Future Manufacturing TRANSSFORM Workshop

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EERE, DOE

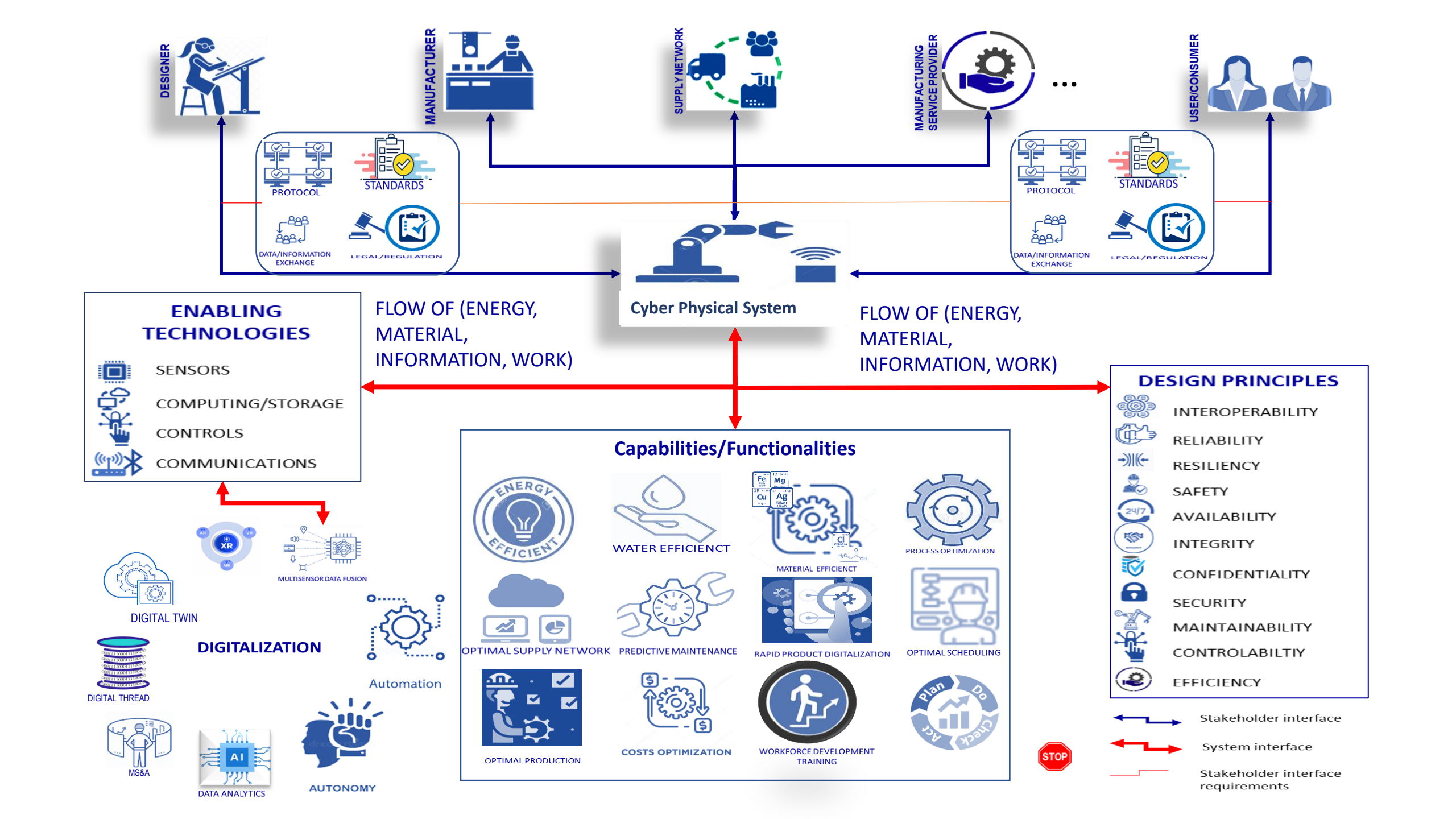
The notion of TRANSSFORM

TRANSSFORM – More than a word play. The main theme is to conceptually connect these

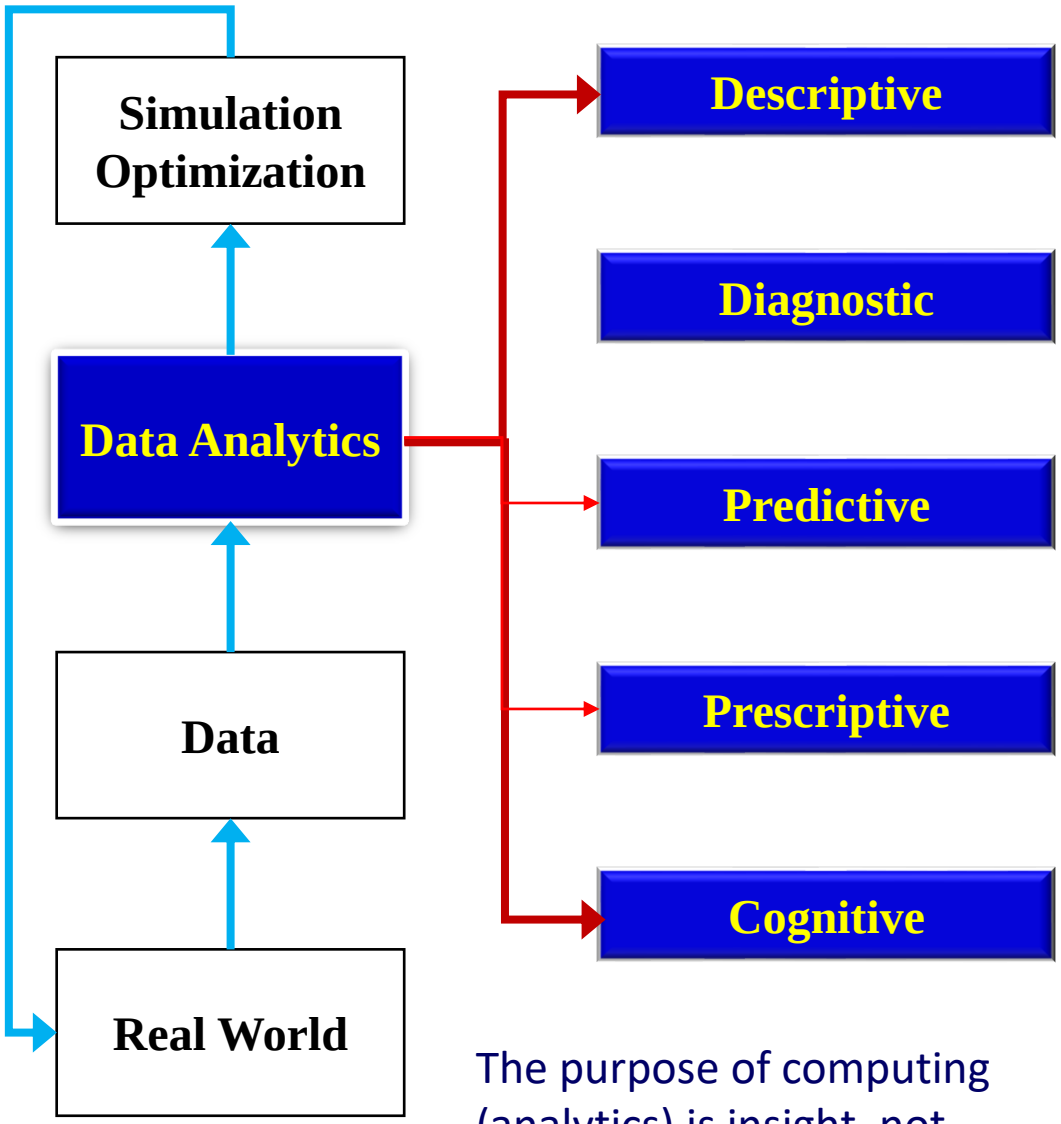
- **T**ransformative
- **R**esilient
- **A**daptive
- **N**imble
- **S**ustainable
- **S**mart
- **F**lexible
- **O**ptimal
- **R**obust
- **M**odel-based

	Motivation Why	Data What	Function How	People Who	Network Where	Time When
Transformative	Whole system thinking, Energy system modeling Multi and cross disciplinary, Leapfrogging and disruptive,	Cyber physical human system, Computing, Communications, Standards, Protocols, Best practices	Enabling technologies, Interoperability, Digitalization, Automation, Autonomy	Industry, Academia, Government, Labs, SMMs, SMEs	Machine, Shopfloor, Plant, Supply network level Innovation ecosystem	On-time, Justin time, Real-time
Resilient	System's ability to avoid, withstand, and recover from adversity	Unexpected, extreme and rare events, cyber attacks	Cyber security, Safety, maintainability, Reliability, Integrity, Confidentiality, resiliency modeling	IT and OT system integrators, Suppliers, security and safety experts	Machine, Shopfloor, Plant, Supply network level	On-time, Justin time, Real-time
Adaptive	Self-optimize manufacturing performances, realize intelligent and adaptive behaviors	Data related to Energy, material, and water and other resources, Process data,	Controllability, Availability, Sensor networks, information fusion, DAQ system, MS&A	Control system and sensors providers, Software and hardware system providers	Machine, Shopfloor, Plant, Supply network level	On-time, Justin time, Real-time
Nimble	Faster, cheaper, better, and greener products, processes, and services	Data related to Cost, quality, throughput, and resources (energy, water, materials)	Connect product design with manufacturing, mathematical models	Industry, Academia, Government, Labs, SMMs, SMEs	Machine, Shopfloor, Plant, Supply network level	On-time, Justin time, Real-time
Sustainable	Minimize negative environmental impacts while conserving energy and natural resources	Data - Cost, quality, throughput, resources (energy, water, materials) Life cycle analysis	Integrate product design and manufacturing, mathematical models, decarbonization	Environmental scientists, Climate change experts, materials scientists, energy experts	Machine, Shopfloor, Plant, Supply network level	On-time, Justin time, Real-time

	Motivation Why	Data What	Function How	People Who	Network Where	Time When
Smart	Integrate operational technologies and information technologies (OT/IT) for **effective** and **secure Cyberphysical human system platform** for **better decision making** and **improving** the **overall productivity and efficiency** of manufacturing **across the networked enterprise**	Data related to Energy, material, and water and other resources, Process data, Digital Thread, Digital Twin, process data, production data	AI/ML, Hybrid models, Sensor networks, information fusion, DAQ system, IT and OT Cloud/Edge Computing CPS Platform, AR/VR/MR, MS&A	Process engineers, System optimization experts, plant and shop floor engineers/managers PLCs/SCADA experts	Machine, Shopfloor, Plant, Supply network level	On-time, Justin time, Real-time
Flexible	Ability to deal with variability and variations	Process, production variability variations Product variety Supply-demand	Flexible manufacturing facilities, materials, parts components substitutions, flexible supply networks	Production managers, shop floor, plant engineers, technicians, managers	Machine, Shopfloor, Plant, Supply network level	On-time, Justin time, Real-time
Optimal	Optimize system level performance	Data related to Energy, material, water,Process, Production, supplier data	Optimization model, Optimal control, forward and inverse problem modeling, supply network integration, Optimal scheduling, MS&A	Production managers, shop floor, plant engineers, technicians, managers	Machine, Shopfloor, Plant, Supply network level	On-time, Justin time, Real-time
Robust	Ability to deal with perturbations or disturbances	Production and supply perturbations and disturbance data	Robust optimization and control, supply-demand modeling, statistical modeling, MS&A	Production managers, shop floor, plant engineers, technicians, managers	Machine, Shopfloor, Plant, Supply network level	On-time, Justin time, Real-time
Model-based	System models for real-time digital continuity between product engineering, manufacturing engineering, and operations	Digital Thread, Digital Twin, Domain specific data, knowledge semantics	MBSE, Domain specific modeling, Model integration, Containerization, Semantic modeling, Ontology	System designers and modelers, domain experts, information, knowledge enterprise modelers	Machine, Shopfloor, Plant, Supply network level	On-time, Justin time, Real-time


DESIGNER
MANUFACTURER
SUPPLY NETWORK
MANUFACTURING SERVICE PROVIDER
...
USER/CONSUMER
PROTOCOL
STANDARDS
DATA/INFORMATION EXCHANGE
LEGAL/REGULATION
PROTOCOL
STANDARDS
DATA/INFORMATION EXCHANGE
LEGAL/REGULATION
Cyber Physical System
ENABLING TECHNOLOGIES
SENSORS
COMPUTING/STORAGE
CONTROLS
COMMUNICATIONS
FLOW OF (ENERGY, MATERIAL, INFORMATION, WORK)
FLOW OF (ENERGY, MATERIAL, INFORMATION, WORK)
DESIGN PRINCIPLES
INTEROPERABILITY
RELIABILITY
RESILIENCY
SAFETY
AVAILABILITY
INTEGRITY
CONFIDENTIALITY
SECURITY
MAINTAINABILITY
CONTROLABILTIY
EFFICIENCY
Capabilities/Functionalities
ENERGY EFFICIENT
WATER EFFICIENCT
MATERIAL EFFICIENCT
PROCESS OPTIMIZATION
OPTIMAL SUPPLY NETWORK
PREDICTIVE MAINTENANCE
RAPID PRODUCT DIGITALIZATION
OPTIMAL SCHEDULING
OPTIMAL PRODUCTION
COSTS OPTIMIZATION
WORKFORCE DEVELOPMENT TRAINING
Plan
Do
Check
Act
DIGITALIZATION
DIGITAL TWIN
XR
MULTISENSOR DATA FUSION
DIGITAL THREAD
Automation
MS&A
AI
DATA ANALYTICS
AUTONOMY
STOP
Stakeholder interface
System interface
Stakeholder interface requirements

Interpretable and Explainable Analytics



What happened?
Describes historical data
Helps understand how things are performing

Why did it happen?
Statistics and sensitivity analysis

What will happen?
ML, Deep Learning

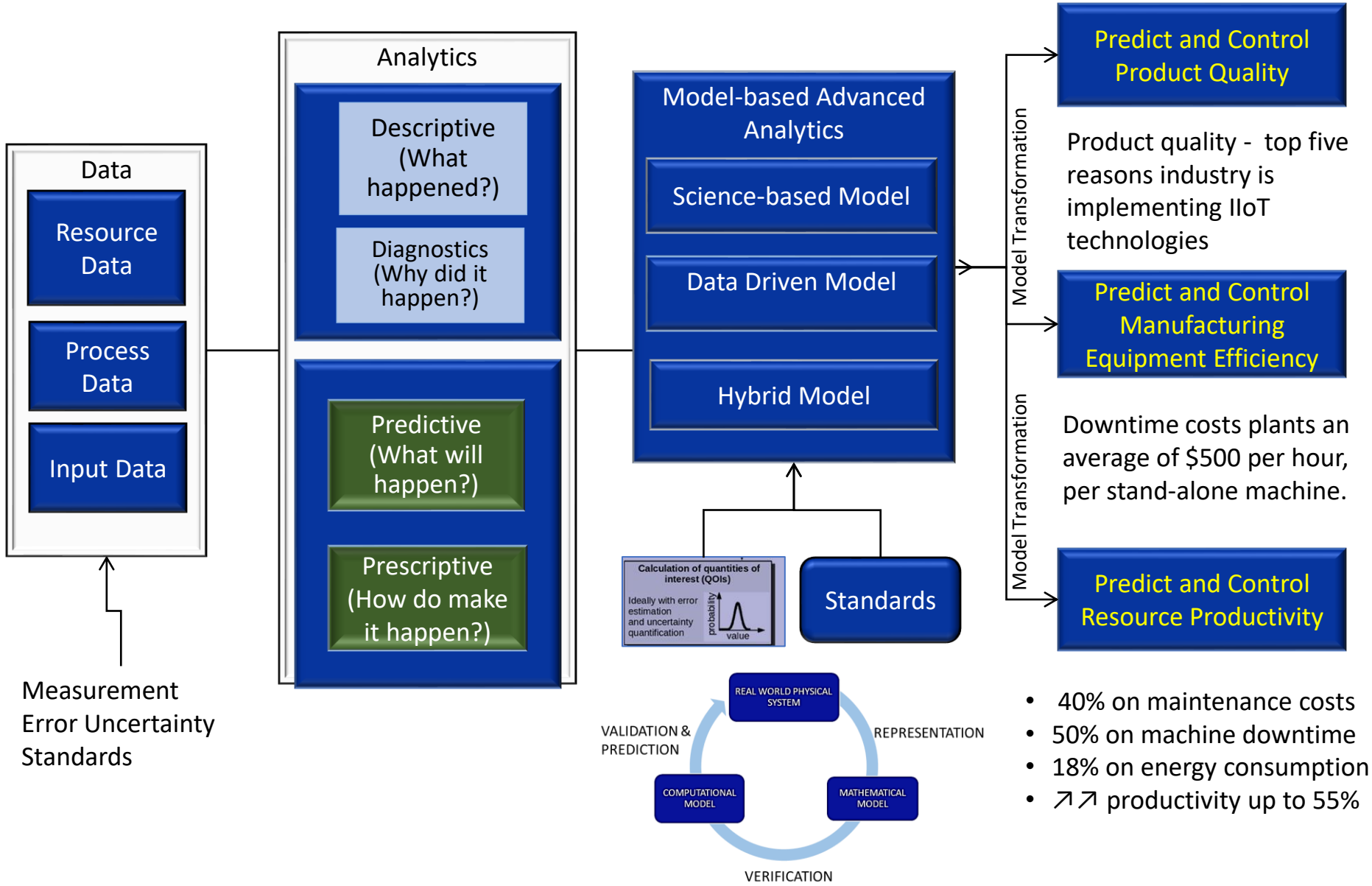
How can we make it happen?
Control (feedback, adaptive, optimal)

What to do, why , and how?
AI, General AI

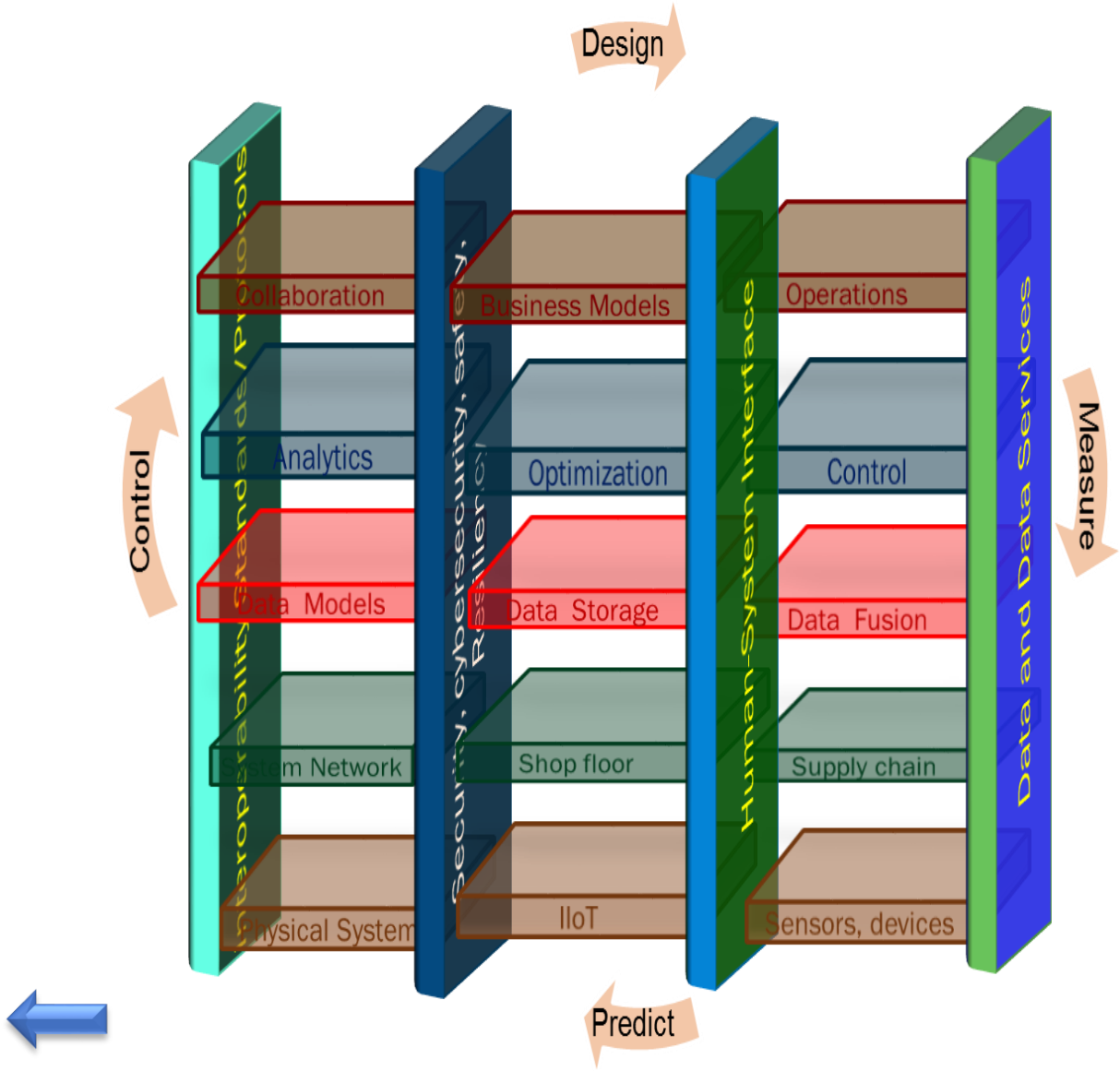
The purpose of computing (analytics) is insight, not numbers. - Richard Hamming

Simply put, DA is the application of quantitative methods and tools to turn data into insight and action

Bringing Manufacturing Domain and Analytics - Model-based Advanced Analytics for Hybrid Model



How to convert data into actionable insights using data analytics
We will need a Cyber Physical Human System architecture



Forward Problem

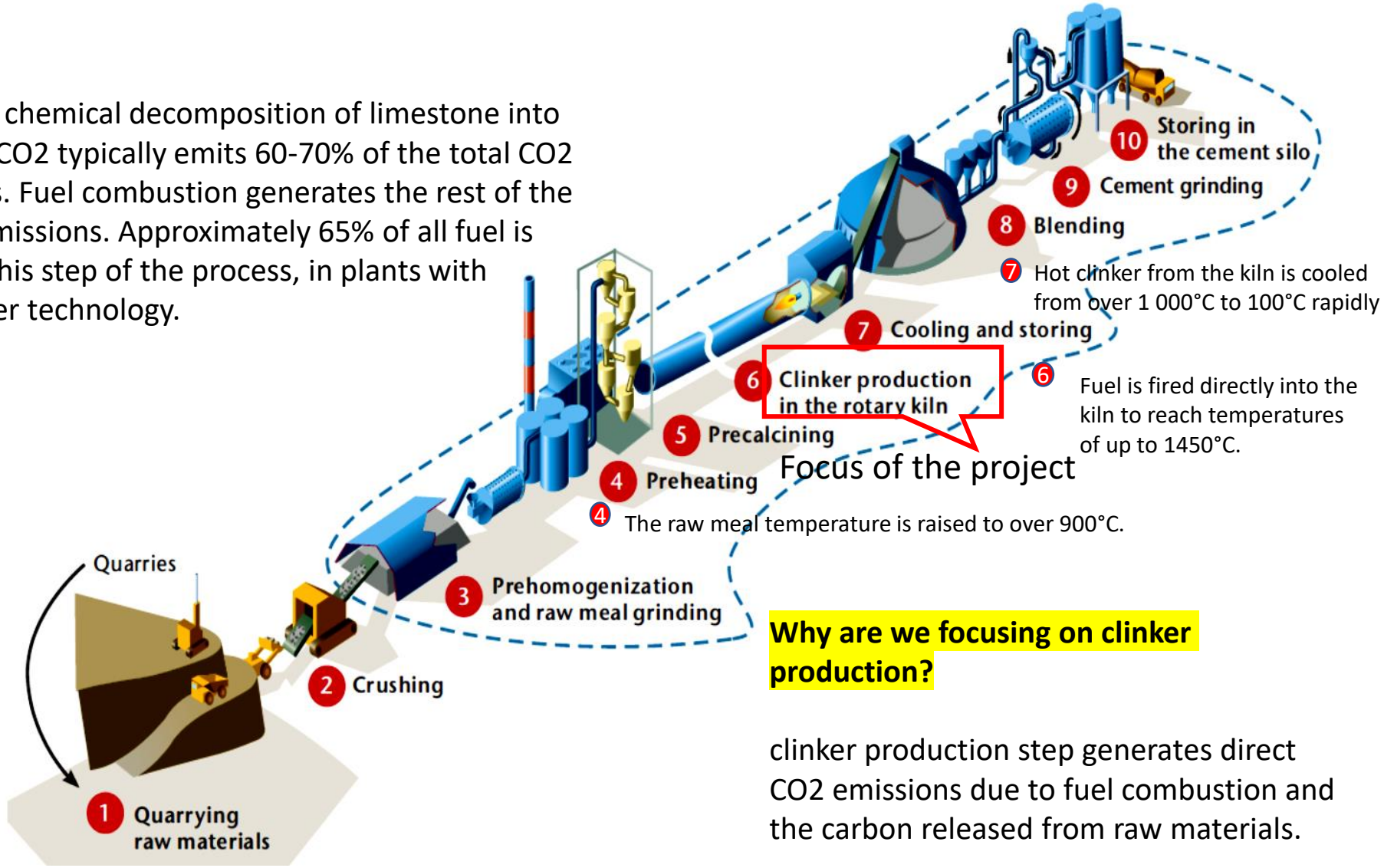
- Autonomy
- Synthesis
- Automation
- Optimize
- Control
- Predict
- Monitor

- Reduce Cost
- Improve Quality
- Improve Productivity
- Improve Resource Productivity
- Improve Flexibility
- Improve Resiliency

Inverse Problem

TRANSSFORM Cement Manufacturing – Process Steps

5 Here, the chemical decomposition of limestone into lime and CO2 typically emits 60-70% of the total CO2 emissions. Fuel combustion generates the rest of the carbon emissions. Approximately 65% of all fuel is burnt in this step of the process, in plants with precalciner technology.

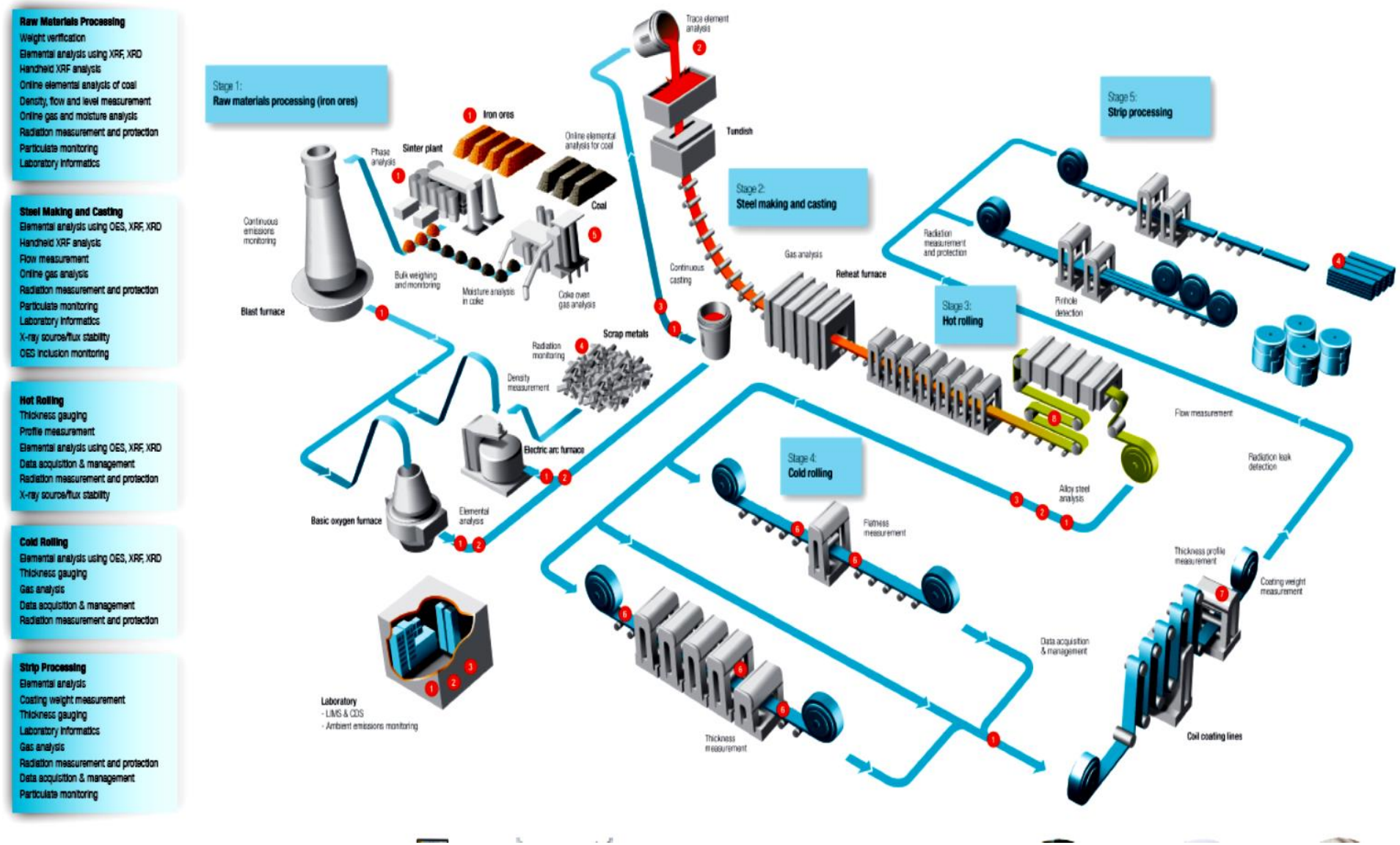


Why are we focusing on clinker production?

clinker production step generates direct CO2 emissions due to fuel combustion and the carbon released from raw materials.

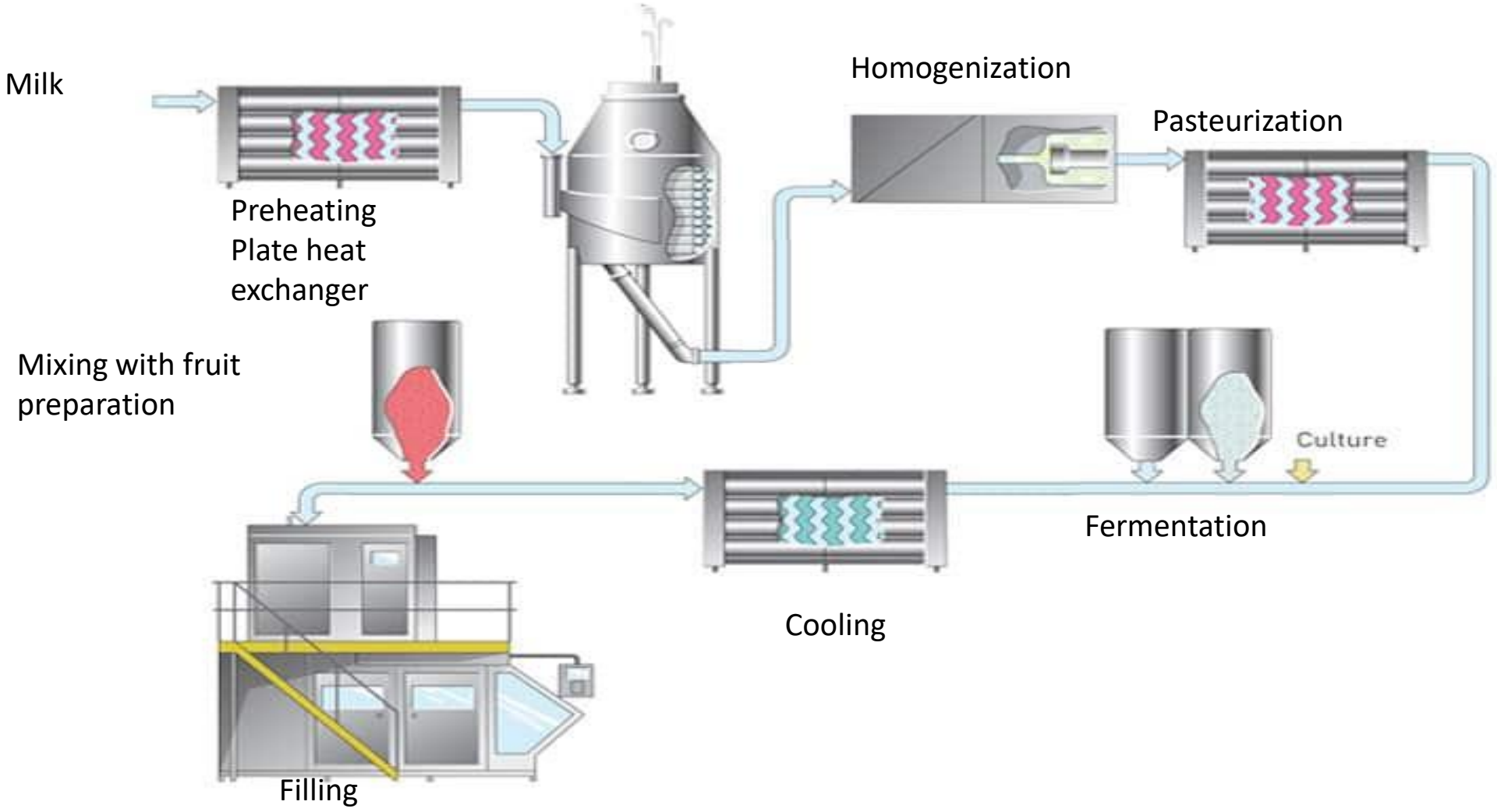
Source: Internet

TRANSSFORM Steel Manufacturing – Process Steps



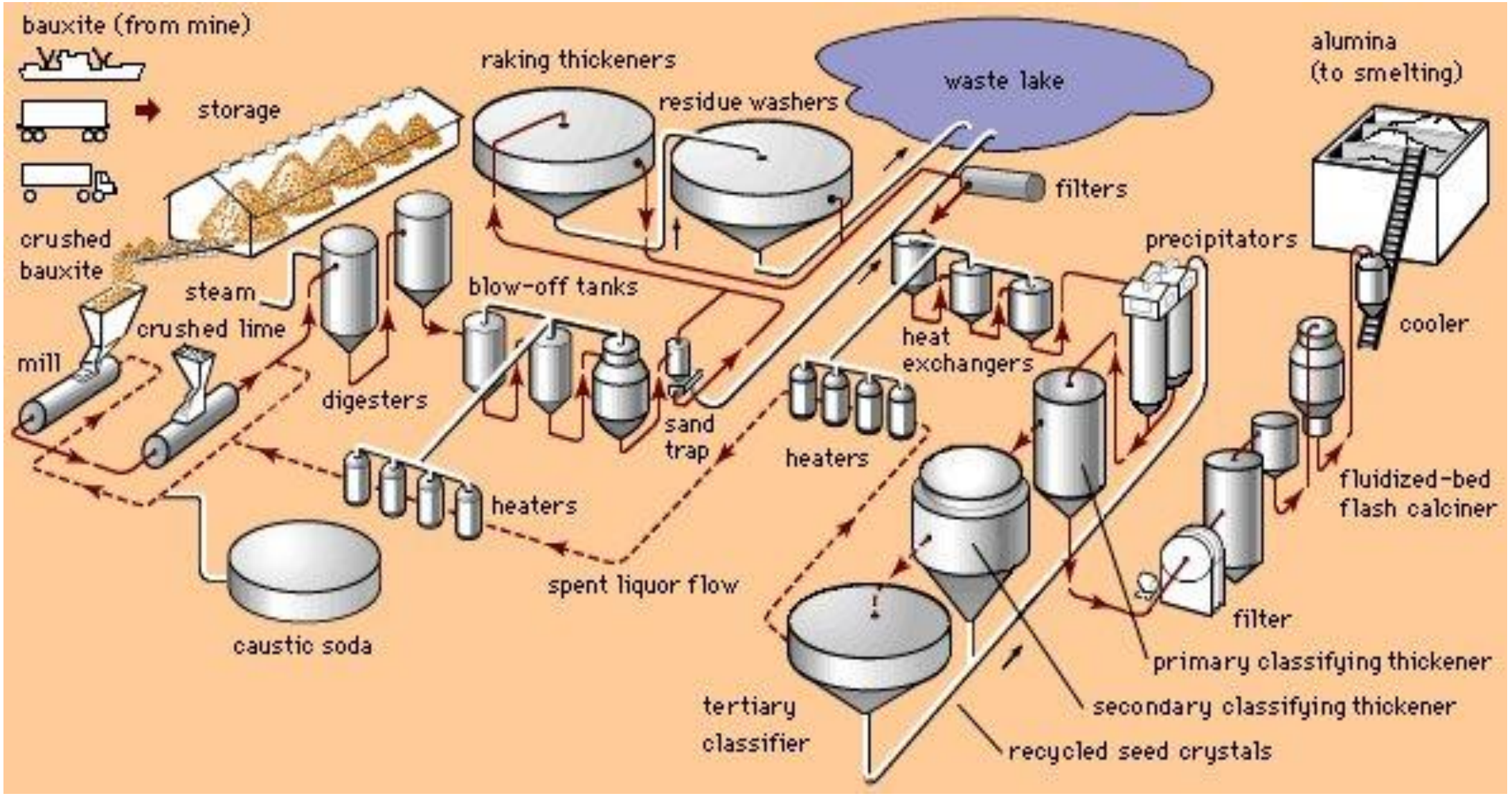
Source: Internet

TRANSSFORM Food Processing - Yogurt Production



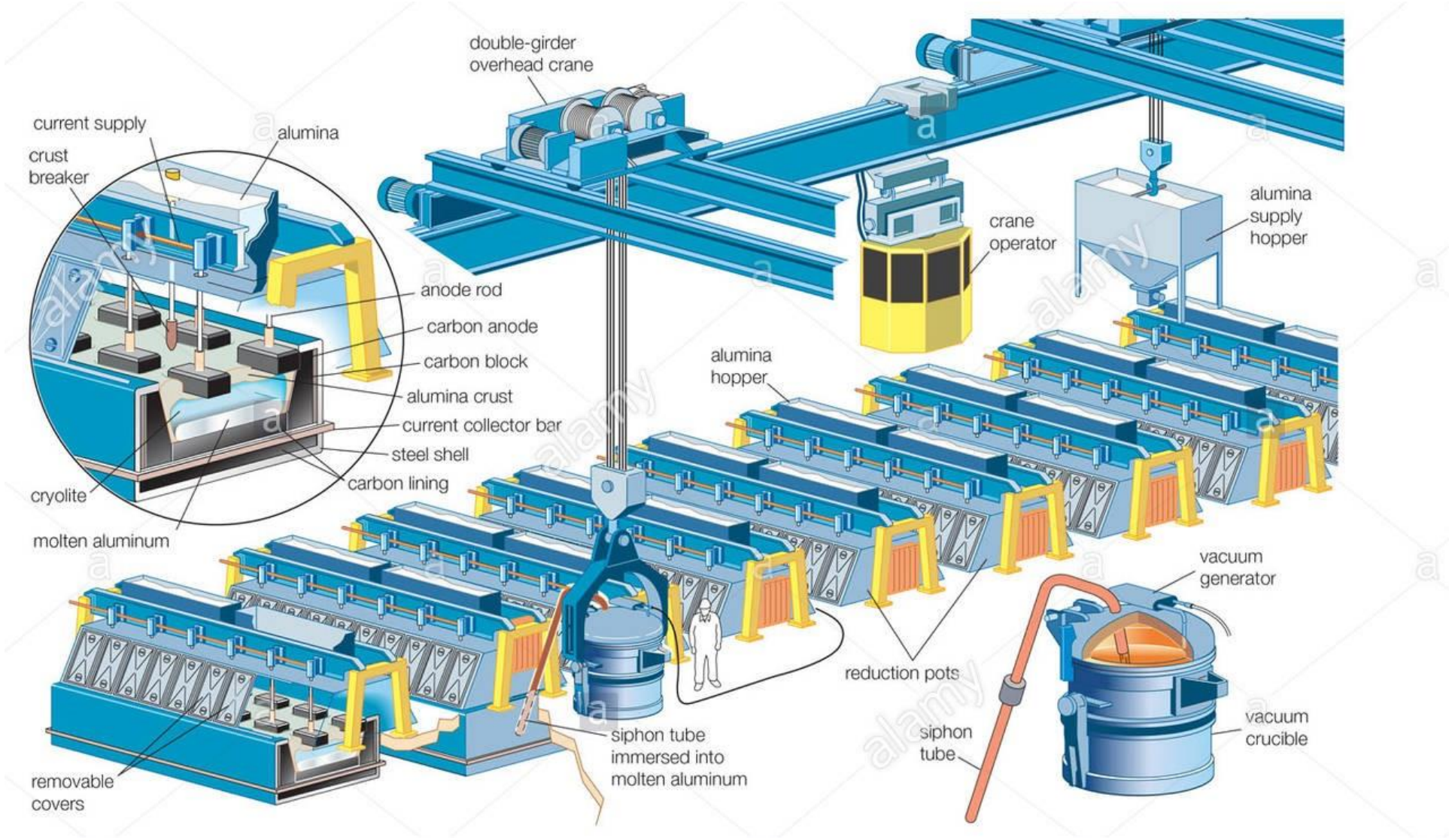
Source: Internet

TRANSSFORM Aluminum manufacturing process



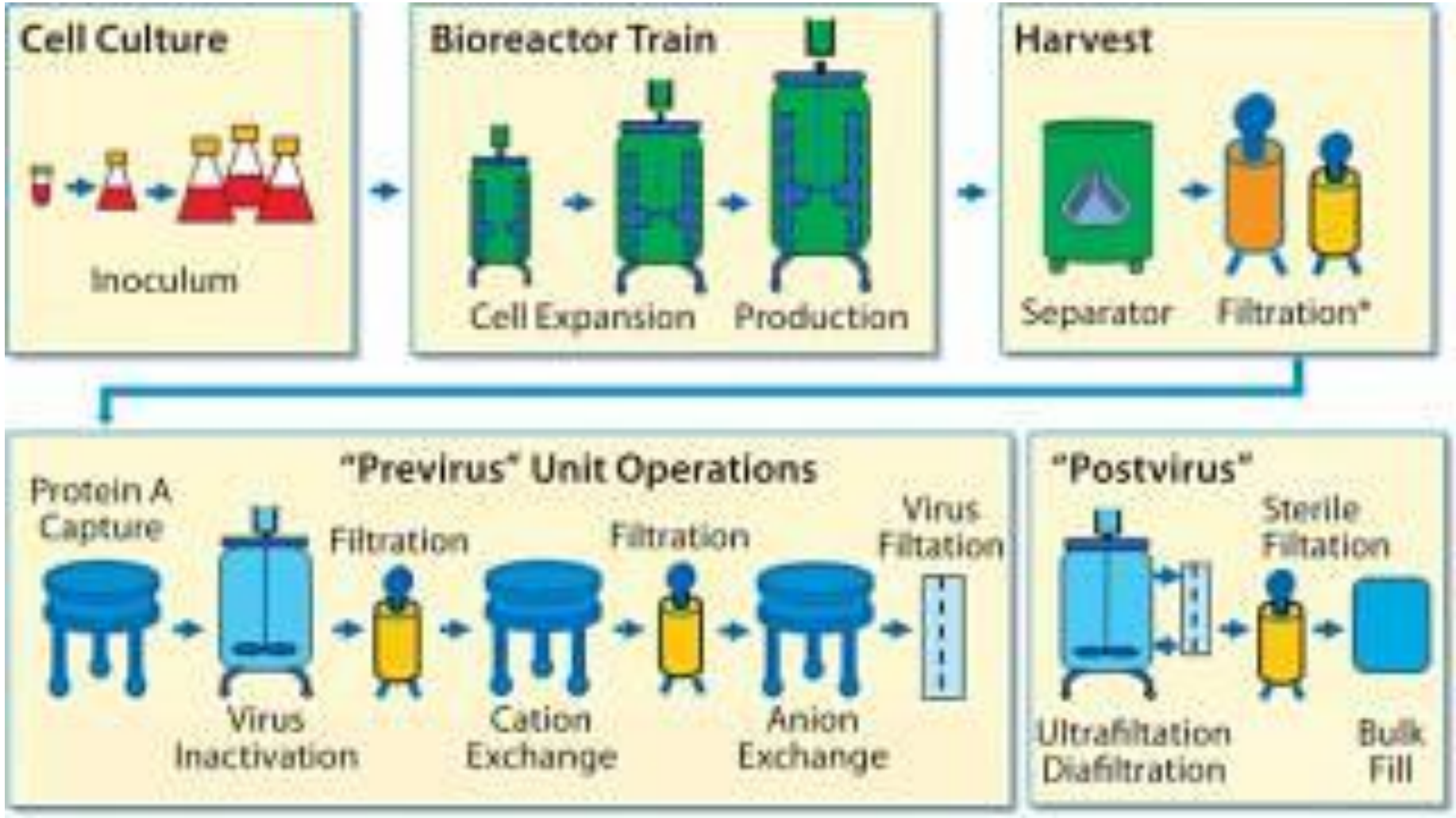
Source: Internet

TRANSSFORM Aluminum smelting



Source: Internet

TRANSSFORM BioPharma for MAb Manufacturing



Source: Internet