Integrated Mass and Energy Balance of olefin plants with PI System and Sigmafine

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Customer situation

- **Business**
  - Large producer of olefins (ethylene and propylene)
  - Large producer of polyolefins
- **Process**
  - Multiple plants with several cracking furnaces each
  - Main feedstock: ethane
  - Interconnections of utilities among plants, especially steam system

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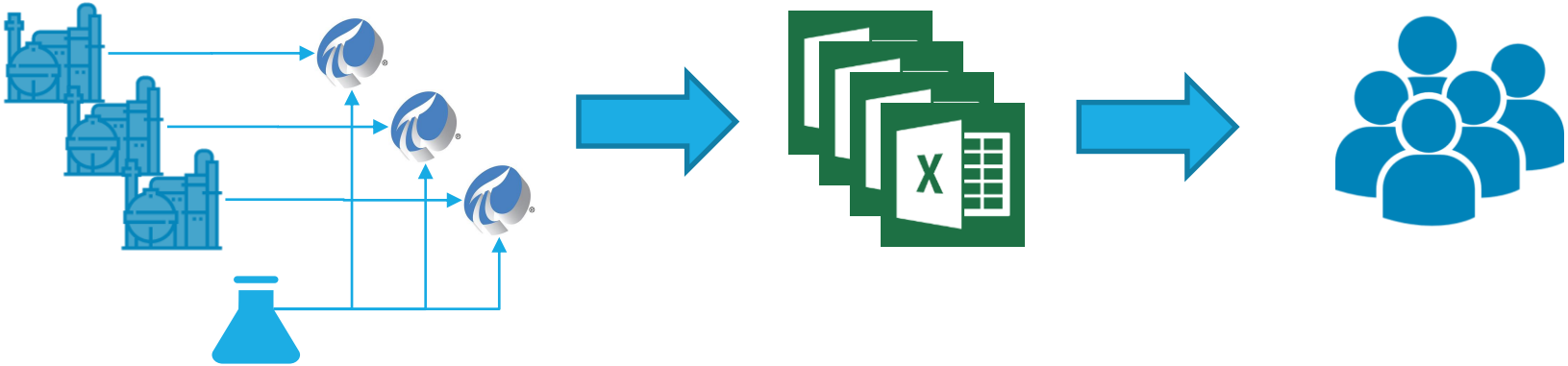
Customer situation

- **Existing infrastructure**
  - PI® system for process and laboratory data (one dedicated to each plant)
  - Excel based reports based on raw data aggregation



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Requirements: a scalable solution natively integrated in existing infrastructure

- **Scalability**
  - Support changes in the plants
  - Add plants to existing base
  - Possibility to expand solution to include polyolefins
- **Integration**
  - Become seamless part of existing infrastructure
  - Boost corporate accounting and reporting in a fully auditable and trackable environment

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Objective: a unique solution for accounting and engineering purposes

- **Production accounting**
  - Get accurate production and consumption of materials
  - Provide validated and reconciled figures to finance (ERP, corporate reporting)
- **Engineering**
  - Support users with reliable parameters and KPIs of main equipment

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Achieving native integration

The “dream team” to address Customer wish list

PI Data Archive	Real time data collection
PI Asset Framework	Hierarchical organization
Sigmafine	Model based Analyses

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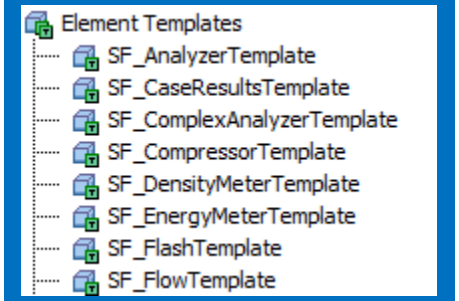
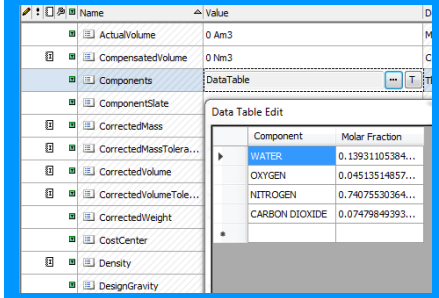
Sigmafine plugs in the PI Asset Framework



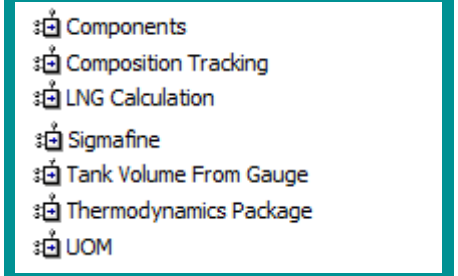
Templates

Sigmafine populates AF with templates for equipment, tanks, meters and streams



Elements

Elements inherits properties from templates and are linked each other through element connectivity



Data References

Calculations to support measurement compensation, accounting, thermodynamic and steam tables

Analyses Rule

Enrich AF with the Sigmafine plugins to perform mass and energy balance data validation and reconciliation

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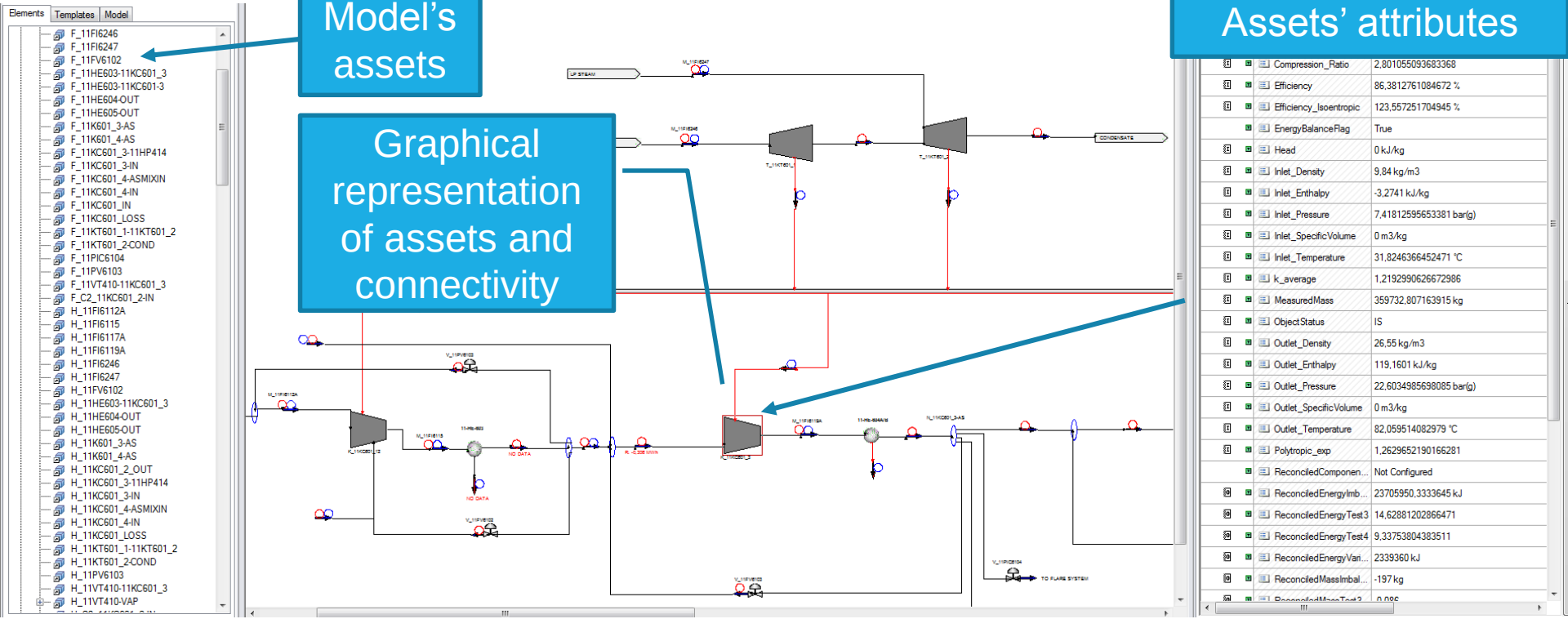
Graphical Sigmafine model within PI system

Model's assets

Graphical representation of assets and connectivity

Assets' attributes



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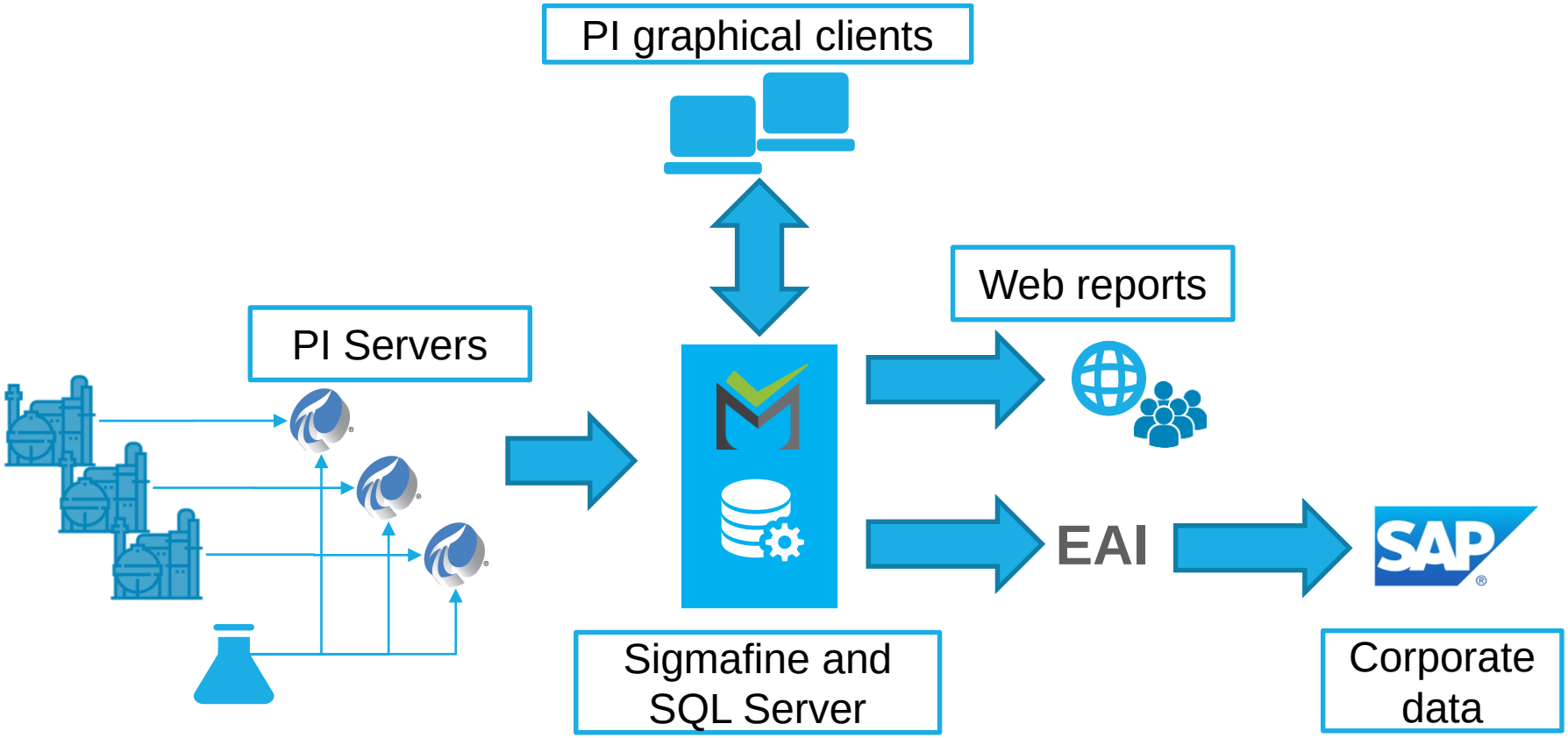
Overall architecture



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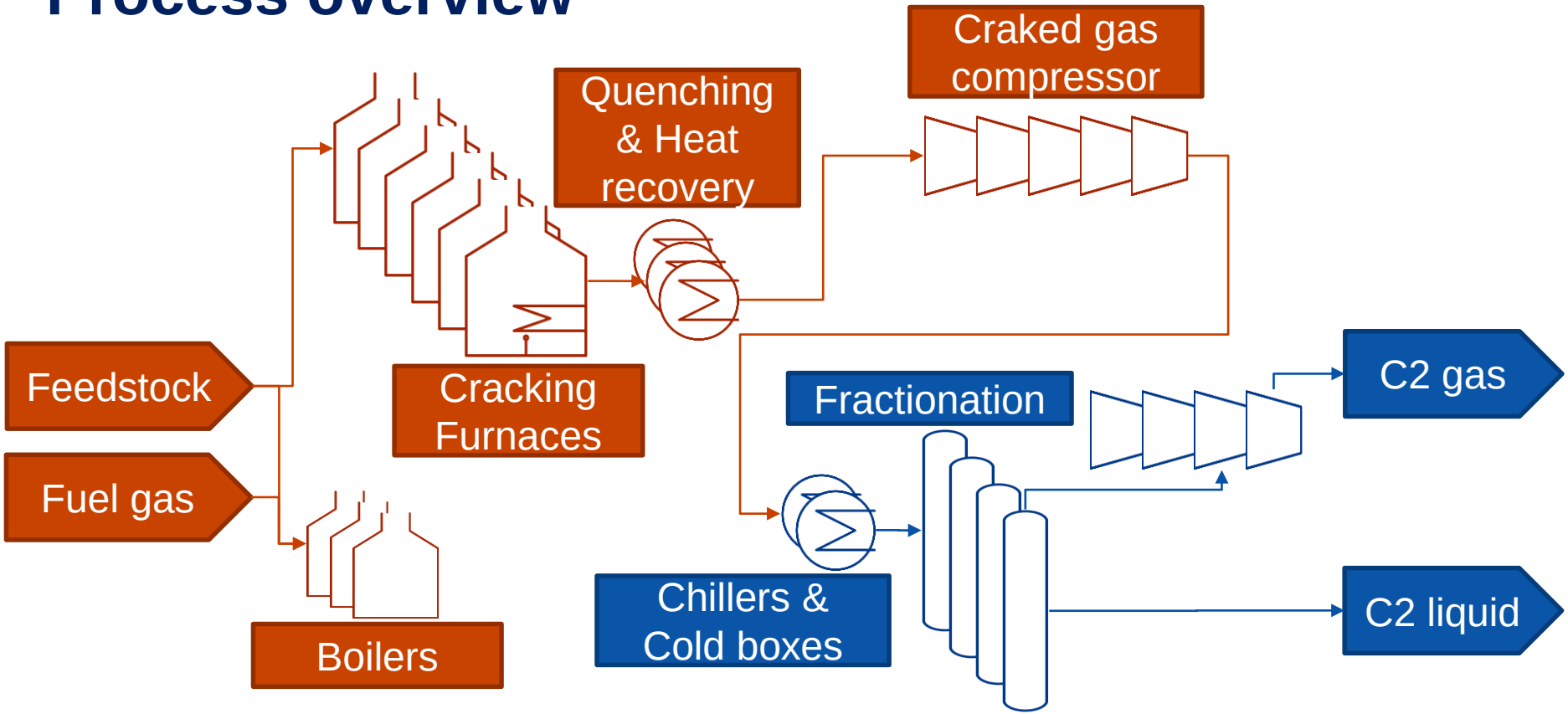
Targeting Business and Process Requirements in one shot

Process overview



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Business and Engineering Targets

ACCOUNTING

- Most valuable productions
- Most valuable consumptions
- Specific hydrocarbon loss and flaring
- Ethylene yield
- Specific energy consumption
- Specific chemicals consumption
- Most relevant utilities consumption including integrated steam system

ENGINEERING

- Cracking furnaces' efficiency
- Cracking furnaces' duty and heat recovery
- Power consumption of largest compressors and turbines (per stage)
- Efficiency of largest compressors and turbines (per stage)

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Detailed Sigmafine model merges Accounting and Engineering targets in one scenario

- **Data validation rules within PI AF**
  - Handling BAD values
  - Data freeze detection
  - Data constraint / replacement
- **Mass and energy balance analysis**
  - Solve simultaneous mass and energy balance

ADVANTAGES	DISADVANTAGES
Increased redundancy level	Higher model complexity
Allows calculation of both material and energy related indicators	Non-linear model requiring iterative solution

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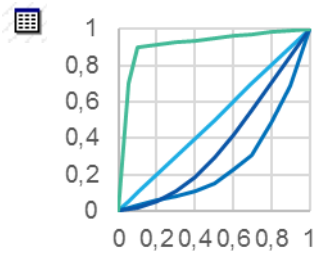
Evaluation of unmeasured streams from valve opening

- Use Sigmafine PI AF templates for valves supporting ISA-like calculation based on valve type and characteristics (e.g. flare flows)
- Include tables in PI AF to look up for flows according to valve opening (e.g. steam let down stations)



Geometric Data

Process data

Fluid properties

Name	Value	Description
ActualOpening	0,0164441043390312 -	Opening of the valve
Area	0,010703914872114	Current valve area according to va
CriticalFlow	False	Check for critical (chocked) flow
Cv	545	Rated valve coefficient
EnergyTolerance	0 kJ	Tolerance
F_gamma	0,88428571428571434	gamma gas / gamma air
Gamma	1,238	Cp/Cv (air = 1.4)
InferredStatus		Inferred status
Kv	632,19999999999993	Rated valve coefficient
MassTolerance	17,466725218504 5 kg	Tolerance
MeasuredEnergy	0 kJ	Measured flow energy
MeasuredMass	873,336260925224 kg	Valve mass flow
MeasuredVolume	0 Nm3	Valve normal volume flow
MolecularWeight	28,05 kg/kmol	Molecular Weight
ObjectStatus	IS	In service out of service
Pin	7,50097012910549 bar(g)	Inlet Relative Pressure
Pout	2,2629507753684 bar(g)	Outlet Relative Pressure
ReconciledMassCorre...	0,1351 kg	Reconciled correction
ReconciledMassTest1	0,0079	Test1
ReconciledMassTest2	0,0049	Test2
ReconciledVolumeCor...	0 Nm3	Reconciled correction
ReconciledVolumeTest1	0	Test1
ReconciledVolumeTest2	0	Test1
Rho_in	9,32 kg/m3	Density at inlet conditions
Temperature	47,5734640371814 °C	Temperature of the fluid
Type	globe	Valve type (globe, rotary, butterfl
VolumeTolerance	0 Nm3	Tolerance for volume balance
X	0,61520835427577358	Critical pressure ratio
X_T	0,7	Critical pressure ratio

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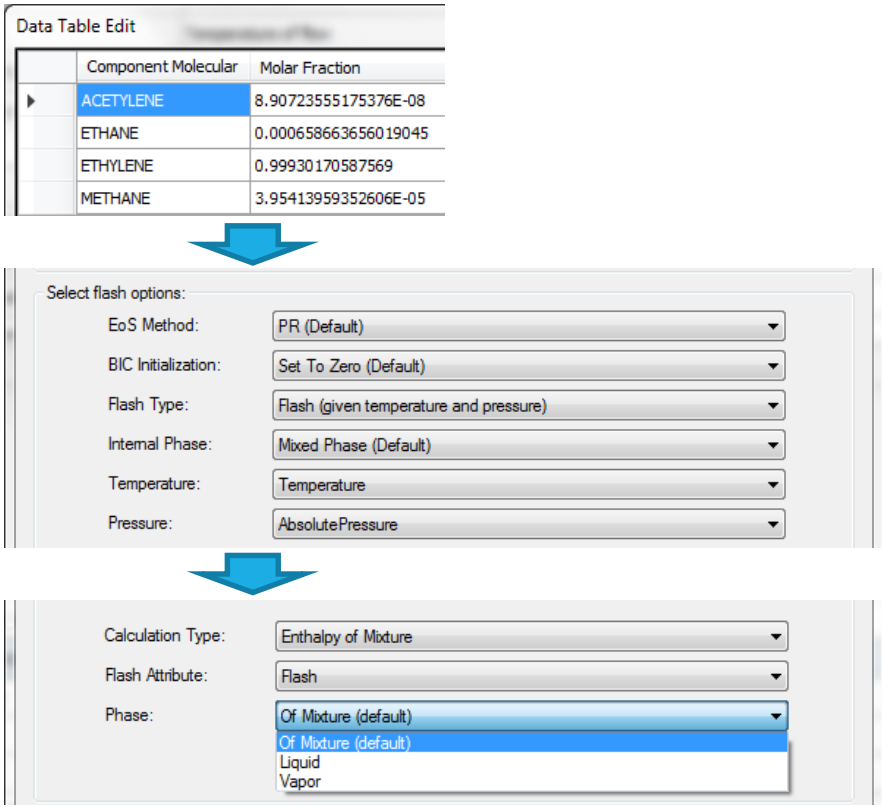
Evaluation of streams' flow rate and properties through Sigmafine Thermodynamic extension

- Evaluation of phase equilibrium through equations of state (e.g. Peng-Robinson) to determine unmeasured vapor and liquid flow rate
- Predict compositions, specific heat, enthalpy, etc. to support the energy balance calculation



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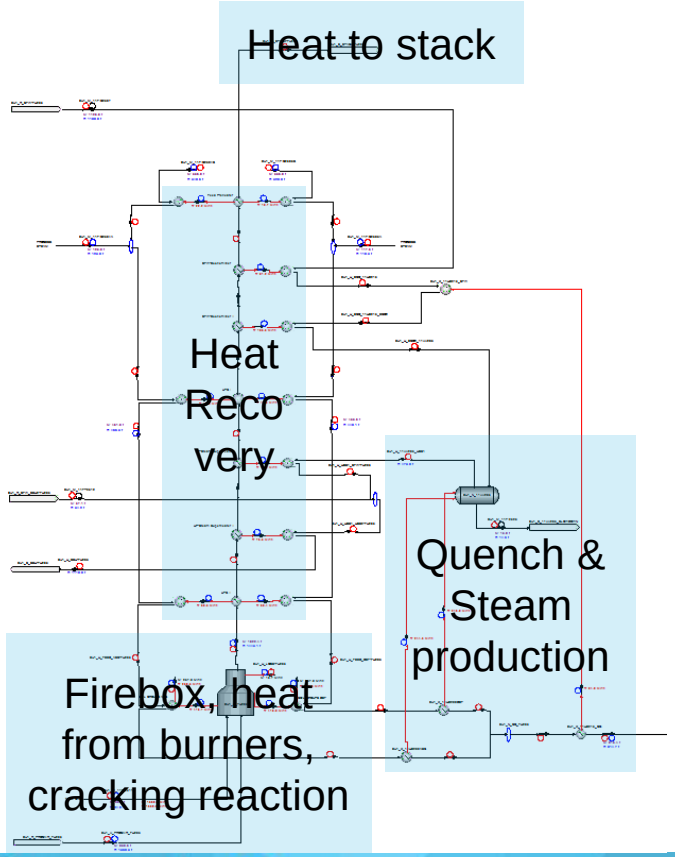
Detailed modeling of a cracking furnace



- **Estimation of unknown inputs:**
  - Air flow to burners
  - Calculation of reaction heat based on conversion
- **Output of data reconciliation:**
  - Estimation of heat recovery from flue gases
  - Estimation of heat losses to stack and radiant heat losses
  - Reconciled process duty and efficiency
  - Effectiveness of quench heat exchangers

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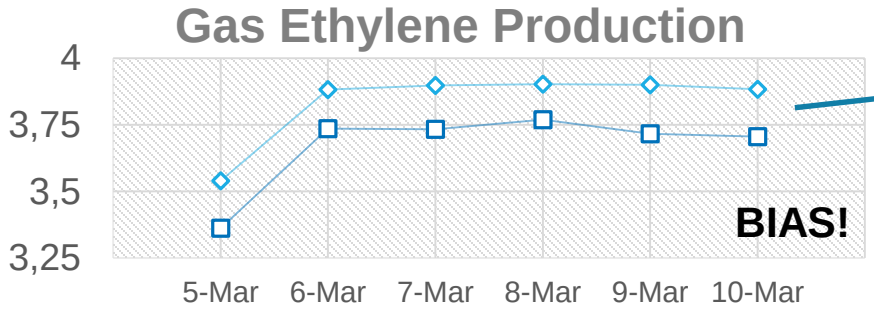
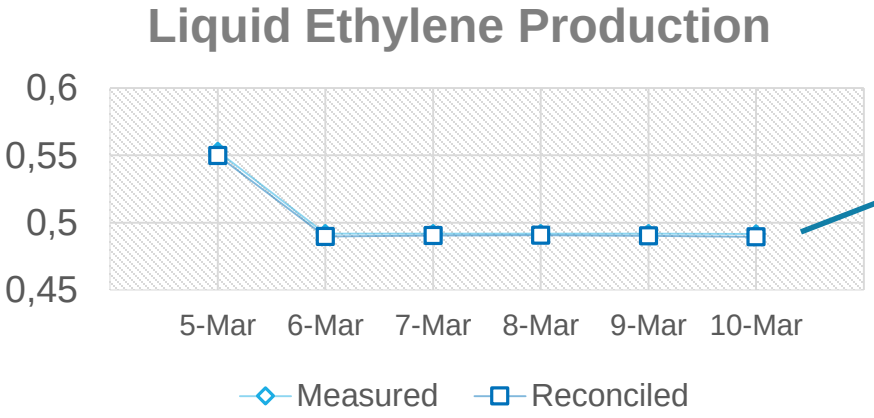
Results and next steps

Reconciled data provide reliable accounting figures



Gas ethylene production is in reality lower than expected



Liquid ethylene production is reliable

Production in ktpd

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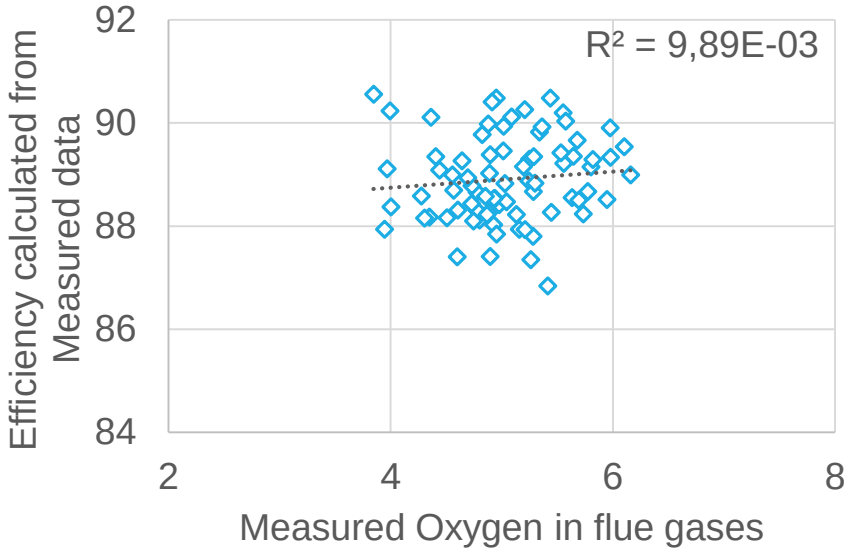
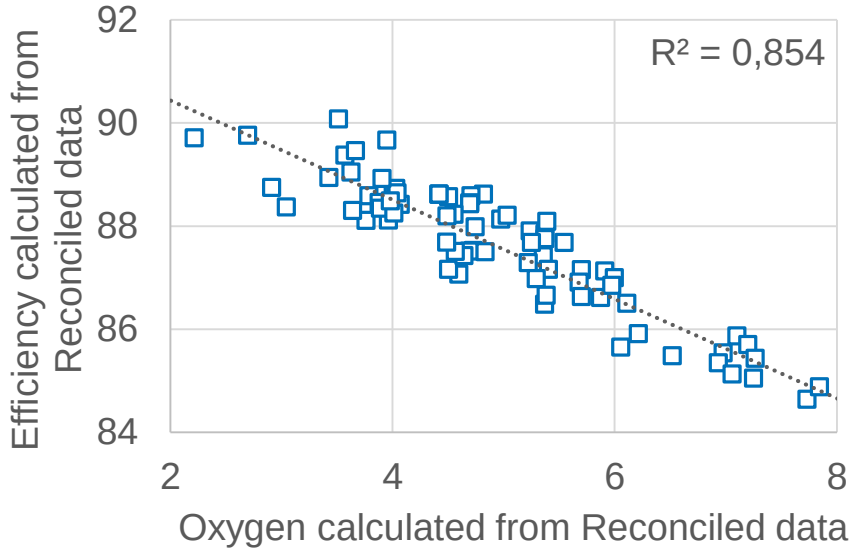
Reconciled data improve KPIs accuracy

- Inaccurate oxygen measurement in furnace flue gases is overcome by use of redundant information





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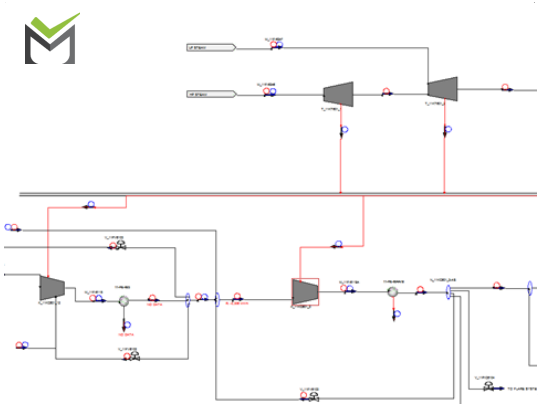
Improve reliability in Production Accounting and Energy monitoring

COMPANY and GOAL

Large olefin producers wants **reliable production data** for corporate accounting and **better accuracy** for KPIs of energy intense equipment

Undisclosed Customer



CHALLENGE

System is large including three production plants, large integrated steam system and auxiliaries

- Business and Engineering look at data with a different level of detail (plant vs equipment)

SOLUTION

Use PI AF to structure the data in assets and link with existing PI systems, plugging Sigmafine to perform the data analyses

- Got material production and consumption, KPIs and main parameters of all furnaces and main compressors in one shot

RESULTS

Higher data consistency and robustness in KPIs calculation and increased plant knowledge

- Corporate data are accurate and underperforming production can be easily identified
- For the first time there is one steam distribution model making life easier for the energy manager

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Next steps… from olefins to polyolefins

- **Expand the current system to include polyolefins**
  - Mass Balance of each line
  - Batch tracking and data aggregation by batch
- **Challenges**
  - Semi-Batch process with many material movements currently not well tracked
- **Currently under evaluation**
  - Use of Sigmafine Material Tracking algorithm to provide information such as batch number and material codes for each production lot
  - Aggregation rule associated with PI Event Frame generation

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Thank You