WP5: Electricity optimization
Final Report

ABB Corporate Research Center, Ladenburg, Germany

Acciai Speciali Terni

Imperial College London

31/03/2015

ITN Research Objective 3: Study ways that energy savings can be achieved

WP5 aims to deliver technology prototypes for energy/cost savings at the scale of production processes:

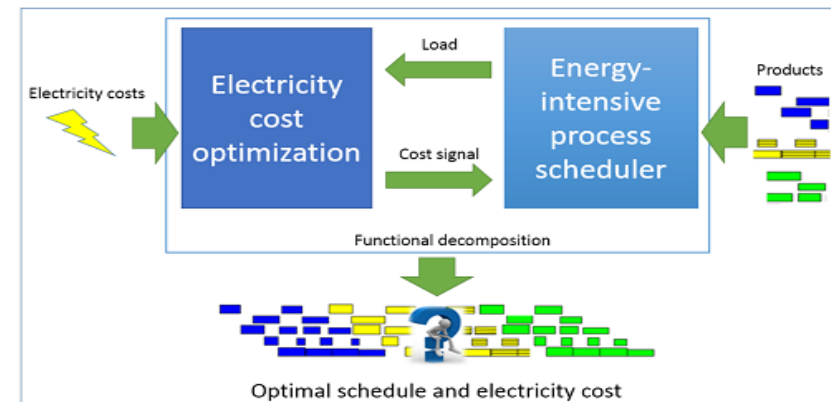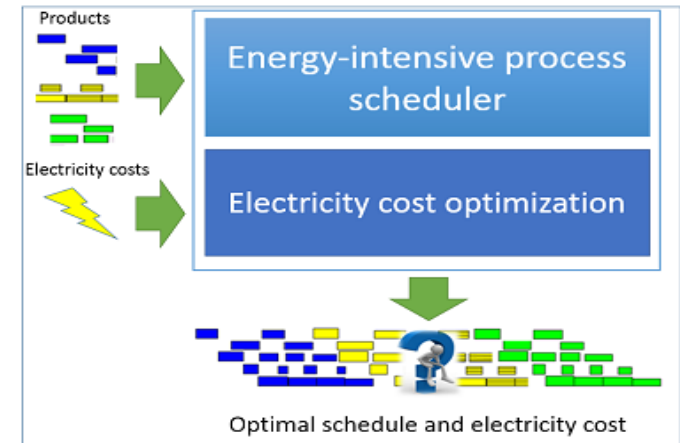|	
By analysing the interaction between large and variable industrial loads and the electrical grid	**ESR-G (Dionysios Xenos)** 6 months @ **Imperial**
By developing and implementing scheduling optimization methods to integrate the production of a steel plant	**ESR-L (Dragoljub Gajic)** 25 months @ **AST**
	ESR-N (Robin Cartoux) 16 months @ **DE-ABB**
By developing a framework and methods for demand response of energy-intensive processes	**ESR-K (Hubert Hadera)** 36 months @ **DE-ABB**

ESR-K (Hubert) Hadera

- WP5 is mainly built around the steel case study

- For this electricity intensive meltshop process, ESR-K (Hubert Hadera) developed an approach to consider simultaneously energy supply and production scheduling in order to cut electricity costs.

- This approach fits into the more generic framework of industrial demand side management and was also applied to other processes (pulp and paper).

Products
Electricity costs
Energy-intensive process scheduler
Electricity cost optimization
Optimal schedule and electricity cost

Electricity costs
Electricity cost optimization
Load
Cost signal
Energy-intensive process scheduler
Products
Functional decomposition
Optimal schedule and electricity cost

ESR-N (Robin Cartoux)

- ESR-N (Robin Cartoux) addressed the coordination between the meltshop and hot rolling mill process in order to reduce reheating energy consumption.

- Reuse and control existing scheduling systems for meltshop and hot strip mill (MSO and HSO respectively)

- Plant-wide approach to integrate the scheduling across different production areas

ESR-L (Dragoljub Gajic)

- His objective was to develop, test and implement creative solutions for energy (cost) savings in stainless steel industry focusing on melt shop and hot rolling mill area

- ESR-L (Dragoljub Gajic) deployed and integrated in AST the melt shop scheduling optimization system

- Integration with other plant IT systems and real-time monitoring
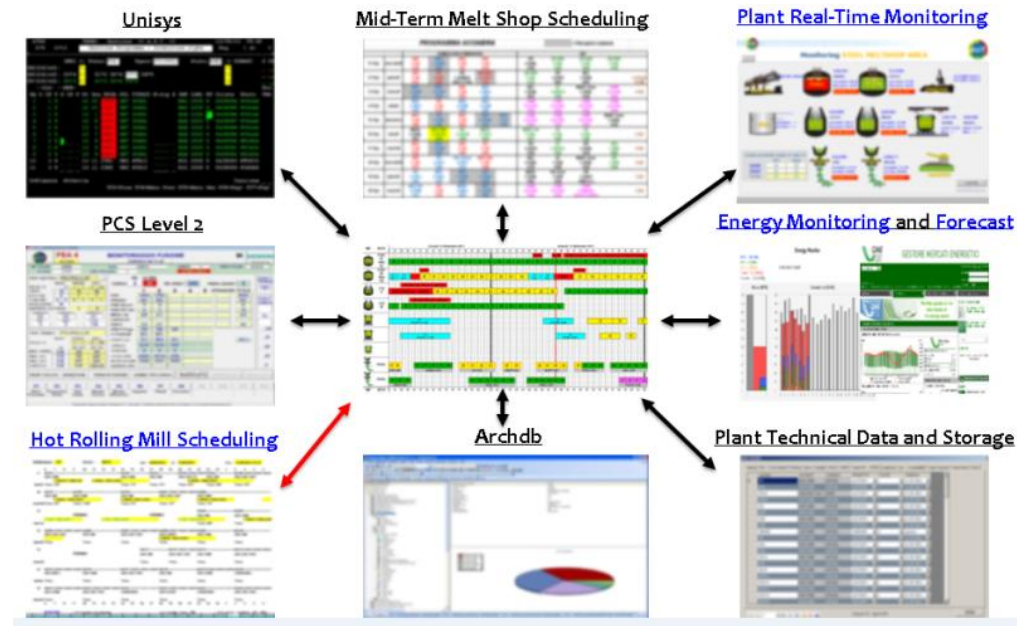
ESR-G (Dionysios Xenos)

- The optimal operation and maintenance of compressors is studied in WP2.

- The integration of operational and energy aspects involves several steps:

  - Investigation of the electricity suppliers characteristics, constraints and parameters which influence the operation of the compressors.

  - Combination of different time scales, a time horizon of few weeks (maintenance time scale) and a time horizon of few days (variation of electricity prices time scale)

Networking
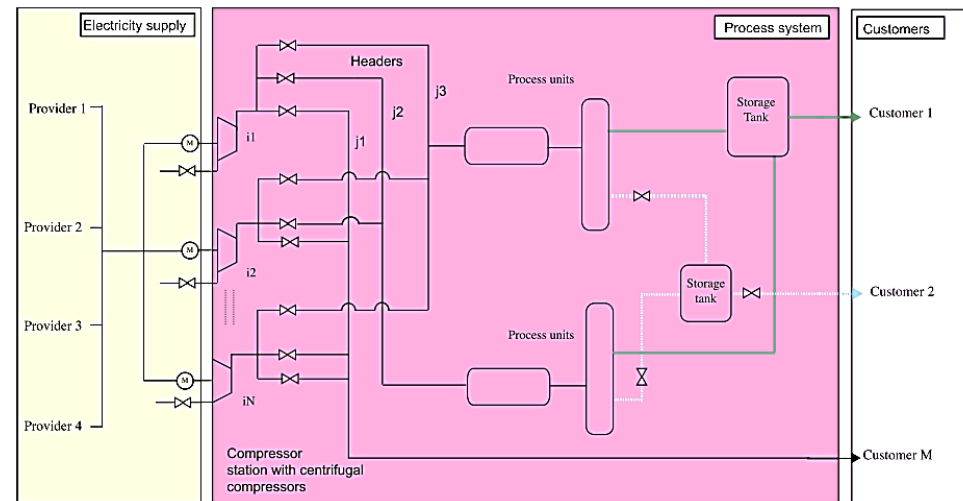
- Tight collaboration between AST and ABB-DE:
  - 5 meetings in Terni and 2 in Ladenburg with ESRs and supervisors
  - Terni case study report drafted and preliminary approved (to be finished by July 2014)

- ITN consortium meetings :
  - Consortium Meeting 2012 in Ladenburg with BASF site visit
  - Workshop 2013 „ *Optimization and Energy Savings*" in Ladenburg
  - Consortium Meeting in September 2014 in Terni with AST stainless steel plant site visit.

- 2 academic secondments at CMU:
  - Feb-May 2013 : Continuous time batch scheduling of steel plant with optimization of energy cost, ESR-K (Hubert Hadera)
  - Jan-Apr 2014 : Theoretical and practical study on mathematical optimization, ESR-L (Dragoljub Gajic)

- University supervision:
  - ESR-K (Hubert Hadera): PhD candidate at TU Dortmund (Prof. Engell). The degree defence is expected in April/May 2015
  - ESR-L (Dragoljub Gajic): PhD candidate at University of Belgrade (Prof.Djurovic). Visiting researcher at University of L' Aquila (Prof. Di Gennaro). The PhD defence will be held on February 9, 2015.

ESR-K (Hubert Hadera):
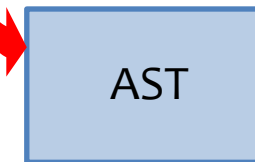July 2013
June 2014 ✓

ESR-L (Dragoljub Gajic):
August 2013
June 2014 ✓

ESR-N (Robin Cartoux):
July 2014 ✓

ABB-DE

AST

Cross-secondments

Training

| Training	Location	Who
Optimization Modeling, Conceptual Design and Integrated Process Operations, optimization short-course	CMU, Pittsburgh (US)	ESR-K (Hubert Hadera, ESR-N (Robin Cartoux), ESR-L (Dragoljub Gajic), ESR-G (Dionysios Xenos)
Project Planning, Analysis and Control, Project management course	ABB, Baden (Switzerland)	ESR-K (Hubert Hadera)
Industrial optimization: compact course and challenge workshop, optimization short-course	Heidelberg University (Germany)	ESR-K (Hubert Hadera), ESR-N (Robin Cartoux)
Power Speech, Seminar on presentation skills	ABB, Ladenburg (Germany)	ESR-K (Hubert Hadera), ESR-N (Robin Cartoux)
SmartOps Professional Skills Course: Series of mini-courses on soft-skills for researchers	Imperial College, London (UK)	ESR-K (Hubert Hadera), ESR-L (Dragoljub Gajic), ESR-N (Robin Cartoux)
Technology Brokerage Program: Technology transfer, intellectual property, business plans and project management	Ministry of Education, Science and Technological Development, Belgrade (Serbia)	ESR-L (Dragoljub Gajic)
Project Management Professional (PMP) Certification	Project Management Institute, USA	ESR-L (Dragoljub Gajic)
MSc courses in Process Systems Engineering	Imperial College, London (UK)	ESR-G (Dionysios Xenos)
Introduction courses to C, C# programming languages	Imperial College, London (UK)	ESR-G (Dionysios Xenos), ESR-K (Hubert Hadera)

Training

| Training	Location	Who
Process simulation and design	Cranfield University (UK)	ESR-G (Dionysios Xenos)
Specification & Performance of Mechanical & Electrical Rotating Equipment	Cranfield University (UK)	ESR-G (Dionysios Xenos)
Language courses (German, Italian)	Ladenburg (Germany), Terni (Italy)	ESR-K (Hubert Hadera), ESR-L (Dragoljub Gajic), ESR-N (Robin Cartoux)
Control & Operation of centrifugal gas compressors	ESD Training (UK)	ESR-G (Dionysios Xenos)
Negotiation Skills course	IMECHE, London (UK)	ESR-K (Hubert Hadera)
Visiting Researcher with Dr. Joakim Ekström	University of Linköping, Campus Norrkoping (Sweden)	ESR-K (Hubert Hadera)

Dissemination

- Website and blog
- Publications
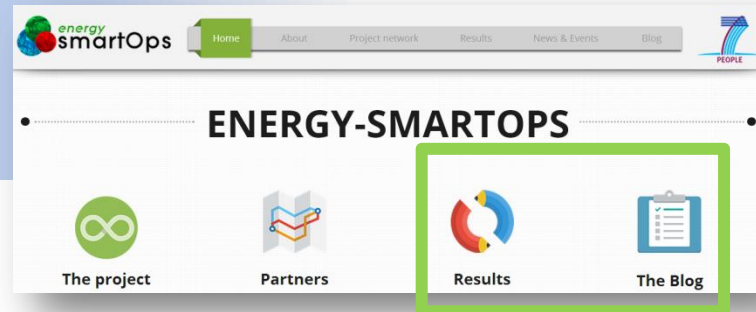
Type	Title	Place and Date	Status	Author
Journal publication	Improved energy-awareness formulation for Mixed Integer Linear Programing continuous-time scheduling models (working title)	Industrial and Engineering Chemistry Research	Under revision by co-authors (01/ 2015)	ESR- K (Hubert Hadera)
Journal publication	Optimization of steel production scheduling with complex time-sensitive electricity cost	Computers and Chemical Engineering	Accepted	ESR-K (Hubert Hadera)
Journal publication	Integration of production scheduling and energy-cost optimization using Mean Value Cross Decomposition (working title)	Computers and Chemical Engineering	Under revision by co-authors (01/2015)	ESR-K (Hubert Hadera)
Journal publication	Modeling and optimization of energy-efficient procedures for removing lead(II) and zinc(II) ions from aqueous solutions using the central composite design	Energy	Published	ESR-L (Dragoljub Gajic)
Conference paper	Continuous-time Batch Scheduling Approach for Optimizing Electricity Consumption Cost	ESCAPE23, Lappeenranta, June '13	Published	ESR-K (Hubert Hadera)
Conference paper	Production scheduling optimization in a melt shop	SDEWES 2014, Bor, Serbia, October '14	Published	ESR-L (Dragoljub Gajic)
Conference paper	Optimization of a bentonite-based heterogeneous system for thermal energy storage	SDEWES 2014, Ohrid, Macedonia, July '14	Published	ESR-L (Dragoljub Gajic)

# Dissemination

Publications(2)

| Type	Title	Place and Date	Status	Author
Conference paper	Modelling and optimization of methylene blue adsorption from aqueous solution using bentonite clay	ESCAPE24, Budapest, June '14	Published	ESR-L (Dragoljub Gajic)
Conference paper	Key Note Lecture: Steel production scheduling under time-sensitive electricity cost	ESCAPE24, Budapest, June '14	Published	ESR-K (Hubert Hadera)
Conference paper	A Cross Decomposition Strategy for Industrial Demand-Side Management of a Pulping Process	ESCAPE25, Copenhagen, June '15	Accepted	ESR-K (Hubert Hadera)
Conference talk	Process and Production Optimization for Industrial Applications	SIAM, Boston, March '13	Published	ESR-K (Hubert Hadera)
Conference talk	Steel Plant scheduling with optimization of time-sensitive electricity purchases	AIChE, San Francisco, Nov '13	Published	ESR-K (Hubert Hadera)
Conference talk	Plant-wide coordination for the energy-efficient scheduling of an integrated steel production process	AIChE, Atlanta, Nov '14	Published	ESR-N (Robin Cartoux)
Conference talk	A Bi-Level Heuristic for Steel Plant Scheduling Under Complex Time-Sensitive Price Structures	AIChE, Atlanta, Nov '14	Published	ESR-K (Hubert Hadera)
Poster	ITN poster sessions	Krakow, '12 Ladenburg, '13	Published	ESR-L (Dragoljub Gajic), ESR-K (Hubert Hadera)
Poster	Enterprise-wide optimization in an integrated stainless steel mill	Pittsburgh, March '14	Published	ESR-L (Dragoljub Gajic)
Poster	Electricity demand-side management in steel plant scheduling	Pittsburgh, March '13	Published	ESR-K (Hubert Hadera)
Interview	ABB de.inside.com Unicum student magazine	Germany, Jan '12 Germany, Jan '12	Published	ESR-K (Hubert Hadera)
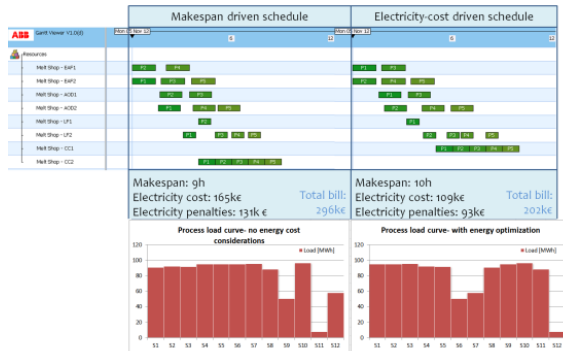
ESR-K (Hubert Hadera)

- The potential impact of intelligent energy-aware scheduling of processes has been evaluated by ESR-K (Hubert Hadera) to a reduction of electricity cost of 2-20%

(See papers and presentations with case study results in the publication list: ESCAPE23, AICHE2013, ESCAPE24)
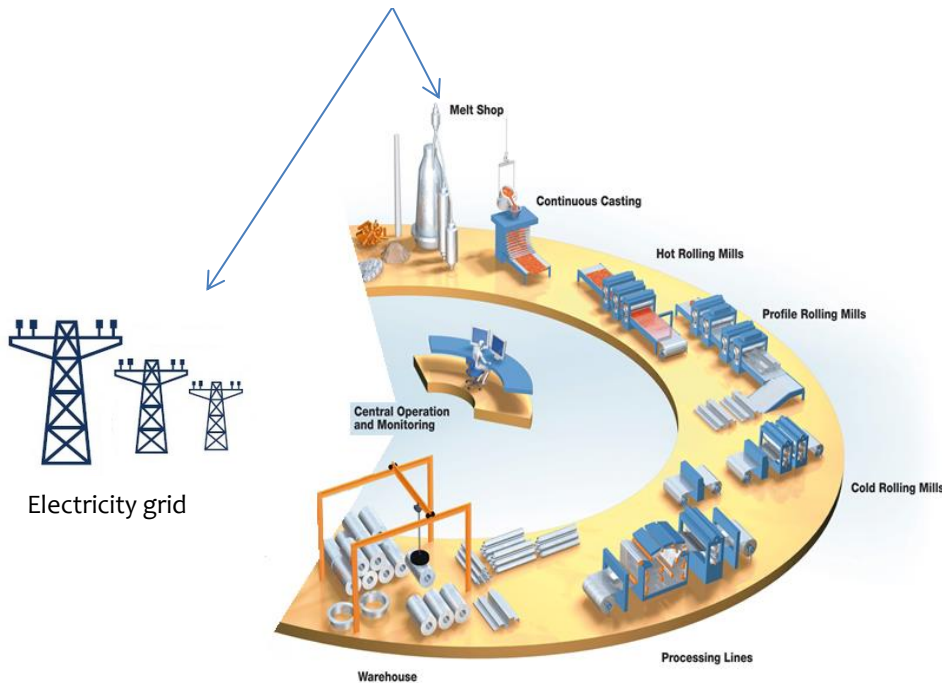
- Improvement of the coordination between the meltshop hot rolling area
- Potential to reduce inventory levels and reheating energy consumption, thus reducing natural gas consumption and GHG emissions. Prototype testing showed potential reheating energy savings up to 20%.

ESR-N (Robin Cartoux)
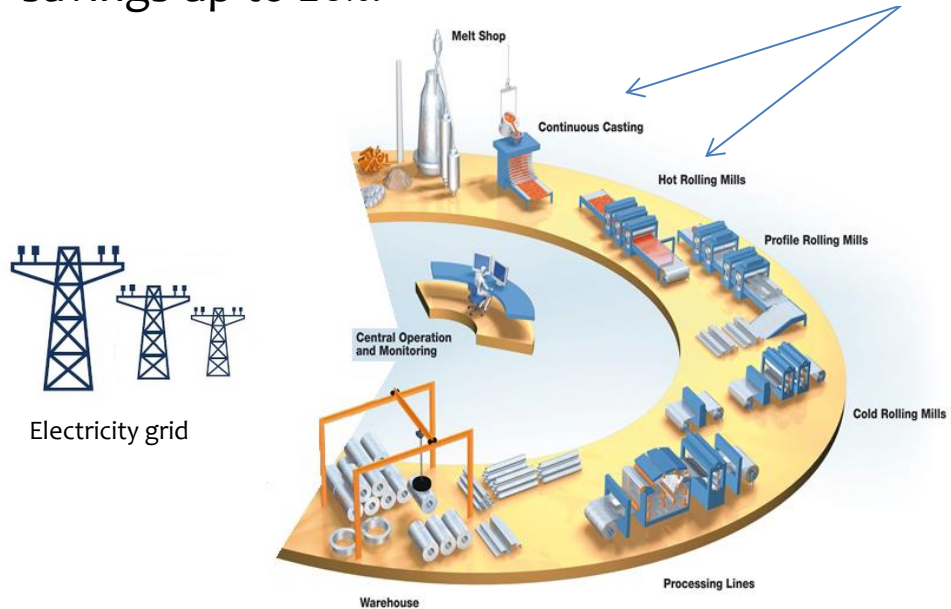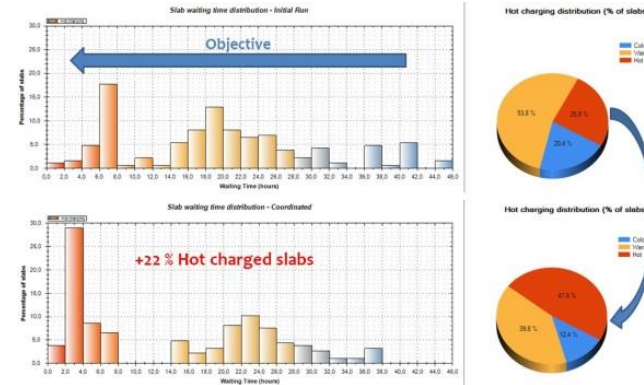
Electricity grid

ESR-L (Dragoljub Gajic)

- The system deployment has improved coordination between different production stages in the melt shop and thus lowered hold-up times, electricity costs and increased production rate.
- Benefits are estimated to be:
    - Reduction in energy consumption: up to 5%
    - Reduction in lead times: 4-5%
    - Reduction in inventory levels: 2-3%

Achievements

energy **smartOps**
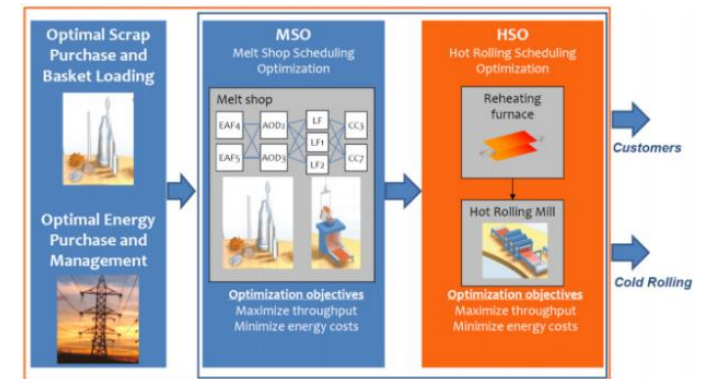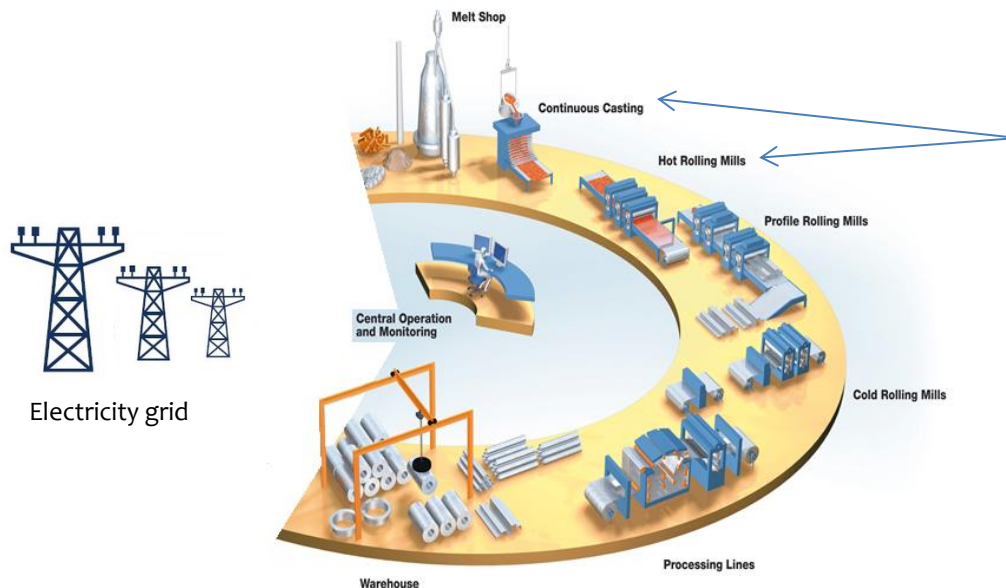
INTENDED OUTCOME

Create the means to deal with increasing volatility in production, energy & raw material availability. The key aspect is to ensure seamless integration and availability of data and information across the plant, enabling user interaction and connection to optimization solutions.

Bridge the gap between production, energy management and maintenance. This can be enabled through intelligent and adaptable advanced analysis tools.

Enable energy and cost savings through optimization. This will require new approaches where traditional planning models must be expanded to cover larger problem instances and energy consumption (industrial demand-side management).

METHODOLOGY DEVELOPED

Level-2 systems have been integrated and all relevant information can be collected and visualized. Flexible user interfaces linked to optimization enable the possibility to perform planning tasks manually, partly or fully supported by the optimization tools.

Data mining applying statistical pattern recognition and signal processing has made it possible to identify maintenance needs more efficiently.

Mixed integer linear programming optimization models have been studied to include production scheduling and energy volatility, i.e. availability and price. Continuous and discrete-time scheduling models using various decomposition schemes have been developed, for instance applying mean value cross decomposition.

MEASURE OF SUCCESS

The use of scheduling optimization improved the coordination between different production stages in the melt shop, lowered the hold-up times and increased the production rate.

The potential benefits have been estimated to
- 5% reduction in energy consumption,
- 4-5% in lead times,
- 2-3% in inventory levels.

The potential impact of intelligent energy-aware scheduling of processes has been evaluated to enable a reduction of electricity cost of 2-20%.

The use of an optimized coordination policy between melt shop and rolling mill reduce thermal losses. The anticipated increase of hot charging ratio is up to +22%

- Optimization models deliver energy savings and reduced energy cost

- Promising results, strong track of publications

- Methodology tested in real world application
  - Implementation in the process
  - Test case AST Terni

- Strong collaboration within the WP5

Thank you for the attention