



Life-cycle optimization of industrial energy efficiency by a distributed control and decision-making automation platform

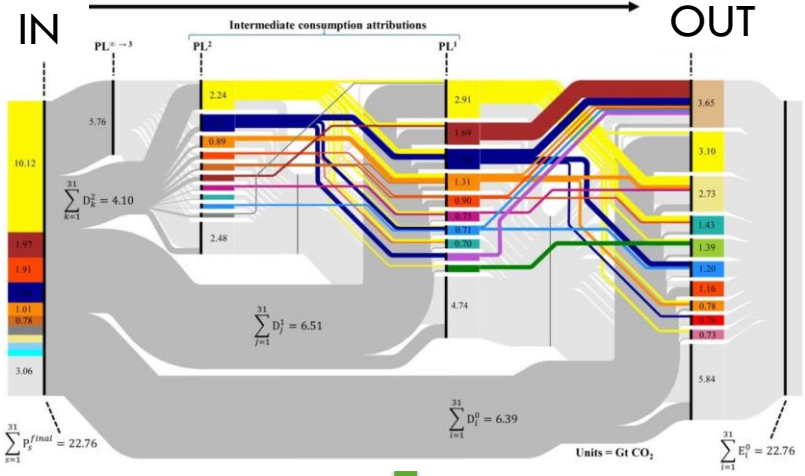
ADVANCED ENERGY MANAGEMENT AND OPTIMIZATION FOR SMART INDUSTRY 5.0 MANUFACTURING

Andrea Ballarino
Project Coordinator



European manufacturing industry today

- material
- energy
- ...
- water

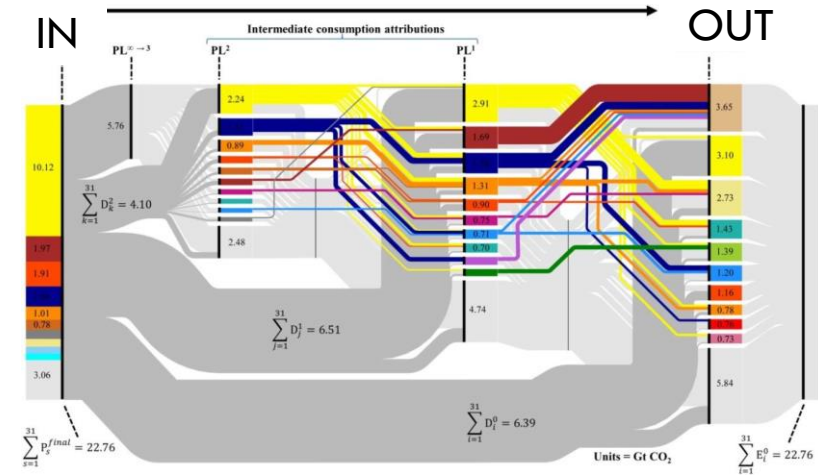
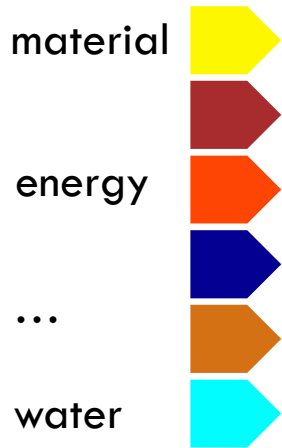


Energy and LC management



Production





Energy and LC management

Production

time

energy (efficiency) and Life Cycle-related aspect management

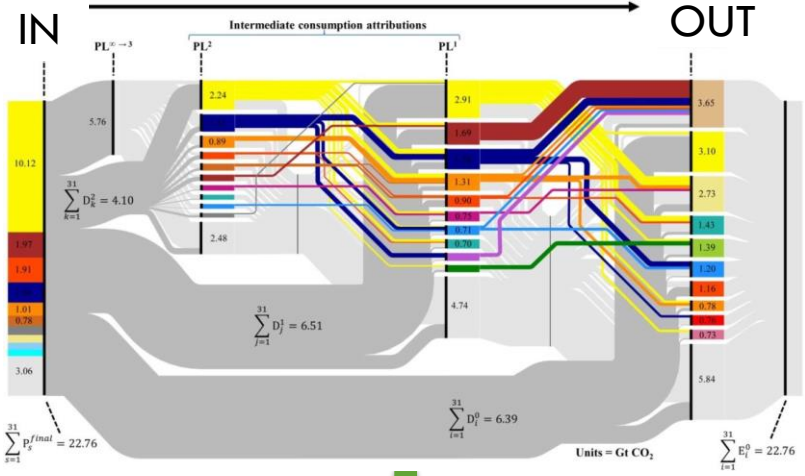
→ (eventually) understanding how (well/bad) the production performed **afterwards**

→ non **homogeneous/incomplete** information granularity

→ Impossibility to **transform information into** respective **actuation** level

European manufacturing industry need (2)

- material
- energy
- ...
- water



Energy and LC management

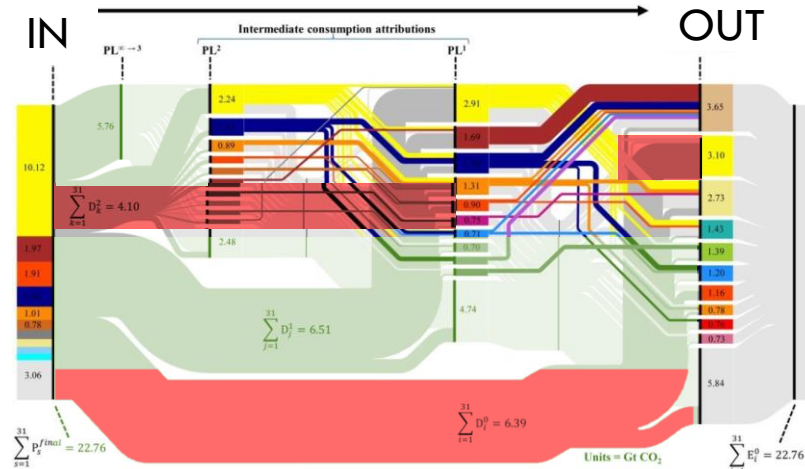


Production



European manufacturing industry need (2)

- material
- energy
- ...
- water



Energy and LC management

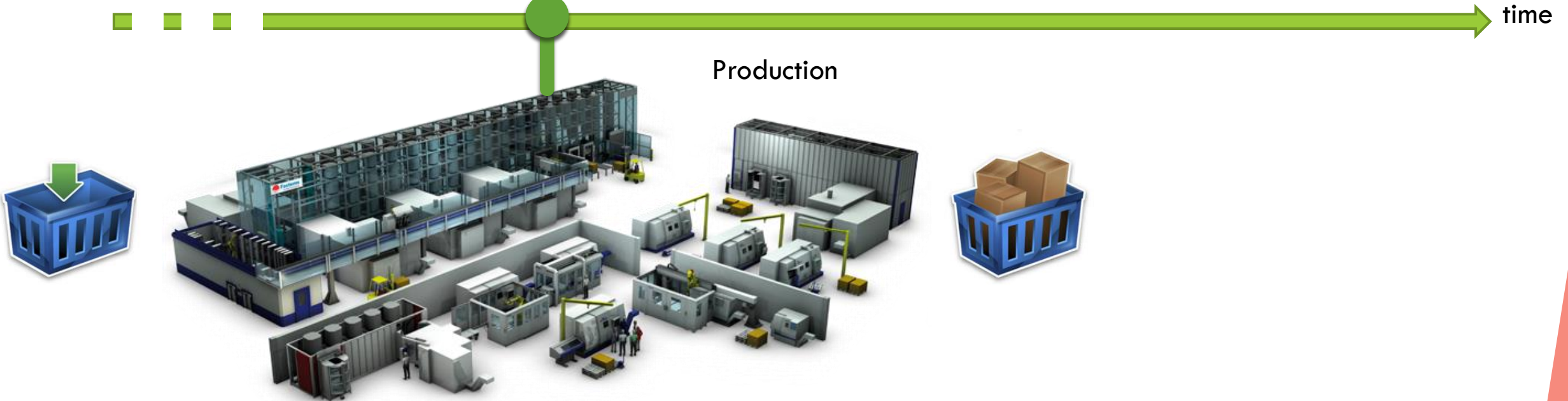
Anticipating: from “after” to “in between”

What does it imply?

- Completing and characterising:** full production-, Material-, Energy-, Life-cycle-related information flow
- Synchronizing:** in time information

What does it offer?

- Decision making:** “how can I energy efficiently/ sustainably steer production”



European manufacturing industry need: the strategy

- material
- energy
- ...
- water



Energy and LC management

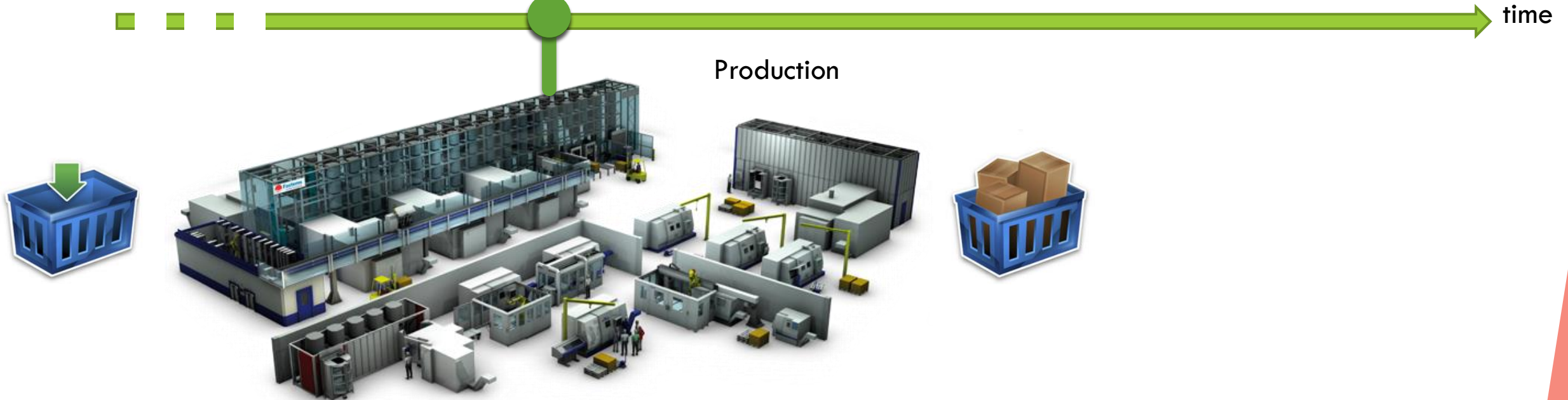
Anticipating: from “**after**” to “**in between**”

What does it imply?

- **Completing and characterising:** full production-, Material-, Energy-, Life-cycle-related information flow
- **Synchronizing:** in time information

What does it offer?

- **Decision making:** “how can I energy efficiently/ sustainably steer production”

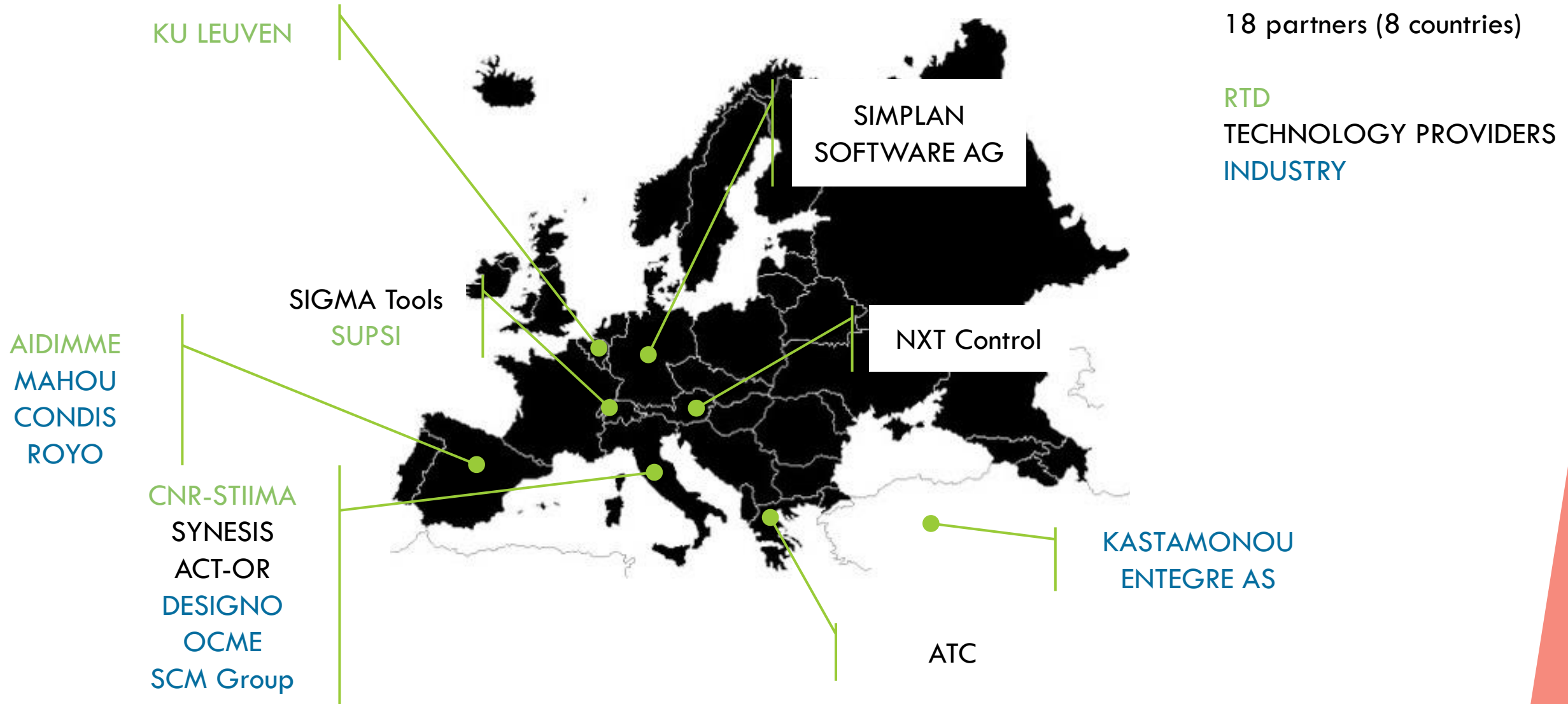




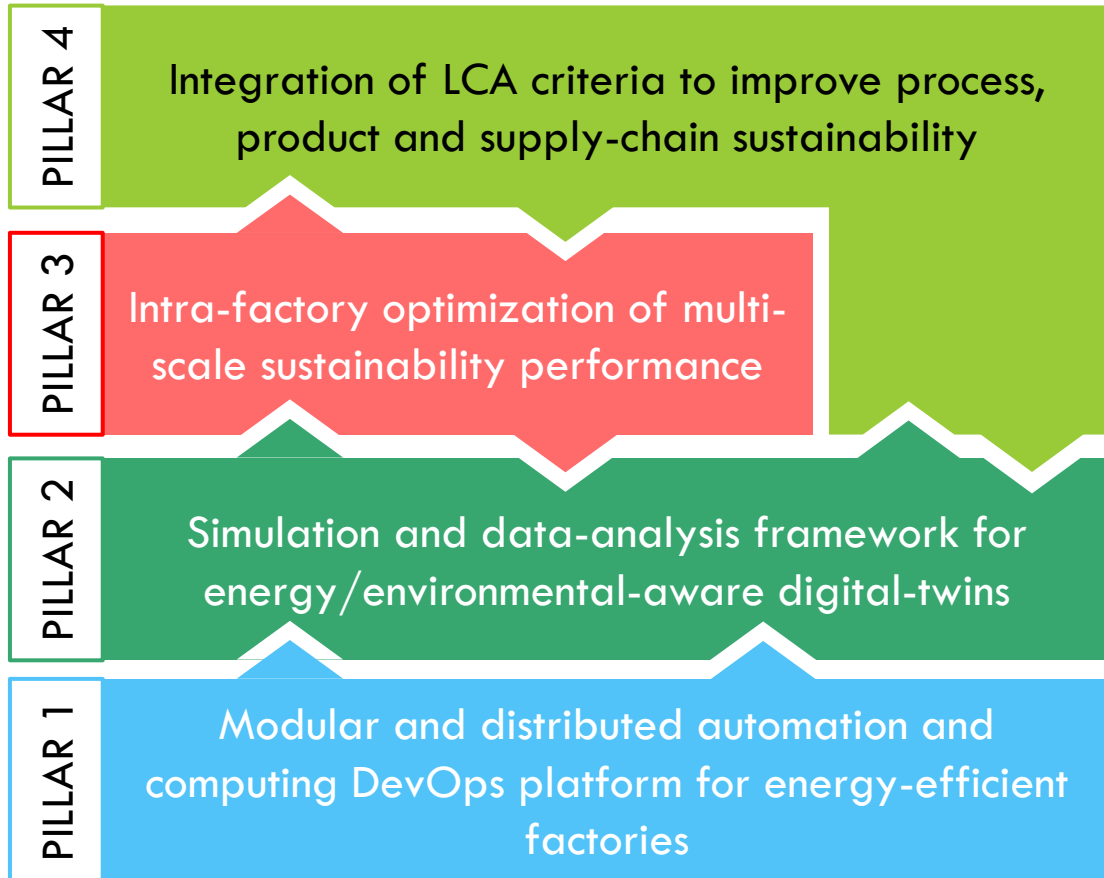
Life-cycle optimization of industrial energy efficiency by a distributed control and decision-making automation platform

E2COMATION H2020 Project at a glance

A rich-in-competence and diversified consortium

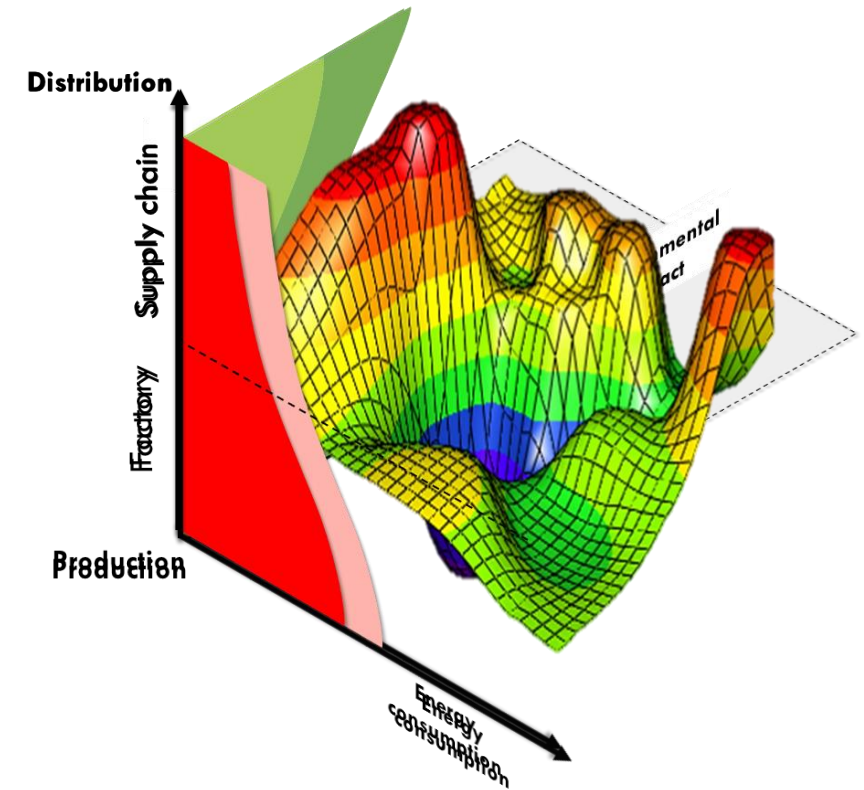


**A novel approach toward
Smart Industry 5.0 manufacturing
based on
Energy Efficiency and Optimization and
Sustainable Management**

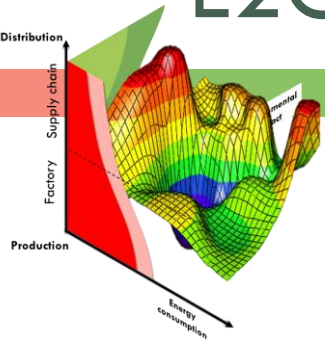


Purpose:

- **Decision making:** “how can I energy efficiently/sustainably steer production



E2COMATION Pillars: Pillar 1..

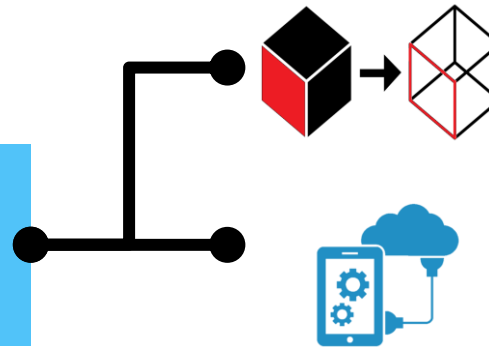


Purpose:

- **Completing and characterising:** full production-, Material-, Energy-, Life-cycle-related information flow
- **Synchronizing:** in time information

PILLAR 1

Modular and distributed automation and computing DevOps platform for energy-efficient factories



Life-cycle conceptual paradigm applied to digital twinning of factory assets

Modular and scalable automation platform for distributed monitoring and supervision.

New data gathering and automation platform

WP3/4

Distributed Stream
Computing & Analytics

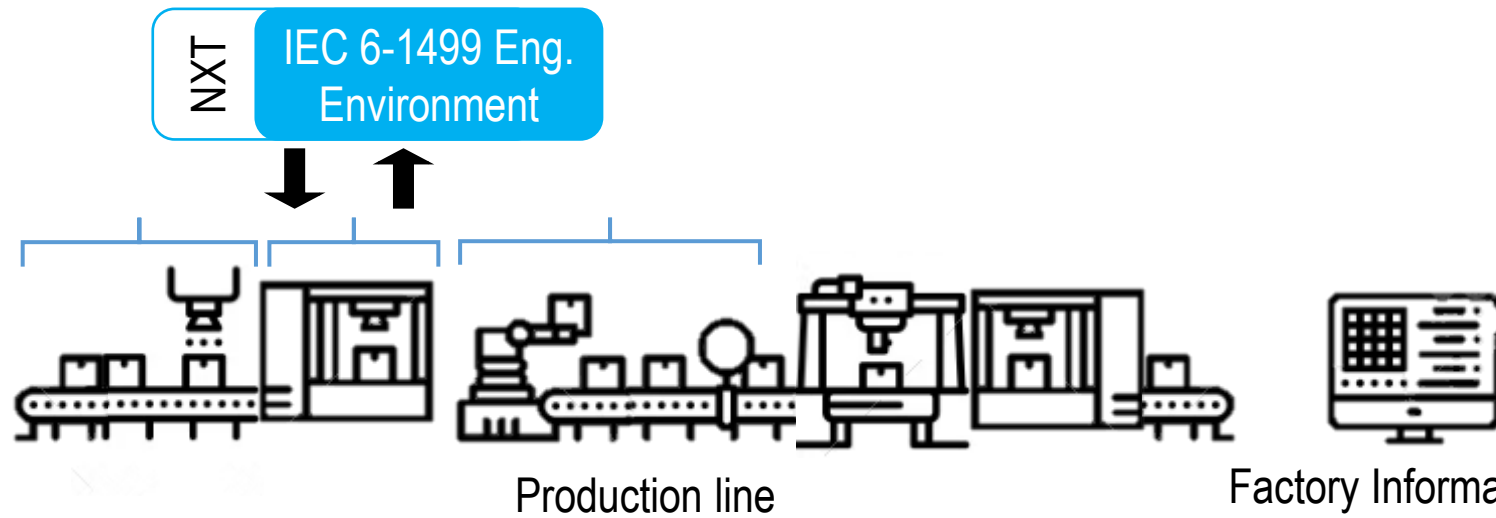
WP3/4

Energy & Production
Data Gathering & Control

IEC 6-1499 Modular and reconfigurable distributed monitoring, automation and control.

A **scalable automation solution** to seamlessly move across the automation pyramid from machine, to cell, to line, till plant level.

- **Gathering data from all greenfield sensors**
- **Providing the control action**



New data gathering and automation platform

WP3/4

Distributed Stream
Computing & Analytics

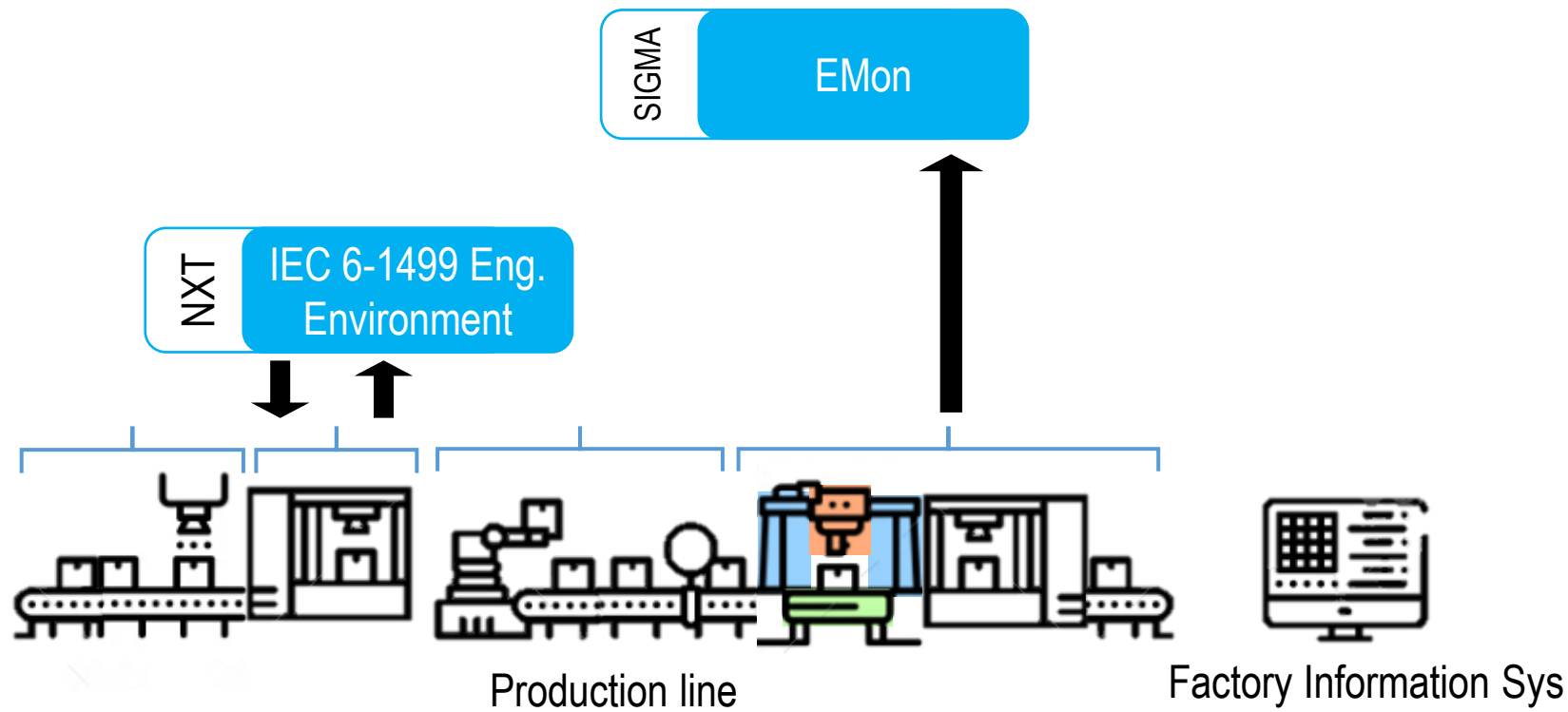
WP3/4

Energy & Production
Data Gathering & Control

EMon – Energy Monitoring

A comprehensive and holistic strategy to **energy monitoring** which is based on **multichannel measurement methodology**

- **Fingerprint** measurement
- **Component** analysis / monitoring
- **KPI / EnPI**



WP3/4

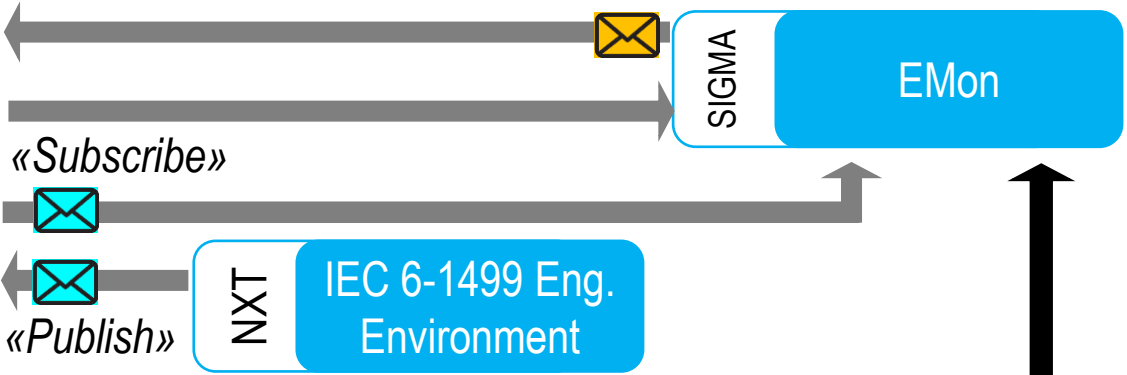
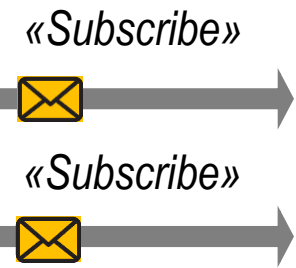
Distributed Stream Computing & Analytics

WP3/4

Energy & Production Data Gathering & Control

«Topic» based broadcast technology

MQTT com bus

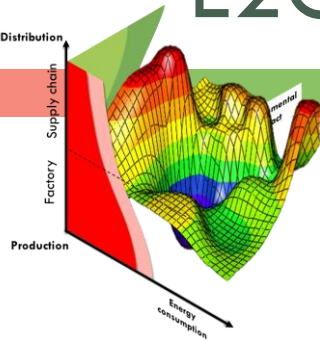


Production line

Factory Information Sys

MQTT as E2COMATION backbone for communication
 MQTT is an OASIS standard **messaging protocol** for the Internet of Things (IoT). It is designed as an extremely **lightweight publish/subscribe messaging** transport that is ideal for connecting remote devices with a small code footprint and minimal network bandwidth.

E2COMATION Pillars: Pillar 2..



Purpose:

- **Decision making:** “how can I energy efficiently/sustainably steer production

PILLAR 2

Simulation and data-analysis framework for energy/environmental-aware digital-twins

PILLAR 1

Modular and distributed automation and computing DevOps platform for energy-efficient factories

Data stream analytics

Holistic analysis of energy-related data streams for production performance forecasting

Live analysing and elaborating the data flows coming from the physical systems for:

- Empowering the **updating of DT model**
- Specific **pattern/event recognition to detect triggering conditions**

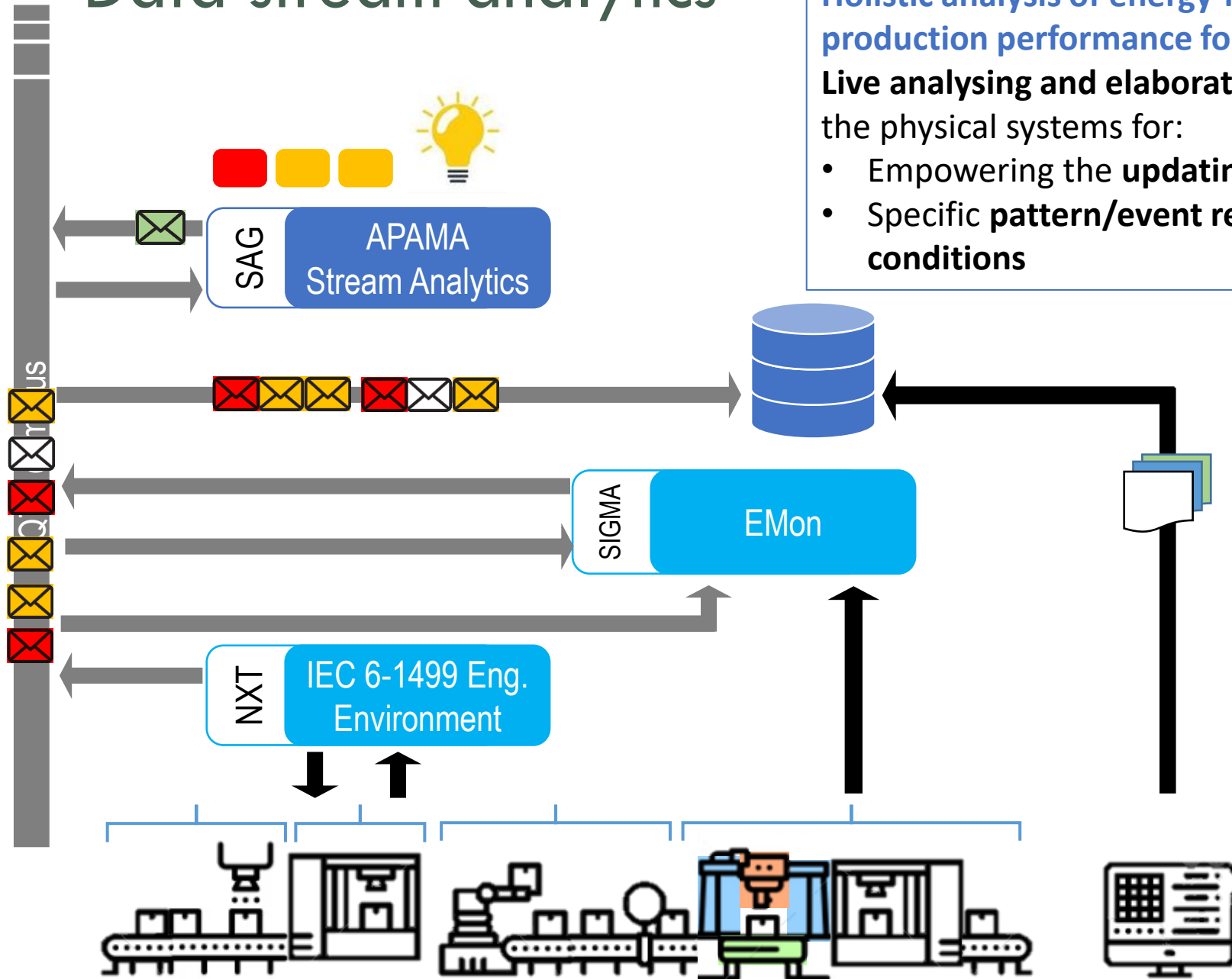


WP3/4

Distributed Stream Computing & Analytics

WP3/4

Energy & Production Data Gathering & Control



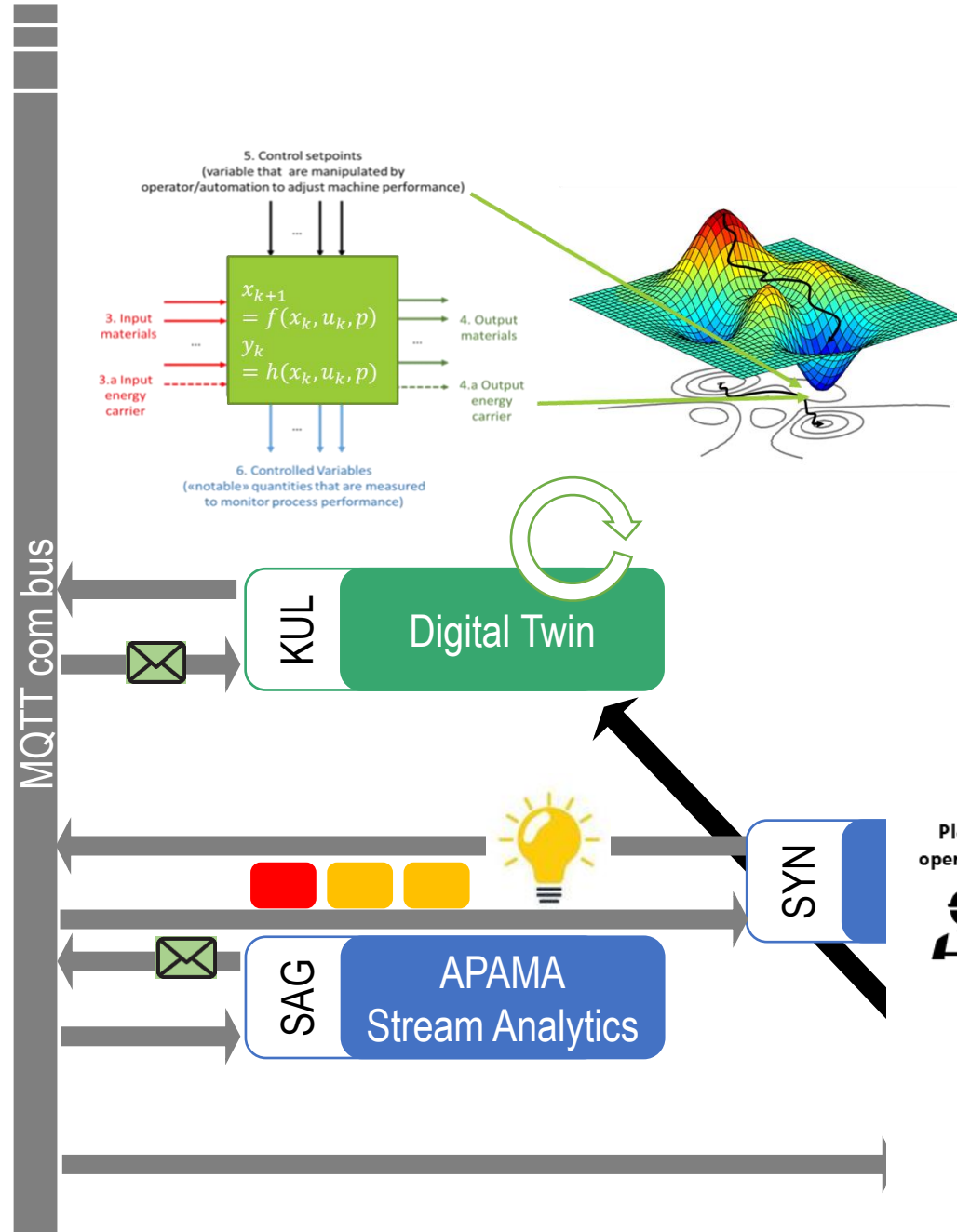
Production line

Factory Information Sys

Digital twin of process factory asset

A computational model to assess the effect of various (potential) changes in the process:

- **Process monitoring:** detect deviations between DT and real process, and generate information that's not directly/continuously measurable e.g. total energy usage, product quality,...
- **Process optimization** – Using DT model to simulate the asset for different operational settings and find best control setpoints

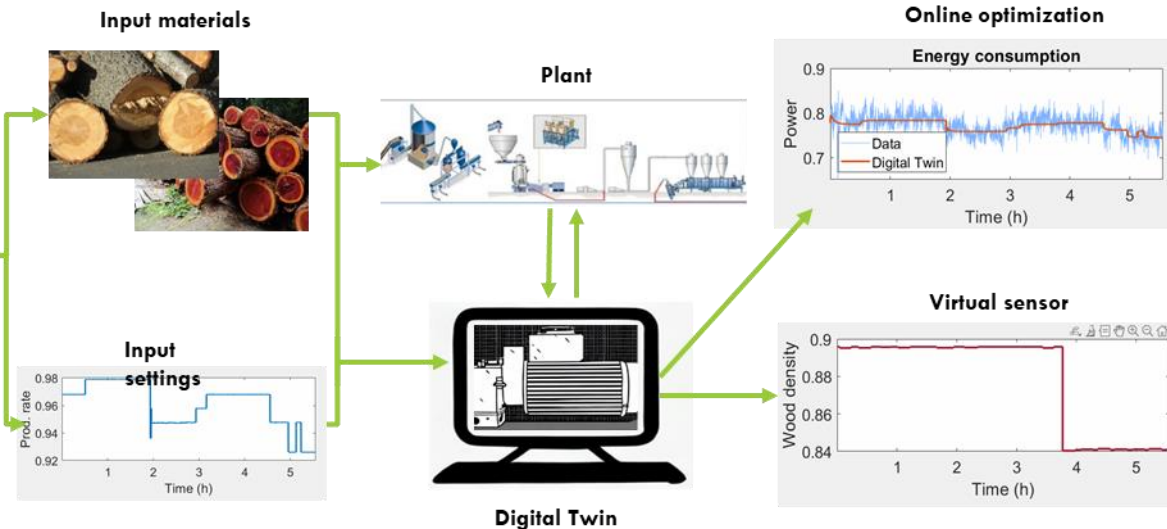


WP4

Process Digital Twin and Simulation tool

WP3/4

Distributed Stream Computing & Analytics

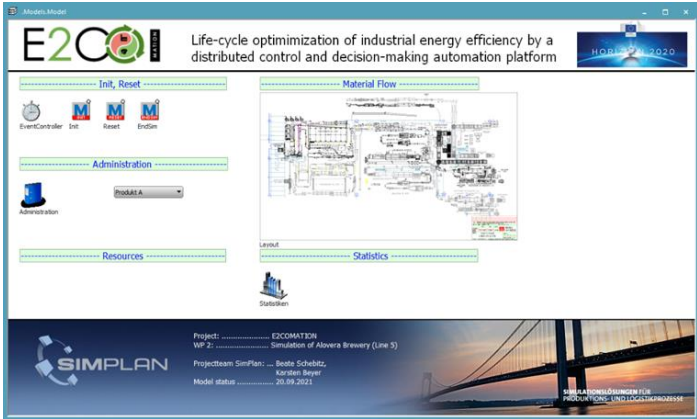
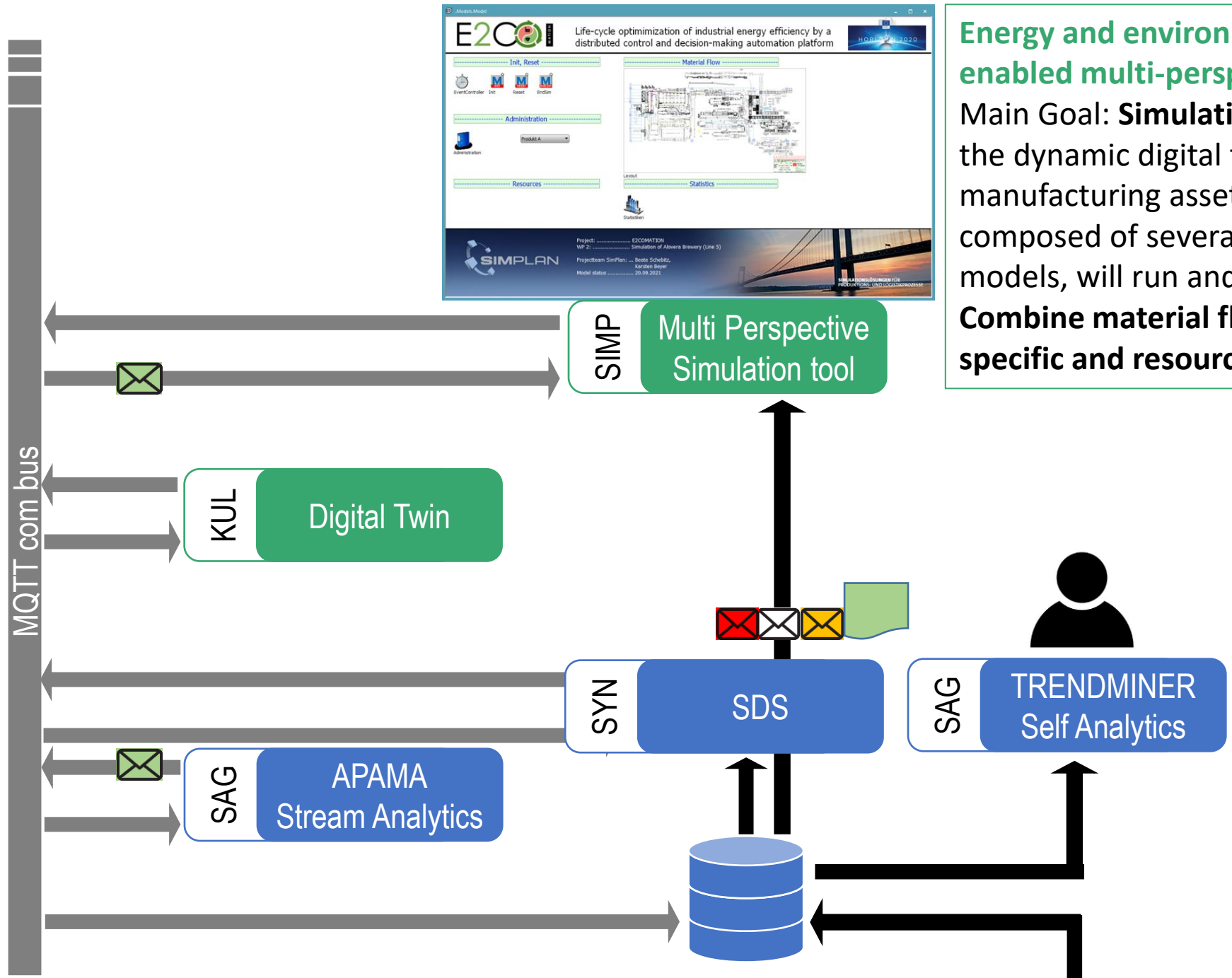


WP4

Process Digital Twin and Simulation tool

WP3/4

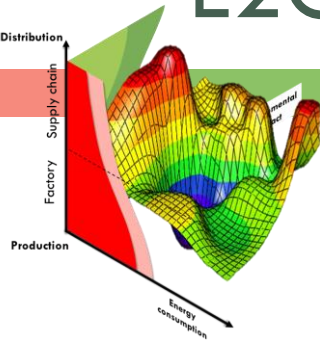
Distributed Stream Computing & Analytics



Energy and environmental performance-enabled multi-perspective simulation
 Main Goal: **Simulation framework** in which the dynamic digital twins of the manufacturing assets of the factory, composed of several independent behavioral models, will run and interact.
Combine material flow analysis with energy specific and resource specific flows

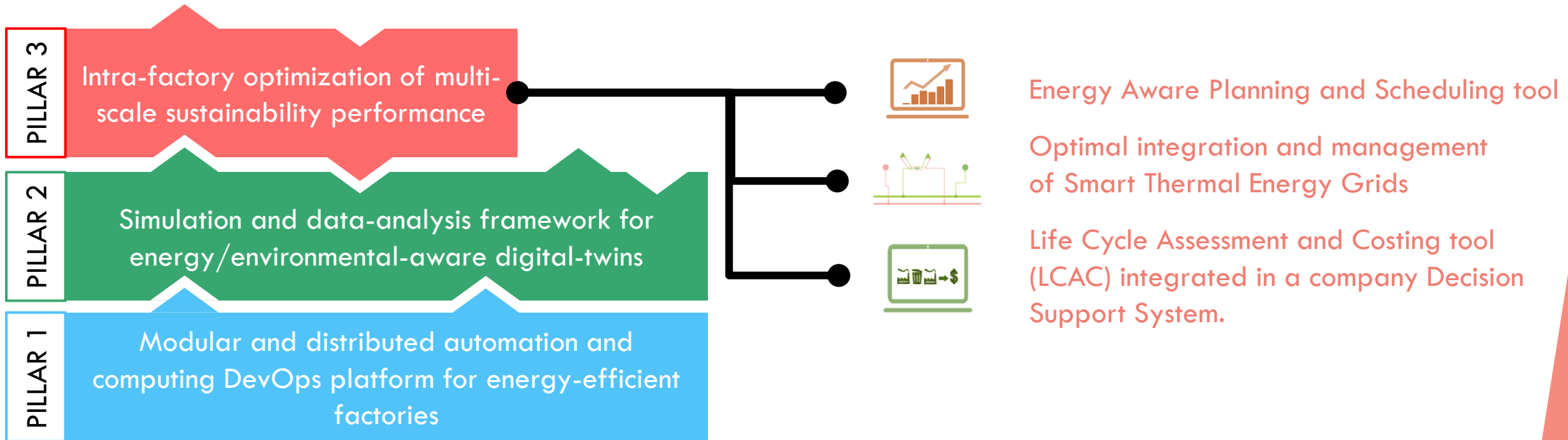


E2COMATION Pillars: Pillar 3..



Purpose:

- **Decision making:** “how can I energy efficiently/sustainably steer production



WP5/6

Energy Optimization
Process Assessment

CNR

EAPS/
EAPC Tools

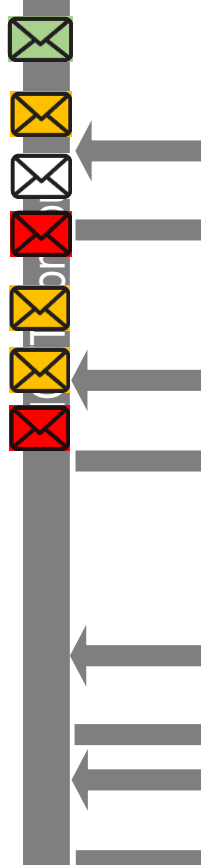
Energy Aware P&S/Process Control

Energy Aware Optimization (Planning & Scheduling in Discrete manufacturing/Process Control in Process Industry) of production process, **conjugating production efficiency and energy saving, by:**

- **using flexibility in energy contracts** based on real time exploitation of energy hourly price and
- **leveraging on available degrees of freedom** in production process

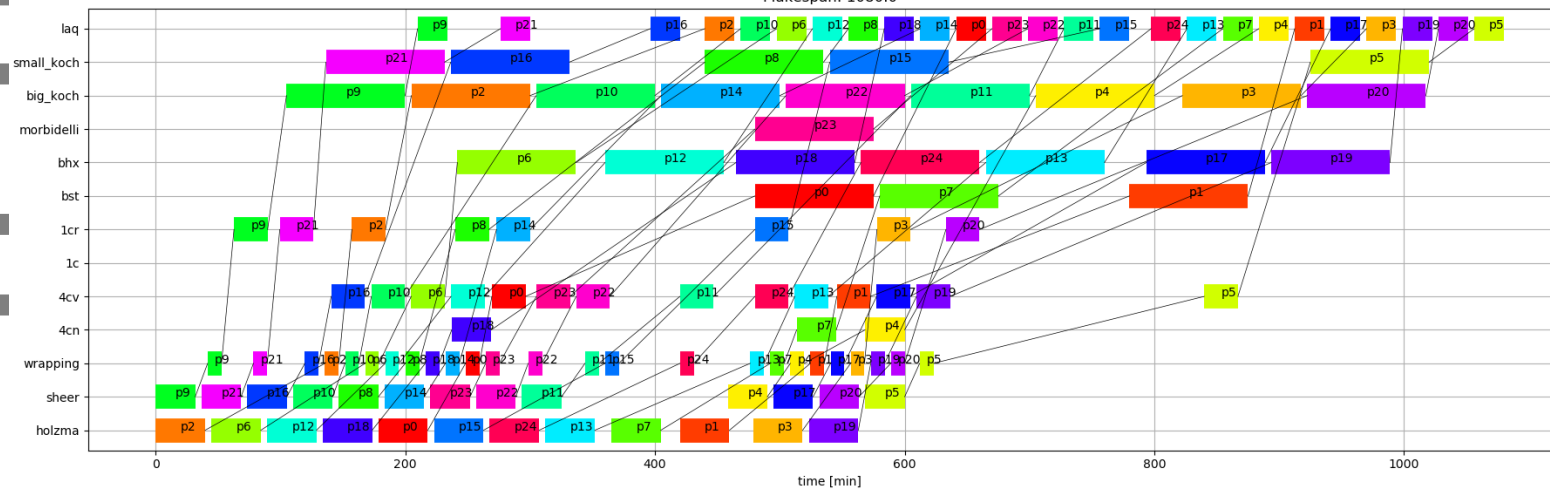
WP4

Process Digital Twin
and Simulation tool



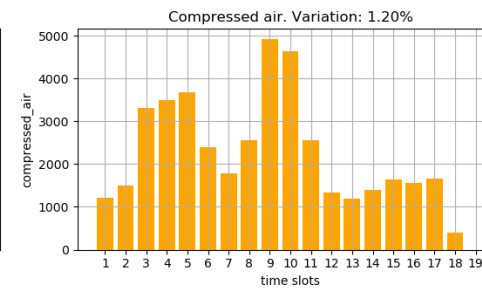
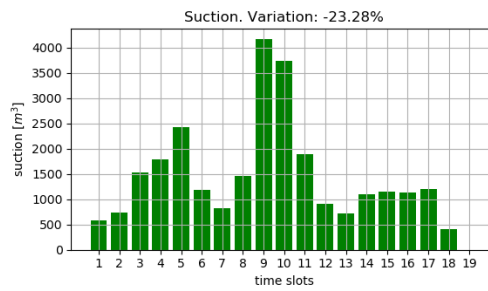
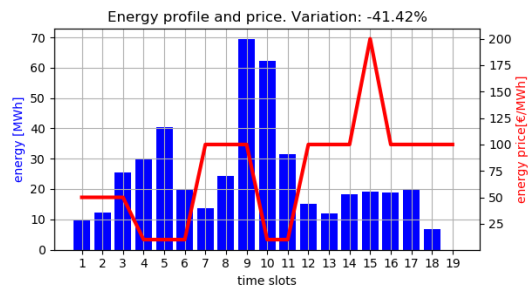
With EAPS

Makespan: 1080.0



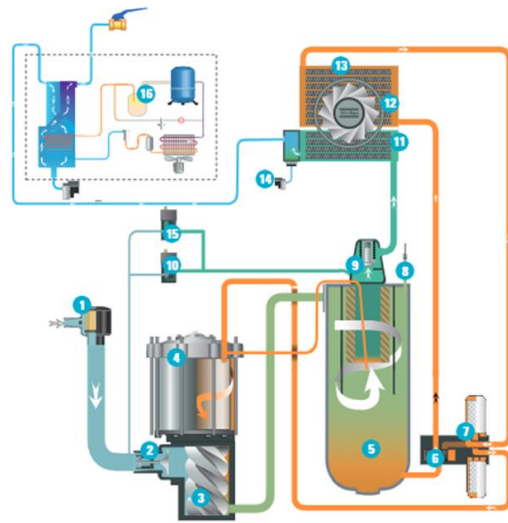
WP3/4

Virtual Stream
Monitoring & Analytics



WP5/6

Energy Optimization
Process Assessment

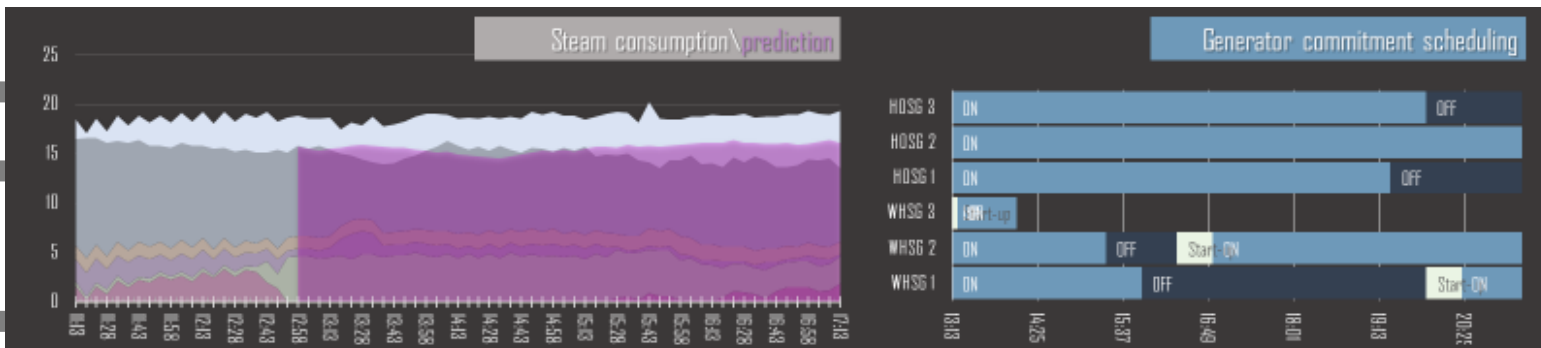


SMART TEG Tool
Smart Thermal/Electric Energy Grid Management, capable of **optimally controlling on-site energy generation units based on high-level dynamic models and forecast of the resource demand (from EAPO):**

- Unit commitment of generators
- Optimal operating point (set-point)

WP4

Process Digital Twin and Simulation tool



WP3/4

Virtual Stream Monitoring & Analytics

STIMA
Sistemi e Tecnologie Industriali Intelligenti per il Manifatturiero Avanzato

E2CO
Smart-TEG Optimizer

LCA&Costing Tool
Modular and dynamic tool to assess Life Cycle Assessment and Costing at factory/value chain levels against PEF/OEF, and also to predict environmental footprint

WP5/6

Energy Optimization
Process Assessment

CNR EAPS/
EAPC Tools

CNR SMART TEG
Tool

CNR LCAC Tool

WP4

Process Digital Twin
and Simulation tool

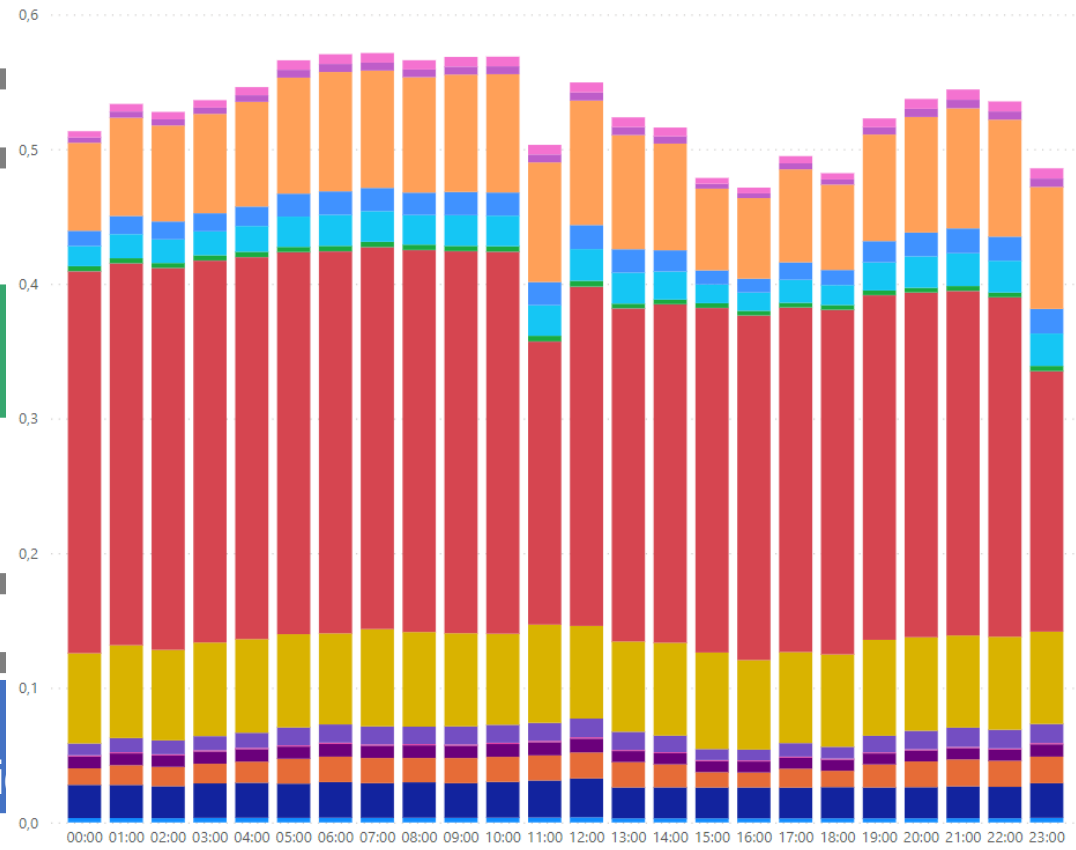
KUL Digital Twin

WP3/4

Automated Stream
Modeling & Analytics

SAG APAMA
Stream Analyti

LCAC IMPACTS OVER TIME BY AREA OR MACHINE



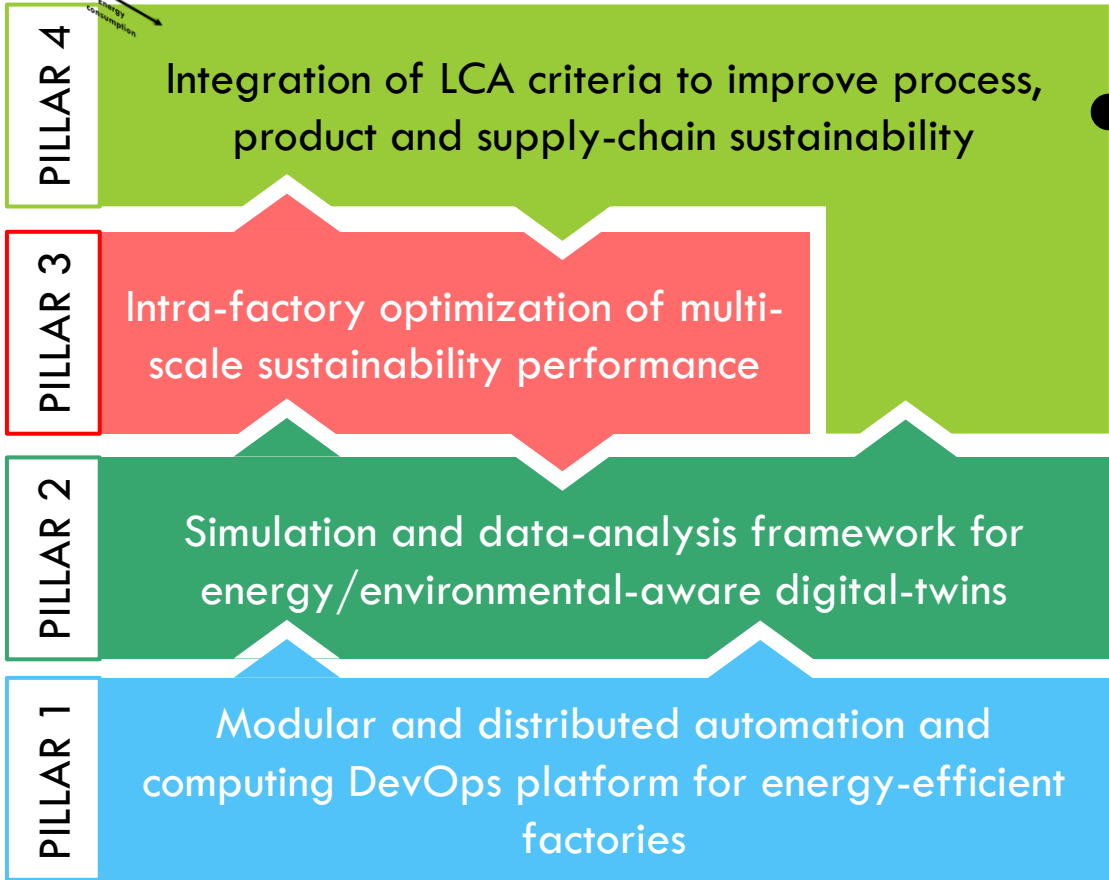
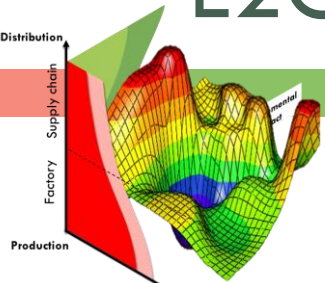
- AREA/MACHINE**
- Chip bin
 - Digester
 - Dryer 1, electricity
 - Ecoresinator/glueing
 - Flush
 - Forming
 - General consumptions
 - Gluing
 - Grinding chamber
 - Mechanical seal
 - Other electricity consumers
 - Pressing
 - Refiner
 - Sizing and storing
 - Wind sifter

ITEM	IMPACTS	UoM
Glue	0,26	kg CO2 eq
Wood	0,07	kg CO2 eq
Electricity	0,02	kg CO2 eq
Steam	0,01	kg CO2 eq

- LCAC IMPACT CATEGORY**
- Economic costs
 - Global warming (GWP100a)
- AREA/MACHINE**
Tutte

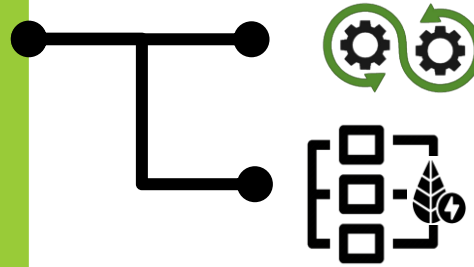


E2COMATION Pillars



Purpose:

- **Decision making:** “how can I energy efficiently/sustainably steer production

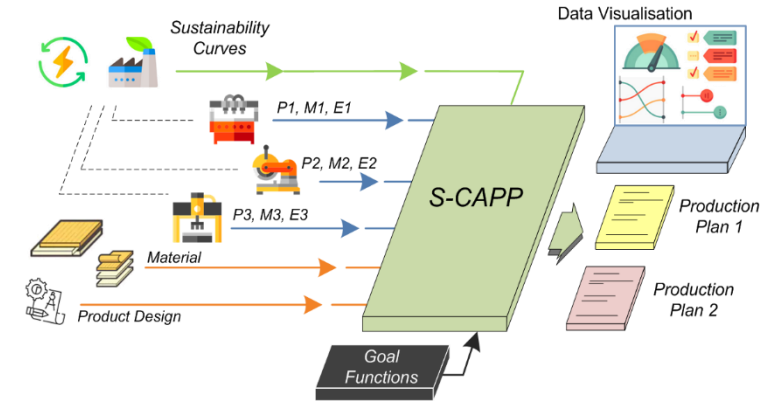


LCA-driven supply chain management (SCM)

Sustainable Computer Aided Process Planning (s-CAPP)

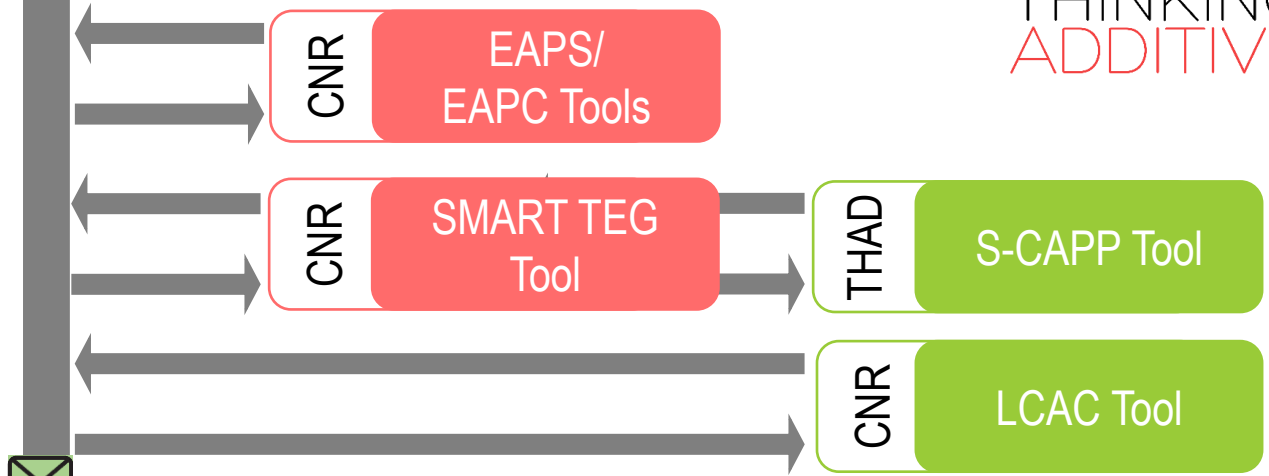
S-CAPP Tool

Generative CAPP Tool where the system automatically checks for requirements of components and selects the right processes
Generating new production pipelines based on different EPD/PEF factors of energy efficiency and environmental impact
 (Sustainability-driven)



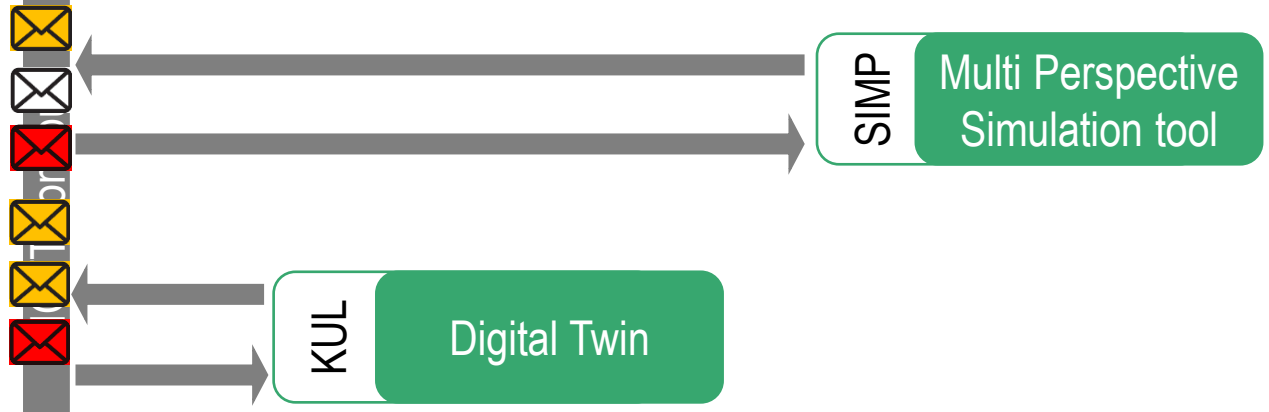
WP5/6

Energy Optimization
Process Assessment



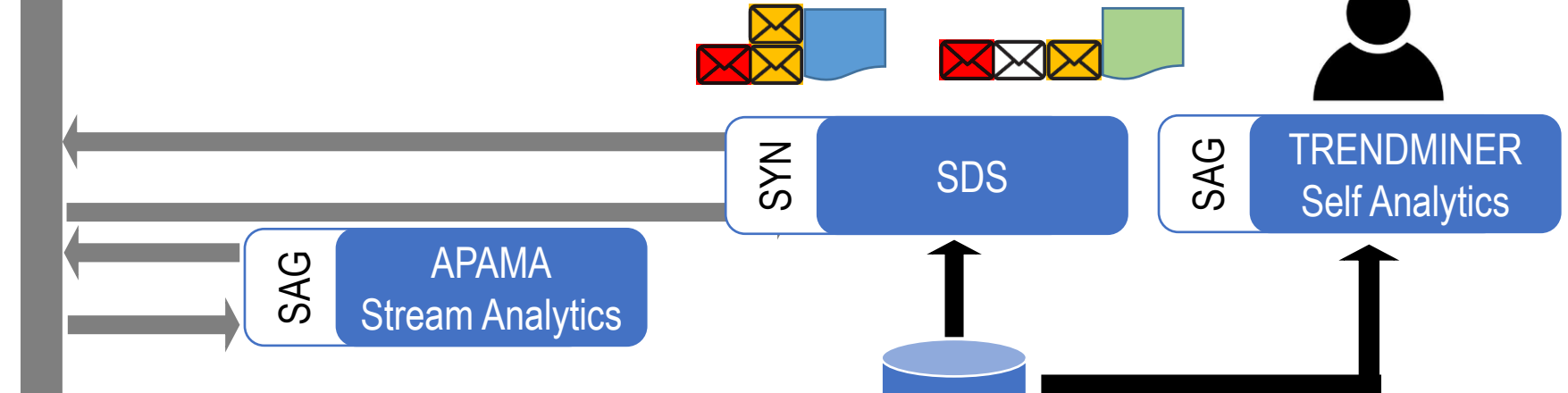
WP4

Process Digital Twin
and Simulation tool



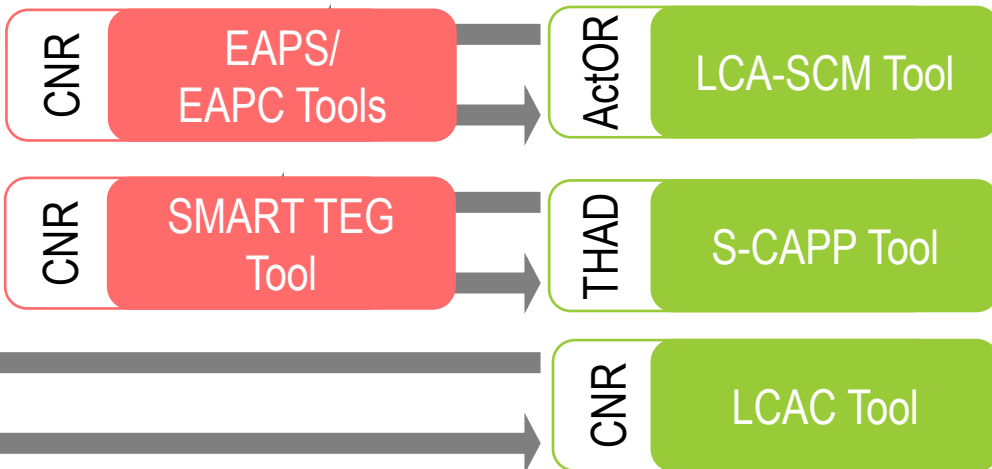
WP3/4

Automated Stream
Monitoring & Analytics



WP5/6

Energy Optimization
Process Assessment



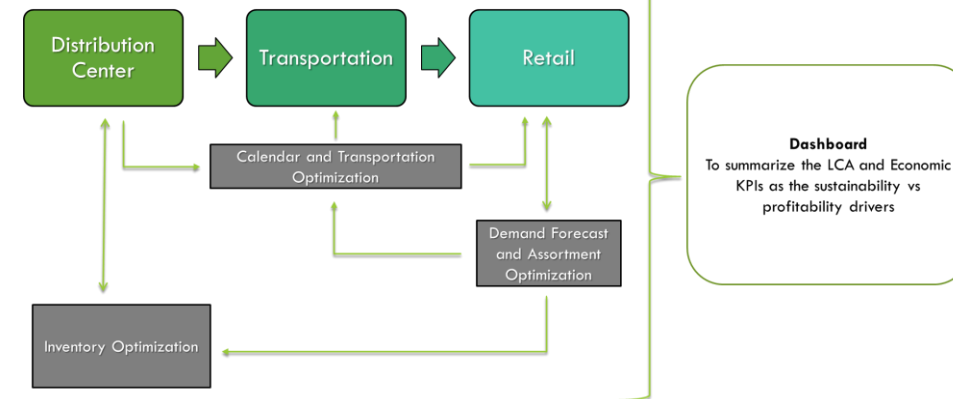
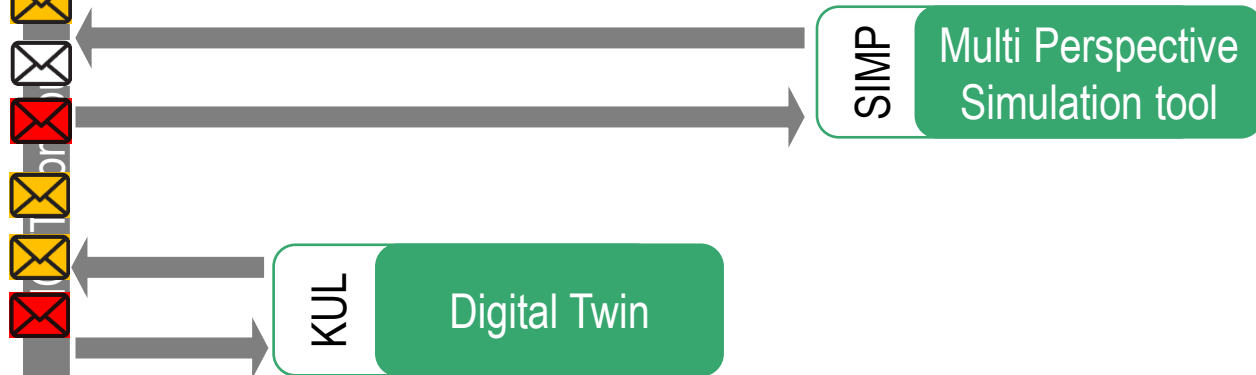
LCA driven SCM tool

Develop an **integrated management system**, by evolving the Bloomy Decision AID based platform, **to improve the value chain in both economic and sustainability terms.**



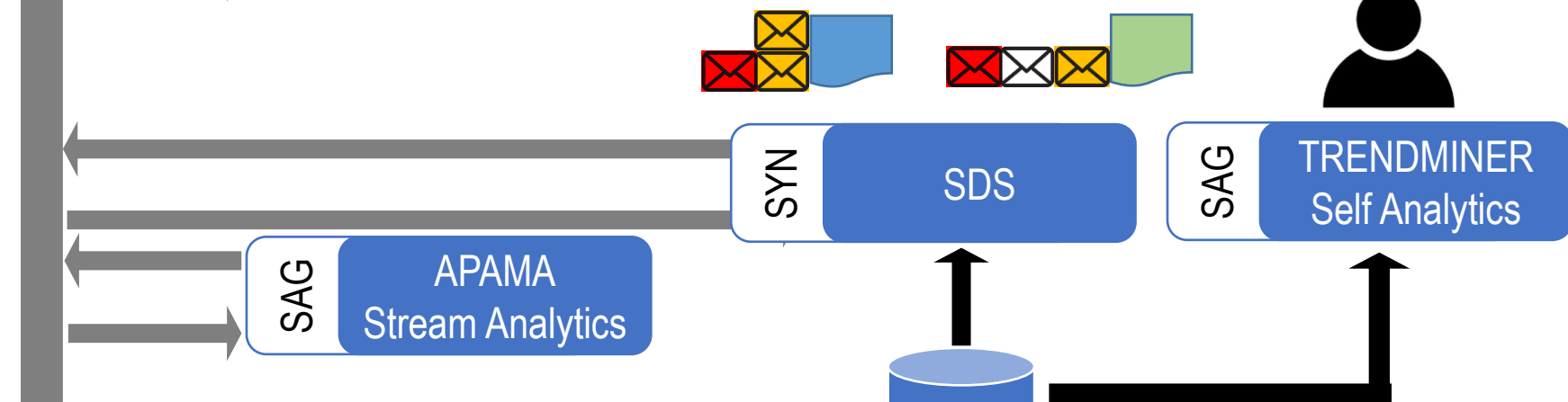
WP4

Process Digital Twin and Simulation tool



WP3/4

Automated Stream Monitoring & Analytics



WP5/6

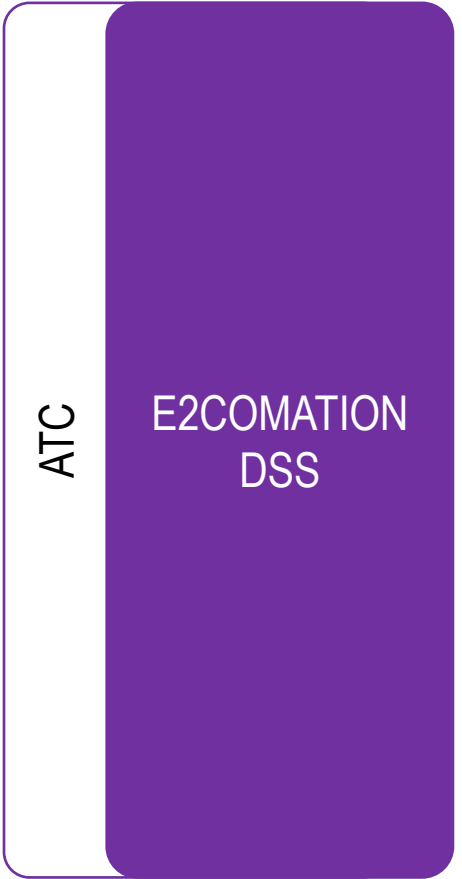
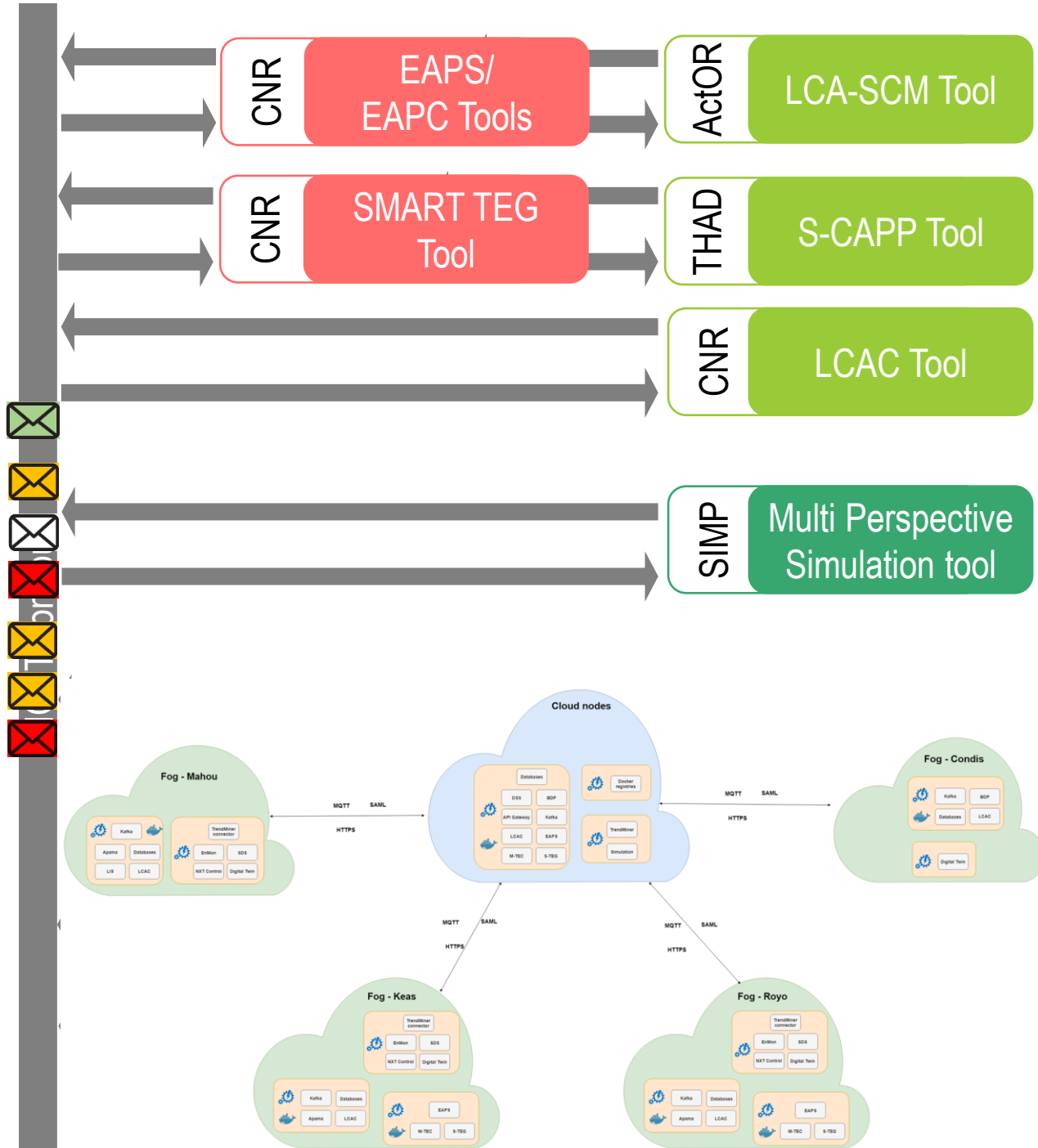
Energy Optimization
Process Assessment

WP4

Process Digital Twin
and Simulation tool

WP3/4

Virtualized Stream
Processing & Analytics



E2COMATION DSS Platform
Decision support platform for energy optimization and life-cycle management

- Implements a Cloud based solution that **integrates all tools and modules** into one robust platform
- **Handles the interaction** of the different modules

Where we are now: incoming validation in 2 Industries

4 Different Use cases

woodworking

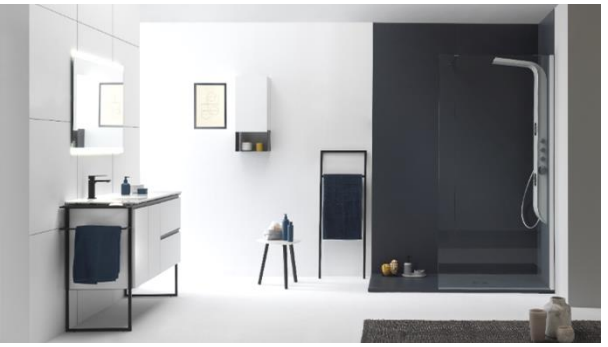
food&beverage



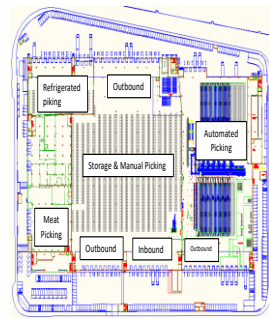
MDF production



Brewery bottling line



Bath Furniture manufacturing



Distribution & retail



Production line



Factory Information Sys



Gebze MDF & Particle Board Plant



- The process is currently monitored with more than **4500 sensing points**
- All data is recorded with a **3-year historical archive** within the existing software and shown in control room to operators
- Manufacturing systems are consumer of **both electricity and thermal energy** and **Kastamonu implements both purchase of energy from the network and internal production through co-generation**

Particle Board Production Capacity
560,000 m³/year
MDF Production Capacity
455,000 m³/year

MDF PRODUCTION

ELECTRIC CONSUMPTION

THERMAL AIR CONSUMPTION

REFINER



CHIPPER



DRYER

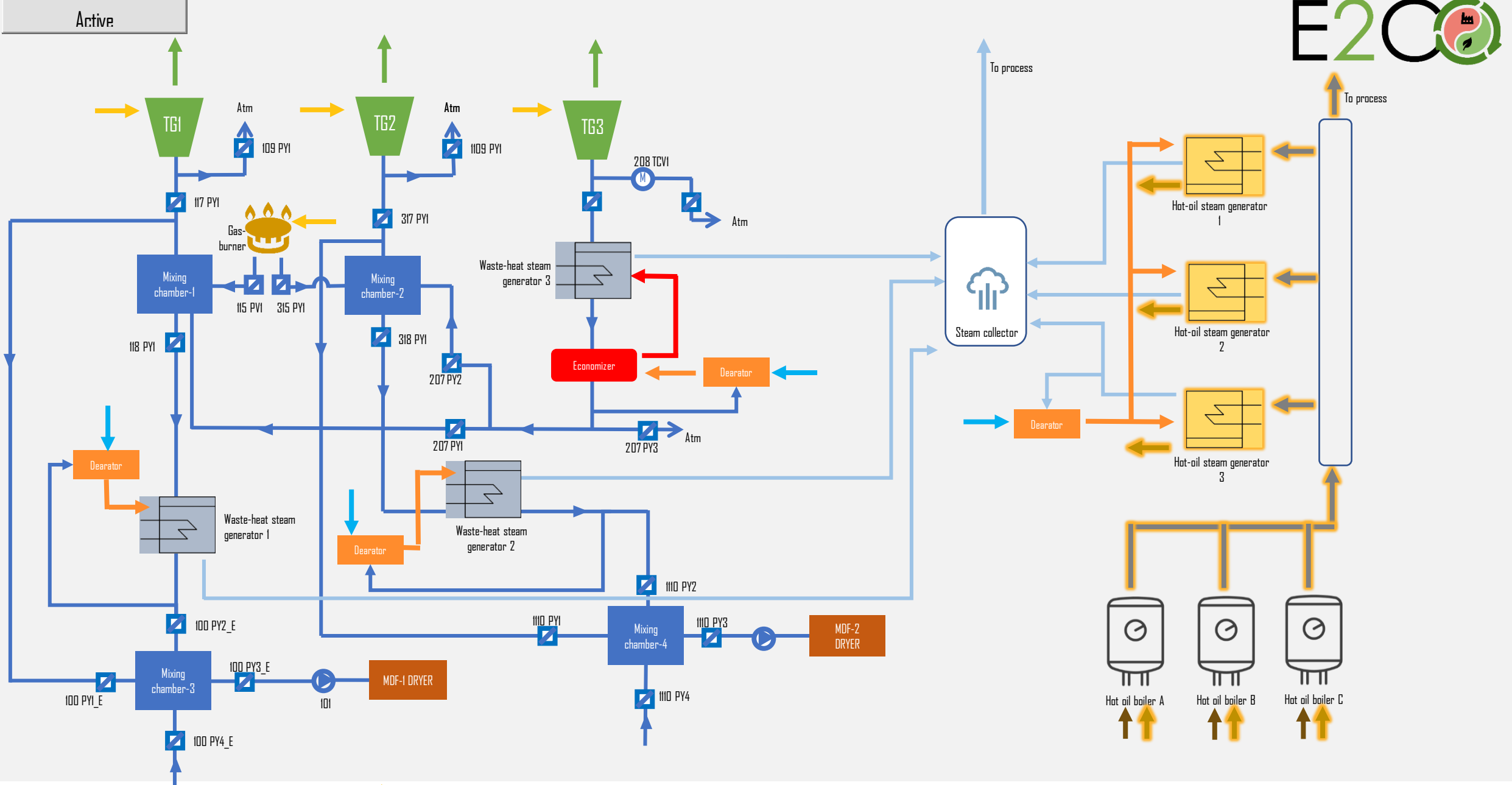


PRESS



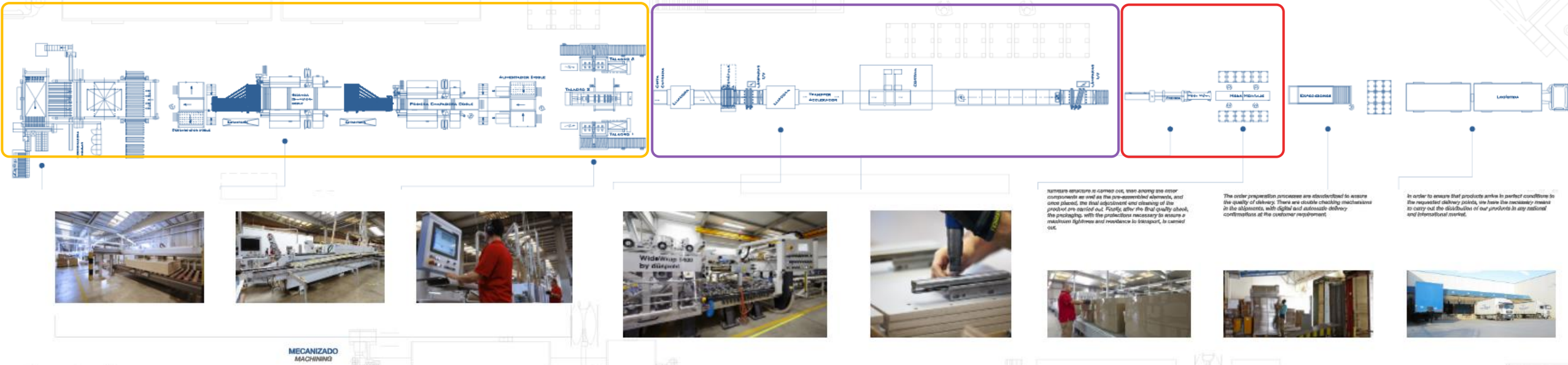
SATURATED STEAM CONSUMPTION

THERMAL OIL CONSUMPTION



- Electricity
- Steam
- Natural gas
- Air
- Hot water
- Warm water
- Water
- Cold oil
- Biomass
- Hot oil

PROCESO / PROCESS



- **Sizing machines (Cutting).**
Starting from the board as raw material, the sectioning is the first operation to be carried out in the manufacturing process, where the final measures of the piece are already defined.
- **Edge banding (Eding).**
Plating is the operation by which the perimeter of the piece is coated with a plastic polymer edge glued with special glues that prevent the entry of moisture that prevent the entrance of moisture.
- **Drilling and milling.**
As the latter machining process, the bore holes needed that allow assembling the structure of furniture by gluing and appropriate fittings are carried out. Occasionally, it is necessary to perform by milling any additional chip removal.

- **Lacquering, wrapping and other coatings.**
In this process for acrylic or polyurethane surface coating, different technologies depending on the geometry of the part, choosing from different colors and finishes, are used. However, there are other alternative processes, as it is that of continuous laminate coverings (through an internal process called Cyclum Process), or those obtained by membrane pressing (Foil Process).

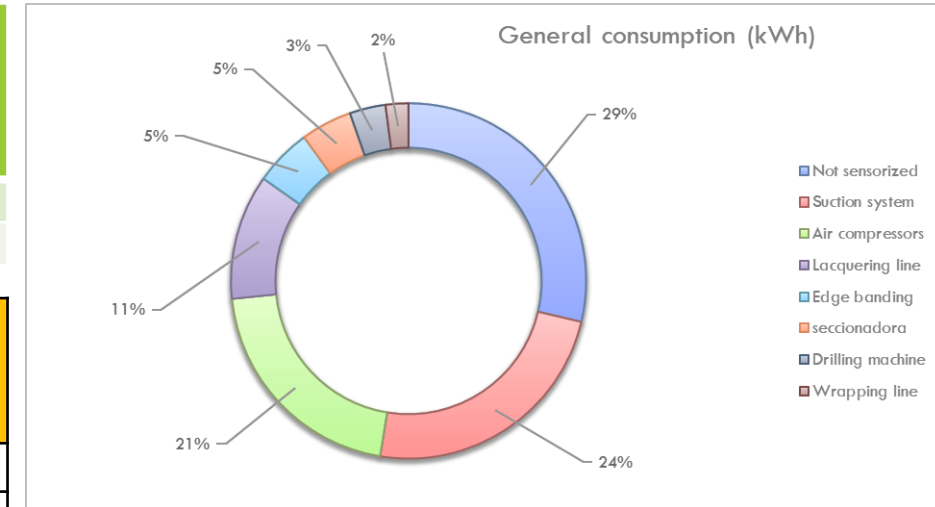
- **Pre-assembly.**
For both the front panels and the doors or drawers, operation prior tot the final assembly are used, where hinges, guides or drawer structures are inserted.
- **Assembly and packing.**
Starting from the machined parts, the pressing of the furniture structure is carried out, then adding the other components as well as the pre-assembled elements, and once placed, the final adjustment and cleaning of the product are carried out. Finally, after the final quality check, the packaging, with the protections necessary to ensure a maximum tightness and resistance to transport, is carried out.

ENERGY CONSUMPTION

	Sizing machines (Cutting)	Edge banding (Eding)	Drilling and milling	Lacquerin g, wrapping and other coatings	Pre-assembly	Assembly and packing	Shipments	Logistic
Electricity	X	X	X	X	X	X	X	X
Gasoil				X				X

	General consumption	Suction system	Air compressors	Sizing	Wrapping line	Lacquering line	Drilling machine	Edge banding machine
TOTAL	3.185.648,00	760.087,50	663.602,10	148.164,10	66.282,90	362.421,20	104.220,70	166.385,10
AVERAGE	362,66	86,53	75,55	16,87	7,55	41,26	11,86	18,94
MEDIAN	201,00	0,00	62,50	0,07	3,50	0,80	6,80	4,30
MAX	948,00	221,40	228,80	62,40	51,80	155,40	34,30	55,60
MIN	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

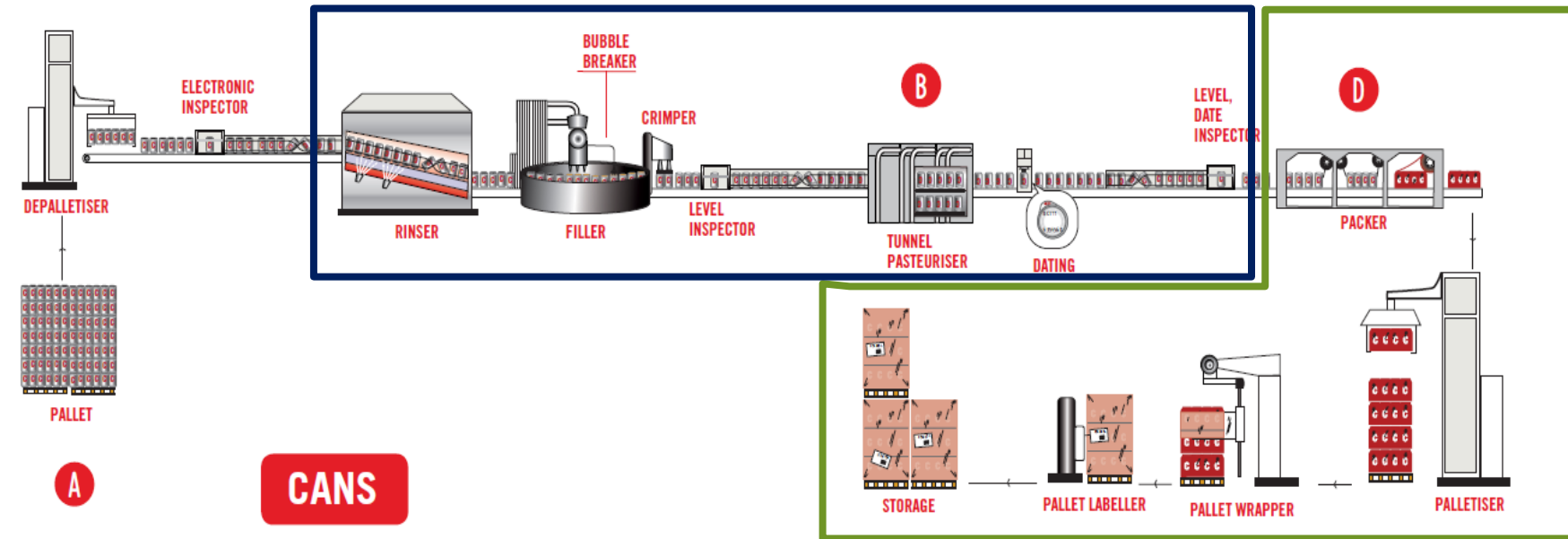
Not sensorised consumption	914.484,40	28,71
----------------------------	------------	-------



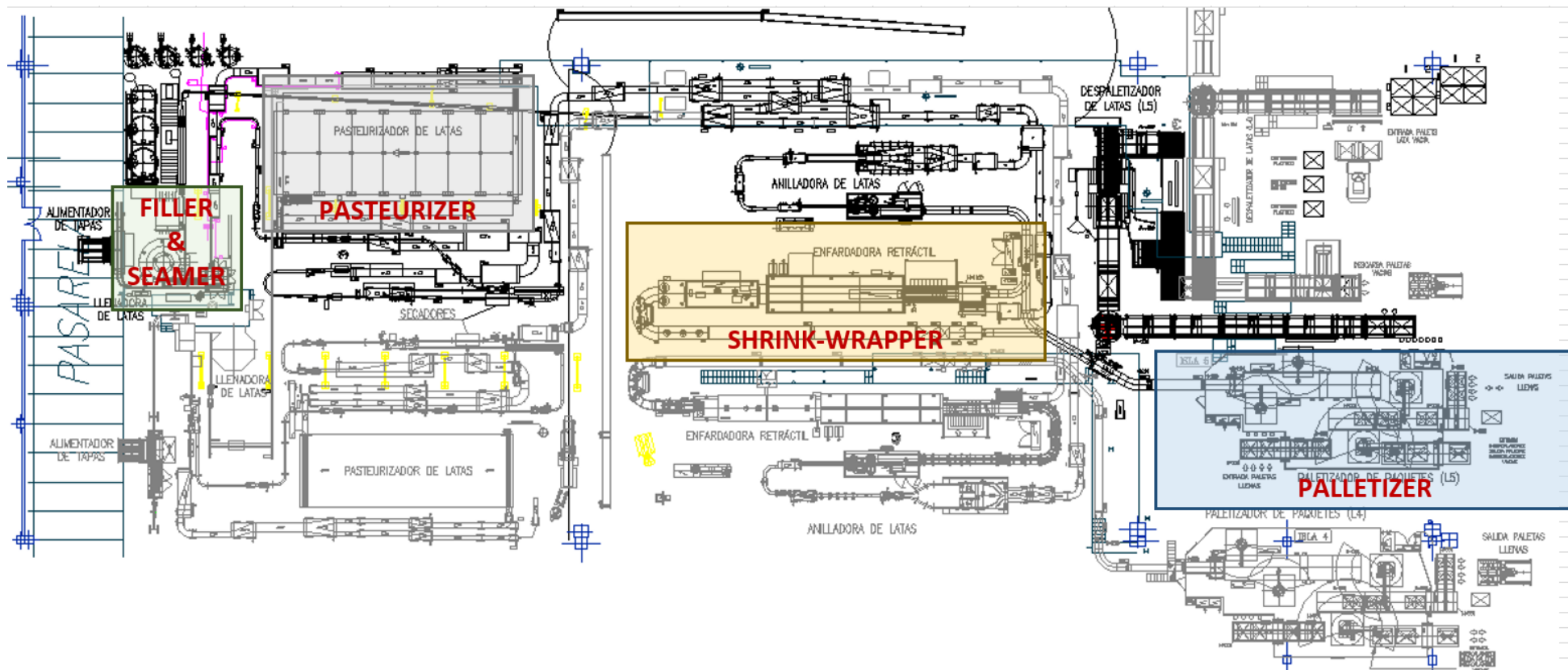
Regarding the non-sensorised consumption. We believe that 9% is for lighting and air conditioning (especially air conditioning) of offices (Non process energy consumption) and the other 20% for factory lighting, assembly lines, etc. (Process energy consumption).

Mahou-Use Case. Production.

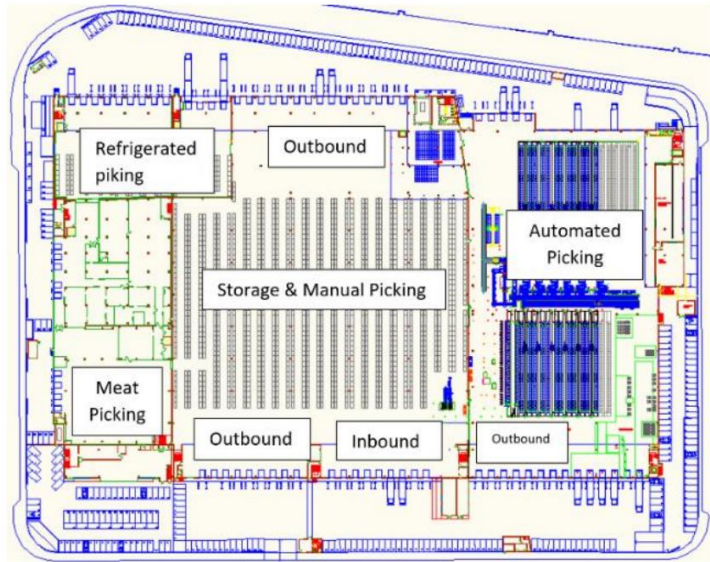
- Main production facility: Alovera brewery (Guadalajara, Spain).
- Capacity: 7 Million hl.
- 13 filling lines; cans, returnable and non returnable bottles, kegs.
- High automation concept and integration (DCS, Robotics, LGVs...)



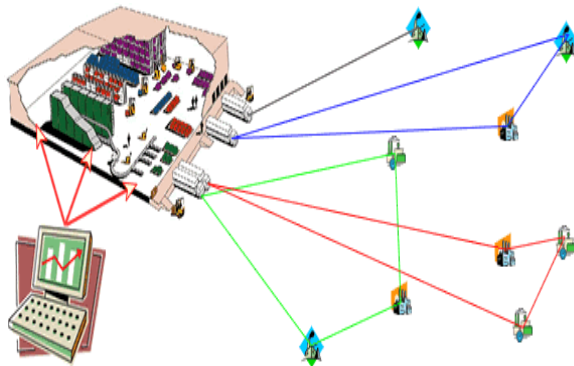
- **Alovera Brewery line 5 has been chosen for the E2COMATION project. Multi format production:**
 - 50.000 cans/hour (0.33cl standard, 0.33cl “sleek”, 0.25cl “sleek” formats)
 - 33.000 cans/hour (50cl standard format)



The main objective is to achieve an optimization in resources utilization in the Groceries Distribution Center or directly related to it. This optimization will come from:



- An optimization of **Inventory Management** in the DC to balance the workload in the DC and improve **energy consumption per SKU** stored and moved.
- A more accurate **Forecasting** model based on merchandise **Assortment** at each step in the supply chain to control the propagation of estimation error from Stores to the DC and **reduce waste**.
- Balanced DC workload in conjunction with optimized **Transportation** and **Calendar** schedules results in better fleet utilization and reduce CO₂ emission.
- This also will help to optimize the product flow upstream in the replenishment of the DC from Suppliers.



Delivery Day	Cases picked	Rolls Shipped	Stores Delivered	Truck trips	Cases/Roll	Rolls/Store	Stores/trip
Monday	159.671	4.676	461	267	34	10,1	1,73
Tuesday	129.510	4.035	456	242	32	8,8	1,88
Wednesday	106.419	3.606	406	215	30	8,9	1,89
Thursday	127.192	3.987	450	238	32	8,9	1,89
Friday	136.483	4.411	443	256	31	10,0	1,73
Saturday	51.624	1.881	185	135	27	10,2	1,37



@e2comation



E2COMATION



e2comation project



Thanks for listening

