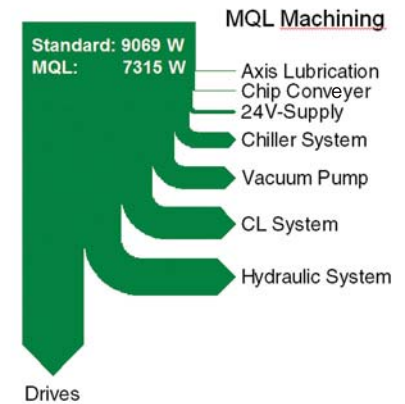
Despite newly available technologies, socio-economic factors and policy frameworks seem to be jointly crucial in assuring new sustainability models for manufacturing in 2020. Aciturri has found a clear opportunity to increase its production efficiency by developing a strong supply chain, increasing the qualification level of the workforce and setting up an ambitious programme for the reduction of production waste and scrap. The latter will be achieved by combining the latest generation production means with different technologies and procedures that emphasise the role of simulation and manufacturing planning tools. This way, future manufacturing problems, automation and the use of intelligent and flexible tooling are taken into account.

Highlight Case on Titanium Machinig

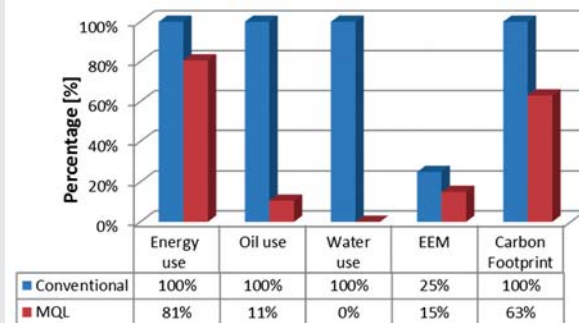
The production of airframe profile components combines the two processes studied within the project: new MQL-assisted machining processes for titanium parts and riveted joints substitution with friction stir welded joints in aluminium profiles.

The impact of MQL use has been monitored in terms of energy, coolant and tool waste and carbon footprint, demonstrating an eco-friendly machining approach that allows a reduction in the coolant waste of 90%. For the aluminium profile joining processes, the mechanical characteristics of the parts reveal the high potential of the technology in the assembly of aeronautical parts, reducing the weight of the set and the processing time.

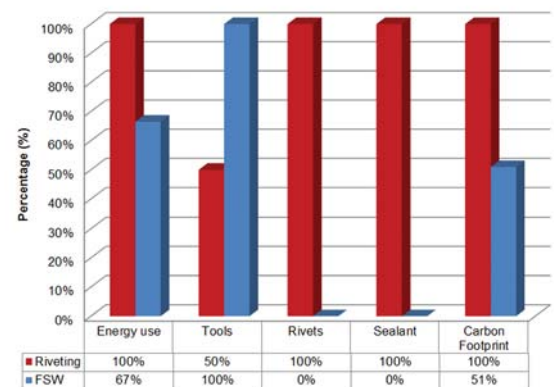
Environmental Assessment of MQL Technology



Carbon Footprint: MQL Pilot



Carbon Footprint: Friction Stir Welding Pilot

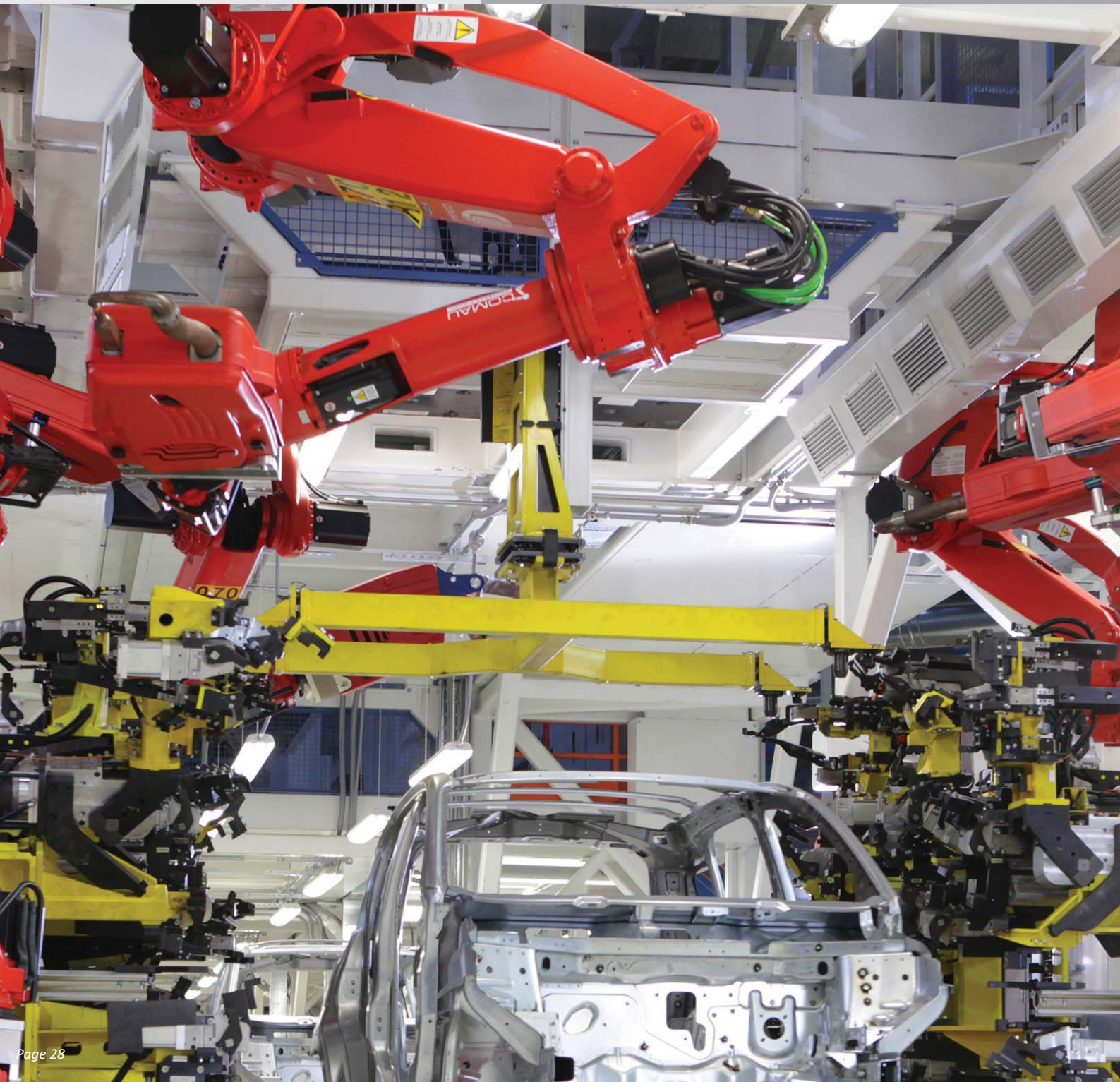


Operation

3

EcoMode in CNCs

Implementation of control strategies to reduce energy waste during machining operation by 15%.



Automotive Pilot

Comau S.p.A., Italy
Medium- and Large-Size Products:
Advanced Manufacturing Systems

“We are specialised in car body welding, robotics, metal cutting and assembly systems.”

L. Migliore, Head of Body Welding Worldwide Global Solutions Development, Comau

Automotive Pilot

Comau S.p.A., Italy

Comau can look back on nearly four decades of experience in advanced manufacturing systems and is leading the global market in sustainable automation and service solutions.

With a strong history in the automotive industry, we have continued to grow, and today we put our skills and know-how to the test in a range of industries and

applications: industrial automation, body welding, machining and mechanical assembly systems and a broad range of industrial robots and services. Comau's international network spans 13 countries and our success stems from the clear goal of exceeding the needs and expectations of our clients through the application of key technologies.

Starting Position of the Project

The pilot focuses on automotive sector components production, namely car powertrain machining and assembly as well as body welding and assembly and will be designed to comply with a very wide range of customers' requirements in accordance with the expectations of the major car manufacturers.

The pilot case has been used to demonstrate the overall project results as well as to assess the actual performance of the new integrated design environments that aim to advance environmental sustainability. It addressed relevant automotive applications such as car engine machining or car body welding lines, integrating intelligent sensing and monitoring devices, new actuators, advanced energy recovery solutions, dry-cutting and minimum quality lubrication (MQL) technologies and lightweight materials for moving axes.

The pilot took into account the different environments of existing plants (brownfield: small or medium investment for adaptation and retrofitting) and new plants (greenfield: emerging industrialisation context with medium or high investments).

Products:

Versa Gun

Versa Gun is a product founded on simplicity and modularity. Three standard chassis ("C", "X", "CXR") provide a robust and compact solution; 100% of typical body shop requirements are satisfied with this versatile product.

Smart Drive

Smart drive is a range of high speed machining centres with direct drives or ball screw on all axes. The architecture has the X and Y axis under the horizontal spindle and the Z axis under the part.

Green DMS

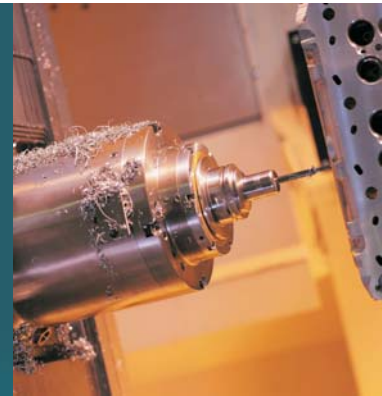
Automated production system data monitoring with access from PC and tablet through a GSM network.

“Comau is turning green commitment and environmental sustainability into real energy-saving results.”

M. Valentini - Director of eComau and Comau Consulting, Comau

Powertrain and Car Body Production

- Cases: Energy-efficient machining of powertrain elements; sustainable body welding lines.
- Challenges at the factory level: Integrating environmentally friendly process technologies with novel control systems through multi-objective simulation.
- Challenge at the process chain level: Increasing effectiveness in aspects such as fluid or coolant reduction.
- Challenge at the machine level: Increasing cutting tool life, energy consumption reduction, equipment lightening.



“Comau today is developing production systems with the most advanced solutions for environmentally friendly manufacturing.”

U. Ghirardi, Powertrain Systems Product Line Assembly & Test Director, Comau

Automotive Pilot



Implemented Solutions at Factory Level

Focusing on retrofitting and retooling of manufacturing systems, generally referred to as brownfield operations, customers are more and more interested in sustainability approaches. Starting from the point of view of a car maker, the need for a plant retrofit is mainly triggered by changes to the product (engine, body in white, ...) or changes in the level of production (throughput increase, introduction of variants, ...). The investments for retrofitting provide an opportunity to invest also in environmental improvements of the existing manufacturing plants following definite steps. Taking into account brownfield business, activities start out from the customer requirements related to plant and machinery modification. Following cost and technical surveys based on energy monitoring and simulation, a detailed technical solution is developed and executed.

Machine Level

The project focused mainly on increasing the effort to propose efficient energy-control strategies through the development of a methodology for building energy state-based models of complex machines as a functional module as well as for the entire machine. As a result, the entire simulation model delivers the power or energy consumption profile.

Planning

1

Green Data Monitoring System

GreenDMS (data monitoring system) is a smart metering system able to associate production data and energy consumption. The concept constitutes a reliable tool to identify optimisation opportunities.

Operation

2

Green Fit

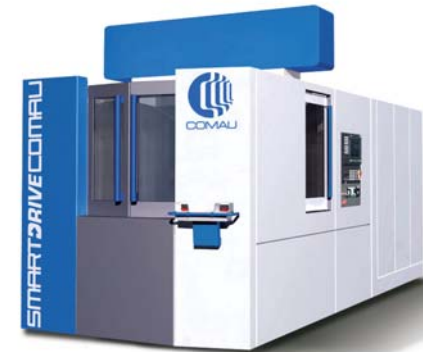
An advanced control strategy related to standby and sleeping status management of machining systems in order to carry out an optimal energy-oriented approach.

Comau Plant in 2020: A Vision

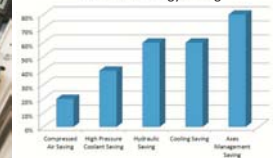
In future, energy saving and waste reduction will be drivers of continuous improvement for automotive production systems. Energy-efficiency control strategies, minimal quantity lubrication, components weight reduction and design optimisation through innovative simulation tools will be adopted by all industrial stakeholders. Moreover, sensing and monitoring technologies will lead to a complete awareness of the energy status from the entire machine to the single component point of view.

Highlight Case on Green Fit

This case considers a cylinder head machine line on which a number of green improvements to sustainability and waste have been conceived, analysed and implemented, following the application of methodologies and guidelines that form the subject of the developed green fit methodology. The energy assessment is the first step in analysing the energy consumption of the production system under consideration, in order to identify the energy profile of the production line. The energy profile is the basis for selecting the actions to be implemented on the existing production line. The preliminary actions to be adopted for energy improvement of the production systems are based on previous experiences organised basically according to best practices and retrofitting developed in the EMC2-Factory project.



Achievable Energy Savings



Operation

3

Welding Line Weight Reduction

New light components for resistance spot welding and innovative archetype on body-frame and body-side for remote laser welding in order to reduce energy consumption.





Rail Pilot

Siemens AG, Vienna

Large-Size Products: Metros, Coaches and Light Rail

6

“We manufacture innovative and energy-efficient metro cars for the worldwide market in the centre of Vienna.”

Robert Bauer, Vienna Plant Manager, Siemens AG

Rail Pilot

Siemens AG, Vienna

The Siemens plant in Vienna is the worldwide location for metros, coaches and light rail and a major cornerstone of Siemens' railway engineering and technology sector. The over 180-year history in rail vehicle design and production goes back to the time of the "k&k-Waggonfabrik" (imperial royal wagon factory). Based on this experience, here is

the know-how for the whole logistics chain and process chain, from research, development and engineering to production and commissioning. Rail vehicles of stainless steel or aluminium are manufactured applying state-of-the-art production technologies such as high performance welding robots. At the Siemens Vienna Plant, approximately

1,000 employees work every day in a total area of 124,000 m², and they are able to complete and deliver up to 400-500 vehicles every year. Metros, coaches and light rail from the Siemens Vienna Plant are used daily all over the world.

Starting Position of the Project

Before EMC2-Factory, the Siemens Vienna Plant had already addressed the topic of energy and resource efficiency with several building renovation projects (insulation, ventilation systems, etc.), a new surface treatment centre, and product design improvements from a life cycle perspective, e.g. lighter materials to consume less energy, use of recyclable material.

Nevertheless, energy efficiency and transparency as part of a holistic approach to production were not yet thoroughly addressed.

In order to focus on concrete solutions and to be able to assess results, the demo pilot for the rail industry was focused on a single building in which welding, machining and grinding of car bodies are performed. This building was chosen since it was already one of the most energy-efficient buildings in Vienna (to avoid focusing on trivial improvements) and since it includes a complex variety of processes that are carried out at the Vienna plant, thereby representing several other buildings and processes, and showing several interactions.

To start the project, an as-is analysis was performed, gathering both energy- and production-related information. On this basis several measures were identified and developed. The main points of the results are included on the next two pages.

Main Products:



“In Vienna we work on technologies and environmentally friendly solutions for manufacturing and products.”

Ing. Herbert Bertl, Head of Manufacturing Technology, Vienna Plant

Metros, Coaches and Light Rail Production

- Case: Manufacture of rail and metro cars applying cutting and joining processes, surface treatment and assembly.
- Challenges at the factory level: reducing the amount of energy used through advanced planning and scheduling.
- Challenge at the process chain level: optimising the economic and ecological footprint of the whole chain, not just of single processes.
- Challenge at the machine level: advancing the eco-footprint of machines and processes by implementing new solutions.

© Source: Siemens AG



“Siemens is able to produce with the latest stir welding technology in the aluminium production line.”

Robert Bauer, Vienna Plant Manager, Siemens AG

Rail Pilot

SIEMENS

FESTO



Machine Level

A new module developed by Festo for monitoring and controlling the use of compressed air has been successfully tested on grinding tools. The module is able to detect leakages and to minimise waste of compressed air automatically.

Implemented Solutions at Process Chain Level

Process chains, in particular focusing on joining technologies as core processes, have been evaluated from an ecological as well as an economic point of view. Current MIG/MAG welding technologies have been compared with alternative processes such as friction stir welding and laser hybrid welding to investigate potentials for improvement. Evaluation is not limited to the energy requirements of the process itself, but also includes impacts of all auxiliary systems. In the case considered, a ventilation system used as an exhaust system for welding gases requires a lot of electricity as well as increased heating in winter.

3



Testing of the Festo Compressed Air Saving Module

Operation

2



© Source: Siemens AG

Alternative Joining Process Chains

Operation

Siemens Plant in 2020: A Vision

In future, the Vienna Plant will operate with energy- and process-optimised technologies such as friction stir welding and robot painting to reduce environmental impacts and save energy and material.

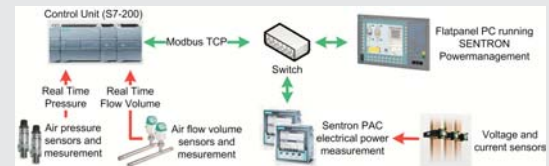
The use of additional computer-aided planning tools will be increased to react quickly to customer demands and help to save energy and natural resources.



Highlight Case on Production Scheduling

At the factory level, tailored production-planning software has been developed to support the production planner in improving decision making when defining daily and weekly production plans. This tool shows transparently the impact of alternative planning solutions in terms of different criteria such as energy consumption, earliness, delay, setup operations, and resources utilisation. The software is now continuously used in a selected building of the Vienna Plant.

Energy Management System for Full Transparency



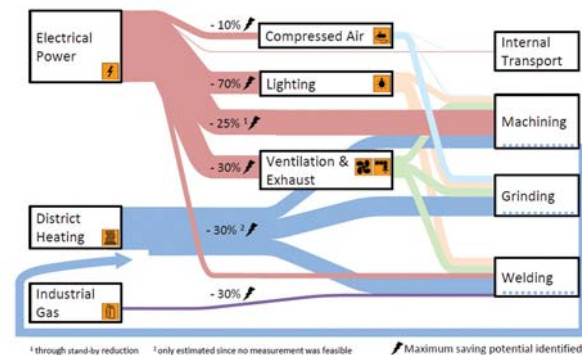
Illustrative representation of the energy management system for the Siemens Vienna Plant

Planning



Production Planning Optimisation

Demonstration







Research and Industry Partners

FP7 FoF Project Cluster

Consortium

“Only a well set-up consortium can produce excellent results through good hierarchical leadership and excellent performance!”

Amit Eytan, Project Coordinator, Centro Ricerche Fiat S.C.p.A



Centro Ricerche FIAT S.C.p.A.



CRF's mission is to develop and transfer innovative products, processes and methodologies in order to improve the competitiveness of the products of the Fiat Group. In addition, through the cooperation with a pan-European and global network of more than 1,700 partners from industry and academia, CRF conducts collaborative research initiatives at national and international levels for Sustainable Mobility and Industry, targeting specifically the industrial exploitation of research. CRF aims to use innovation as a strategic lever for the business of the Fiat Group and to give value to the results of its activities through the promotion, development and transfer of innovative contents which make the product competitive and distinct.

CRF activities in EMC2-Factory have focused on project coordination, spearheading of process technologies re-engineering, representing the automotive sector in production control and planning re-engineering. CRF has also supported community building creation, led dissemination and exploitation activities, and guided EU clustering activities.

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Politecnico di Milano



Politecnico di Milano, founded in 1863, is the most important technical university in Italy and one of the largest in Europe. Politecnico di Milano is involved in this project with the Department of Economics, Management and Industrial Engineering (DIG) and the Department of Mechanical Engineering (MECC) with their specific competences.

As part of EMC2-Factory, Politecnico di Milano has developed the Holistic Perspective, providing a framework for eco-factory modelling and assessment as a theoretical reference and in order to guide the project activities. Furthermore, Politecnico di Milano provides methods and tools for energy-aware line and machine modelling and total factory modelling and simulation, as well as providing project dissemination, exploitation and knowledge transfer activities.

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COMAU S.p.A.



Comau is a global supplier of industrial automation systems and services mainly for the automotive manufacturing sector. Comau broadened its presence all over the world, becoming the ideal partner for the automotive industry in developing solutions for all industrial production programmes. Comau's utmost goal is customer satisfaction, anticipating needs and exceeding expectations. The continuous improvement of products, processes and services through the application of the most advanced innovative technological solutions allows Comau to contribute to its customers' competitive advantage. Comau contributes to EMC2-Factory with its high expertise in the design and development of advanced body welding and powertrain systems for the automotive sector, where radically new energy saving concepts have been tested and applied in real pilots.

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Siemens AG



Siemens AG, headquartered in Berlin and Munich, is a global powerhouse in electronics and electrical engineering. Its 360,000 employees work to develop, manufacture and implement products, complex systems and projects and a wide range of solutions, achieving a turnover of €73.5 billion in FY2012.

Siemens is involved in EMC2-Factory with the Siemens AG's Rail Plant in Vienna, where solutions from the project are piloted, and with Siemens AG's Corporate Technology (CT), the cross-sector research unit.

Siemens CT contributes within EMC2-Factory to manufacturing processes assessment with focus on joining processes, to the development of energy-oriented production planning tools, and to factory planning and life cycle evaluation methods. The aim is to develop and integrate different approaches that can be broadly applied at Siemens factories and later at customer sites. As the rail industry pilot of EMC2-Factory, Siemens Rail Plant in Vienna is performing several tests and implementations of different solutions resulting from the project, to evaluate them in terms of industrial applicability.

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Festo AG & Co. KG



Festo is a leading worldwide supplier of automation technology and pneumatic products. Festo offers innovations and problem-solving competence in all aspects of automation including tailored training programmes. Our mission is long-term value enhancement for our customers, our company, our employees and our partners. With our sophisticated concept for energy efficiency in automation we cover a total of four areas: engineering, products and solutions, services and industrial education. Each of these four areas contributes to an increase in energy efficiency – regardless of where the road begins. Within the EMC2-Factory project, Festo brings in long term experience in applied research in an industrial environment. Therefore, Festo provides knowledge to design and operate energy-efficient automation solutions and services.

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Technische Universität
Darmstadt PTW

The Institute of Production Management, Technology and Machine Tools (PTW) focuses on education and research in the fields of cutting of metallic materials, the design and construction of machine tools and components, and process optimisation, production organisation and energy efficiency in the technical production environment. PTW, as partner of the EMC2-Factory consortium, provides energy simulation models and assessment methods that can be used during the development of energy-efficient machine tools, production planning or efficient machine controls. Beyond single production machines, the question of holistic energy optimisation of production environments is also one of our research fields.

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**Technische Universität
Braunschweig IWF**



The Sustainable Manufacturing & Life Cycle Engineering Research Group is part of the Institute of Machine Tools and Production Technology (IWF) and is embedded in the Technische Universität Braunschweig. The research group provides a wide range of core competencies in the fields of Sustainability in Production and (Automotive) Life Cycle Engineering. We developed the concept of Total Life Cycle Management which serves as a framework for our research and education activities, which take place in close cooperation with industry.

As part of the research consortium we provide methods and tools to enable energy metering and monitoring, life cycle evaluation of factories and dynamic energy and resource flow simulation of factories.

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TNO



TNO is an independent research organisation whose expertise and research is an important contribution to the competitiveness of companies and organisations, to the economy and to the quality of society as a whole. TNO's unique position is attributable to its versatility and capacity to integrate this knowledge.

As part of the EMC2-Factory consortium, TNO provides and integrates knowledge and expertise on wireless sensor networks and indoor climate modelling. The result: an indoor climate monitoring system, providing real-time information on machine-related thermal emissions, technical building services operation and propagation of fumes.

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TWI Ltd.



TWI is one of the world's foremost independent research and technology organisations, with expertise in solving problems in all aspects of manufacturing, fabrication and whole-life integrity management technologies. Established in Cambridge, UK, in 1946 and with facilities across the globe, the company has a first class reputation for service through its teams of internationally respected consultants, scientists, engineers and support staff, whose knowledge and expertise are available to its industrial members as and when they require.

The role of TWI within EMC2-Factory is to employ its expertise to help define and optimise energy-efficient manufacturing processes. The specific focus is energy reduction in joining processes, but also takes into account the influence of other supporting ancillary processes such as water cooling, fume extraction, cleaning operations, robotisation and automation.

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TECNALIA Research & Innovation



Tecnalia Research & Innovation is the first privately funded applied research centre in Spain and one of the leading such centres in Europe. Tecnalia is determined to change its way of working with companies to promote the transformation of knowledge into wealth.

Tecnalia is involved in EMC2-Factory, piloting the aerospace demonstration activities with its expertise in design and simulation of advanced manufacturing systems, as well as the capacity to devise new technical solutions aimed at improving the environmental impact of production systems.

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CECIMO



CECIMO is the European Association of the Machine Tool Industries. We bring together 15 national associations of machine tool builders, which represent approximately 1,500 industrial enterprises in Europe, over 80% of which are SMEs. CECIMO represents its members' interests towards authorities and other stakeholders, and promotes the European machine tool industries and their development in the fields of economy, technology and science. CECIMO covers more than 99% of the total machine tool production in Europe and 30% worldwide.

As a part of the consortium we are engaged in dissemination activities, community building and innovation transfer. We also provide relevant knowledge on the sector and standardisation activities at the European and international level.

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SENSeOR



Created in 2006, SENSeOR is headquartered in Sophia-Antipolis (France) and employs 20 people. SENSeOR has been part of the WIKA group (Germany) since July 2012. Its expert engineer team provides field engineering services and customised developments in addition to a standard sensor portfolio, to help its customers solve their measurement challenges in harsh environments.

As part of the EMC2-Factory consortium SENSeOR provides its expertise in wireless and passive SAW sensors which will be integrated into machines for real-time monitoring of key parameters (such as temperature and strain), allowing an optimal use of the machines.

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Nicolás Correa S.A.



Nicolás Correa is one of the leading industrial groups in Europe, both in size and in innovation, conception, design and manufacture of milling machines. Eco-design is a core element of the Nicolás Correa strategy. Applying eco-design concepts to the machine takes into account safety criteria, ergonomics and minimum environmental impact from conception to scrapping, hence optimising the cost of the complete life cycle of the machine.

As part of the EMC2-Factory consortium, Nicolás Correa provides detailed knowledge about eco-design of machine-tools and how the machines of the eco-factory should be designed and operated to assure minimum impact in terms of energy consumption and cooling waste while maintaining high productivity and reliability.

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**Aciturri Metallic
Parts S.L.U.**



Aciturri is a 100% Spanish industrial group that produces parts and assemblies for the aeronautical sector in the market segments of aerostructures, engines and mechanisms, both in metallic and composite materials. With over 35 years of aerospace experience, Aciturri is nowadays a first tier supplier and risk-sharing partner for the aeronautical sector, employing approximately 1,100 people, and has an annual turnover of €155 million.

Aciturri Metallic Parts S.L.U. is the group division involved in EMC2-Factory where the project developments are piloted. Specialising in manufacturing metallic parts, the company continuously develops new advanced and innovative solutions for its manufacturing processes to offer an integral, profitable, different and close service to its customers.

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Institute of Industrial Technologies and Automation - ITIA-CNR



ITIA-CNR is a promoter of industrial innovation and performs strategic activities of scientific research and technological development to enhance competitiveness and sustainability of Italian and European manufacturing industries. Specific research areas are adaptive control and automation systems, high performing operating machines, responsive factories, with particular attention to energy efficiency and sustainability of the developed manufacturing solutions.

As part of the EMC2-Factory consortium ITIA-CNR provides detailed knowledge about development of simulation environments and definition of eco-control strategies at machine and system level.

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Automation Informatics Telemetry Robotics Sp. z o.o.



AIUT is an engineering company established in 1991. AIUT provides services and technical solutions in the field of automation, process control and production management for various kinds of industries. AIUT has vast experience in the design and execution of electrical projects, automation and process control software engineering. Another of AIUT's activity areas is electronic design and production of wireless media meter systems. The above automation/electronic services are fulfilled using pure software services at specific, problem-oriented areas. The company employs over 200 people, experienced and skilled engineers in: automation, computer science and electrotechnology.

As part of the research consortium, we share our experience of energy-efficient electronic and telemetry production profiles, laboratory abilities to verify different functionality concepts, and a wide partnership with one of the automotive pilot plants located in Poland.

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Clustering Activities

Shared Knowledge and Resources

The initiation of the FP7 included a focus on certain fields of research. By now, various solutions and innovations were developed by European Commission funded research projects within the cluster of Eco-Factories and Eco-Manufacturing. Formulated aims of the Commission and the consortia of the projects are the broad dissemination and exploitation of the

developed results to industry. Transparency is one of the most important drivers of this transfer. Therefore, the European Commission has initiated a number of clustering activities. The aim of these activities is to foster and enhance the transfer of knowledge to industry, to increase overall efficiency and to identify common and overlapping research topics.

Furthermore, the activities are meant to encourage projects to work together on these topics, as well as to combine dissemination and training events to give a consistent message to industry and to enable easy and focussed exploitation of the results in the EU market.

Positive Effects of Project Clustering

Clustering activities can be divided into two macro areas: technical activities and non-technical activities.

For technical clustering activities to take place, clear benefits to all participating projects should be identified, using mainly the clustering efforts to tackle common problems and to exchange valuable knowledge that will benefit each of the projects. IPR issues are critical and should be studied well to avoid legal problems. Developing and sharing methodologies (e.g. environmental and economic assessment methods) would be easier and more fruitful to carry out, rather than the specific know-how that is the basis of each project's competitive advantage. It has been suggested that knowledge should be shared at the level of publications and other public material, where critical details can be left out and partners can veto publication in case they have a negative impact on their core business, so as to protect IPRs. From an industrial perspective, clustering could reduce project costs on dissemination and exploitation tasks, which would free up budgets to be used on project-specific technical work. More standardisation efforts are also seen as beneficial.

Non-technical clustering activities would be easier to carry out as they avoid issues such as IPR and are easier to organise. Overall, these activities would also have a higher impact than if carried out single-handedly by each different project, enhancing the target audience and possible customers, and are easier to be worked on jointly.

Partner Projects

AREUS | Automation and Robotics for European Sustainable Manufacturing



ENEPLAN | Energy Efficient Process pLAnning system



REFORM | Resource-Efficient Factory Of Recyclable Manufacturing composite components



“Synergy: It’s the turbo for faster development without losing on quality!”

*Paul Lemmens,
Project Technical Adviser of the European Commission*

Coordinators and Experts meet up

As a result of these clustering initiatives the European Commission recommended that four Eco-Factory projects – AREUS, EMC2-Factory, ENE-PLAN, and REFORM – should be joined together, to meet and to discuss ways in which they could collaborate for the benefit of all the projects. The first technical meeting of the cluster was held in Sheffield on 15 October 2013, and yielded many ideas for possible technical and non-technical common efforts.



Learning from EMC2-Factory

Guidelines

Within the EMC2-Factory project, numerous solutions for improving energy efficiency in manufacturing were developed. The solutions cover a broad variety of applications, e.g. from process chain design and manufacturing equipment selection to line and plant layout as well as machine component design, machinery development and the design of factory buildings

with building services. Consequently, managers and engineers responsible for the implementation of improvement measures have to be supported as much as possible with concentrated descriptions of the main steps to apply a certain solution. For providing this description, the solutions developed have been compiled in the form of 'Lean and Green Guidelines', providing a

standardised description of the measure itself as well as of the necessary information on the main steps to implement a specific measure.

Delivering Knowledge

EMC2-Factory dissemination and innovation transfer activities aim at delivering project solutions to their final users, production planners and managers by exploiting in an integrated way different channels such as academia and research institutions, manufacturing experts or science and technology parks. The main elements of knowledge delivery are industrial and scientific publications, workshops and presentations at international and national events and scientific conferences. The whole delivery process is supported by public relation material such as the project website, flyers and posters, together with the project brochure at hand.

Selected Publications from International Conferences

B. Stahl et al., **Combined energy, material and building simulation for green factory planning**, CIRP Conference on Life Cycle Engineering, Singapore, 2013.

T. Heinemann et al., **Life Cycle Evaluation of Factories: Approach, Tool and Case Studies**, Global Conference on Sustainable Manufacturing, Berlin, 2013.

N. Weinert et al., **Lean and green framework for energy efficiency improvements in manufacturing**, Global Conference on Sustainable Manufacturing, Berlin, 2013.

F. Müller et al., **Green Factory Planning: Framework and Modules for a Flexible Approach**, Advances in Production Management Systems, Pennsylvania, 2013.

C. Mose et al., **Energy efficiency optimization of joining processes on shopfloor and process chain level**, CIRP Conference on Life Cycle Engineering, Trondheim, 2014.

T. Heinemann et al., **Hierarchical Evaluation of Environmental Impacts from Manufacturing System and Machine Perspective**, CIRP Conference on Life Cycle Engineering, Trondheim, 2014.

G. Posselt et al., **Extending Energy Value Stream Models by the TBS Dimension – Applied on a Multi Product Process Chain in the Railway Industry**, CIRP Conference on Life Cycle Engineering, Trondheim, 2014.

S. Borgia et al., **A reduced model for energy consumption analysis in milling**, CIRP Conference on Manufacturing Systems, Windsor, 2014.

P. Fantini et al., **Towards Environmental Conscious Manufacturing**, IEE International Conference on Engineering, Technology and Innovation, Bergamo, 2014.

A. Cataldo et al., **Management of a production cell lubrication system with model predictive control**, Advances in Production Management Systems, Ajaccio, 2014.

“Focused dissemination and exploitation is the key to evolve the maturity of academic inventions to industrial innovations.”

Michael Bernas, Head of Research Production Systems, FESTO AG & Co. KG

Important dissemination and knowledge transfer events include:

- Industrial Technologies (2012, Aarhus), workshop
- LAMIERA trade show (2012, Bologna), booth
- Innovation opportunities for SME (2012, Faenza), workshop
- EMO trade show (2013, Hanover), seminar
- INTELLIMECH Consortium Kilometro Rosso (2013, Bergamo), workshop
- Industrial Technologies (2014, Athens), workshop
- BIEMH International Machine Tool Exhibition (2014, Bilbao), conference
- Further publications and presentations at international scientific conferences

