



ADVANCED ANALYTICS SMART GRIDS & INDUSTRIAL ENERGY EFFICIENCY

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TOPICS



- **THE FRAGILITY OF OUR WORLD**
- **ADVANCED ANALYTICS**
- **SMART GRIDS**
CASE: OIL PRODUCTION
- **ENERGY EFFICIENCY & INDUSTRIAL PROCESS**
CASE: HEAVY INDUSTRIES (CEMENT)
- **MANAGEMENT OF ENERGY IN INDUSTRIAL SYSTEMS**
CASES: OIL REFINING
OIL TRANSPORT



ADVANCED ANALYTICS SMART GRIDS & INDUSTRIAL ENERGY EFFICIENCY

THE FRAGILITY OF OUR WORLD



La noción del compromiso que cada generación tiene con sus sucesores está en el corazón del concepto de desarrollo sostenible, el cual fue plasmado por la World Commission on Environment and Development (Brundtland Comisión, WCED 1987) en su informe "Our Common Future" que afirma que el desarrollo sostenible:

"satisface las necesidades de la presente generación sin comprometer las posibilidades de las futuras generaciones para satisfacer sus propias necesidades".

Esto solo se consigue con el uso racional (científico) de los recursos naturales, renovables y no-renovables, cuya gestión óptima y eficaz es responsabilidad de toda la humanidad.





“La realidad suprema de nuestro planeta es su vulnerabilidad.”

John F. Kennedy

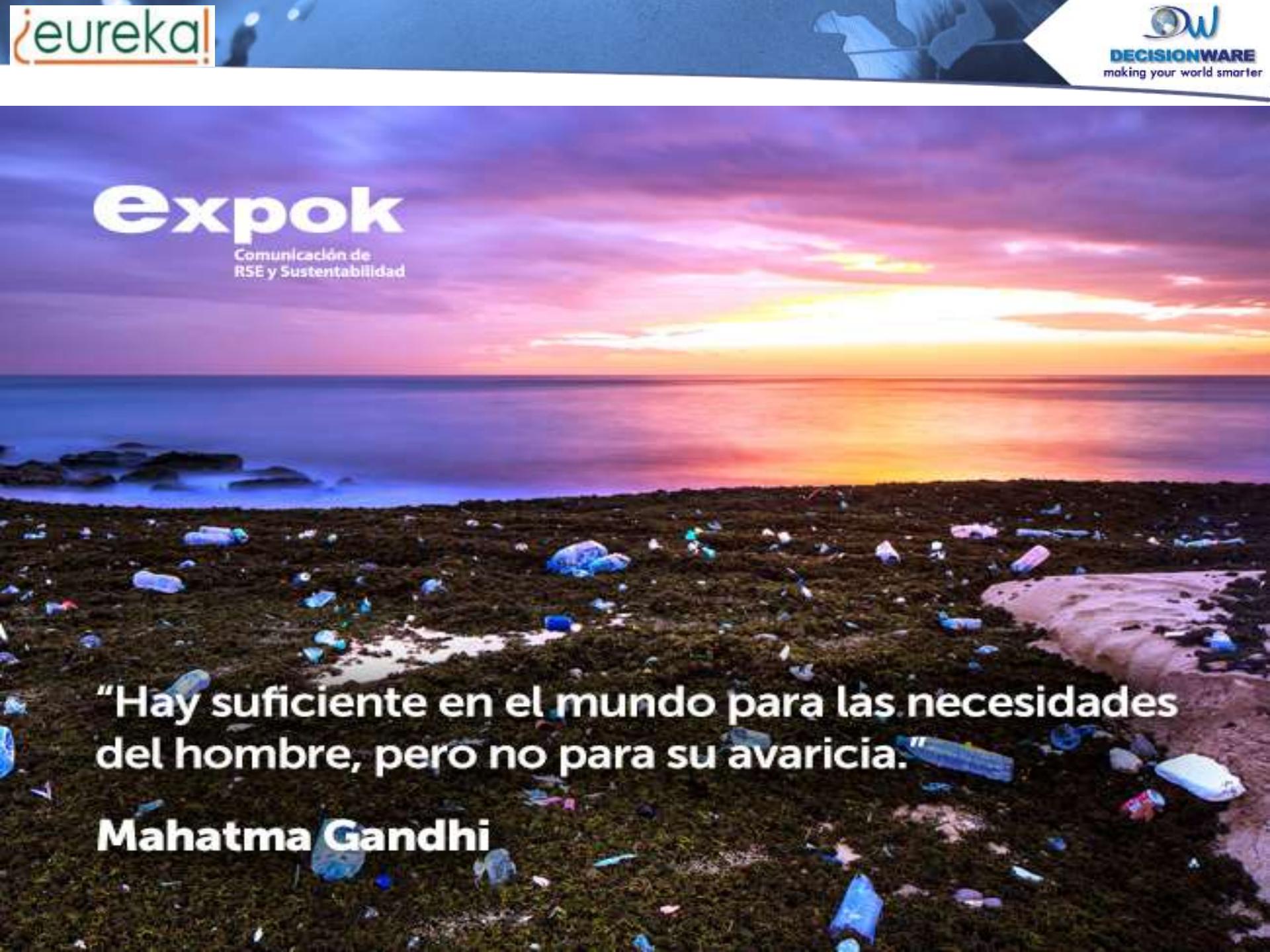


"Pretender que el cambio climático no es real, no hará que desaparezca."

Leonardo Di Caprio

expok

Comunicación de
RSE y Sustentabilidad

A photograph of a beach at sunset. The sky is filled with vibrant orange, yellow, and pink hues. In the foreground, the dark sand is covered with numerous pieces of plastic debris, including bottle caps, plastic bags, and other small plastic fragments, creating a stark contrast between the natural beauty of the sunset and the environmental pollution.

"Hay suficiente en el mundo para las necesidades del hombre, pero no para su avaricia."

Mahatma Gandhi



expok

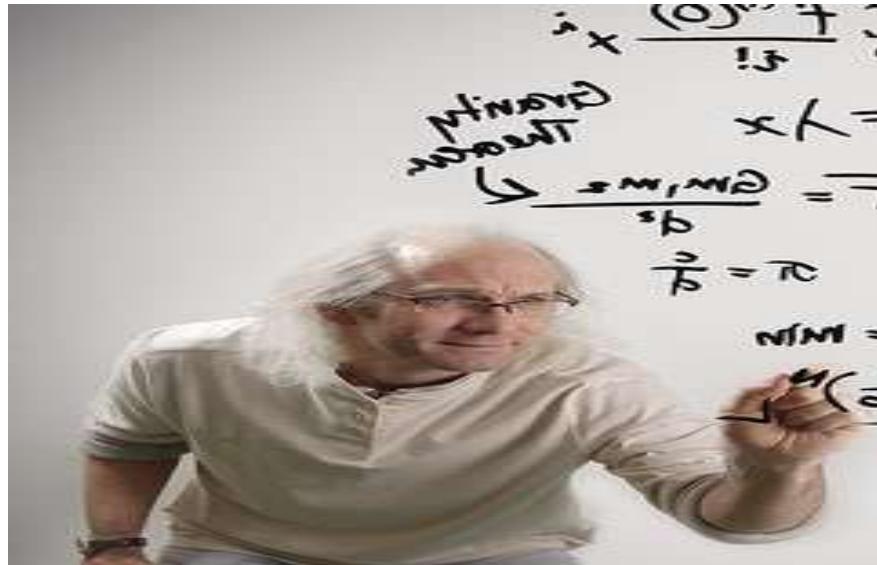
Comunicación de
RSE y Sustentabilidad

**"Las compañías contaminantes no
merecen parte de nuestros impuestos,
necesitan nuestro control."**

Leonardo Di Caprio

ADVANCED ANALYTICS SMART GRIDS & EFICIENCIA ENERGÉTICA INDUSTRIAL

ADVANCED ANALYTICS



The whiteboard contains the following handwritten mathematical notes:

$$x \cdot \frac{(0)^n + \sum_{0=s}^n}{!s} = (x)^n$$

$$\left(\frac{1}{n} + 1 \right) \in \mathbb{N} \quad n = 0, 1, 2, \dots$$

$$x \cdot 1 = x \cdot A$$

$$(x)^n = x^n \cdot (x)^0 = x^n$$

$$\frac{x^n}{x^0} = x^n$$

$$\frac{x^n}{x^0} = x^n$$

$$\|y\| + \|x\| \geq \|y + x\|$$

$$|z| < |a| \leq 1$$

$$NM = x^b (x, n, m)$$

$$\frac{\left(\frac{a}{0.005} + 1\right) \left(\frac{a}{0.005}\right)}{\left(\frac{a}{0.005} + 1\right)}$$

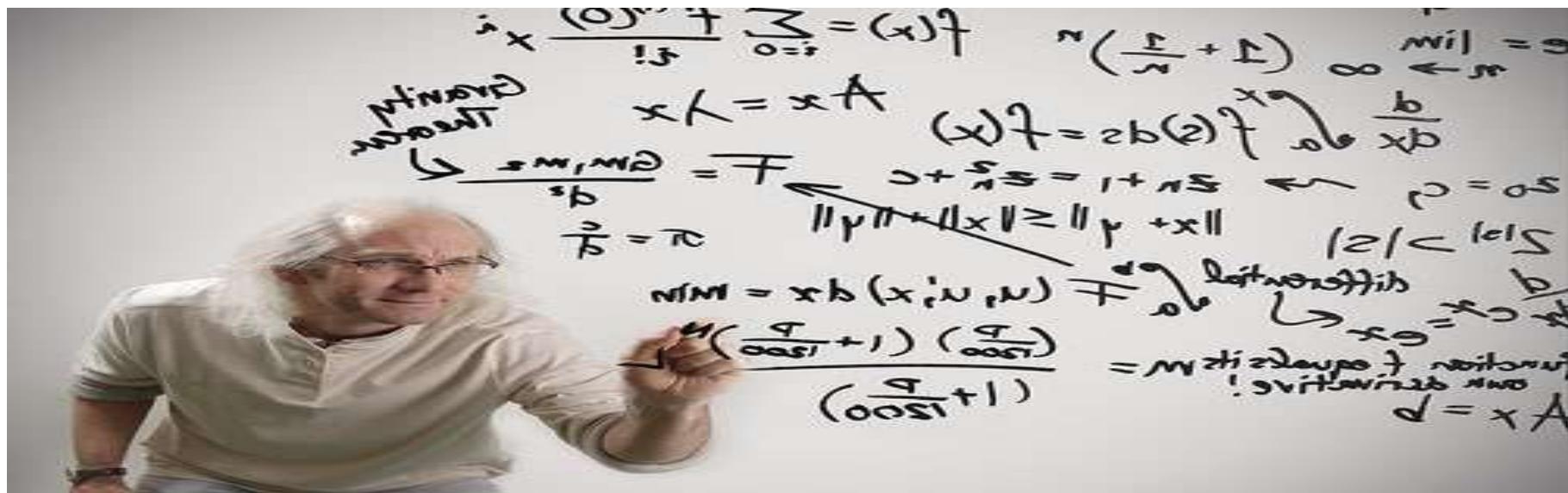
$$= M \text{ mit } a \text{ Länge } + \text{ rechteckige } \frac{a}{0.005}$$

$$d = x \cdot A$$

El ser humano tiene una capacidad de procesamiento numérico limitada que no se ha incrementado significativamente en las últimas centurias.

Lo que ha incrementado la humanidad es su capacidad de análisis. La capacidad de cálculo de los computadores y del software se ha incrementado en miles de millones de veces en los últimos veinte años.

La unión de mentes analíticas con máquinas, dotadas de gran capacidad de cálculo, es lo que determina el rápido cambio tecnológico que experimenta la humanidad.



Key finding 1

Analytics correlates to performance



IBM Smarter Industries Symposium
Barcelona

3x

5.4x

Organizations that lead in analytics outperform those who are just beginning to adopt analytics

Top Performers are more likely to use an analytic approach over intuition*

Big data makes a big difference

Organizations using big data and analytics are up to

23x

more likely to report they are

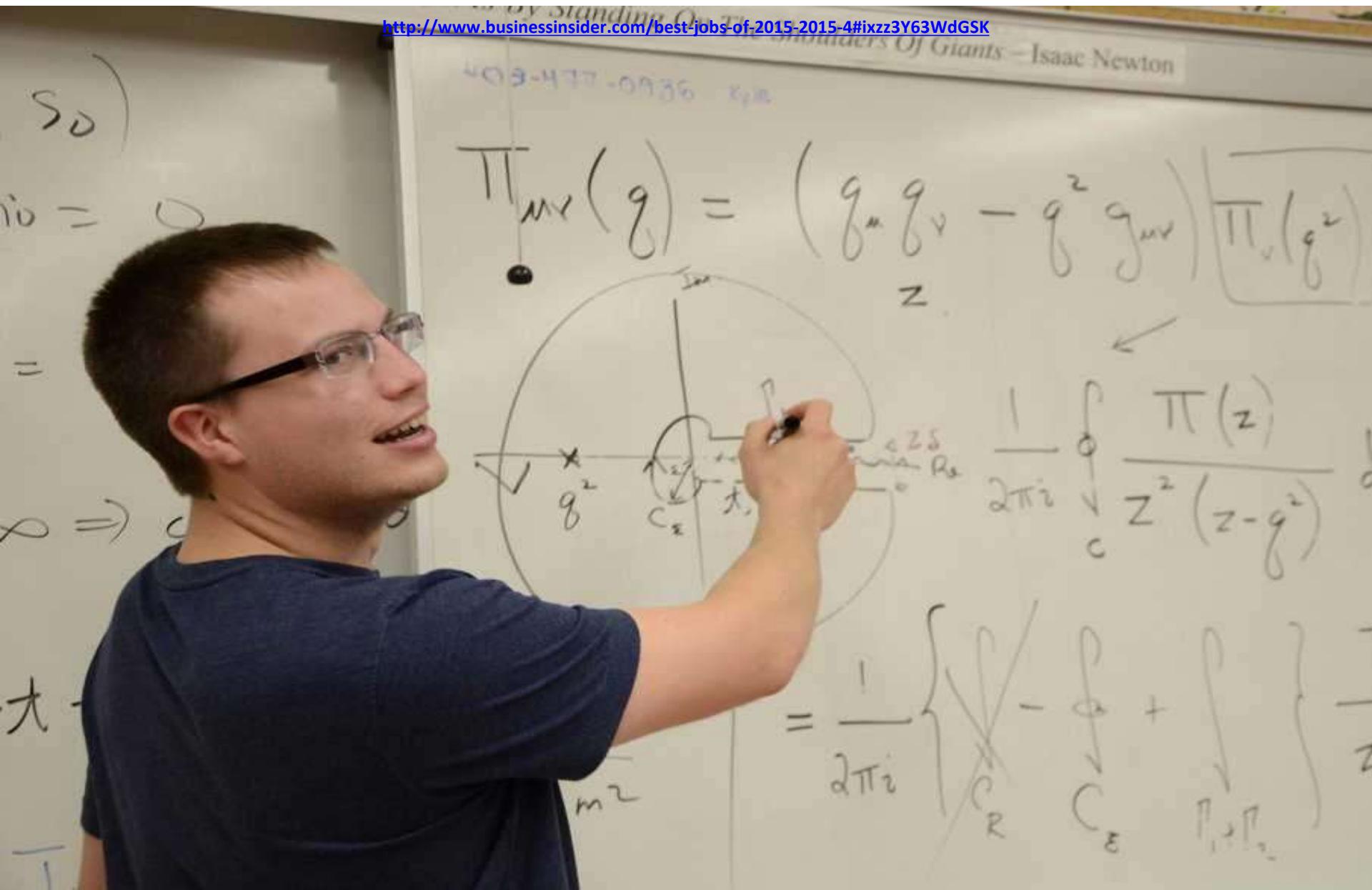
**substantially outperforming
their competitors**

than those who do not use big data and analytics



DATA SCIENTIST: THE BEST JOB OF 2015

<http://www.businessinsider.com/best-jobs-of-2015-2015-4#ixzz3Y63WdGSK>



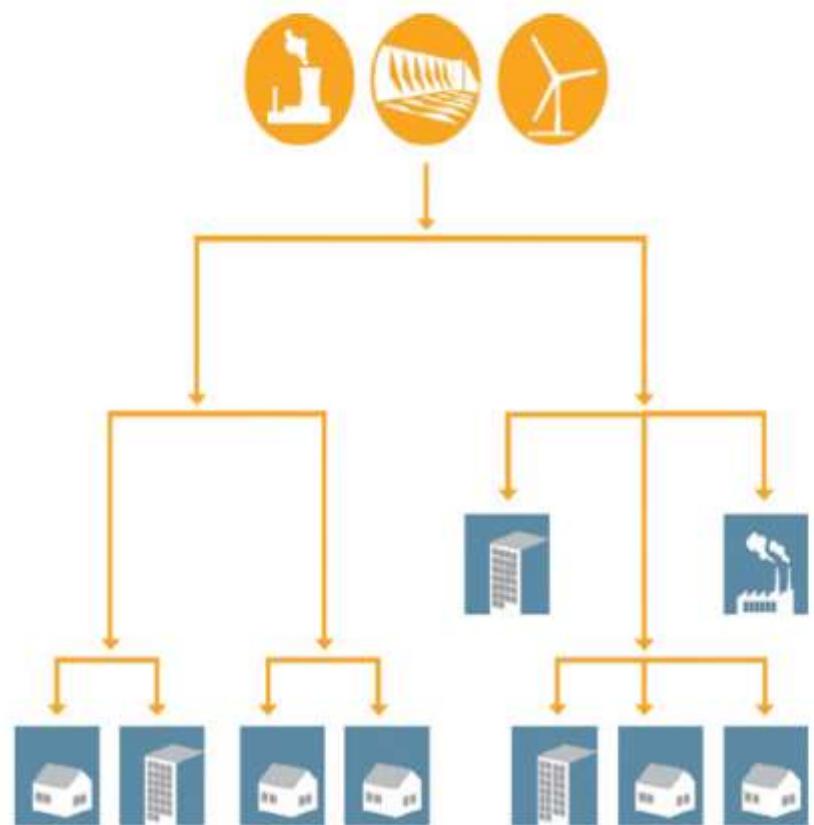


ADVANCED ANALYTICS SMART GRIDS & EFICIENCIA ENERGÉTICA INDUSTRIAL

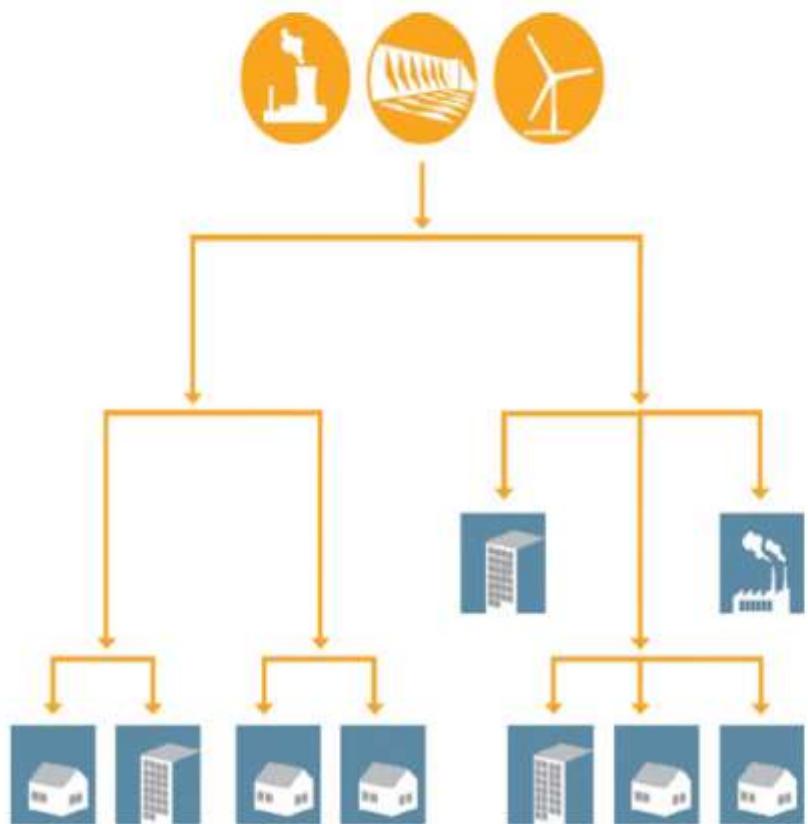
SMART GRIDS



Today's hierachial power system



Today's hierachial power system



Fully realized smart grid



Source: Toward a Smarter Grid ABB's Vision of the Power System of the Future

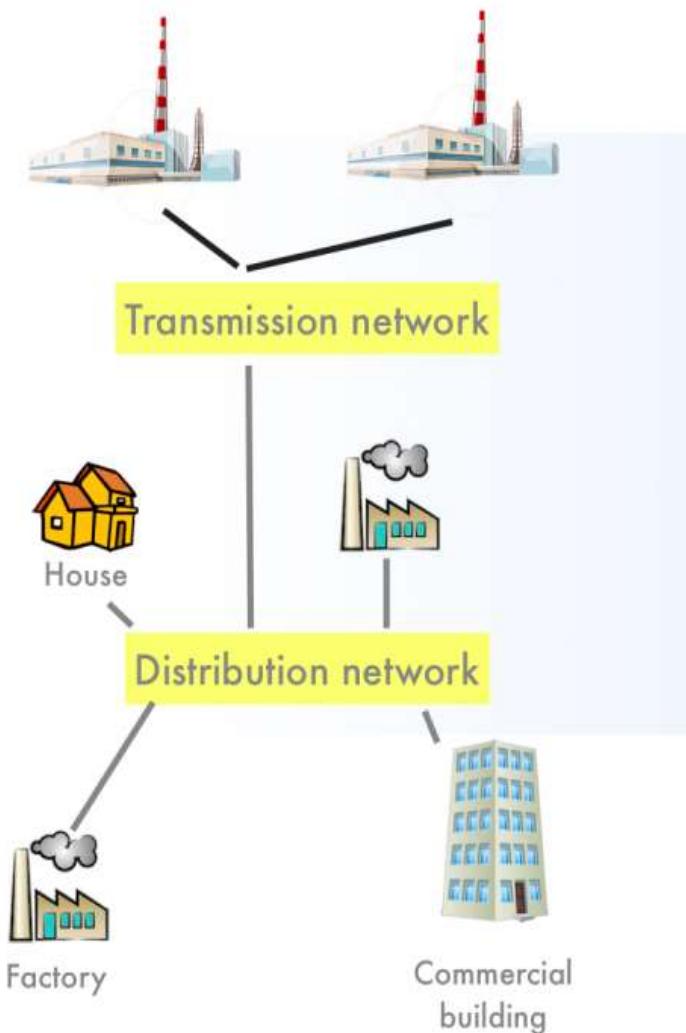
Fully realized smart grid



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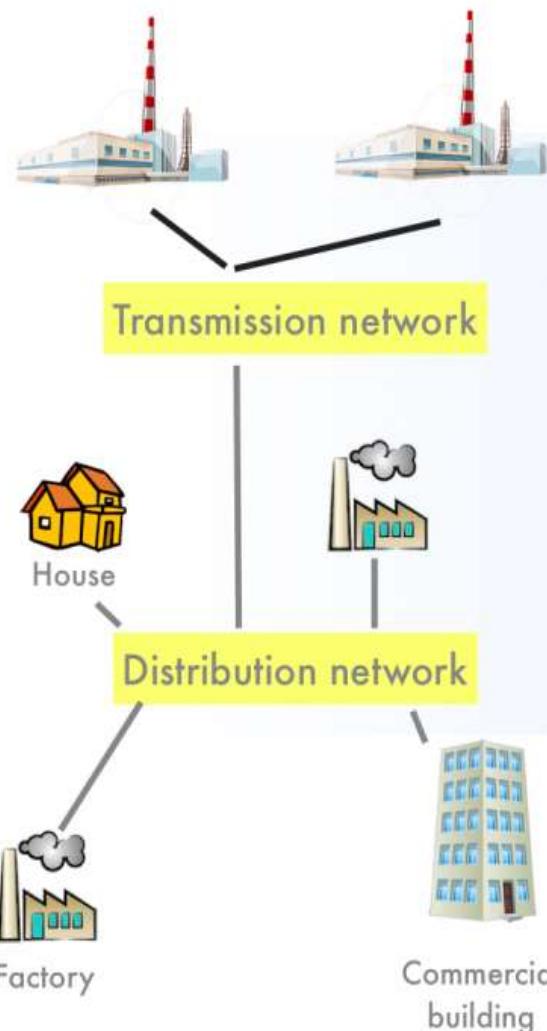
Yesterday

Centralized Power



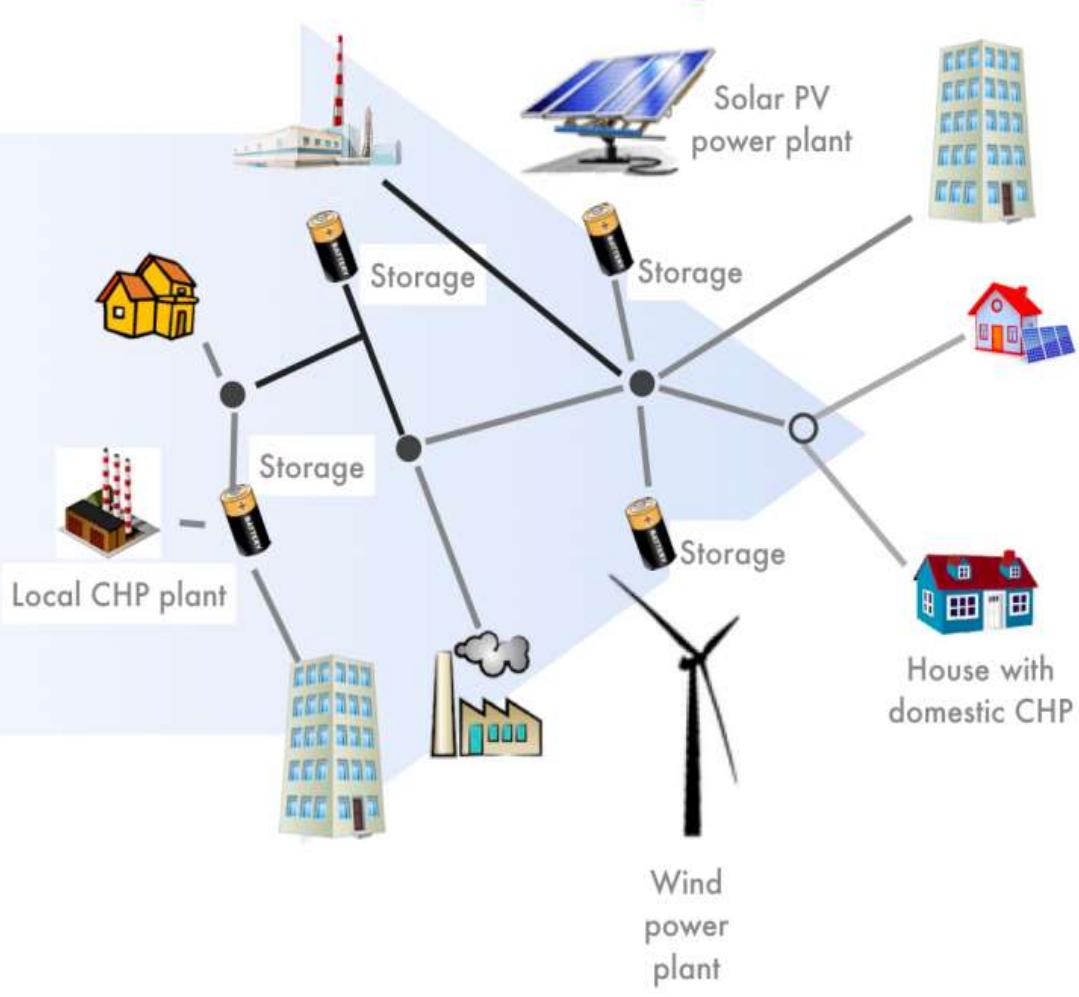
Yesterday

Centralized Power



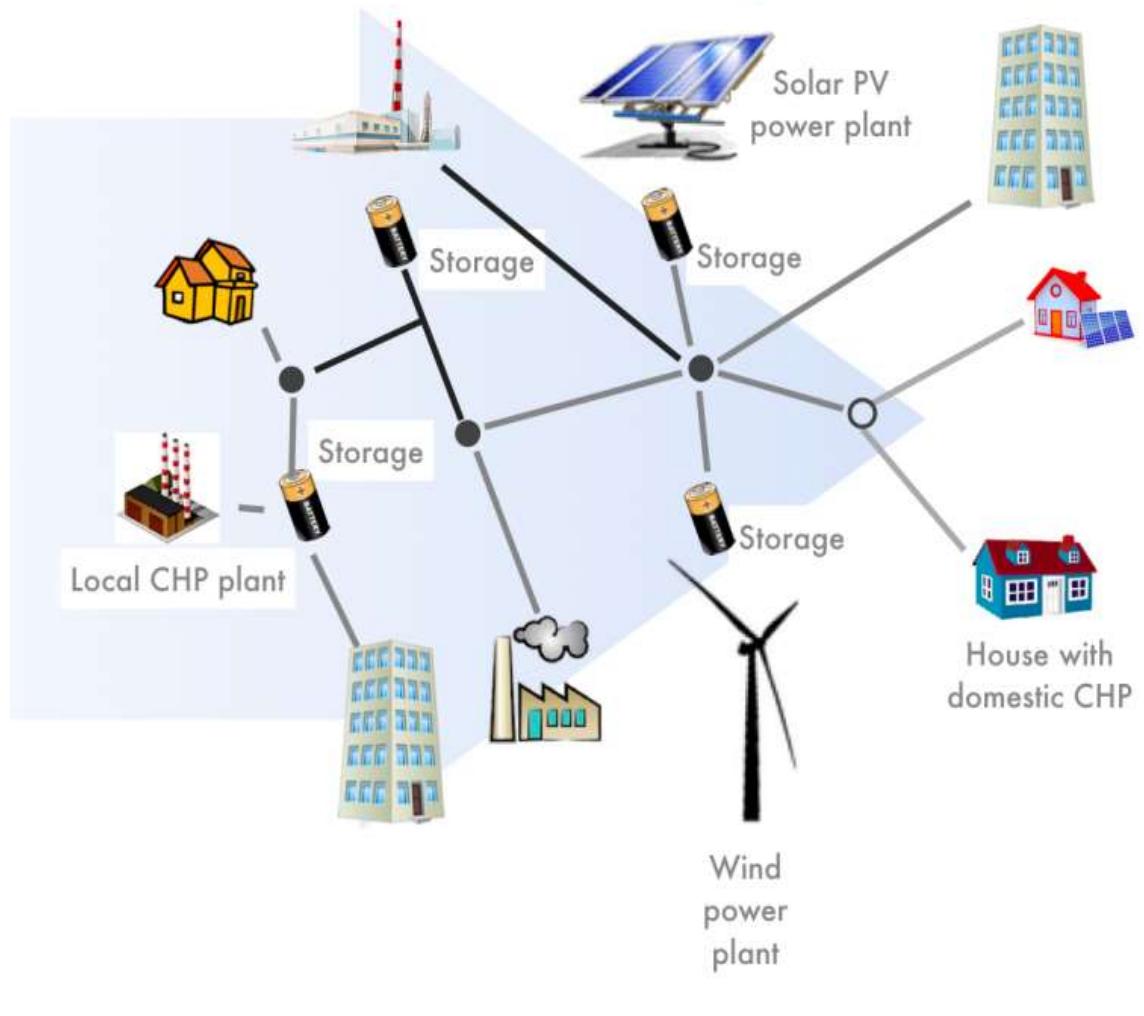
Tomorrow

Clean, local power



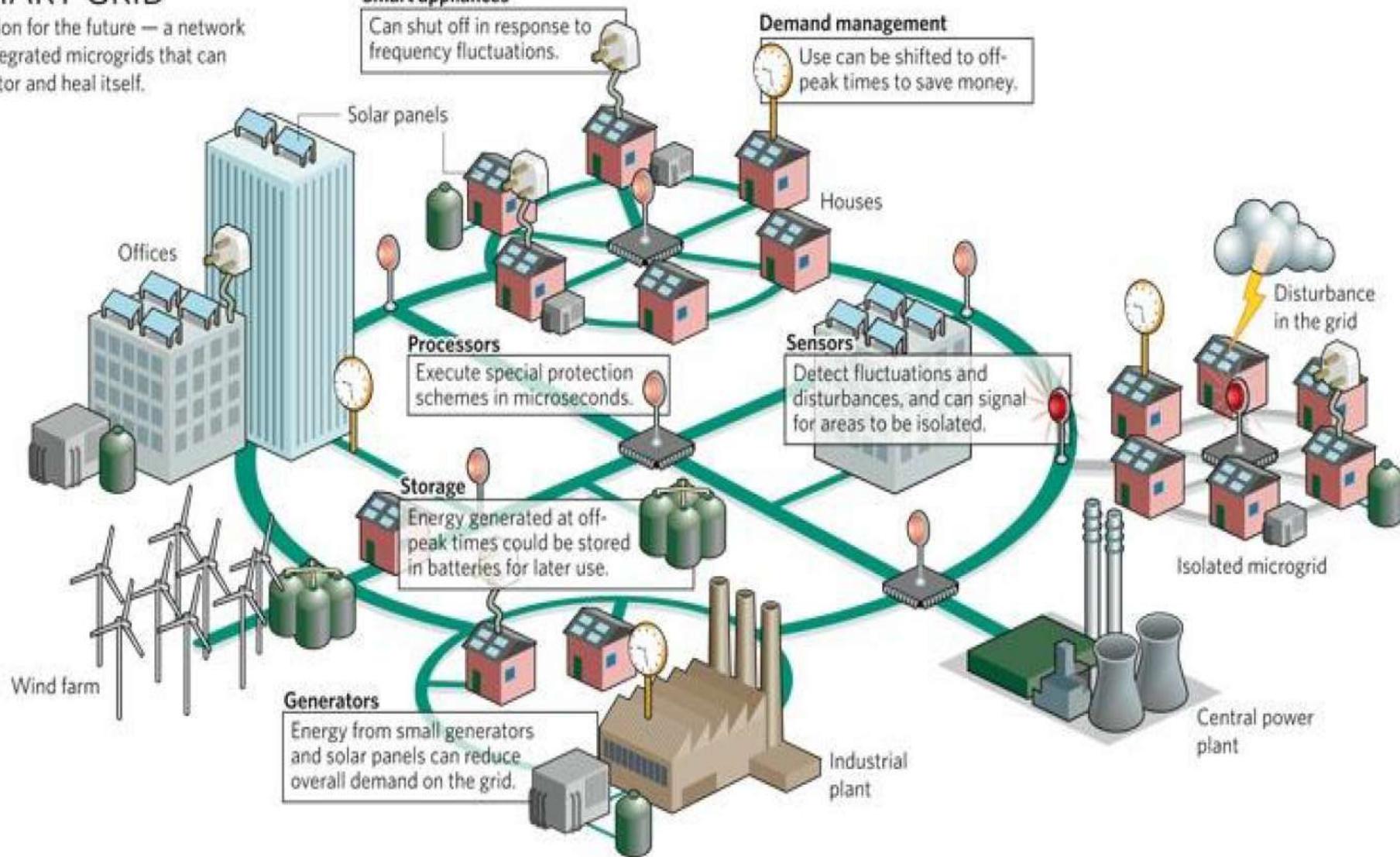
Tomorrow

Clean, local power



SMART GRID

A vision for the future — a network of integrated microgrids that can monitor and heal itself.



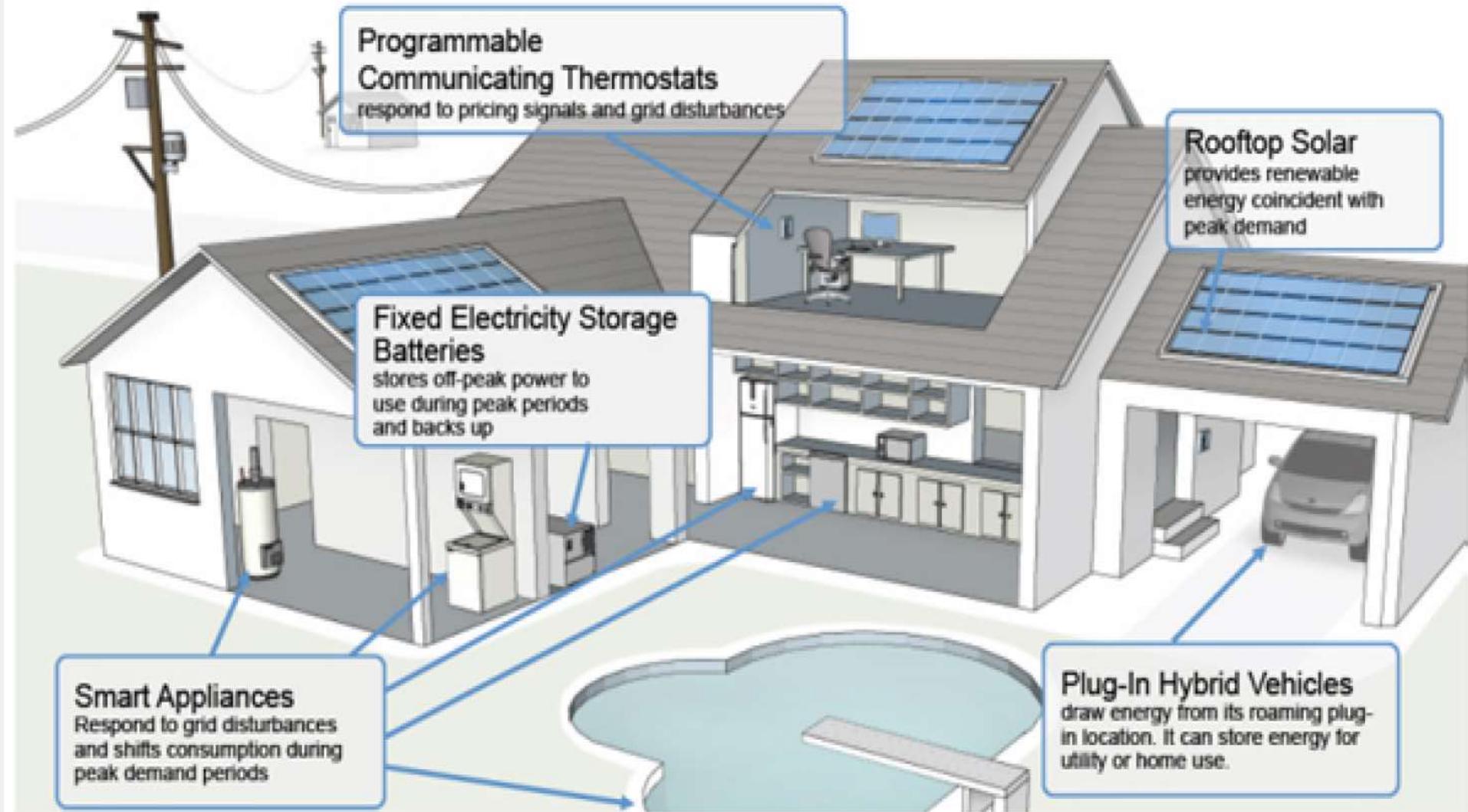


Figure 2: Example of a smart house

ENERGY EFFICIENCY ADVANCED ANALYTICS STRATEGY



OFF LINE OPTIMIZATION (PLANNING)

1. RE-DESIGN THE ENERGY SUPPLY SYSTEM
2. OPTIMIZE THE INDUSTRIAL PROCESS IN THE PLANTS USING COMPLEX MATHEMATICAL MODELS
3. INTEGRATE THE PLANNING AND SCHEDULING OF THE INDUSTRIAL PROCESS (MATTER TRANSFORMATION) WITH THE INDUSTRIAL SERVICES (ENERGY TRANSFORMATION) INCLUDING THE TRANSACTIONS IN THE ENERGY MARKETS (ET-RM) USING OPTIMIZATION MODELS.

ON LINE OPTIMIZATION (OPERATING)

1. USE AN OPTIMIZATION MODEL FOR PRE-DISPATCH THE ENERGY SYSTEM , 24 HOURS IN ADVANCE
2. USE MODELS ORIENTED TO OPTIMUM CONTROL IN REAL TIME (DISPATCH OF ENERGY SYSTEM)
3. SHORT TIME ET&RM



ADVANCED ANALYTICS SMART GRIDS & INDUSTRIAL ENERGY EFFICIENCY

REDESIGN OF POWER SUPPLY SYSTEMS CASE: OIL PRODUCTION

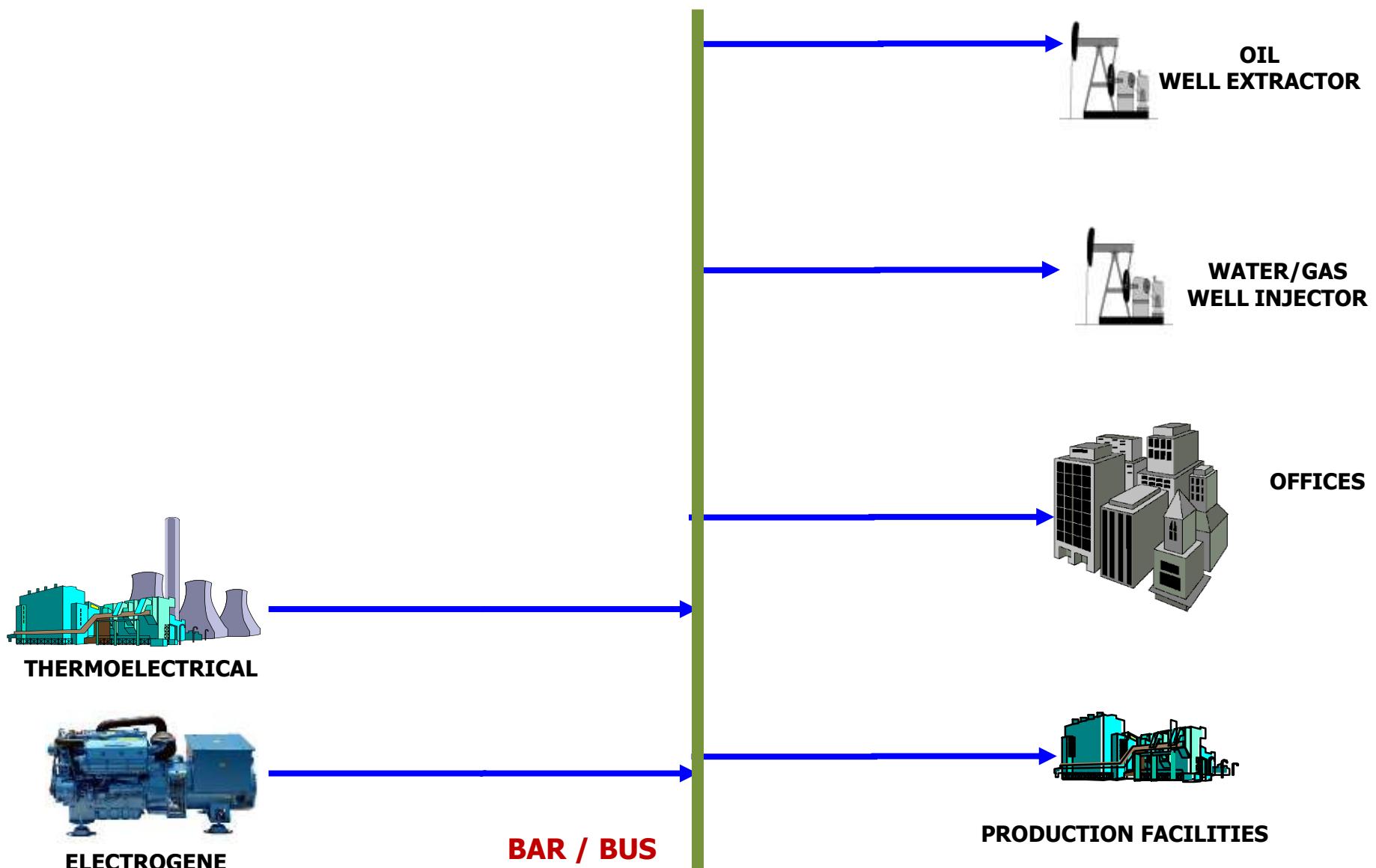


The first step in achieving energy efficiency in industrial plants is related to the redesign of systems of power supply, since in many cases the design of such systems does not include the concepts and technologies associated with the new paradigm: distributed generation and storage of energy, foundation of the "smart grids".



ELECTRIC SYSTEM – OIL FIELD

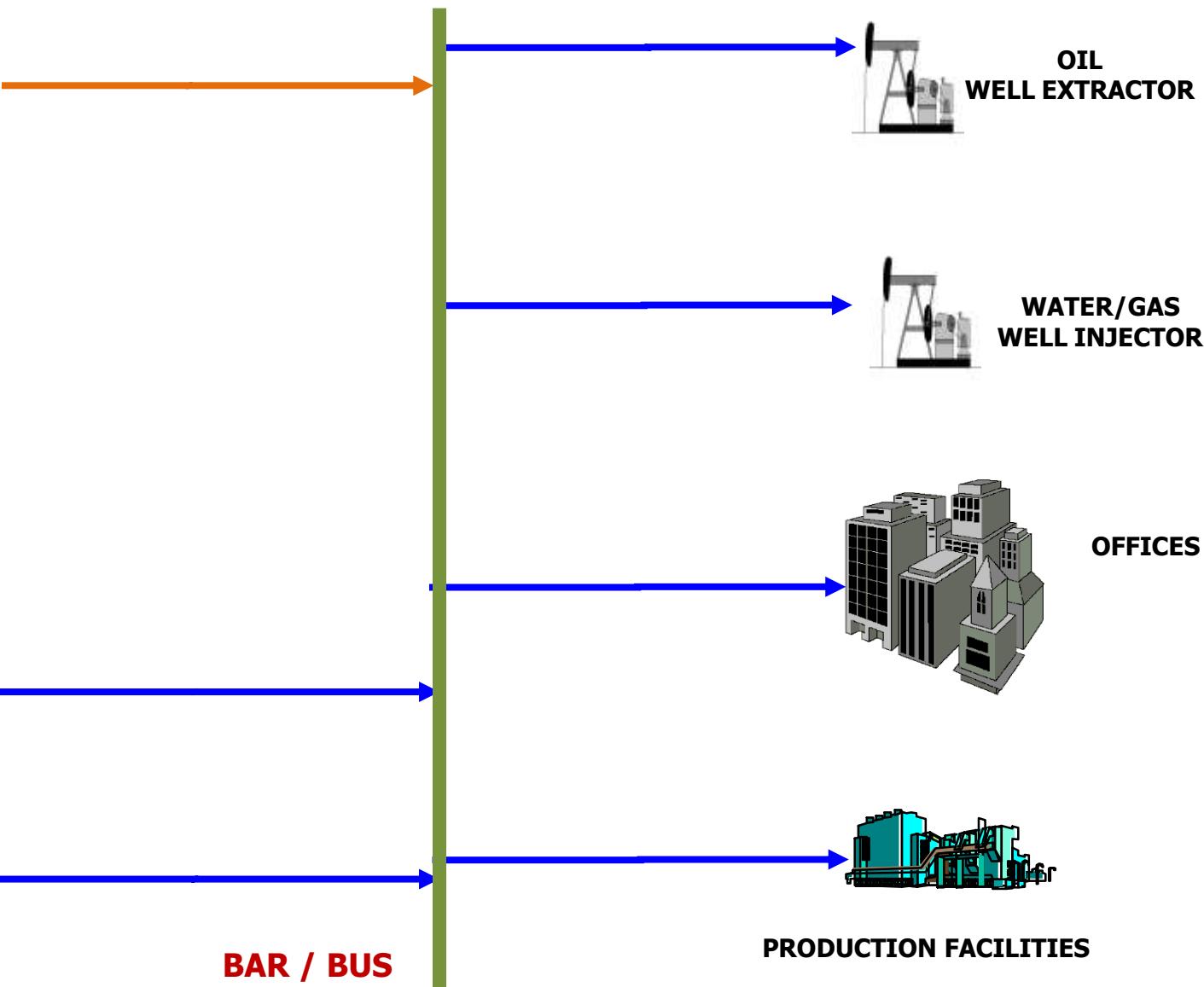
2005



ELECTRIC SYSTEM – OIL FIELD

2005

INTERCONNECTION
NATIONAL SYSTEM



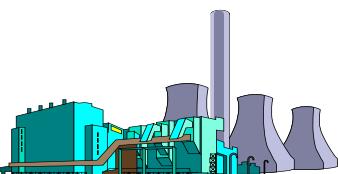
ELECTRIC SYSTEM – OIL FIELD

2014

INTERCONNECTION
NATIONAL SYSTEM



RENEWABLE
SOURCES



THERMOELECTRICAL



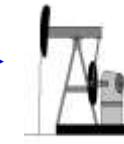
ELECTROGENE



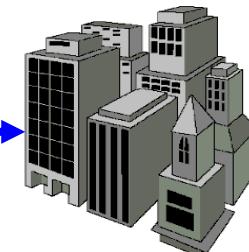
BAR / BUS



OIL
WELL EXTRACTOR



WATER/GAS
WELL INJECTOR



OFFICES



PRODUCTION FACILITIES



ENERGY
STORAGE

ADVANCED ANALYTICS SMART GRIDS & EFICIENCIA ENERGÉTICA INDUSTRIAL

ENERGY EFFICIENCY & INDUSTRIAL PROCESS



All industrial processes have variable speed.

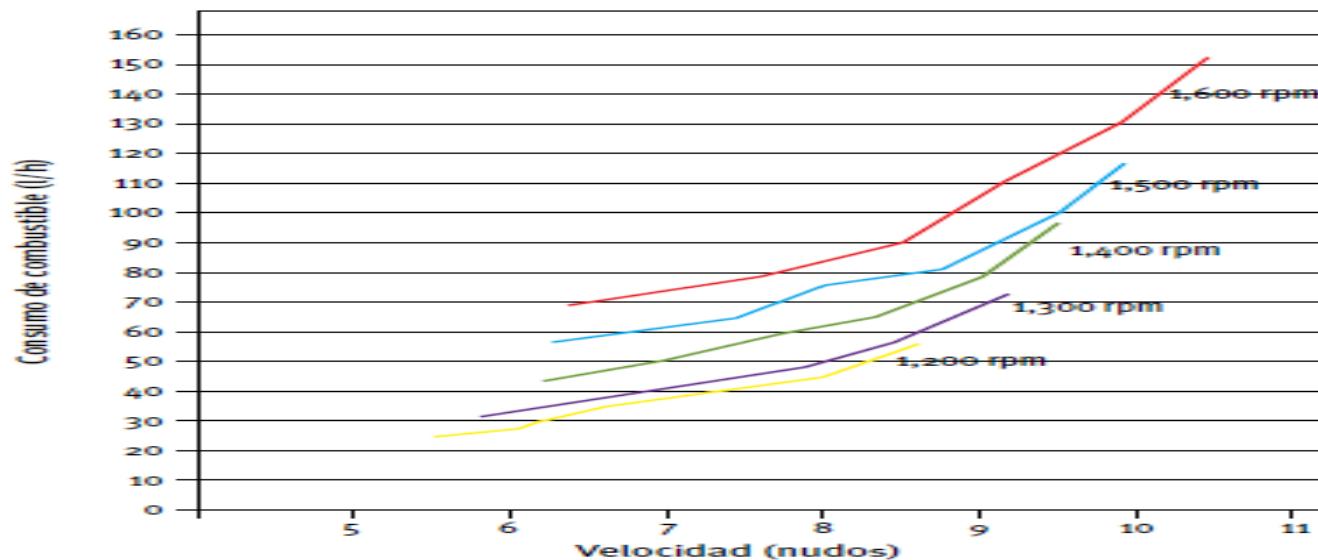
Power consumption as a function of the speed of the process is not linear, it is exponential.

The production facilities do not have defined a fixed capacity, it is established in accordance with the speed of the process and the time running at that speed.



CONSUMO DE ENERGÍA EN UN MEDIO DE TRANSPORTE BARCO

Fig. 9.4. Navegación: consumo de combustible en función de la velocidad para distintos regímenes de giro del motor (distintos pasos de pala) (Fuente: IMARES)



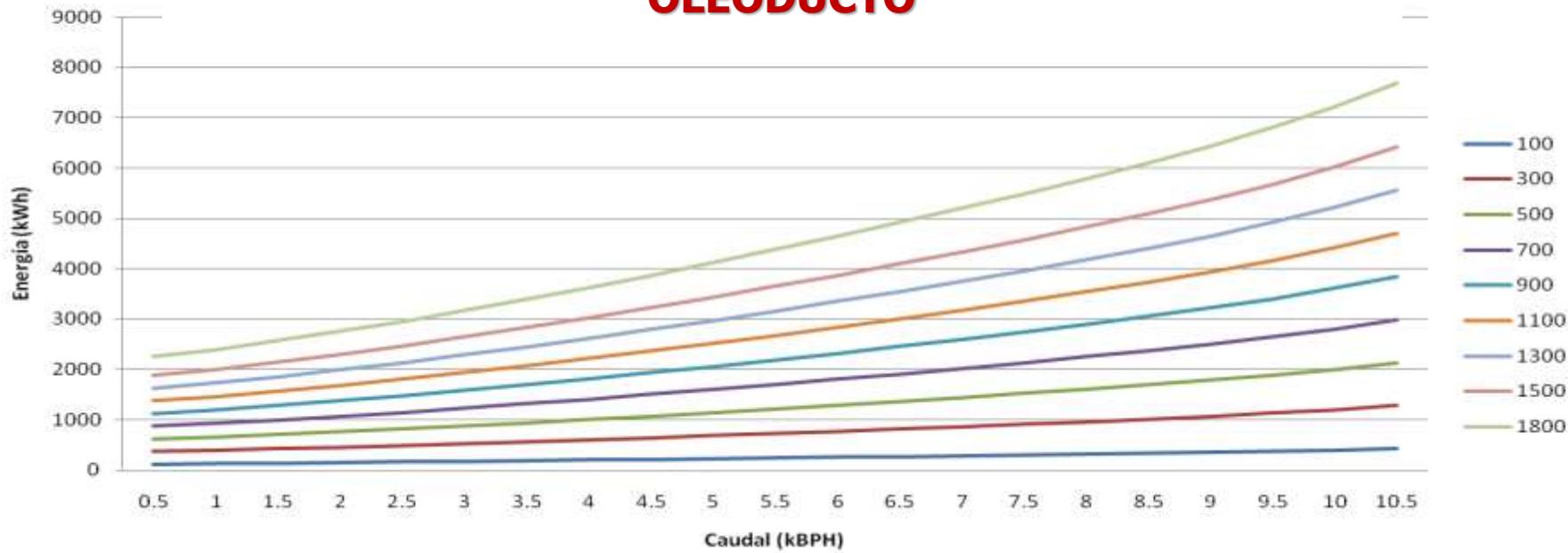
CONSUMO DE ENERGÍA EN UN MEDIO DE TRANSPORTE TREN DE ALTA VELOCIDAD

**Consumo "equivalente a partir de la estación de servicio" trayecto Madrid-Barcelona
(650 km, ocupación 65%, consumos AVE según proyecto)**

Medio de transporte	kWh trayecto completo por pasajero	kWh /100 pkm	Consumo en litros gasolina/100 pkm
AVE 103, v max 300 km/h	99,8	15,4	1,7 l
AVE 103, v max 320 km/h	117,4	18,1	2,0 l
AVE 103, v max 350 km/h	129,6	19,9	2,2 l
Avión (aproximado)			6,3-6,8 l



CONSUMO DE ENERGÍA EN UN MEDIO DE TRANSPORTE OLEODUCTO



ADVANCED ANALYTICS SMART GRIDS & INDUSTRIAL ENERGY EFFICIENCY

REAL TIME OPTIMIZATION



REAL TIME OPTIMIZATION

Real Time Optimization maintains the operating process is its "optimal" set-points based on the periodic re-optimization, taking into account the difference between the environmental conditions with the forecasted conditions. It is composed of the following models :

- **MPI:** Identification of the model equations and the parameters that define the system dynamics.
- **STE:** State estimation and reconciliation model of system oriented to the re-estimation of the system parameters (state estimation, data reconciliation and gross and random error detection)
- **OCO:** Optimal control model using real-time variables.

COORDINACION DE HERRAMIENTAS EN LA PLANIFICACION INTEGRADA

STRATEGIC PLANNING

INVERSIÓN A LARGO PLAZO

LI: LÓGICA DE INVERSIÓN

OM: OPERACIONES MENSUALES

SALES & OPERATION PLANNING

MEDIUM TERM

METAS OPERACIONALES A MEDIANO PLAZO

OM: OPERACIONES MENSUALES

SALES & OPERATION PLANNING

SHORT TERM

METAS DE OPERACIONALES A CORTO PLAZO

OM: OPERACIONES MENSUALES

OS: OPERACIONES SEMANALES

OPCHAIN-APS



OPERATIONS SCHEDULING

ORDENES DE OPERACION

OS: OPERACIONES SEMANALES

OD: OPERACIONES DIARIAS

OPCHAIN-APS

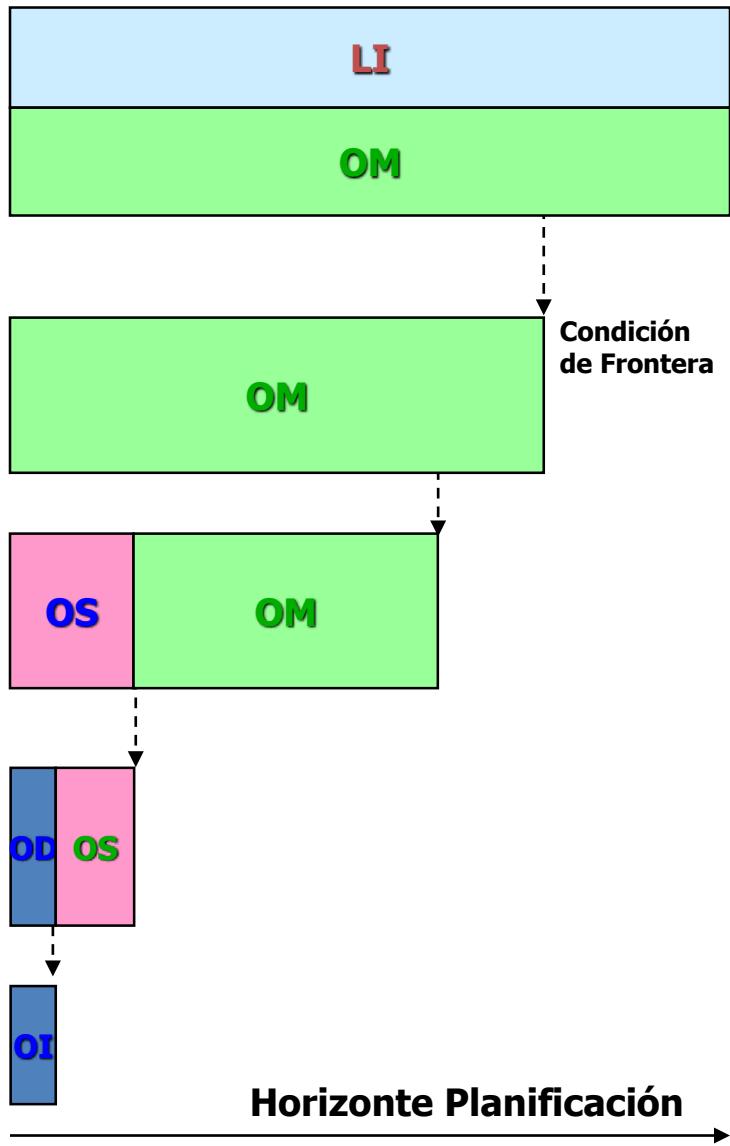


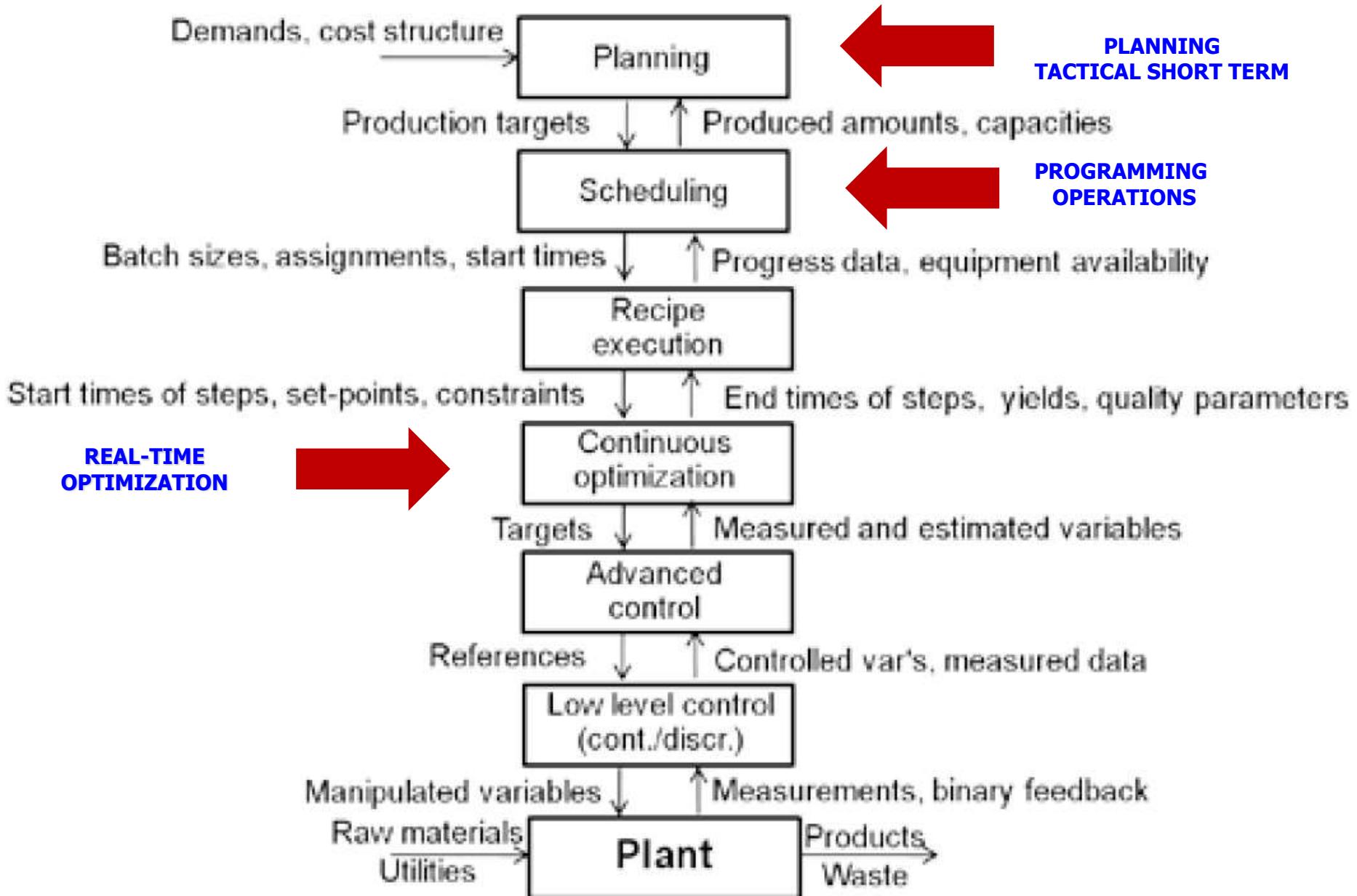
REAL-TIME OPTIMIZATION

CONTROL DE PROCESOS

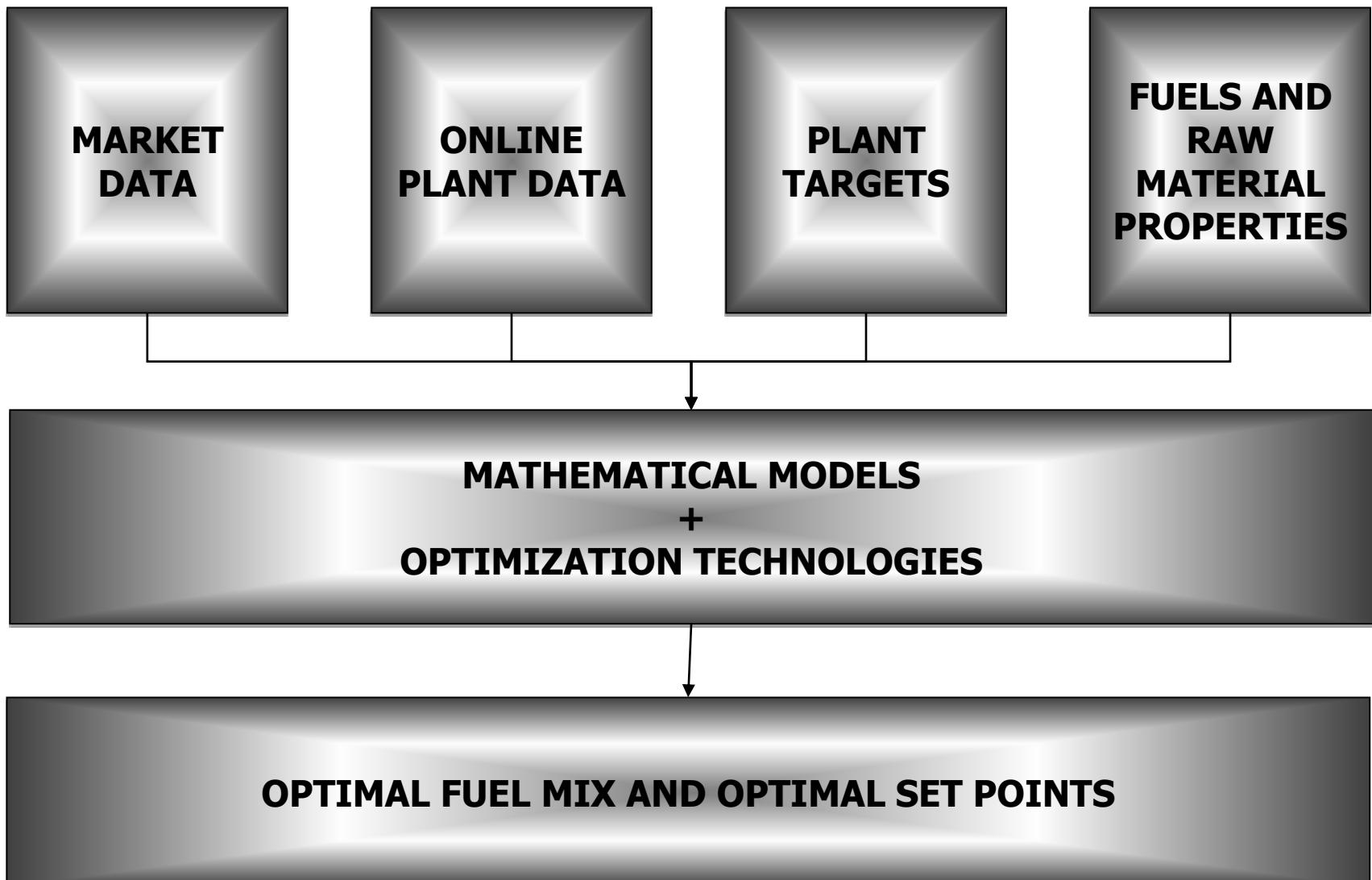
OI: OPERACIONES INSTANTANEAS

OPCHAIN-RTO





TECHNO-ECONOMICAL OPTIMIZATION OF THE INDUSTRIAL PROCESS



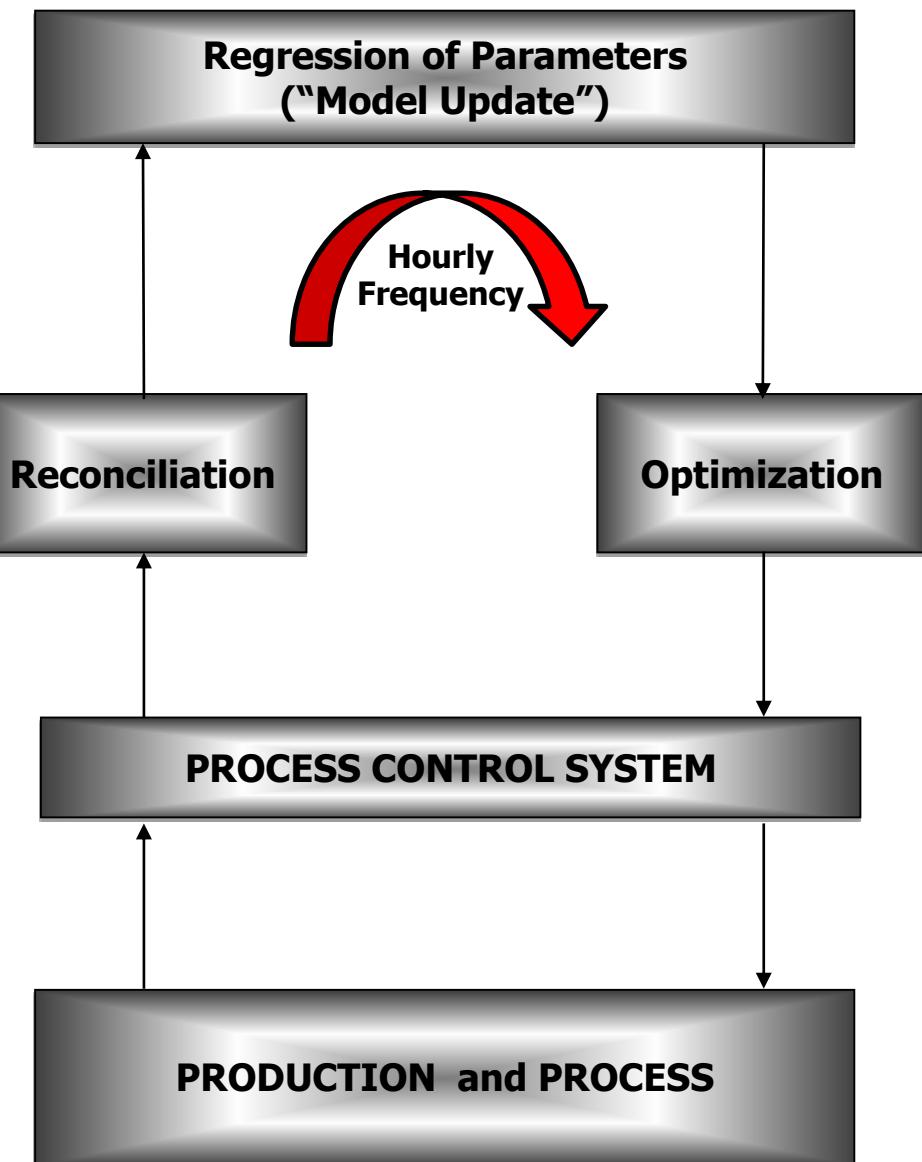
REAL TIME OPTIMIZATION

RTO is a well-known mathematical approach to keep the process running on its set-points or targets "optimally" based on periodic re-optimization, as a means to take into account changing process and environmental conditions (uncertainty).

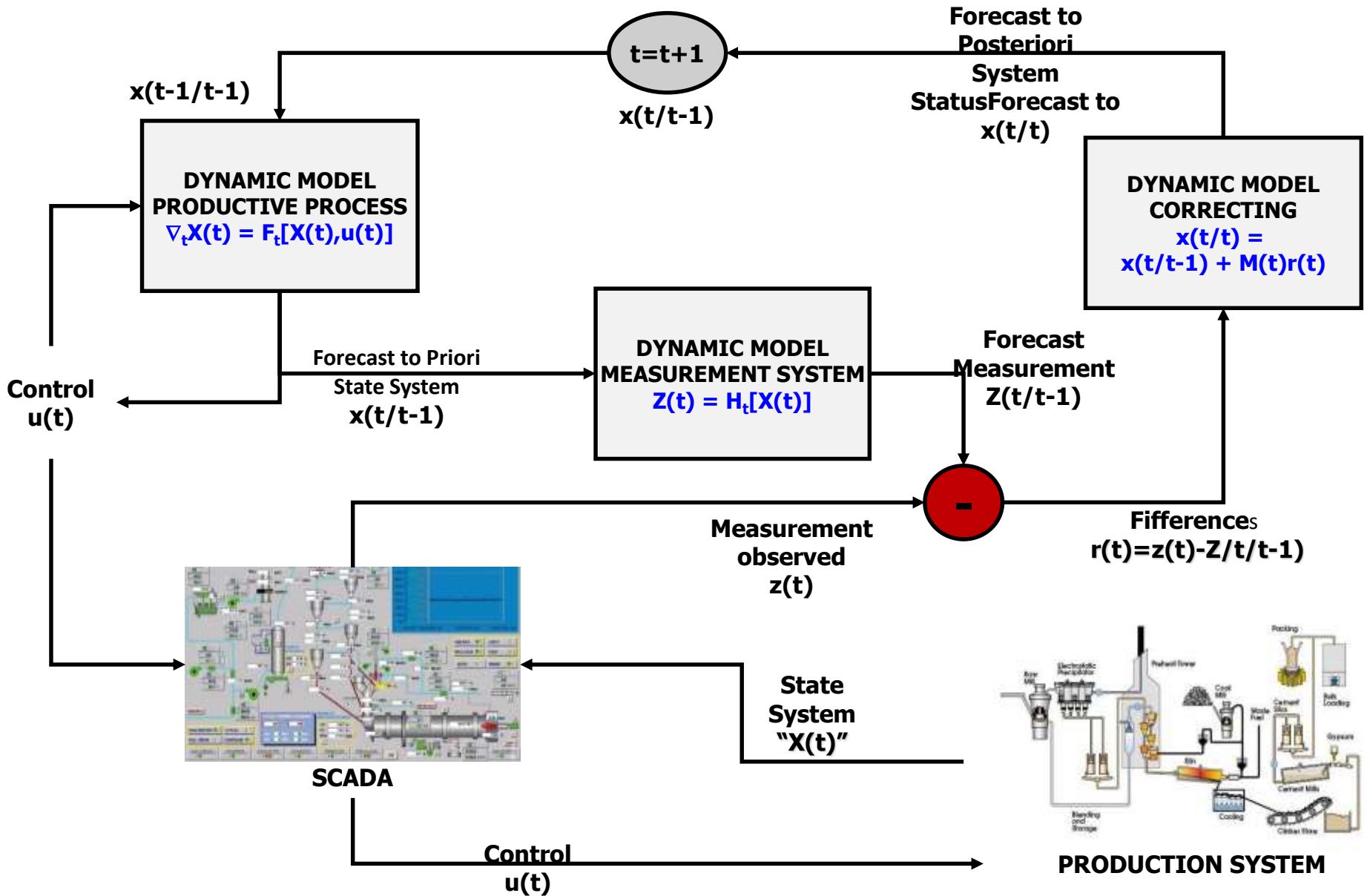
Results:

- Stable processes ("smoother operation"),
- Better control of process variables,
- Optimal production levels,
- Reduction in energy consumption (kW/ton),
- "Exact" control of emissions,
- **Increased profits, etc.**

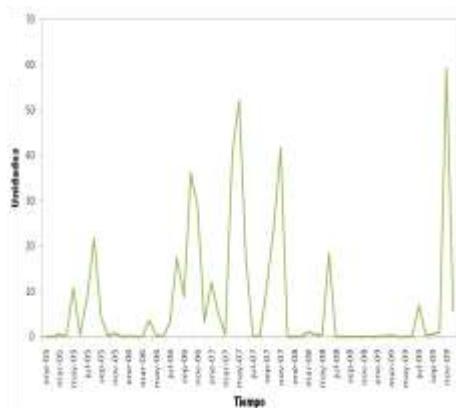
UNCERTAINTY



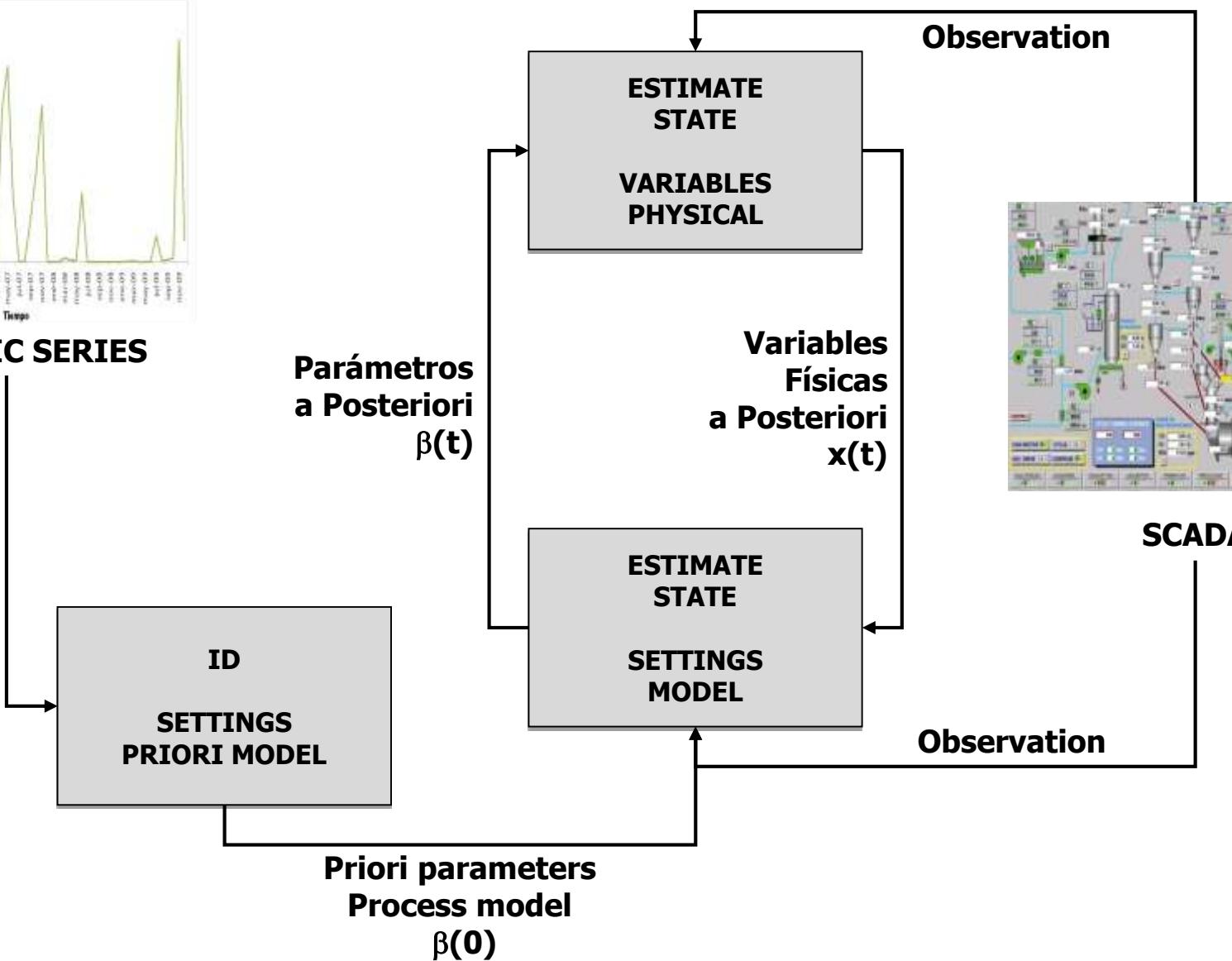
STATE ROUTE ESTIMATED KALMAN FILTER



DUAL STATE ESTIMATE

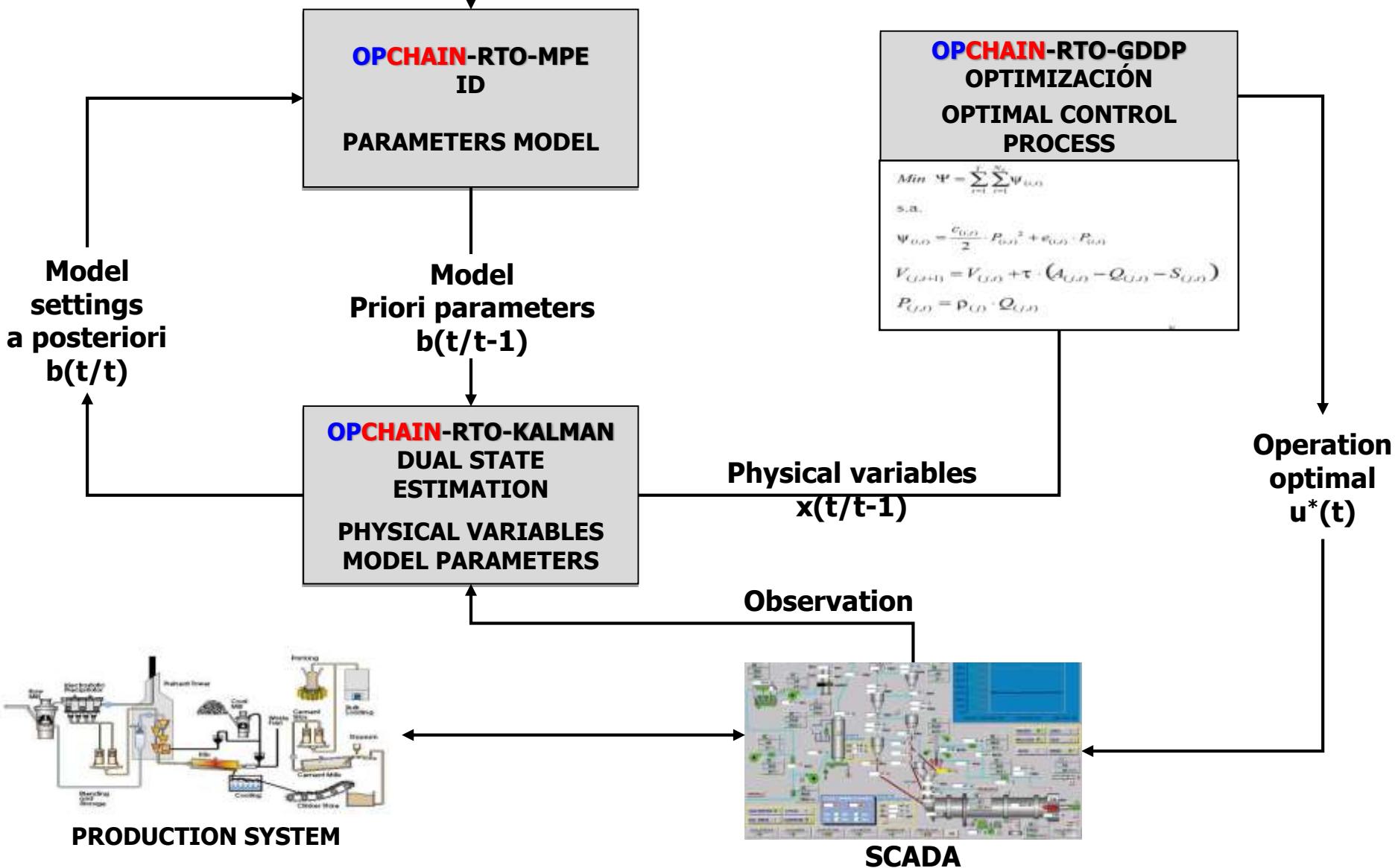


HISTORIC SERIES



SERIES
HISTORY

OPCHAIN-RTO





ADVANCED ANALYTICS SMART GRIDS & INDUSTRIAL ENERGY EFFICIENCY

CASE: CEMENT PRODUCTION



To achieve energy efficiency, it is necessary to optimize industrial processes guiding them to points of operation of minimum energy consumption, considering indicators of profitability of the operation, and control of contaminant emissions, which are more demanding every day.

The via is the design and implementation of mathematical models that represent, with detail, such processes and thus allow the optimization of them.



CADENA DE PRODUCCIÓN EN LA INDUSTRIA PESADA

INDUSTRIA DEL CEMENTO

CANTERAS

EXTRACCIÓN DE MATERIAS PRIMAS

1. Mineral rico en calcio o en materiales calcáreos:
 - Piedra Caliza;
 - Tiza;
 - Etc.
2. Mineral rico en sílice o arcillosos:
 - Arcilla.

Transporte →
Trituradoras

TRITURACIÓN

REDUCCIÓN DE TAMAÑO

1 metro → < 80 mm

PRE-MEZCLADO

MATERIALES TRITURADOS

↓
ANALIZADOR EN LÍNEA

(Composición química)

Apilador → diferentes pilas de materiales y para reducir la variabilidad en la composición química de las materias primas.

MOLIENDA Y MEZCLADO

TRANSPORTADOR DE CINTA

↓
ALIMENTADOR

↓
Proporciones adecuadas
(Tipo de clíker a producir)

↓
Trituración a finura deseada en molinos

↓
Polvo → silo

↓
Reducción de Variaciones
(mezcla con aire)

CADENA DE PRODUCCIÓN EN LA INDUSTRIA PESADA

INDUSTRIA DEL CEMENTO

QUEMADO Y ENFRIADO

CLINKERIZACIÓN

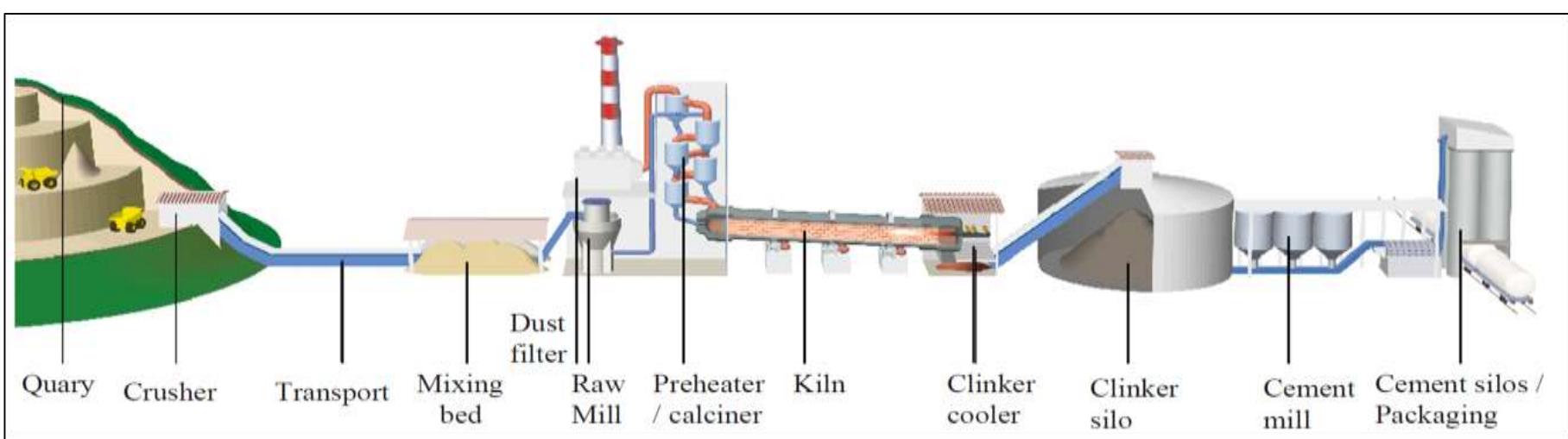
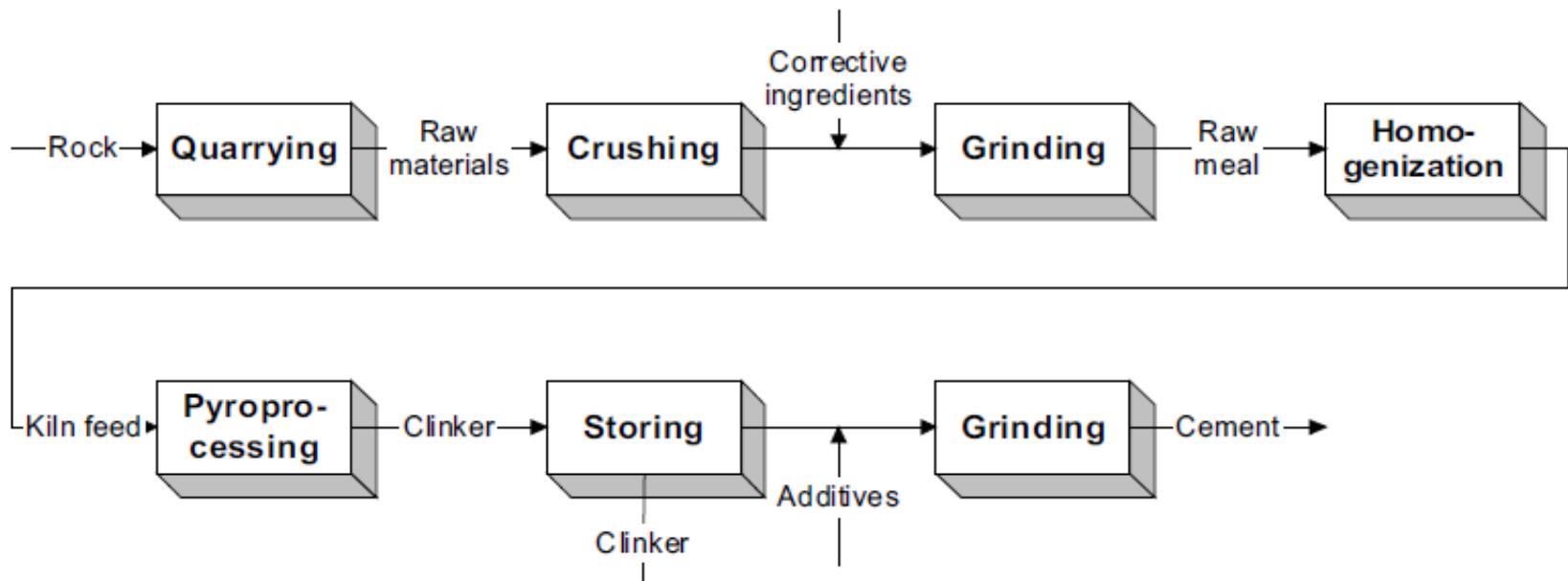
Mezcla en bruto homogenizada
 ↓
 pre-calentador
 (calcinación parcial)
 ↓
 Hornero rotatorio
 ↓
 Clíker
 ↓
 Enfriador
 ↓
 Clíker (~ 100°C) → Silo Clinker

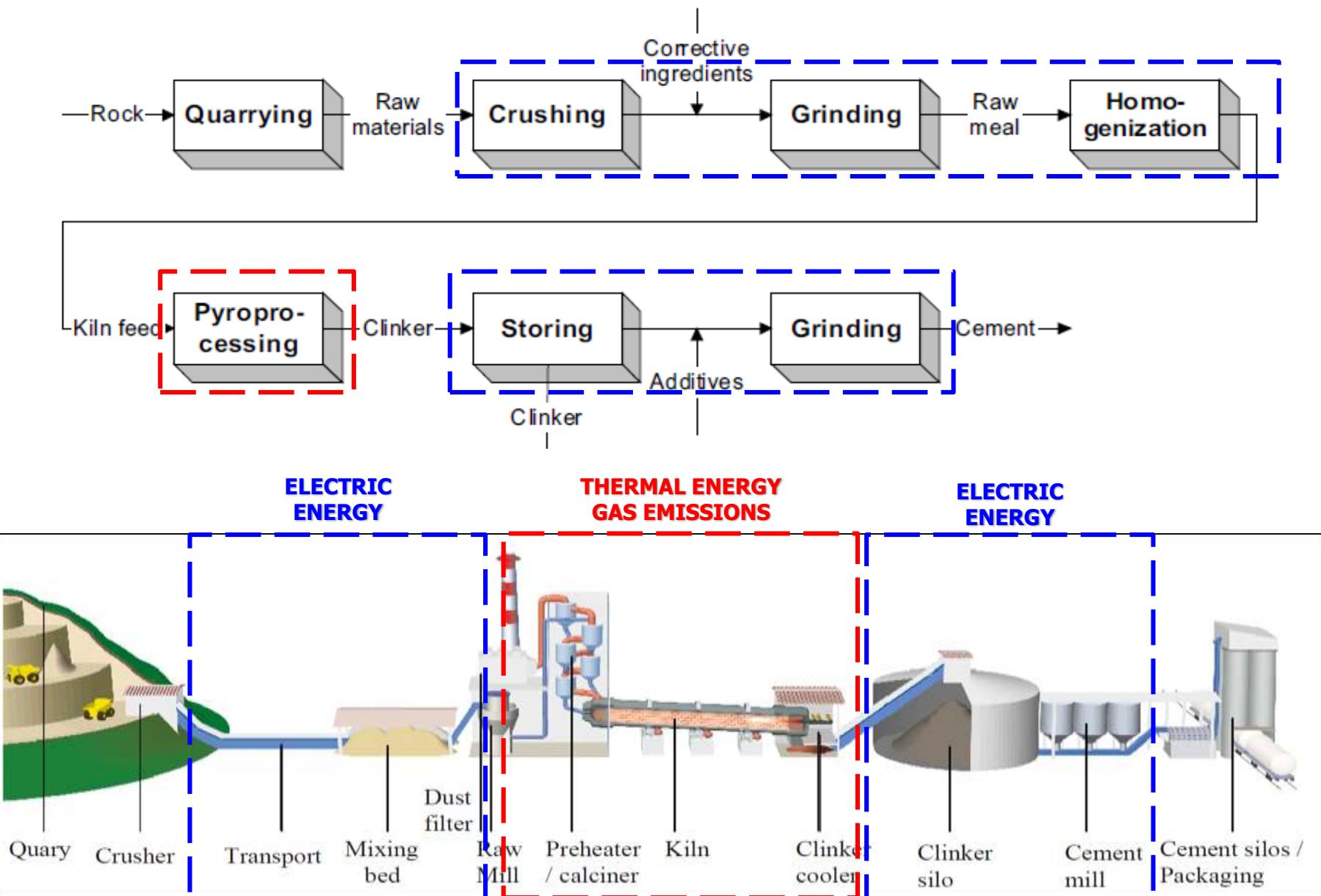
MOLIENDA FINAL

Silo de clíker
 ↓
 Alimentador
 (proporción con yeso y materiales adicionales)
 ↓
 Molienda final
 ↓
 Silos de cemento

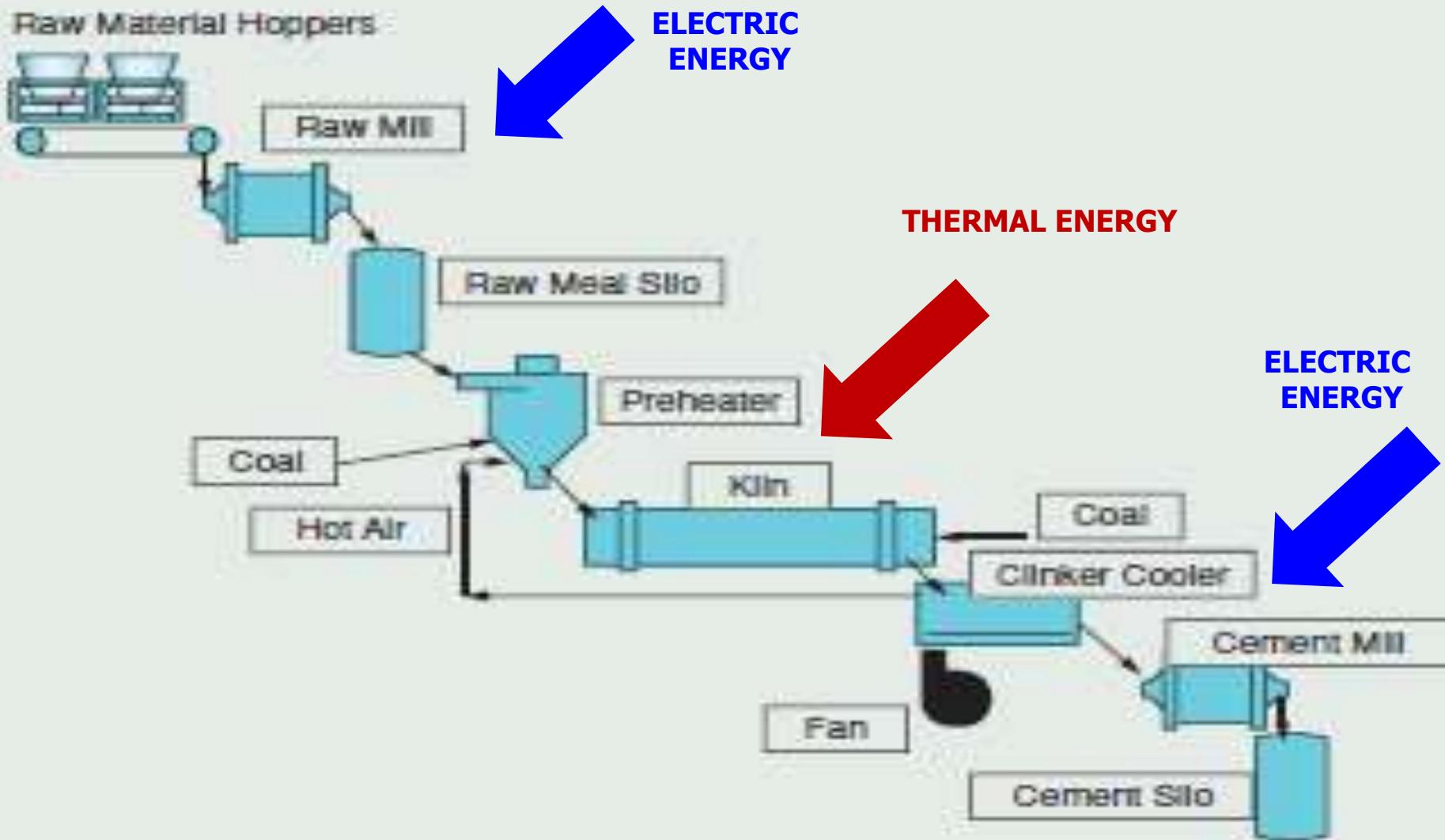
DISTRIBUCIÓN

Cemento (silos)
 ↓
 Empaqueado Bolsas
 Carga a granel.
 ↓
 Distribución
 ↓
 • Vía terrestre;
 • Vía marítima.

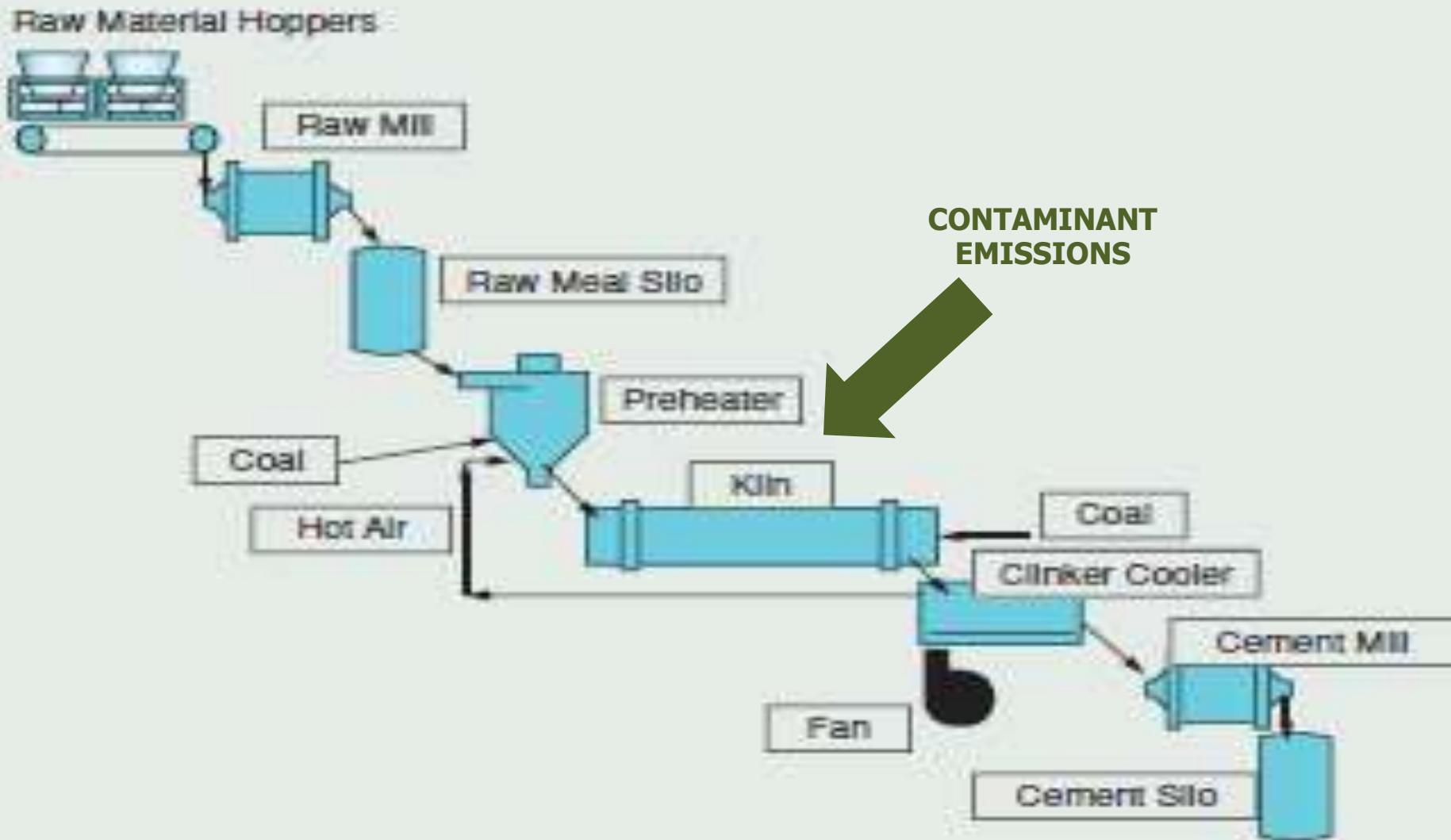




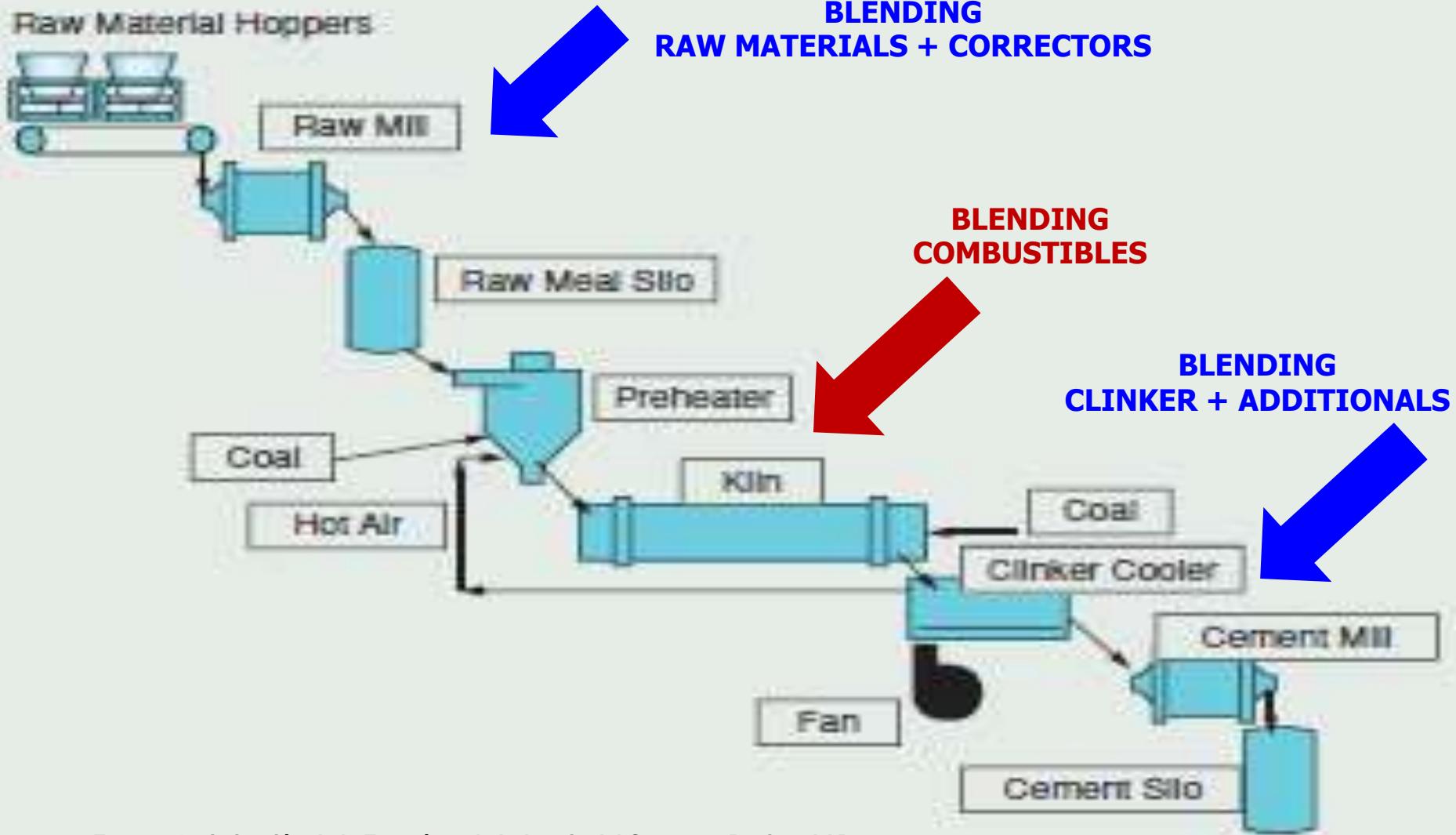
ENERGY EFFICIENCY OPTIMIZATION



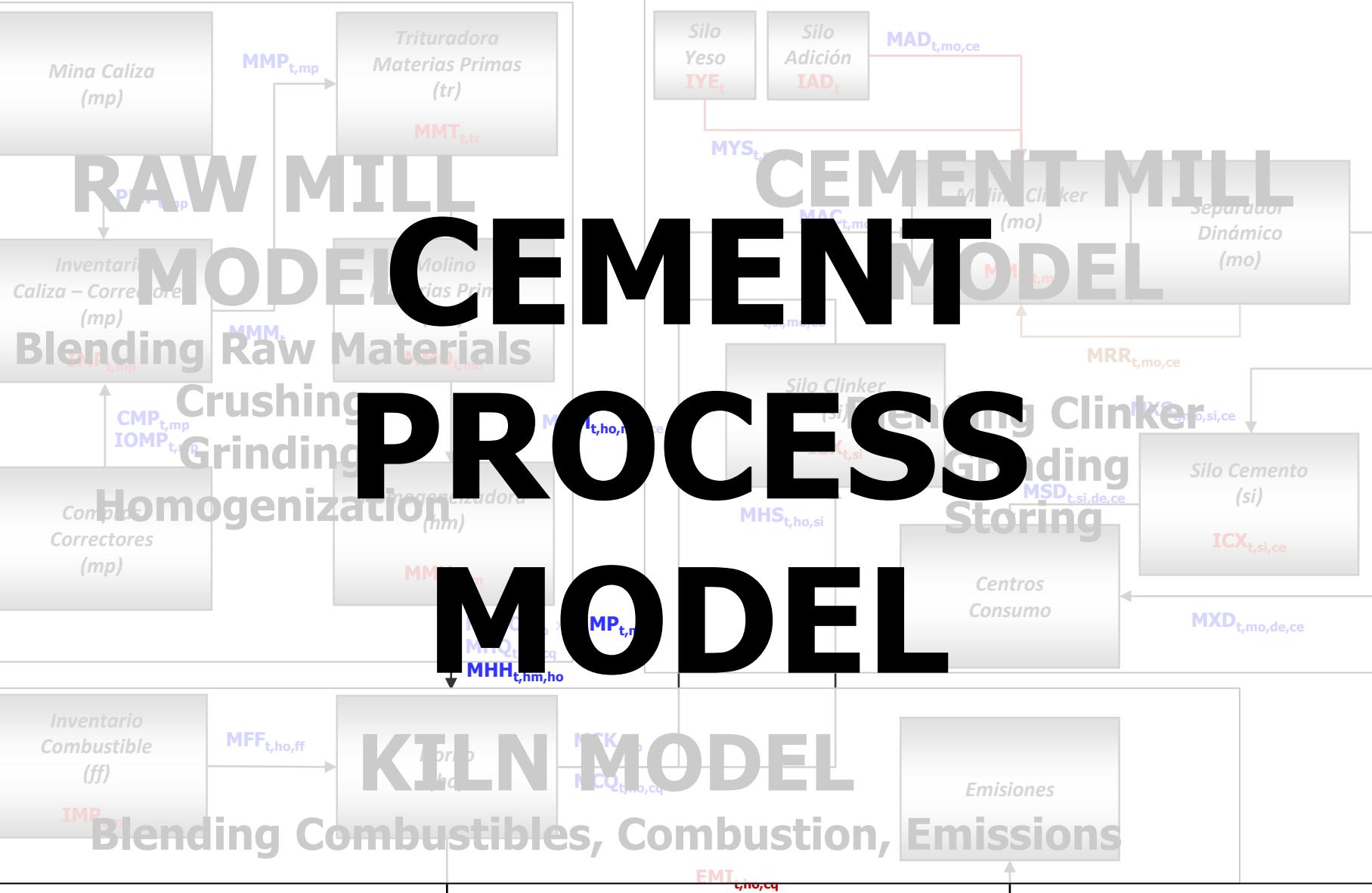
ENERGY EFFICIENCY OPTIMIZATION



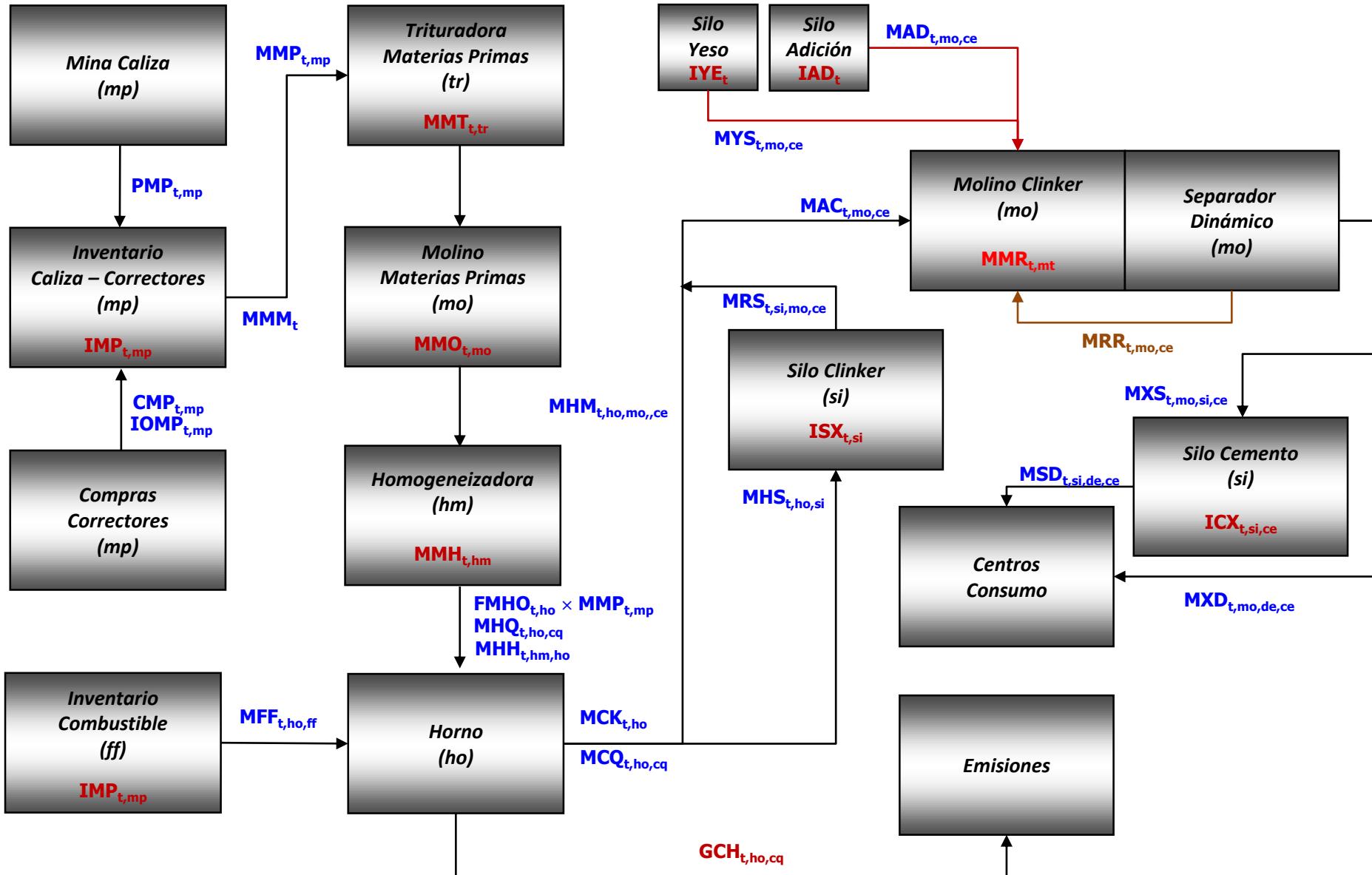
ENERGY EFFICIENCY OPTIMIZATION



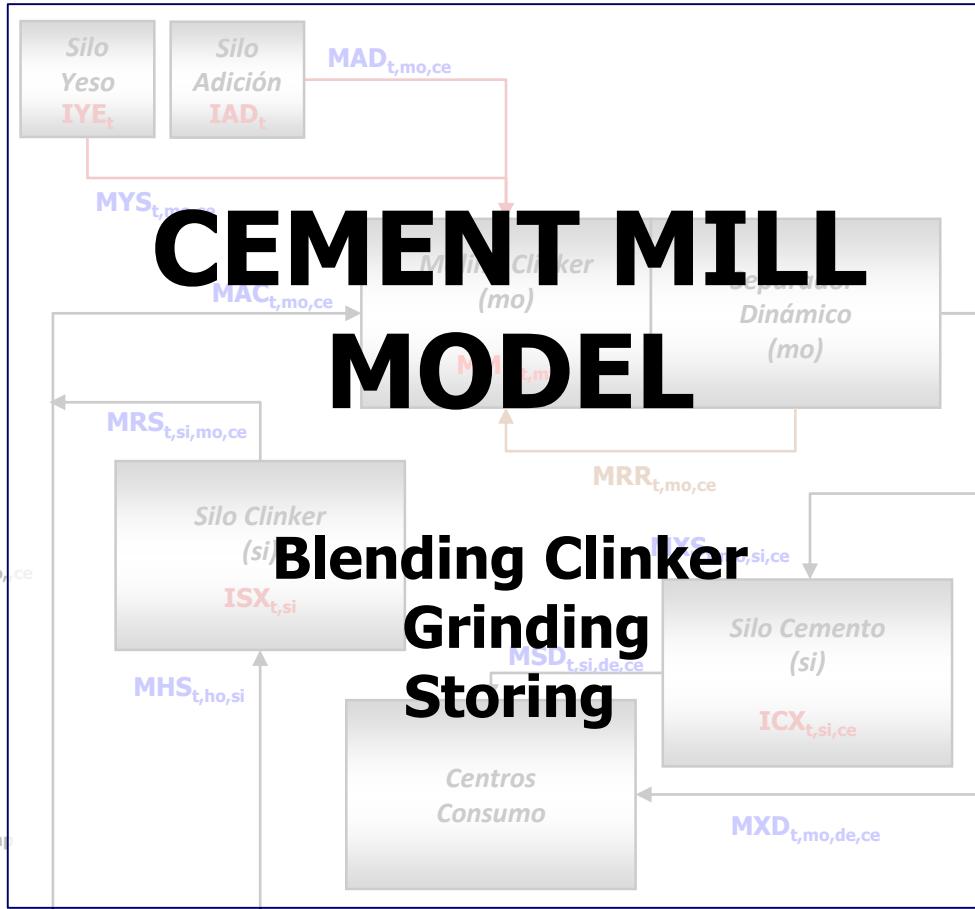
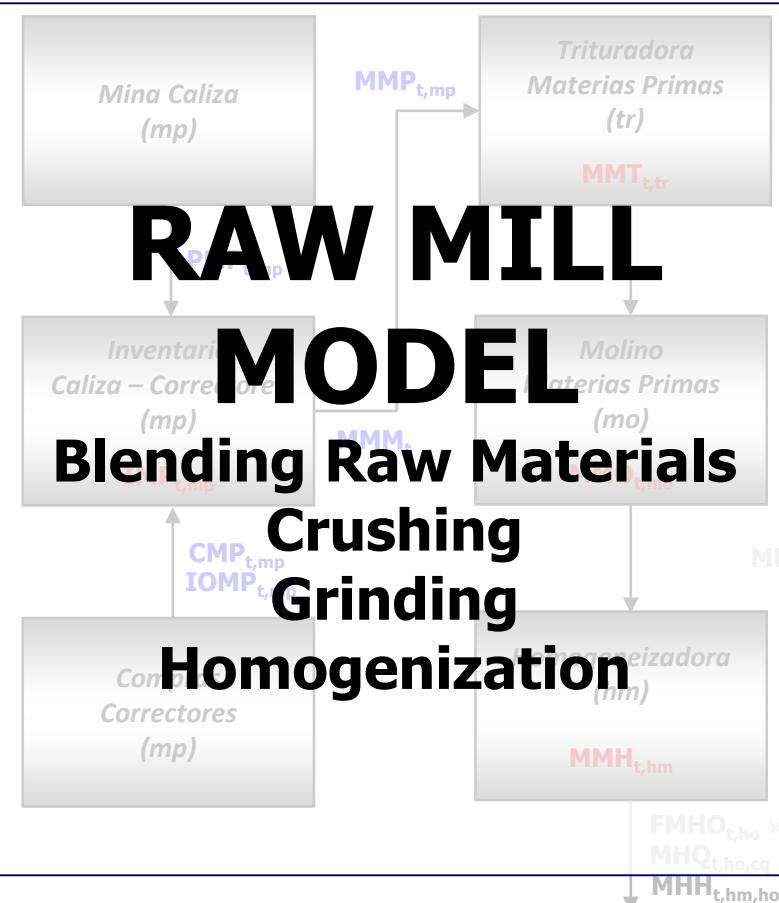
MODELING OF THE PRODUCTION PROCESS OF THE CEMENT



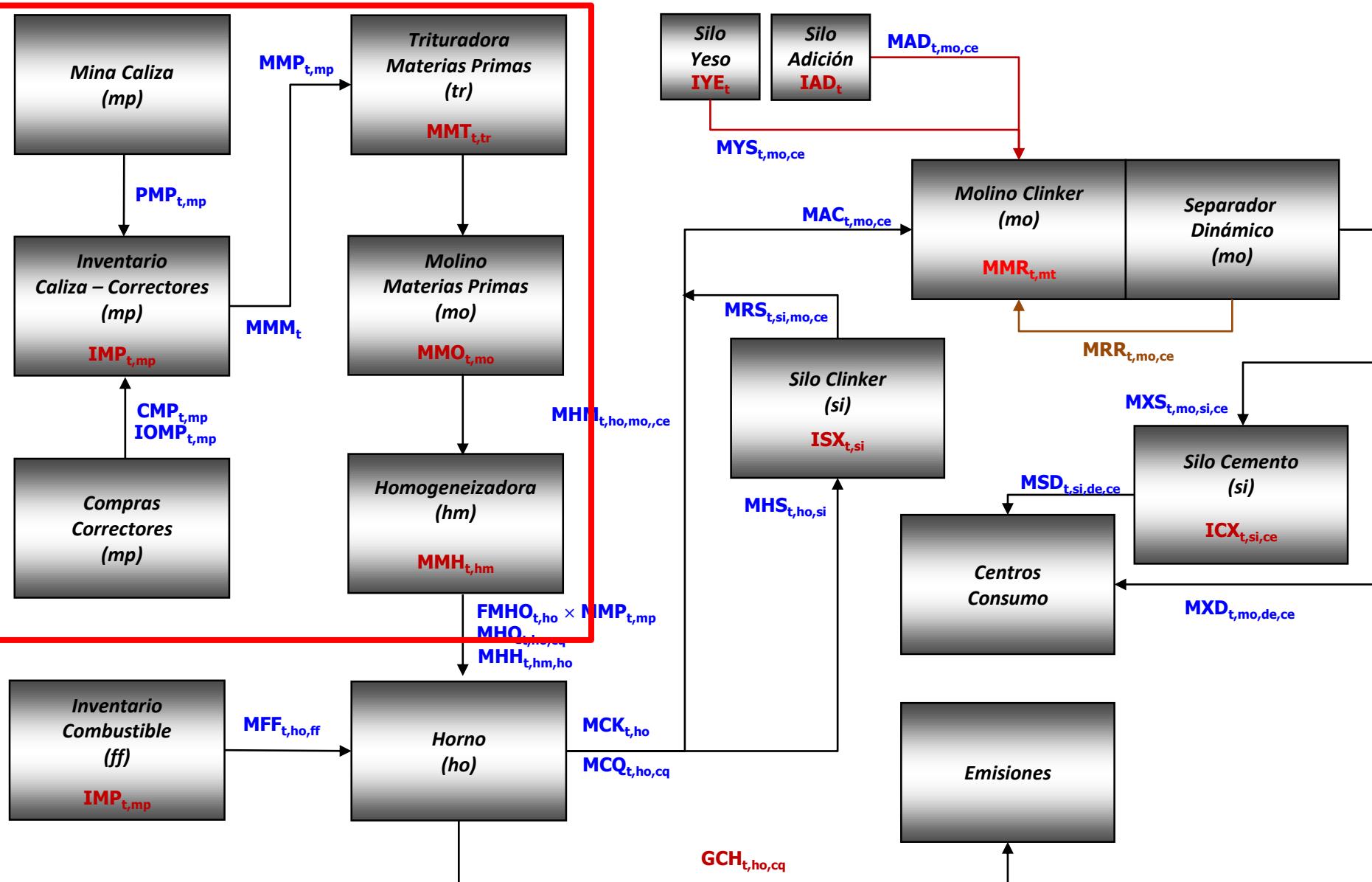
MODELING OF THE PRODUCTION PROCESS OF THE CEMENT



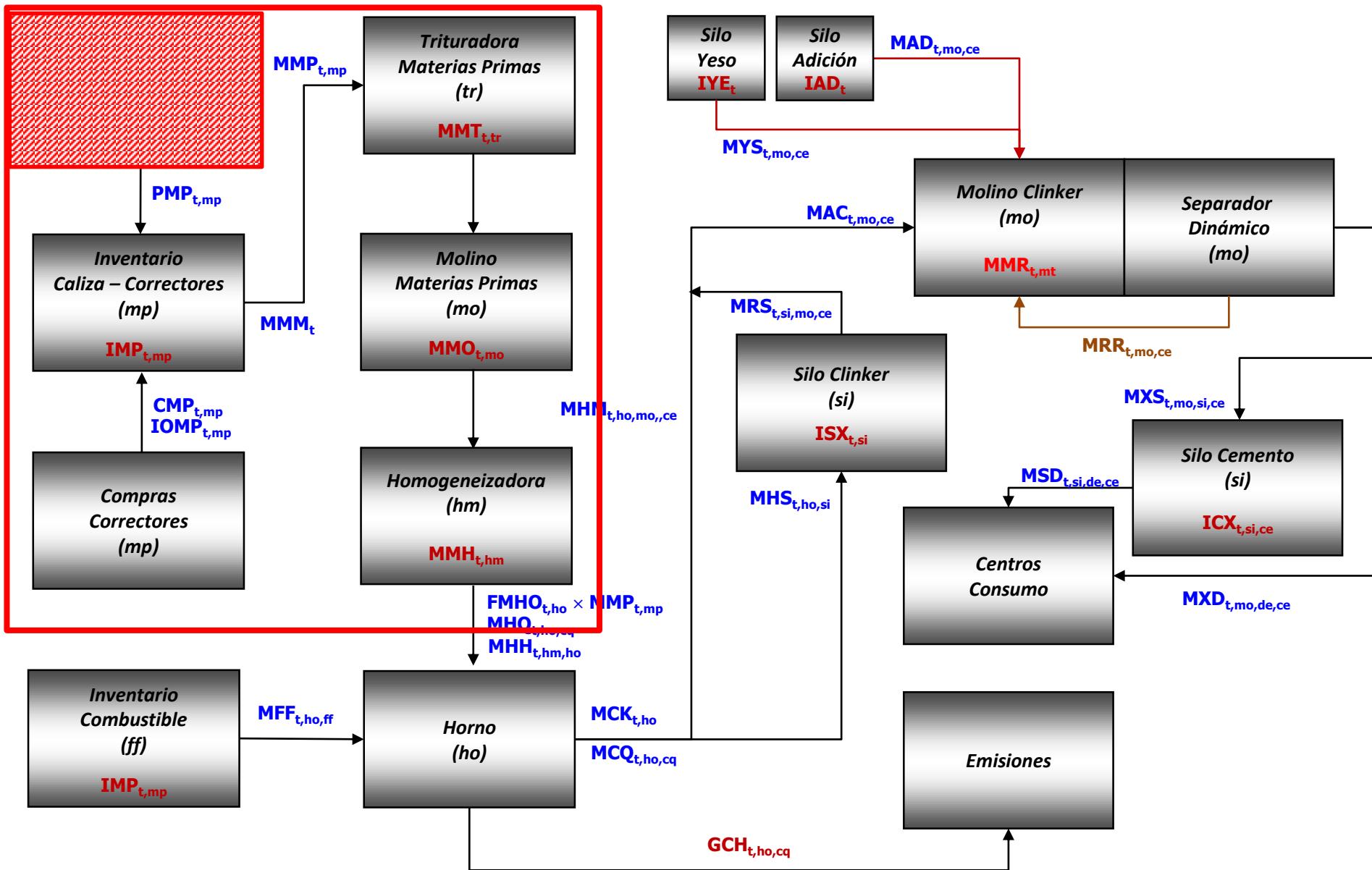
MODELING OF THE PRODUCTION PROCESS OF THE CEMENT



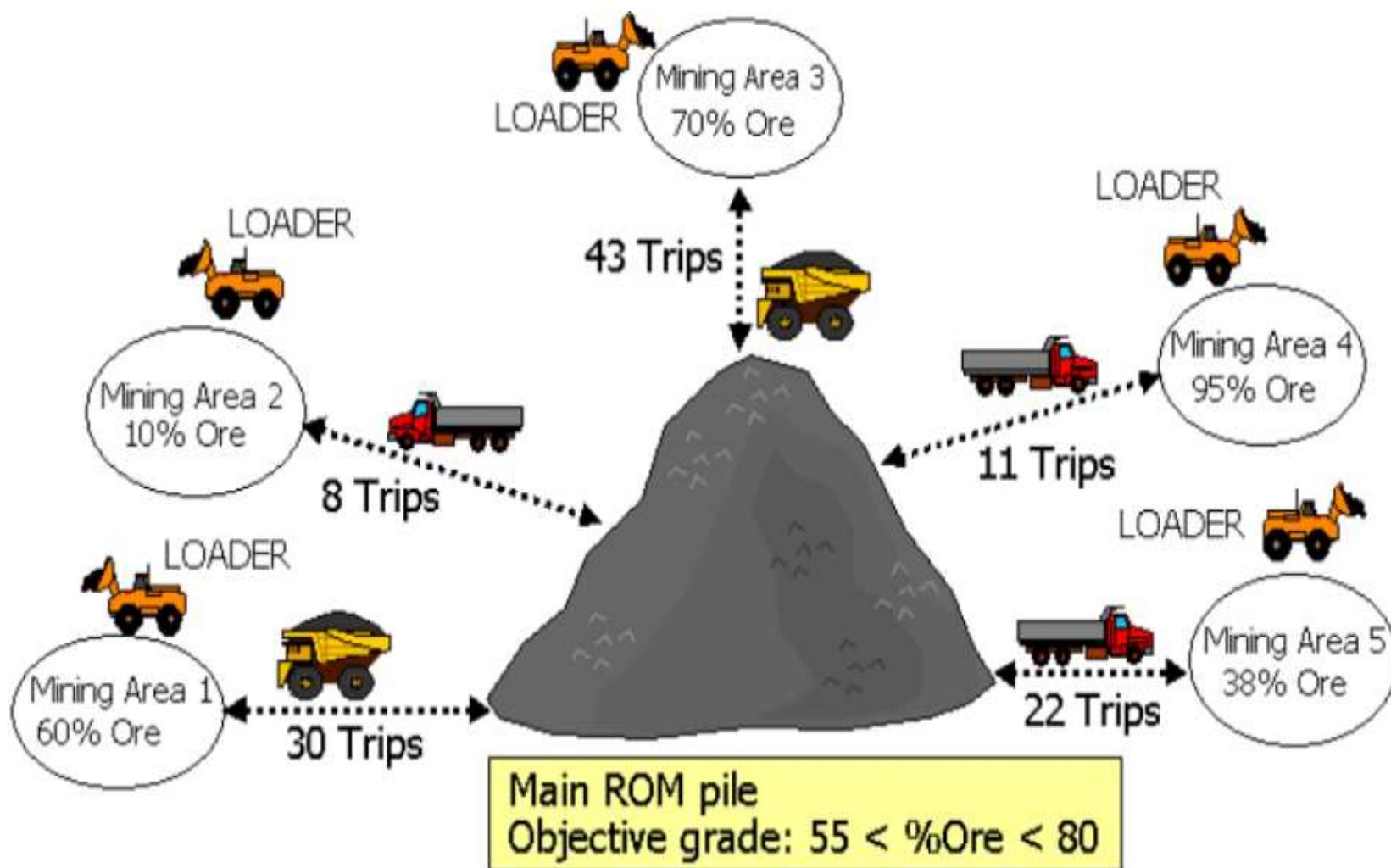
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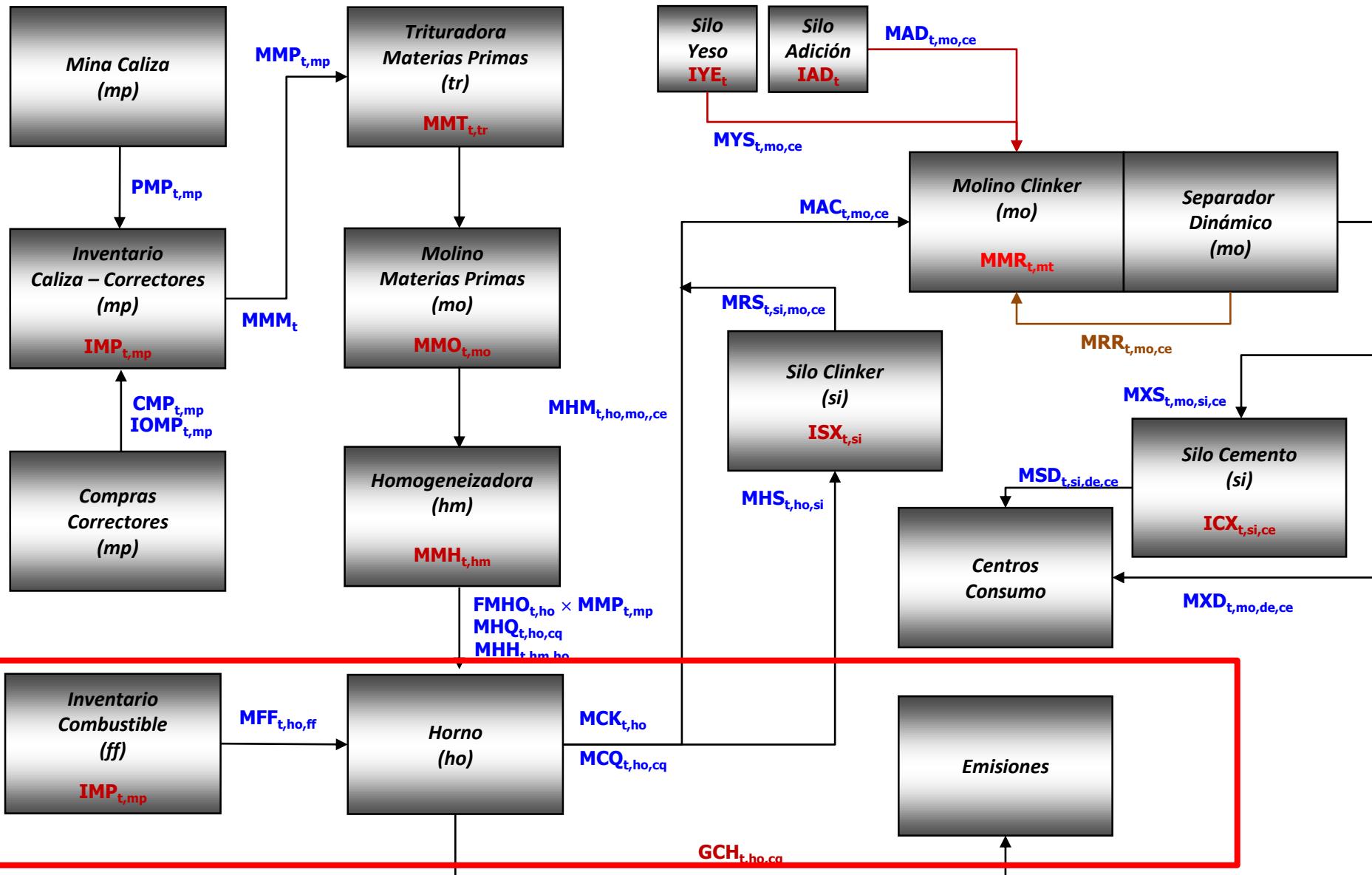
MODELING OF THE PRODUCTION PROCESS OF THE CEMENT



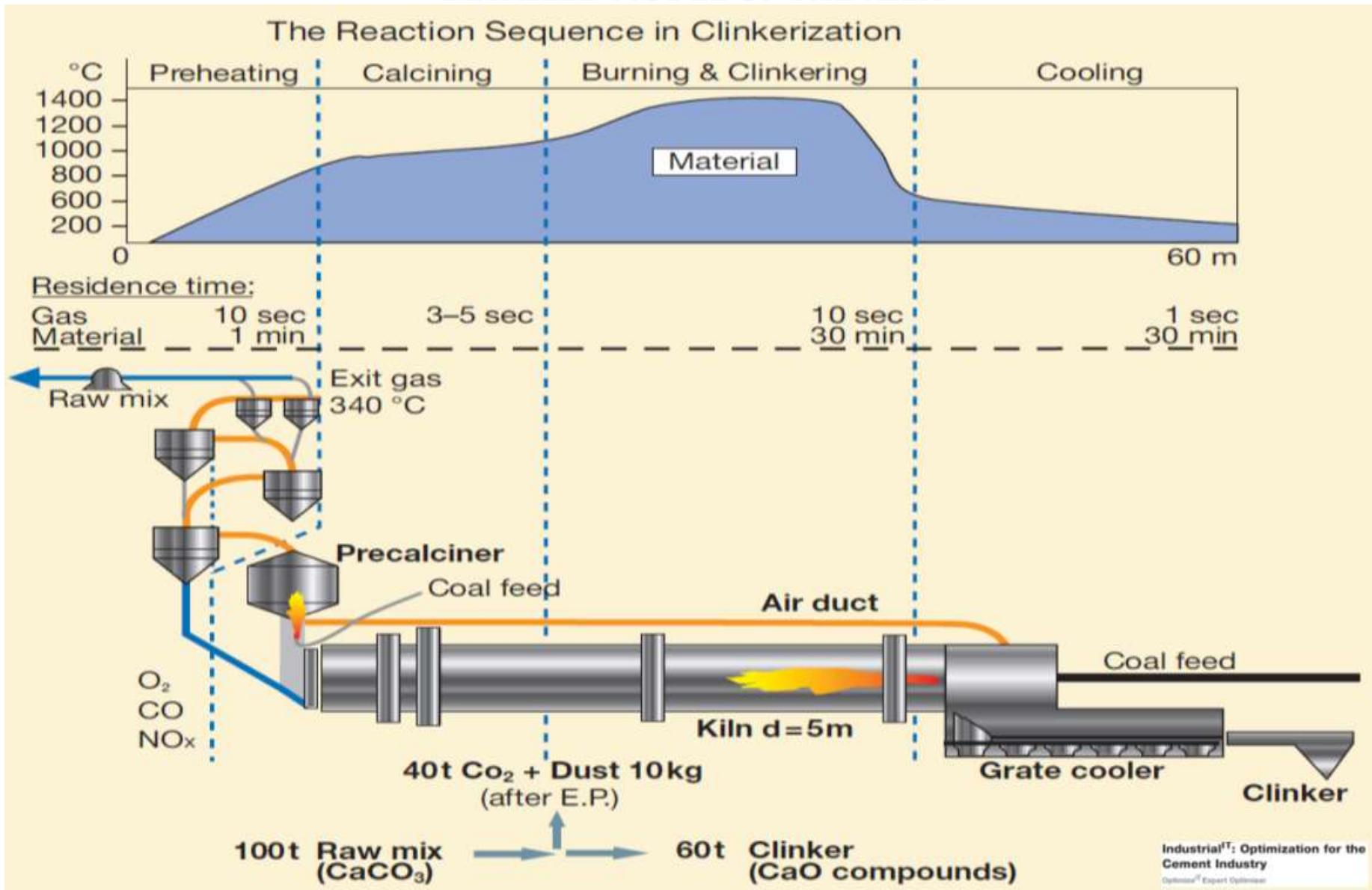
BLENDING RAW MATERIALS + CORRECTORS



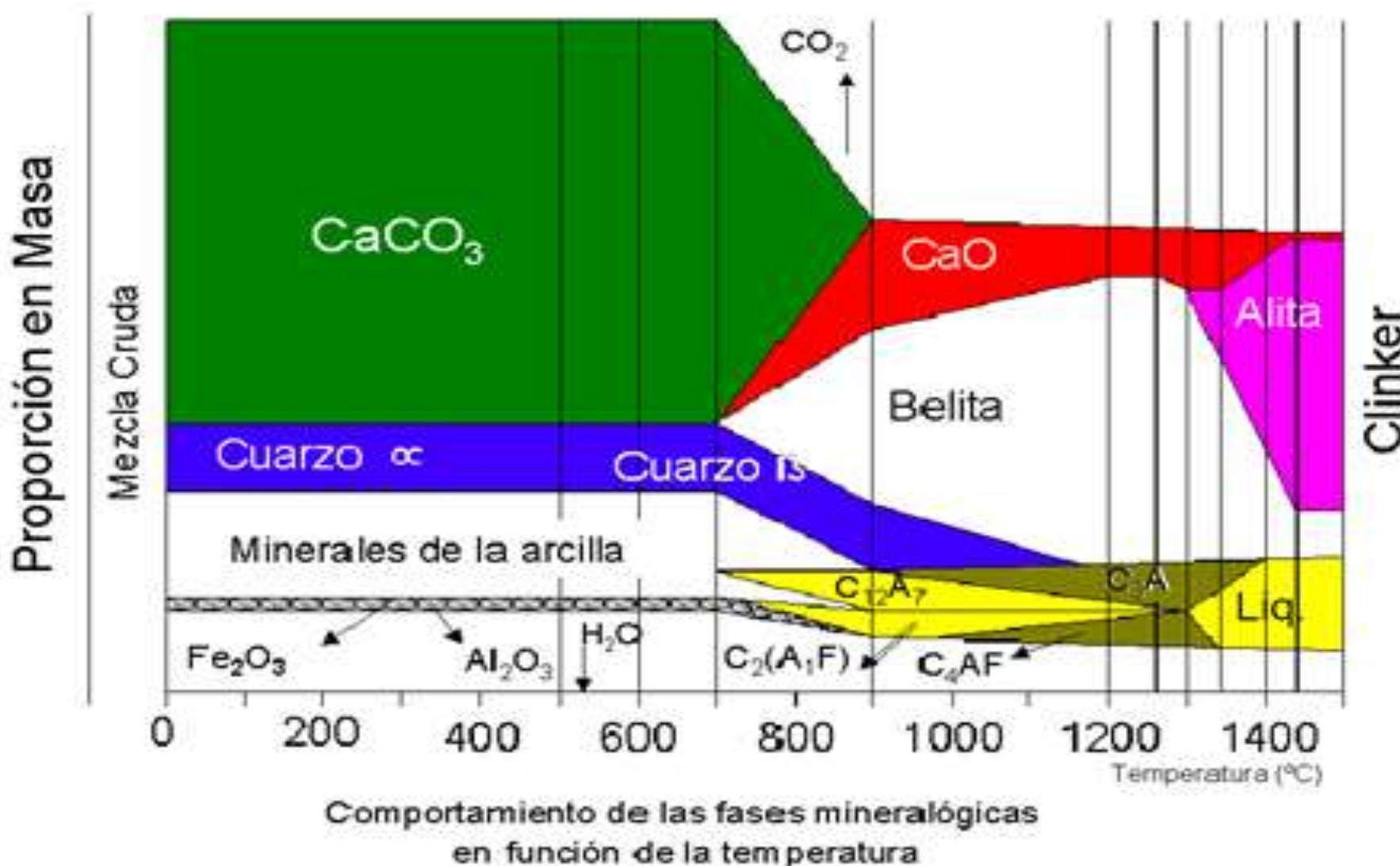
MODELING OF THE PRODUCTION PROCESS OF CEMENT



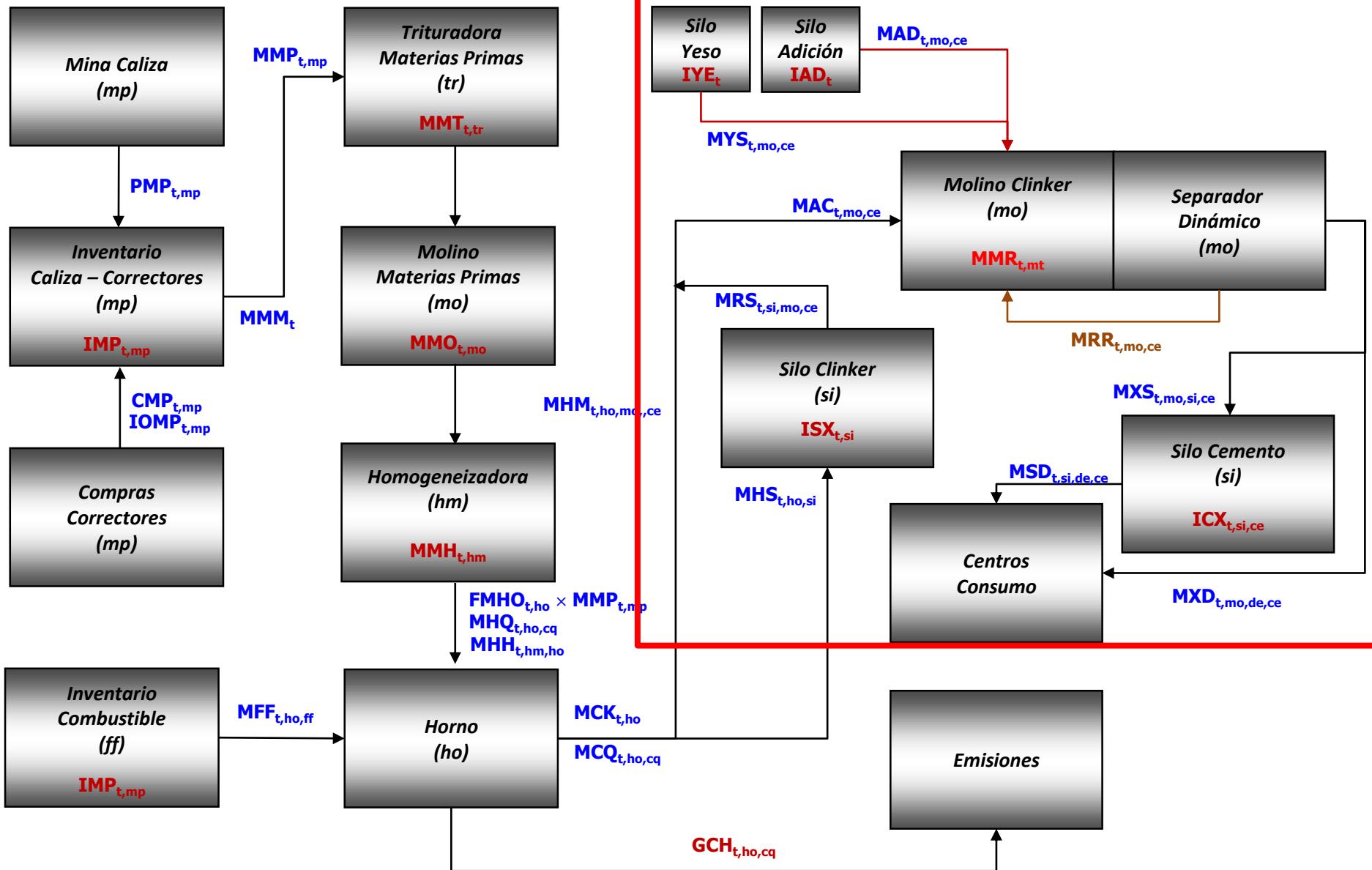
DETAILED MODEL OF THE KILN



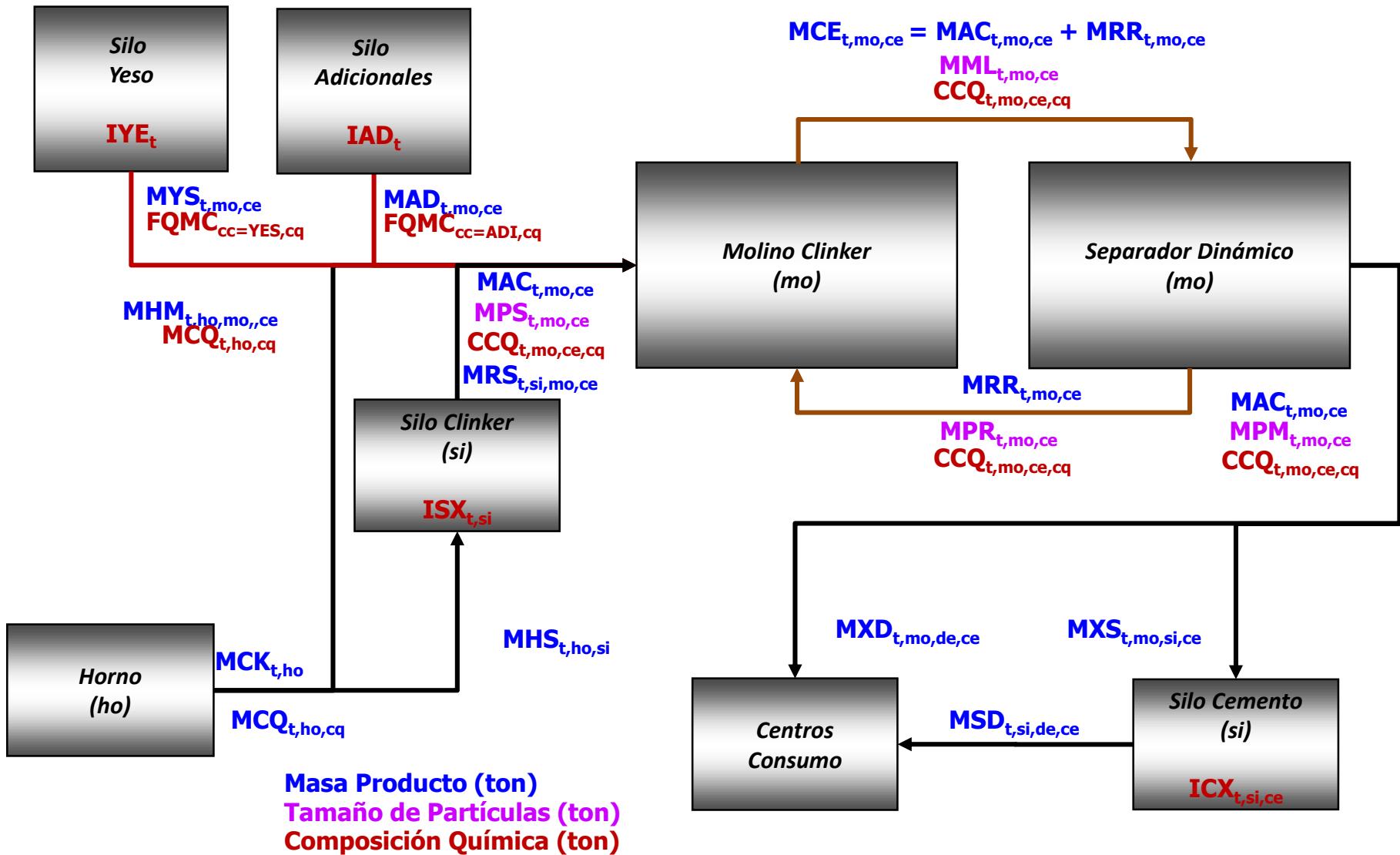
DETAILED MODEL OF CLINKERIZATION



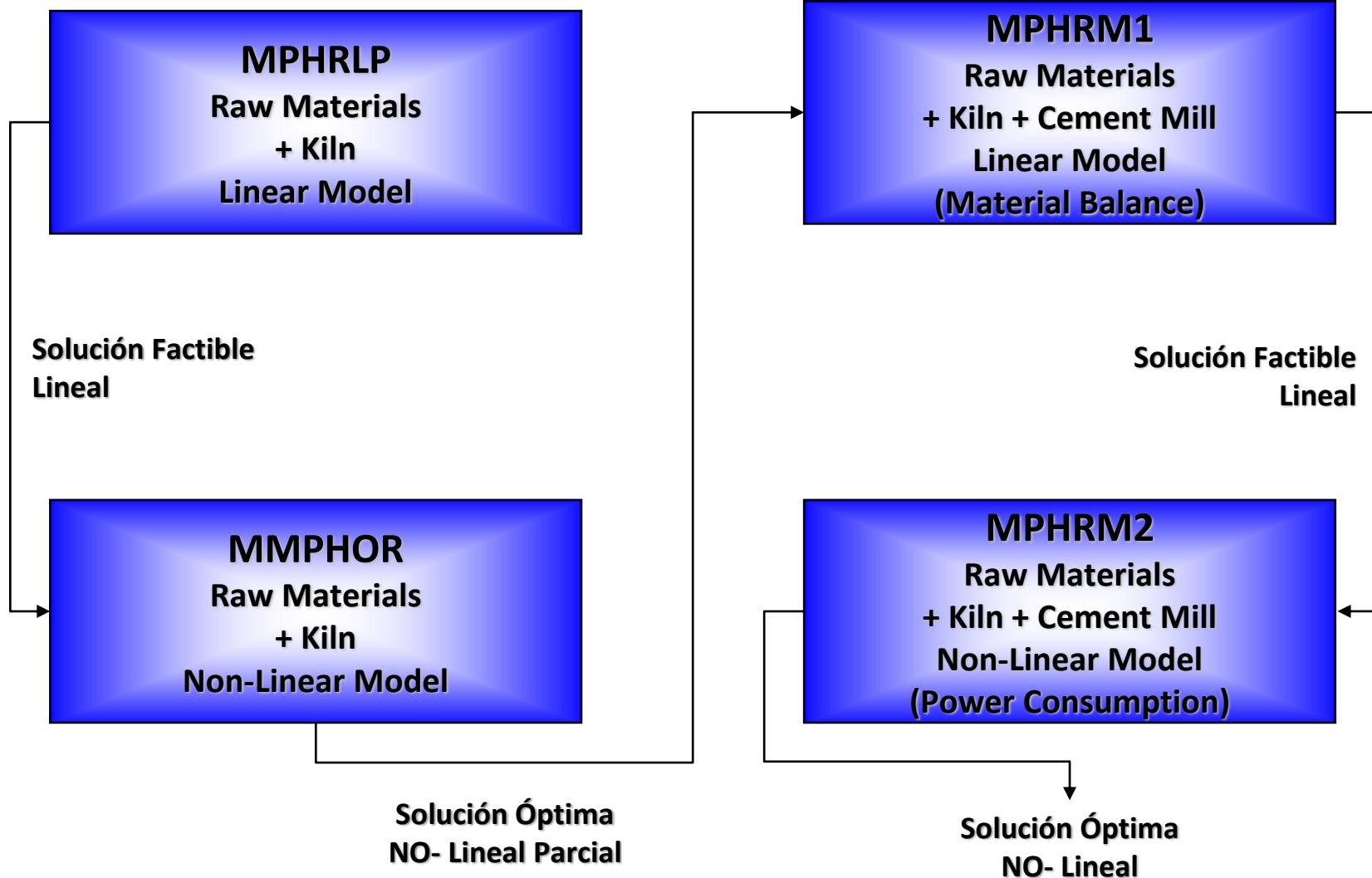
MODELING OF THE PRODUCTION PROCESS OF CEMENT



CONECTIVIDAD DE VARIABLES PROCESO: MOLIENDA DEL CLINKER



CEMENT PLANT PRODUCTION MODEL





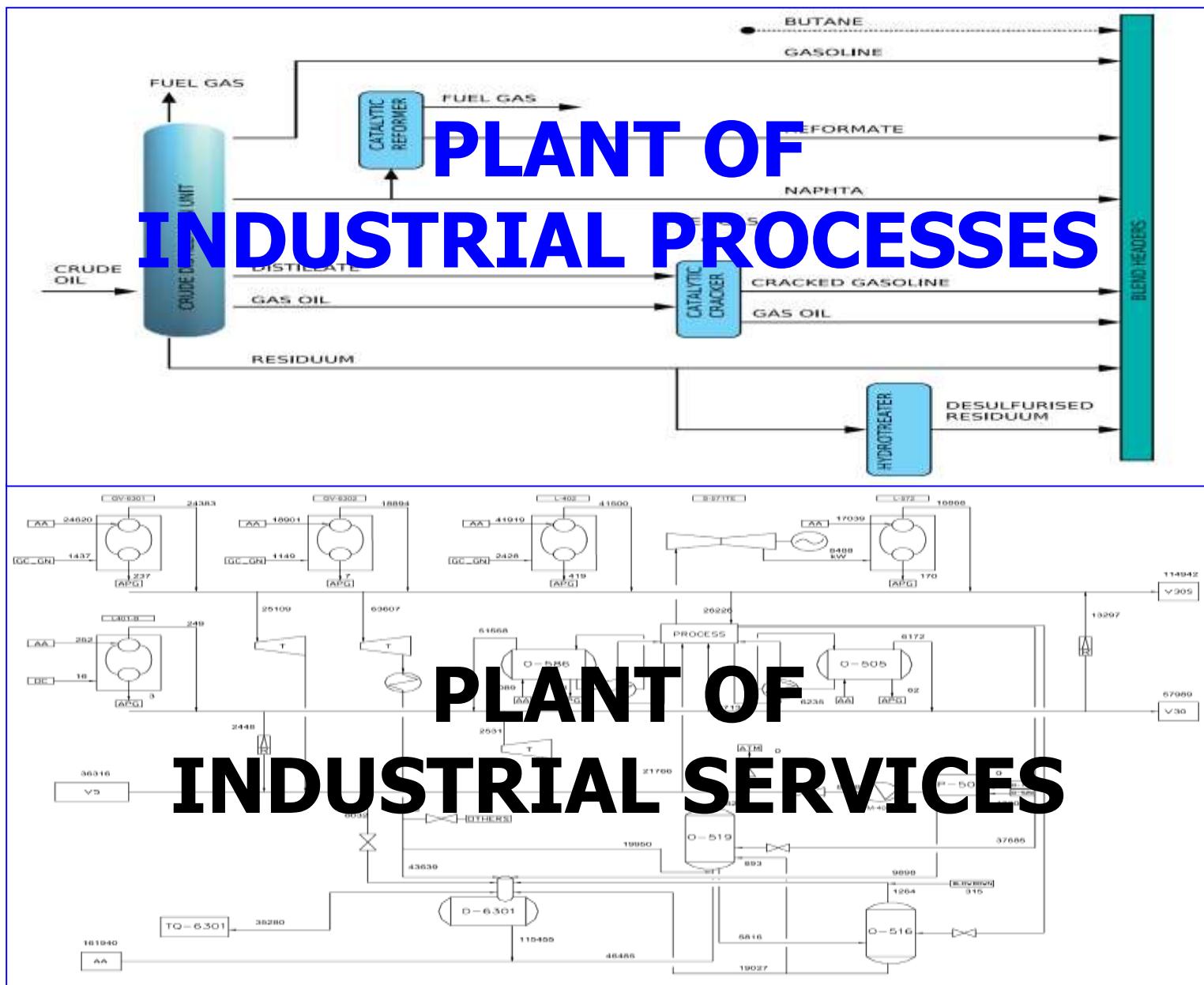
ADVANCED ANALYTICS SMART GRIDS & INDUSTRIAL ENERGY EFFICIENCY

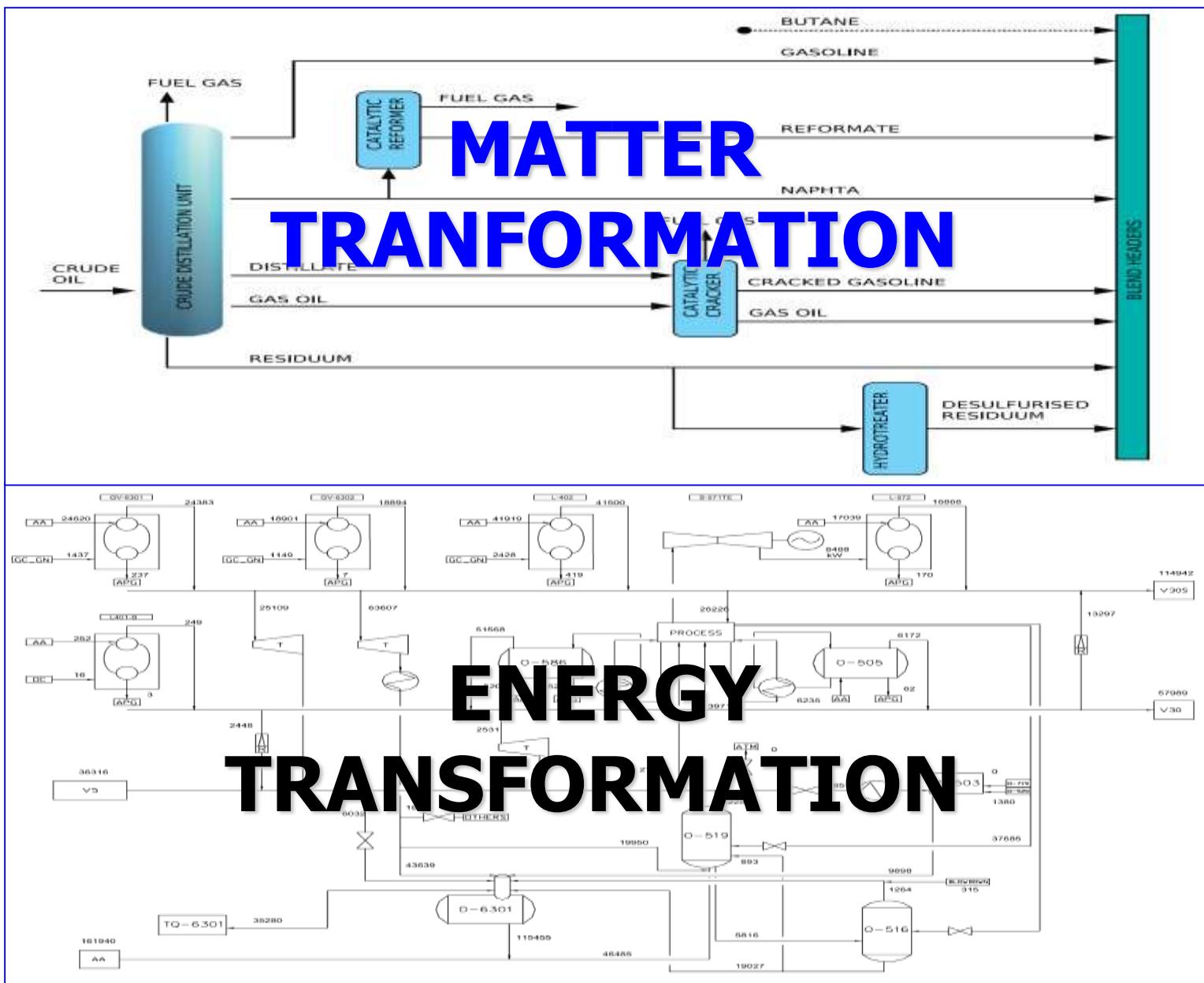
**INTEGRATE ENERGY MANAGEMENT
IN INDUSTRIAL SYSTEMS**



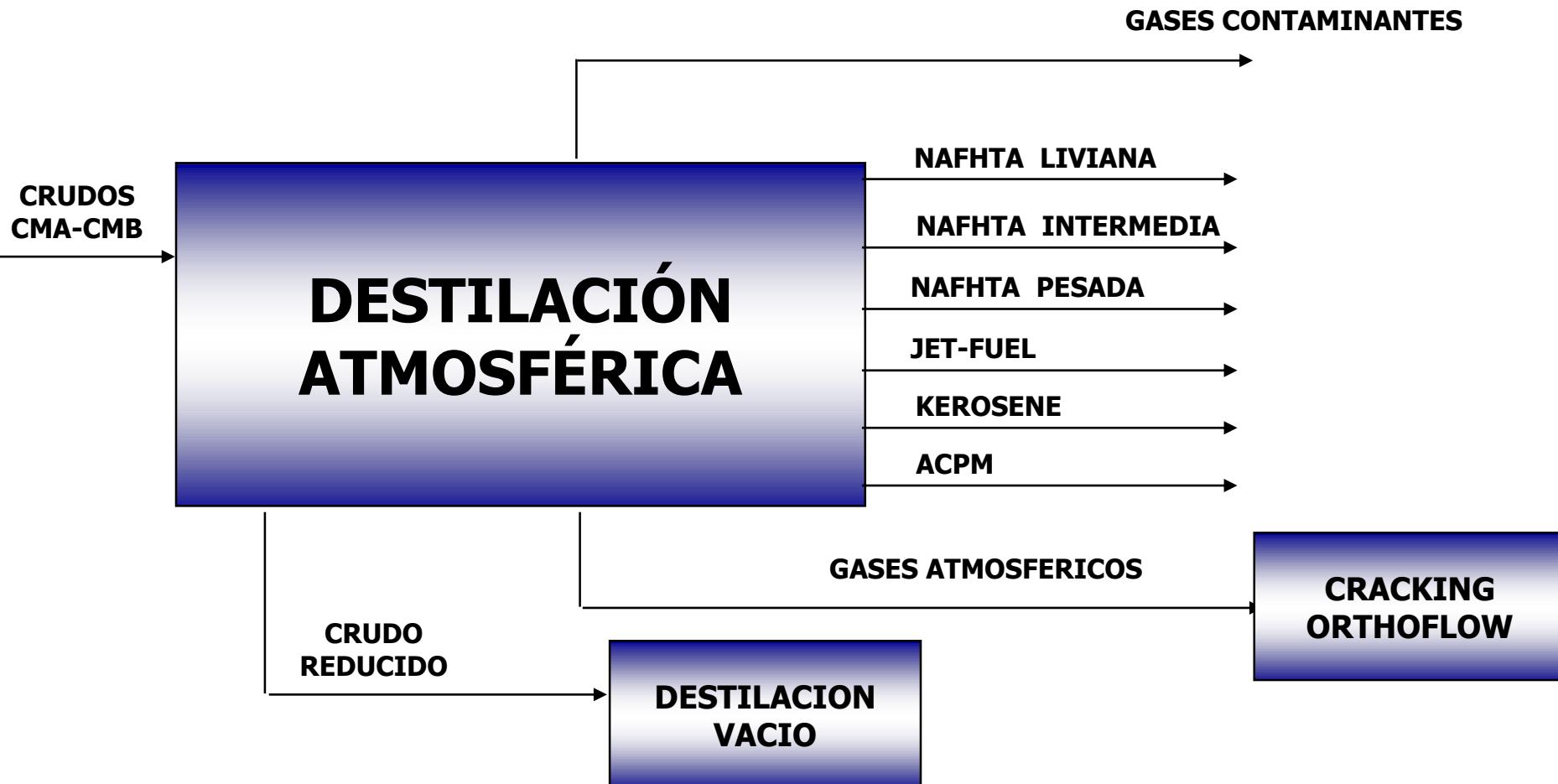
Optimal management of power of industrial systems implies a holistic position oriented to integrate the production planning of goods with energy services that are consumed in the production plant; and finally integrate it with possibilities of self-production and negotiation of this energy in the energy markets.



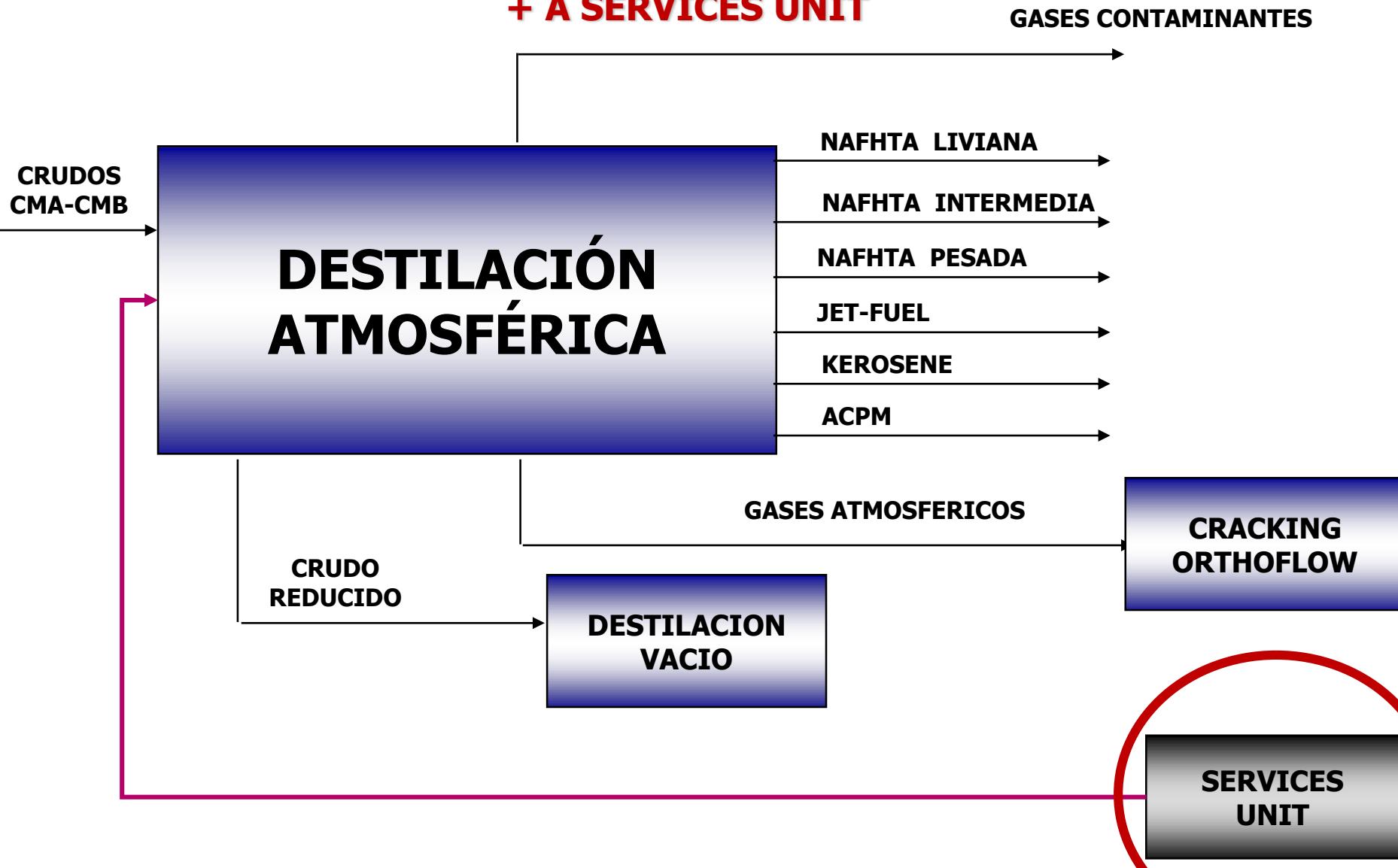




MODELING OF A PROCESS UNIT



MODELING OF A PROCESS UNIT + A SERVICES UNIT



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Operational optimization of the utility system of an oil refinery

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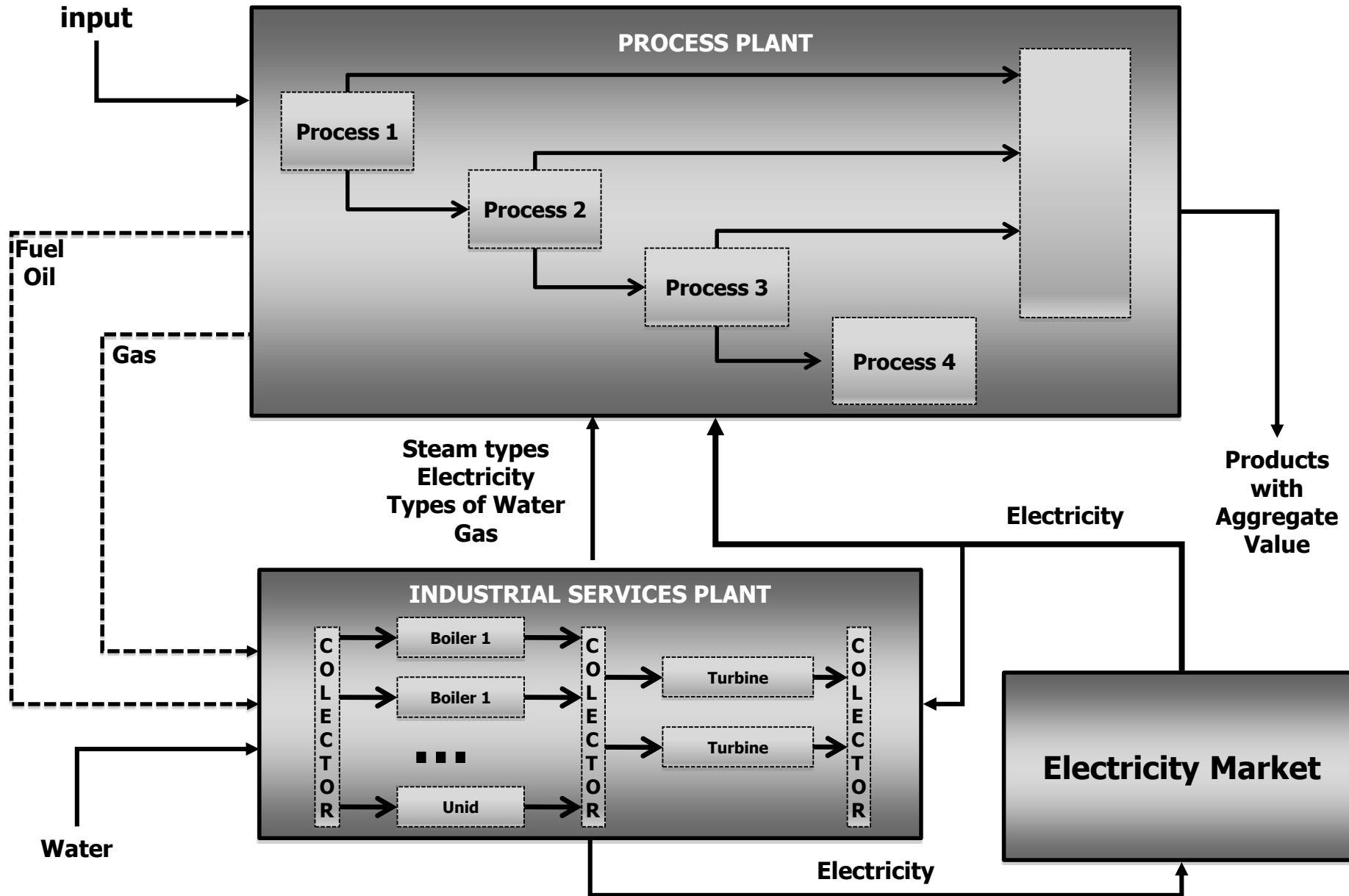
Available online 25 May 2007

Abstract

The objective of this work is to develop a mathematical programming model applied to the operational planning of the utility plant of the RECAP Refinery (São Paulo, Brazil), as well as its interconnections with the process units. The problem is formulated as a mixed-integer linear programming (MILP) model where the mass and energy balances, the operational status of each unit, and the demand satisfaction are defined in multiple time periods. The model determines the operational configuration of the plant by minimizing utility costs, and identifies steam losses as well as inefficient units by comparing the optimal solutions with the current operation. The MILP is able to accurately represent the topology and optimize the operation of the real-world system under different utility demands and abnormal situations in single and multiperiod scenarios, achieving up to 10% cost reduction. The MILP is currently integrated with the plant database and used for the planning of the refinery utility system.

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Raw Material input



**Sell/Buy Energy
Support System**

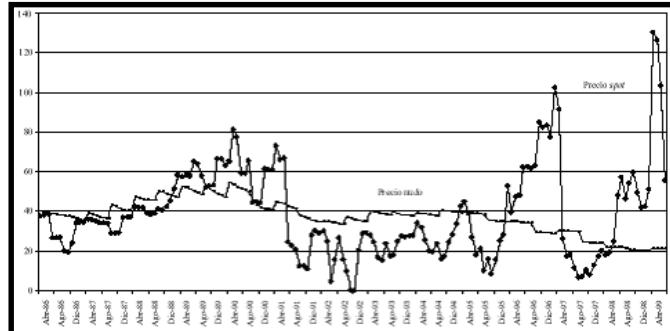
**INTERCONNECTION
NETWORKS
ELECTRICITY**

**Contracts
Trading**

**PLANT SERVICES
AUTO-GENERATOR**

ENERGY MARKET

PROCESS PLANT





ADVANCED ANALYTICS SMART GRIDS & INDUSTRIAL ENERGY EFFICIENCY

CASE: OIL TRANSPORT VIA PIPES



In all industrial systems, the economic efficiency go through the energy efficiency, and vice versa; however, when exist differential tariff for basic energetics exist two different criteria to approach to the optimality: the economic and the environmental.

Then, the mathematical models are the foundation to provide the information needed to balance these two objectives when they enter in contradiction.



OLEODUCTO VASCONIA CAUCASIA

SISTEMA OCENSA

Terminal Marítimo de Coveñas, ubicado en el límite entre Sucre y Córdoba, el crudo es almacenado en tanques y posteriormente transportado por la línea submarina hasta la monoboya para el cargue de los buquetanques.

CAUCASIA encargada de darle más presión a los 20.000 barriles de crudo que se reciben por hora desde la estación de Vasconia y que se envían al terminal marítimo de Coveñas.

VASCONIA recibe los crudos de Ocensa y los provenientes de los campos ubicados en el Alto Magdalena. Desde esta estación, el crudo destinado a consumo interno del país es impulsado hacia la refinería de Barrancabermeja.

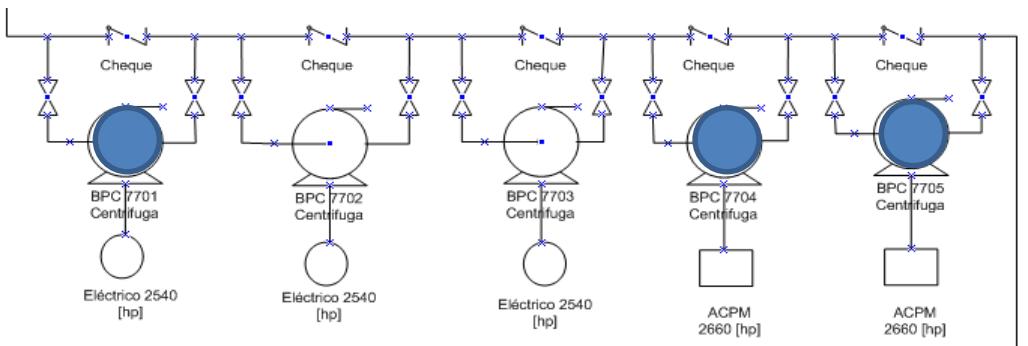
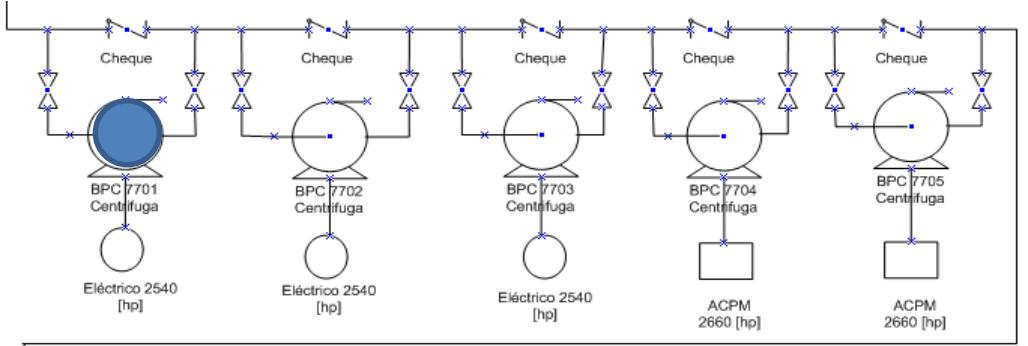
Sistema Ocensa

OLEODUCTO VASCONIA CAUCASIA SISTEMA OCENSA



OPERATION OF THE PUMPING STATIONS

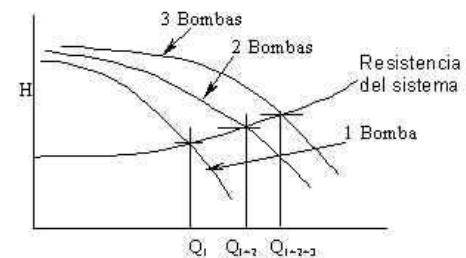
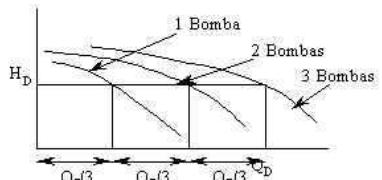
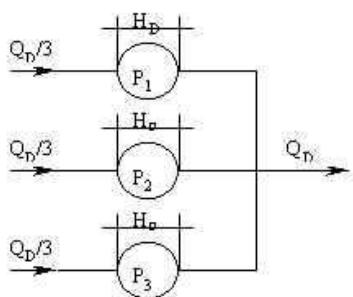
OPERATION PATTERNS



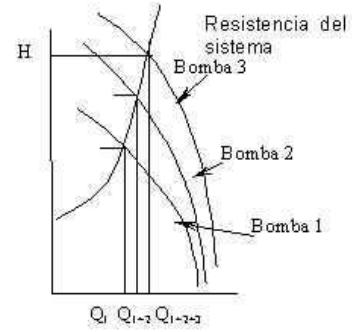
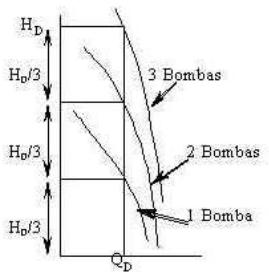
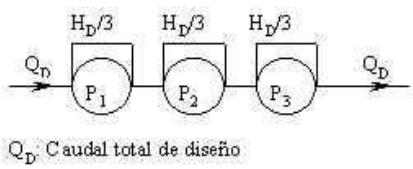
OPERATION OF THE PUMPING STATIONS

OPERATION PATTERNS

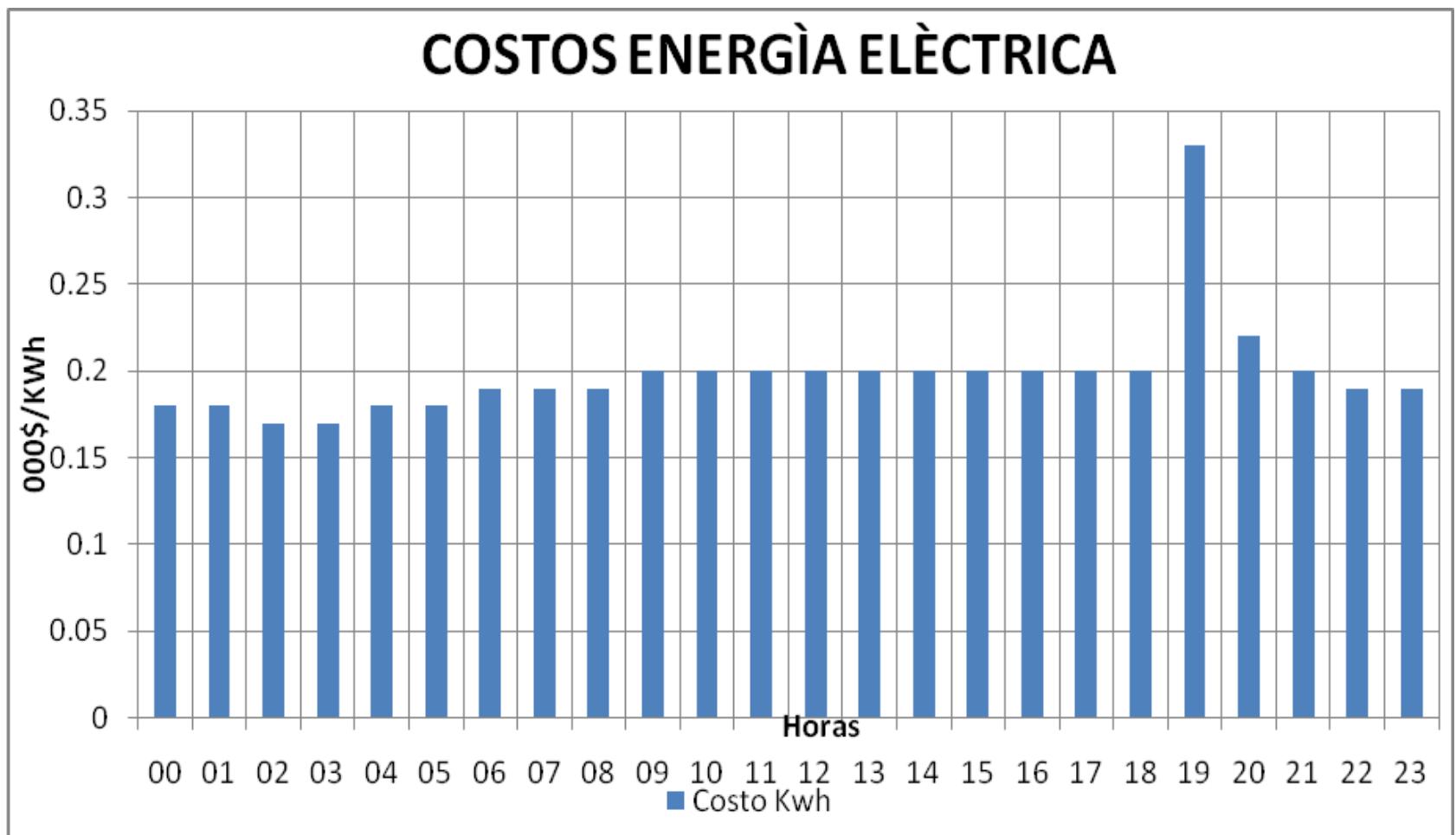
PARALLEL



SERIAL



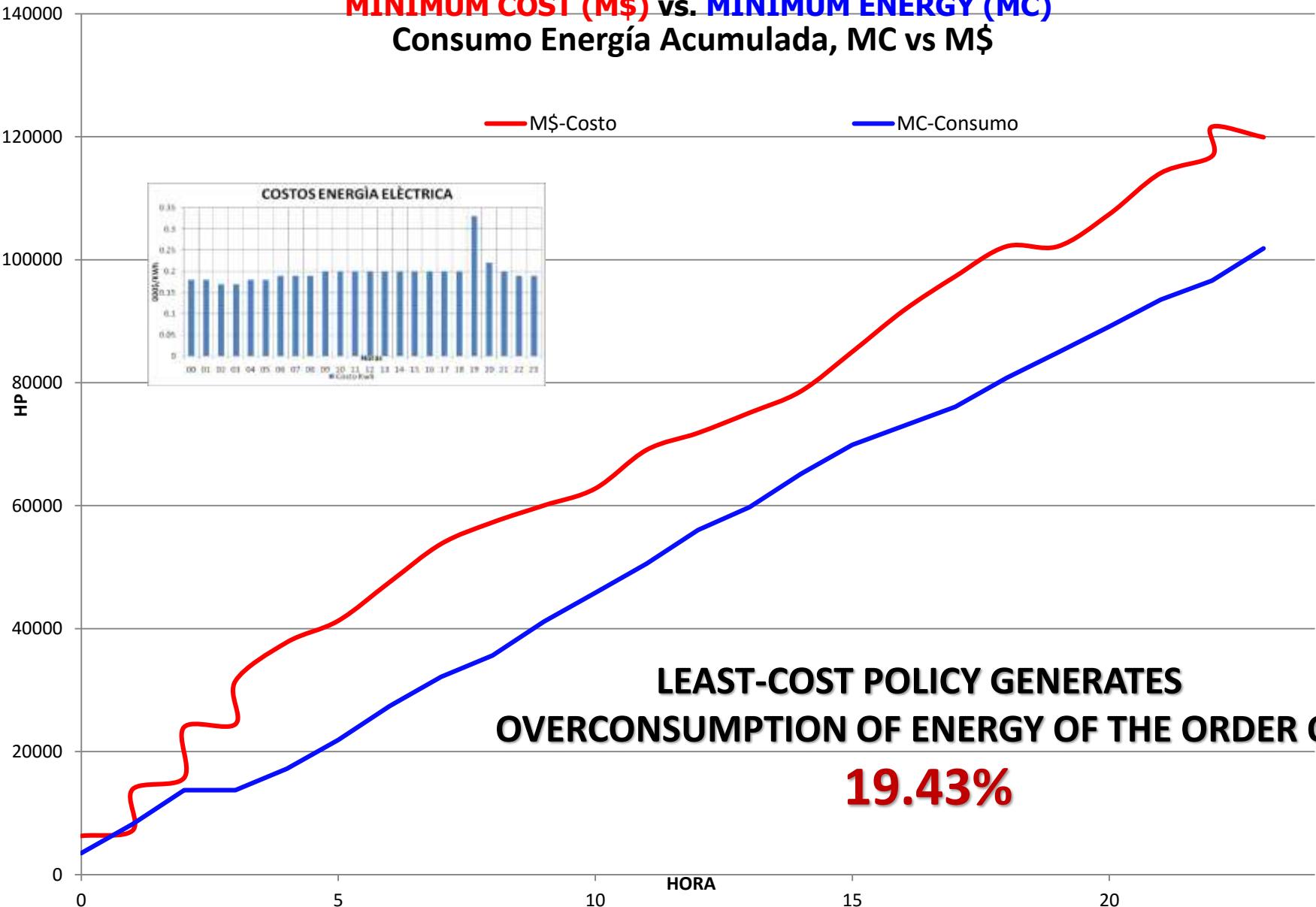
REAL COLOMBIAN CASE



OLEODUCTO XXXXX

MINIMUM COST (M\$) vs. MINIMUM ENERGY (MC)

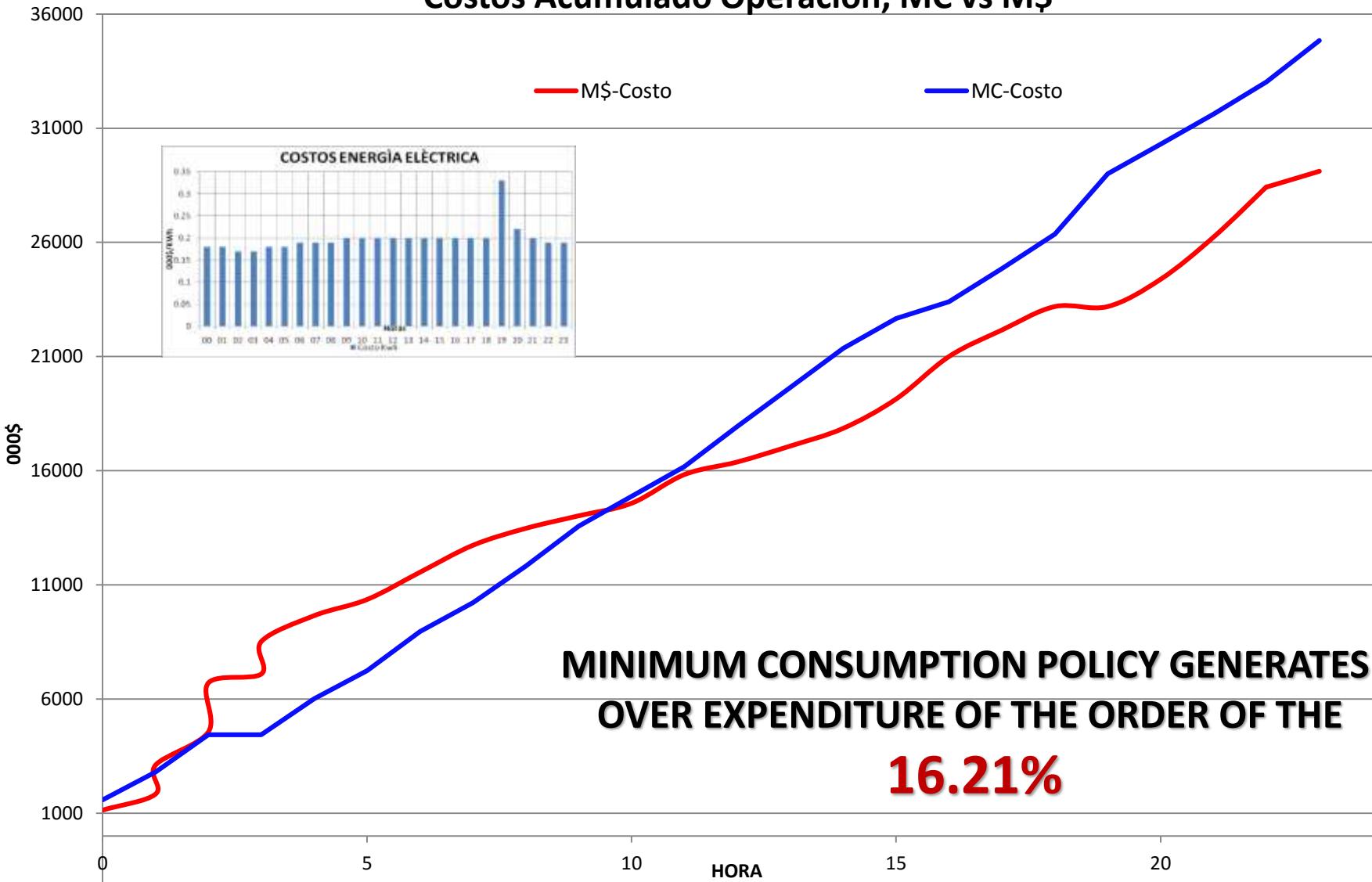
Consumo Energía Acumulada, MC vs M\$



OLEODUCTO XXXXX

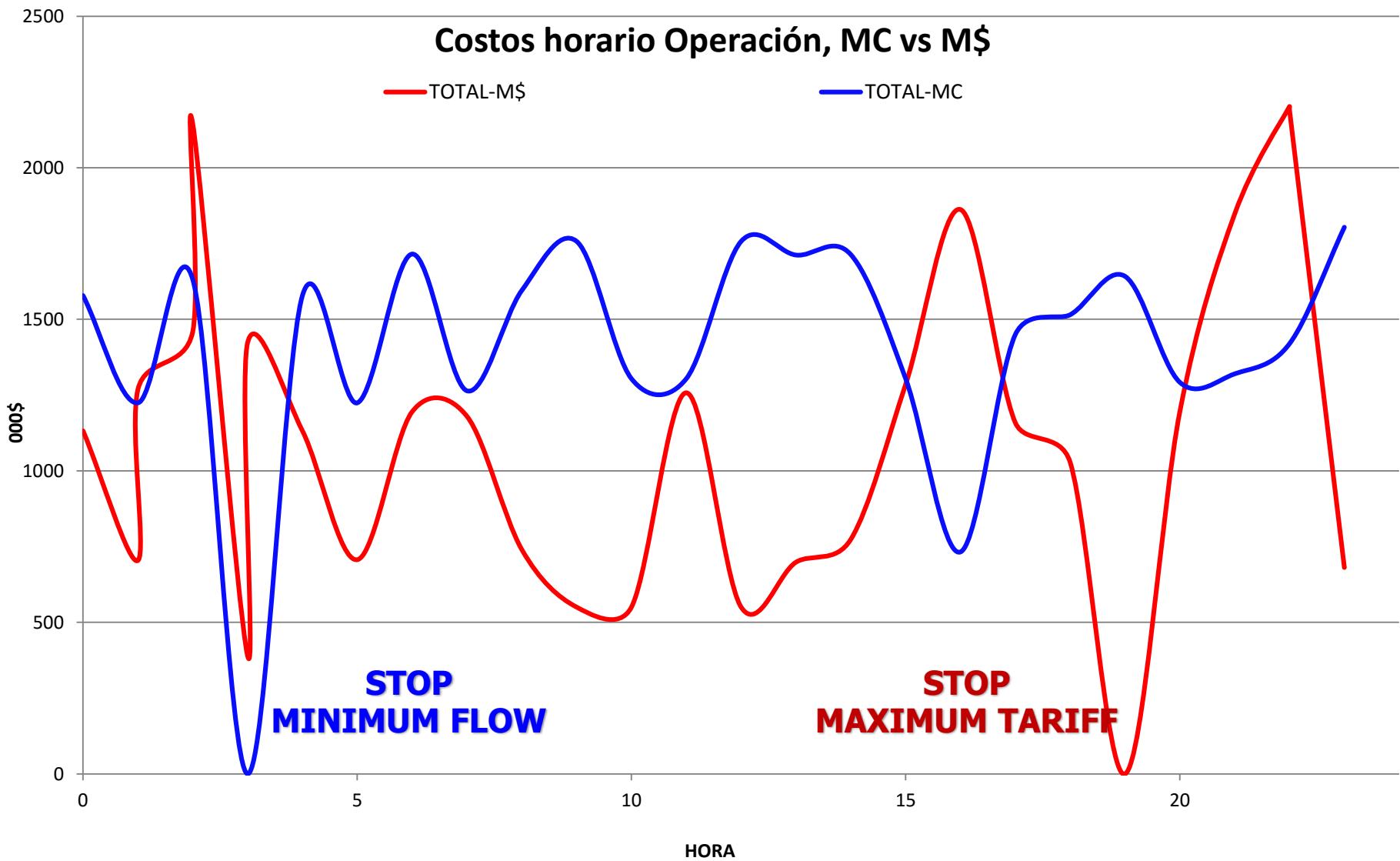
MINIMUM COST (M\$) vs. MINIMUM ENERGY (MC)

Costos Acumulado Operación, MC vs M\$



OLEODUCTO XXXXX

MINIMUM COST (M\$) vs. MINIMUM ENERGY (MC)



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