OPTIMIZE HYDROGEN NETWORK IN REFINERIES WITH RIGOROUS SIMULATION TOOLS

María J. Guerra, Manel Serra & Josep A. Feliu*

6th TRC-JCC / IDEMITSU International Symposium

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H_2 Network Operational Optimization

- Introduction
- Solution Overview
- References
  - Production optimization
  - Consumers and purifiers optimization
- Conclusions

inprocess Simulation to Business. Knowledge to Profit.

INTRODUCING INPROCESS

- Independent Process Simulation Services Company
- Established in Barcelona in late 2006 by four Process Simulation experts, nowadays employing more tan 50 employees, with commercial offices in:
  - Wiesbaden, Dubai, Houston, Mexico DF, Buenos Aires Caracas, Rio Janeiro, Moscow
- In any case, our ***mission*** has not changed:
  - to help companies, which use process simulation, to get the whole of the value from their investment in software

- Technology Transfer / Training
  - Process Simulation Courses
  - Knowledge Improvement Program
  - Operations Training
- Process Simulation Projects
  - Steady State
  - Dynamics
- Lifecycle Projects / OTS
  - Dynamic Simulation Studies
  - DCS Check-out
  - Operator Training Systems
- Software Applications
  - PSA Simulator
  - H_2 Network Management Tool
  - Instructor Station

CLIENTS

- Operating Companies

CLIENTS

- EPCs

Tecnimont
HYUNDAI ENGINEERING CO., LTD.
eni
KVÆRNER
saipem
idom
TECNICAS REUNIDAS
SENER
FW
Technip
SBM OFFSHORE
maris SRL
NPCC
MUSTANG
SEVAN marine
MAUREL & PROM
AkerSolutions

CLIENTS

- Equipment Manufacturers and Instrumentation Providers

Honeywell

GE Oil & Gas

Atlas Copco

EMERSON. Process Management

MAN

SIEMENS

CCC

YOKOGAWA

Rockwell Automation

INTRODUCTION

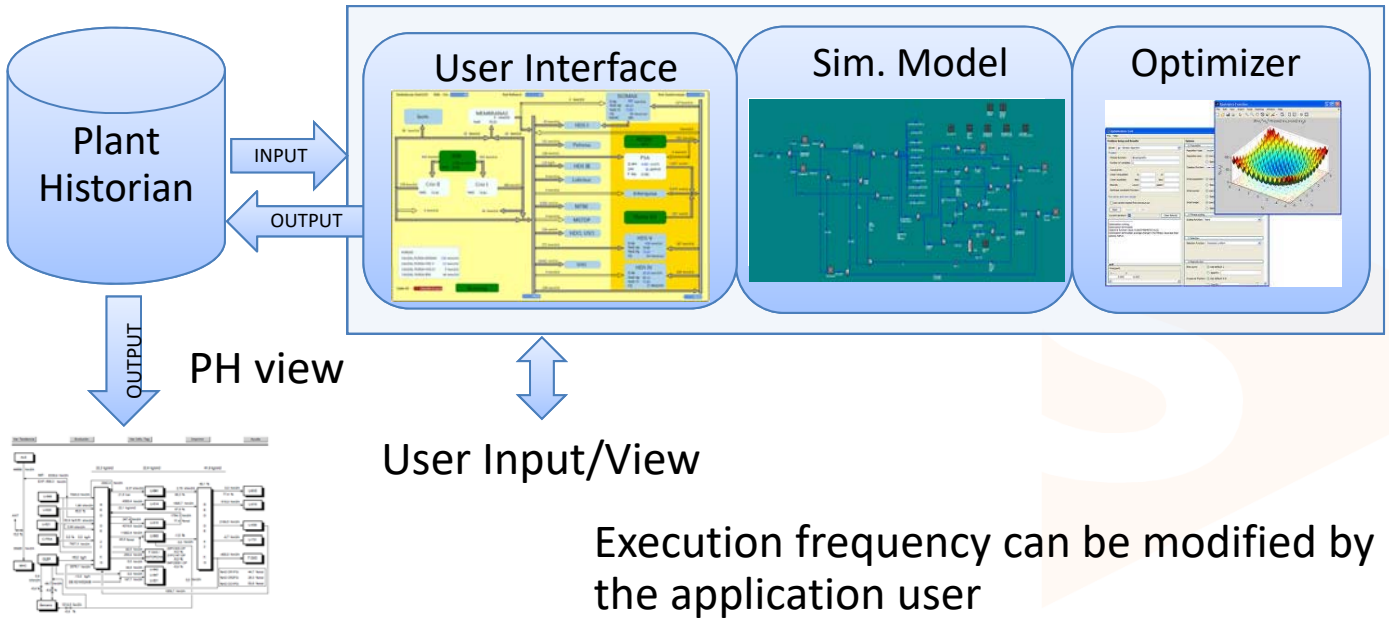
- Hydrogen cost is becoming more significant due to increases in:
  - Demand (Sourer and heavier crudes, more Hydroprocessing capacity)
  - Price (Natural Gas price)
- Existing hydrogen networks should be operated in a way that:
  - Profitability of each process unit (hydroprocessing) is maximized
  - Hydroprocessing catalysts are not exposed to hydrogen partial pressures below operating limits
  - Is flexible enough to adapt to adjustments made in response to day-to-day changes in the refinery
  - The amount of hydrogen sent to fuel is minimized

INTRODUCTION

- A H_2 network on-line advisory tool, that can propose optimal operating conditions, would help to achieve such objectives
- It requires:
  - Connectivity application to handle communication with real plant on line data
  - Interface with continuous operational recommendations
  - A detailed simulation model of the existing network connectivity and involved units
  - Calibration and optimization every 15 min
  - Interface for what-if studies

SOLUTION OVERVIEW

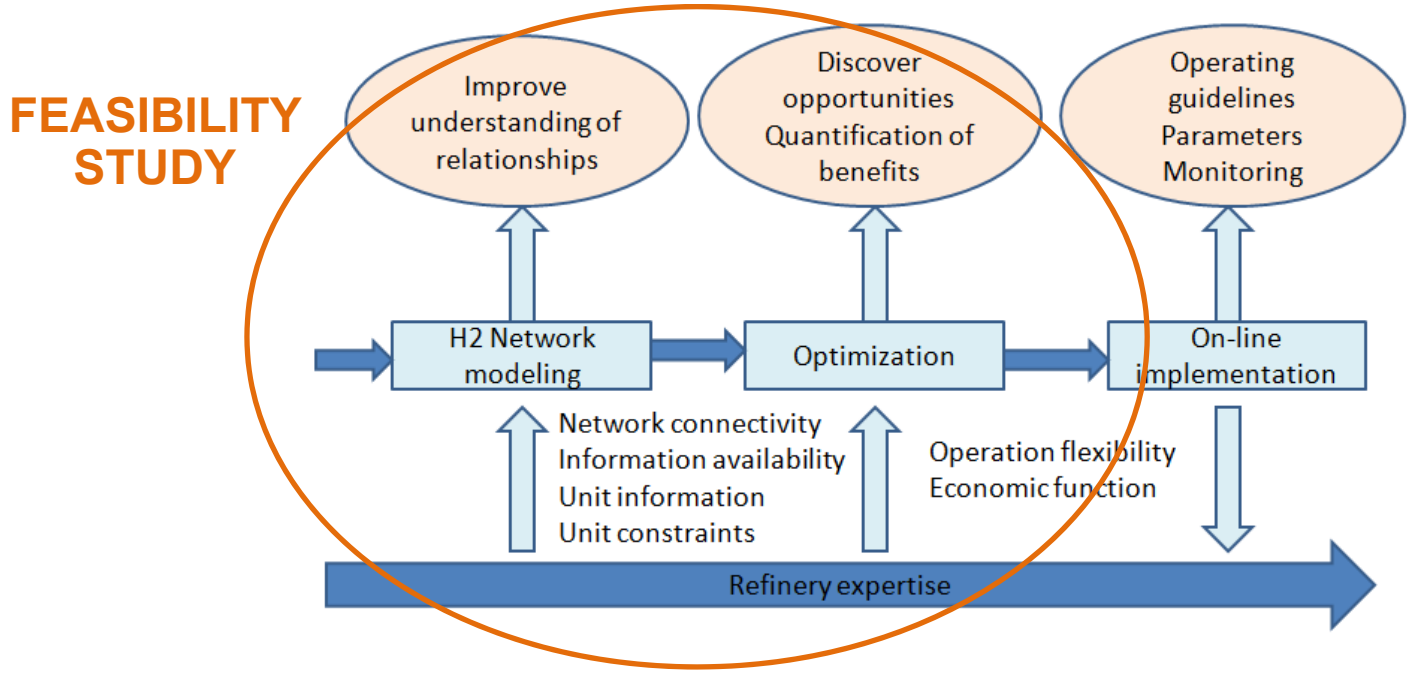
- Configuration



Execution frequency can be modified by the application user

SOLUTION OVERVIEW

- Phases of a H_2 Network Optimization Project



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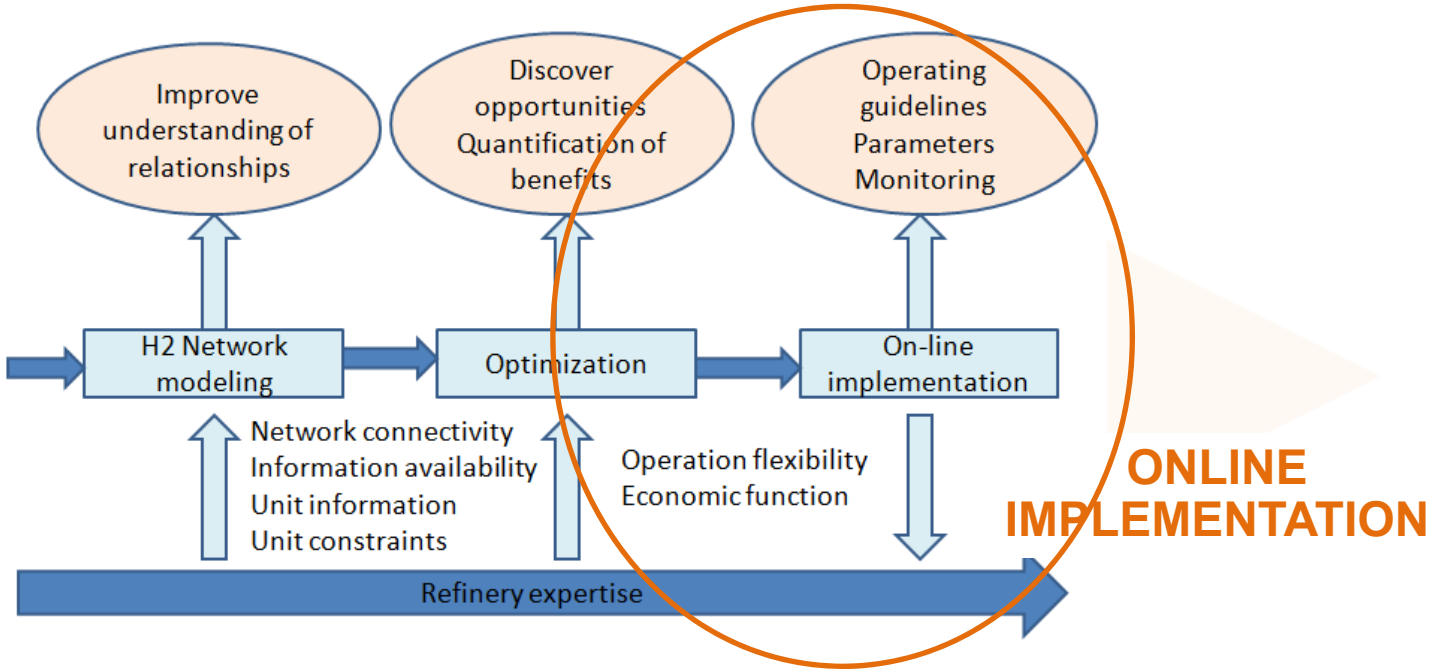
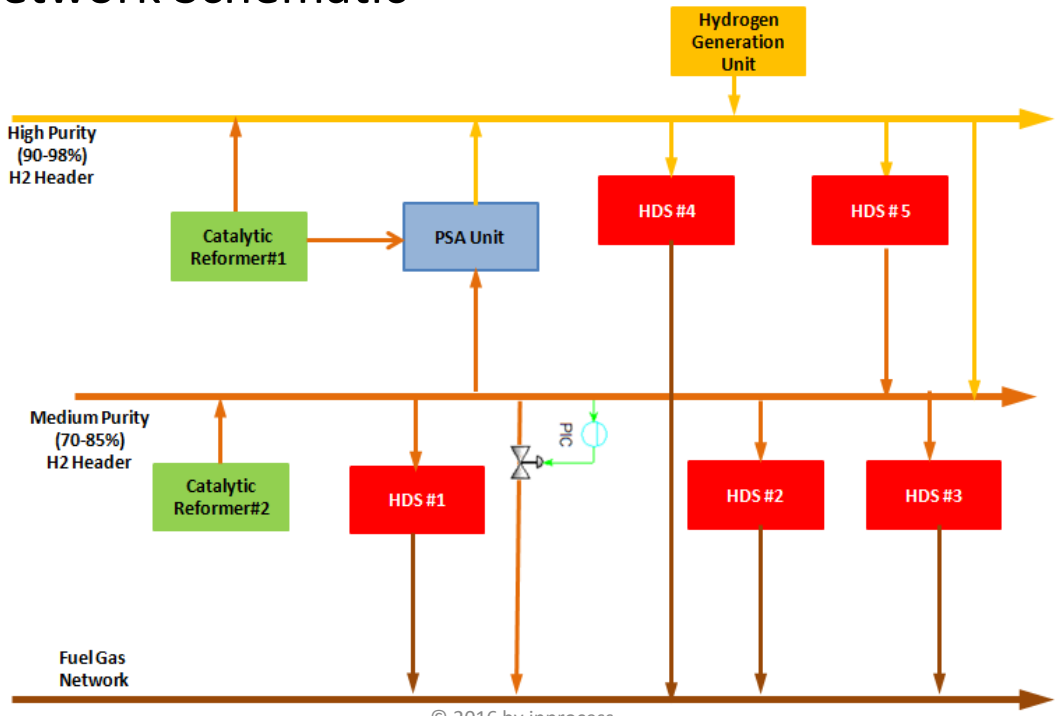


SUCCESS STORY 1: CEPSA'S GIBRALTAR-SAN ROQUE REFINERY

CEPSA

- Hydrogen Network Schematic



SUCCESS STORY 1: CEPSA'S GIBRALTAR-SAN ROQUE REFINERY

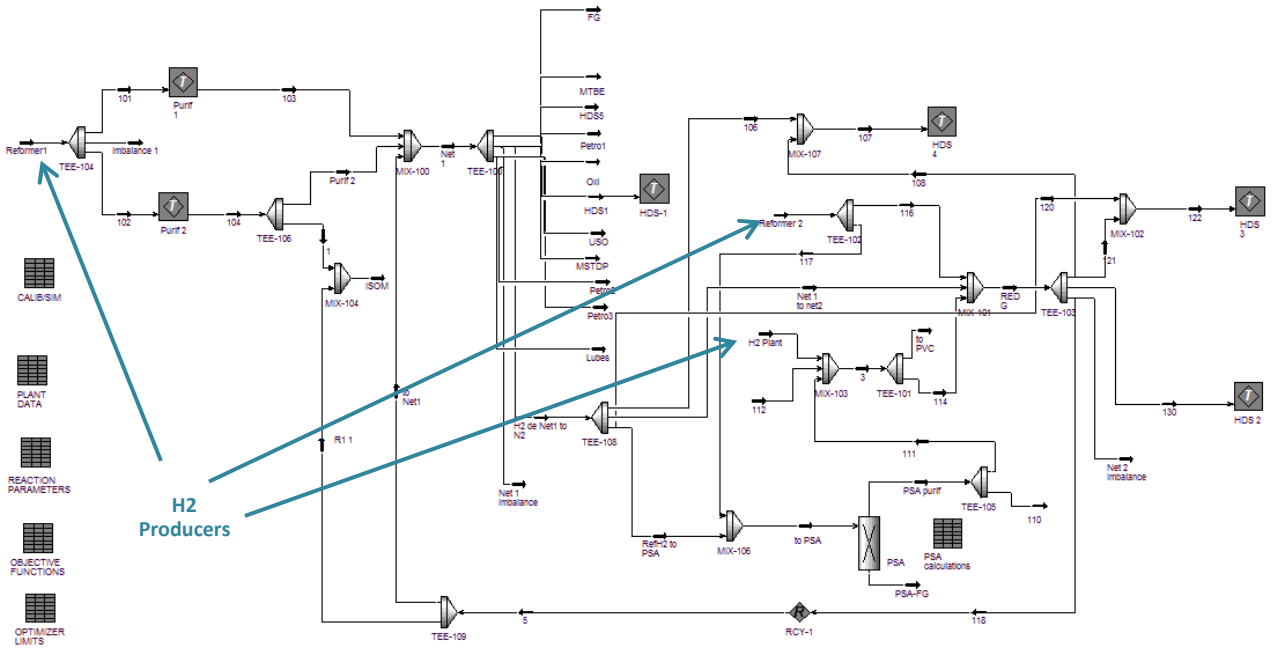
CEPSA

- Challenges:
  - Collect and reconcile H_2 network related plant information
  - Minimize cost of hydrogen
    - Minimize H_2 plant load
    - Minimize Reformer#2 Load (if product price scenario allows it)
    - Minimizing all purges to fuel gas
    - Maximize recovery in PSA unit
  - Crude changes and capacity changes
  - Plan unit shut down

SUCCESS STORY 1: TECHNICAL SOLUTION

CEPSA

- Aspen HYSYS Simulation model of the H_2 network



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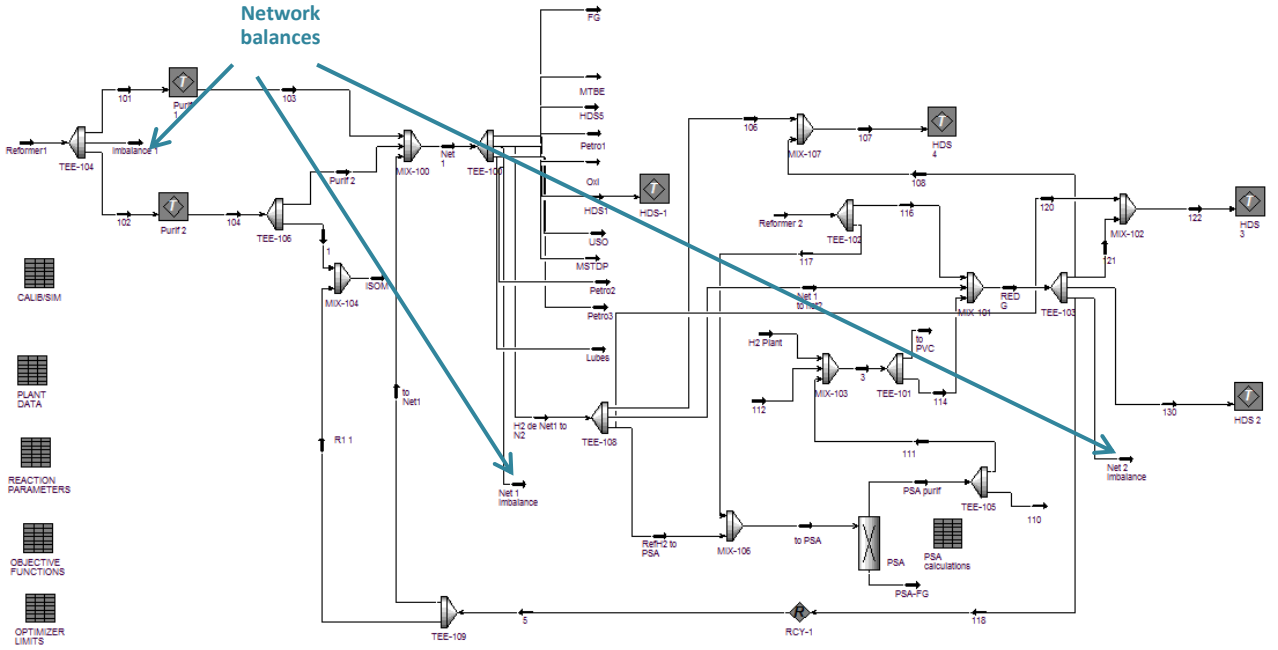

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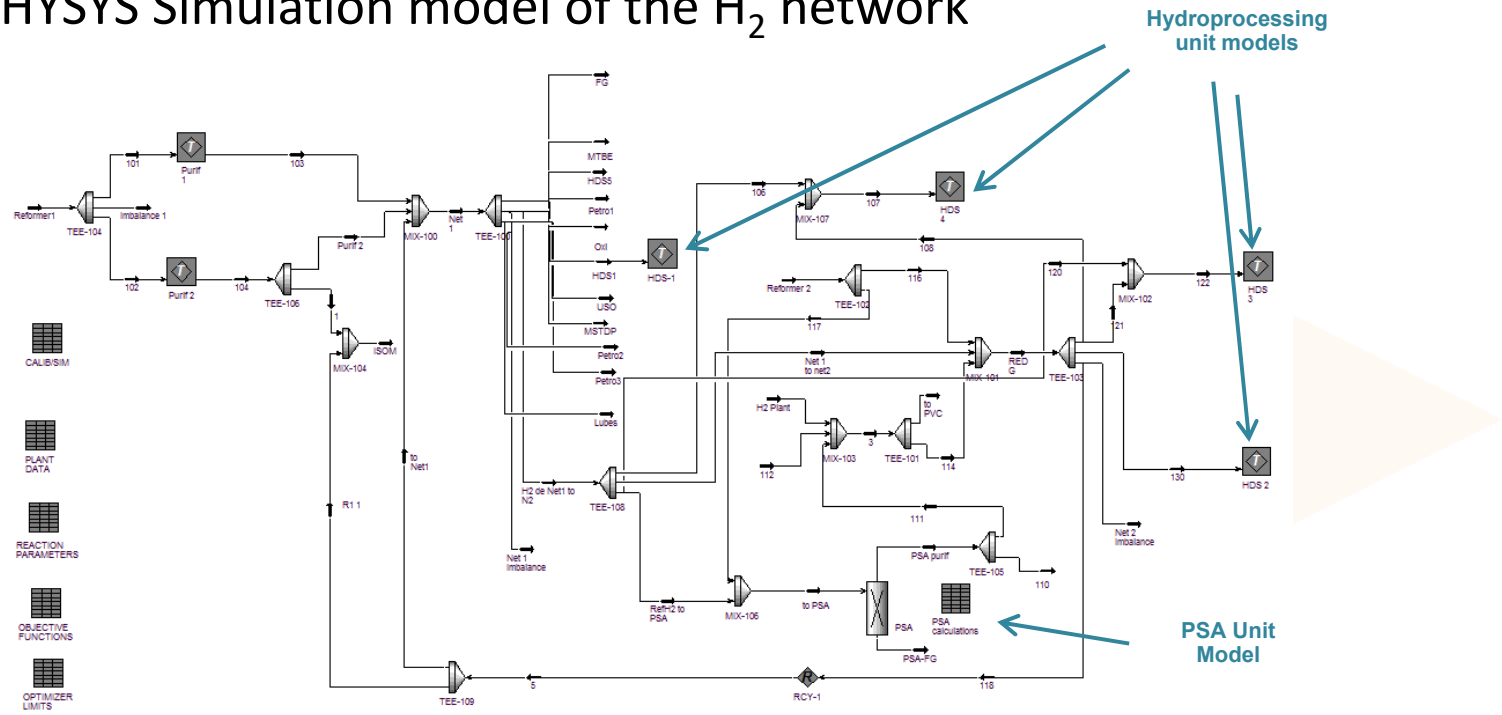
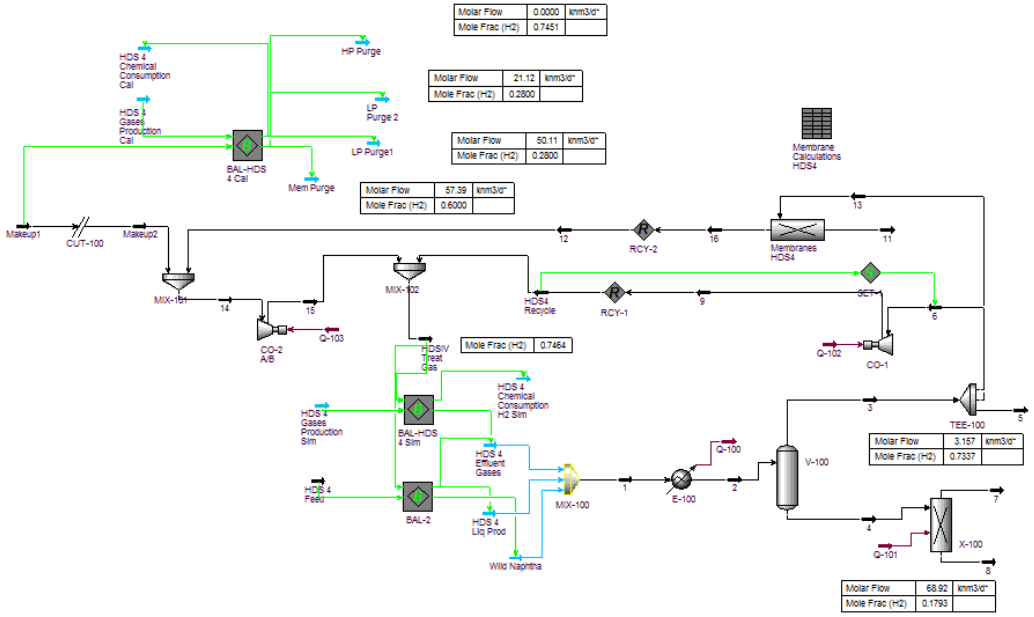


SUCCESS STORY 1: TECHNICAL SOLUTION

CEPSA

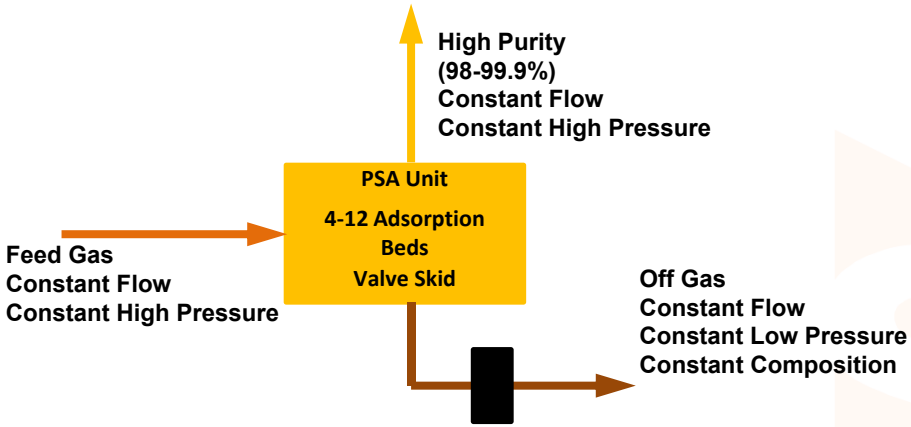
- Hydroprocessing unit models
- Specific simulation model for every unit
  - Calibration and Simulation within the same model
  - Monitoring of hydrogen consumption



SUCCESS STORY 1 – TECHNICAL SOLUTION, PSA SIMULATION

CEPSA

- Pressure Swing Adsorption Unit was a key element in the network operation



- Unit operates on a cyclic basis: combination of multiple adsorption beds that provide constant product and off gas flows
- Adsorbents are able to retain more impurities at high pressure than low pressure. Pressure swings to regenerate beds

SUCCESS STORY 1 – TECHNICAL SOLUTION, PSA SIMULATION

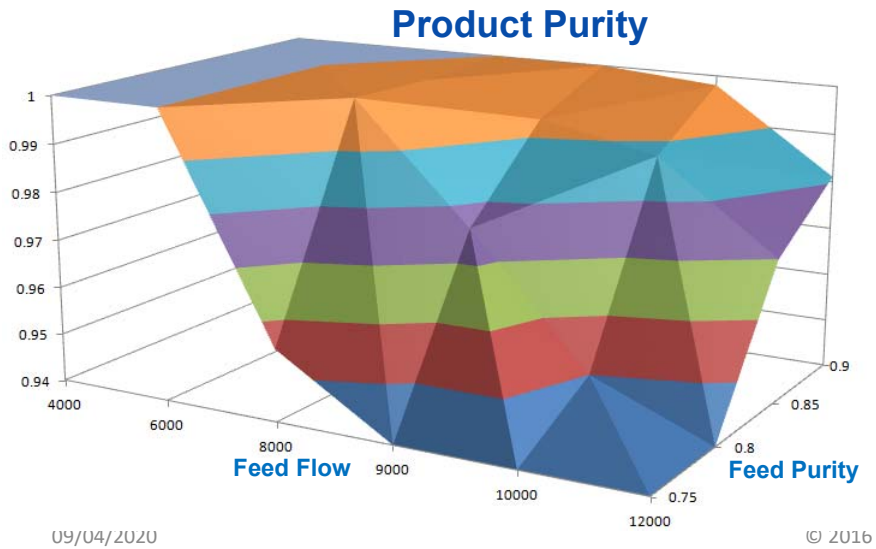
CEPSA

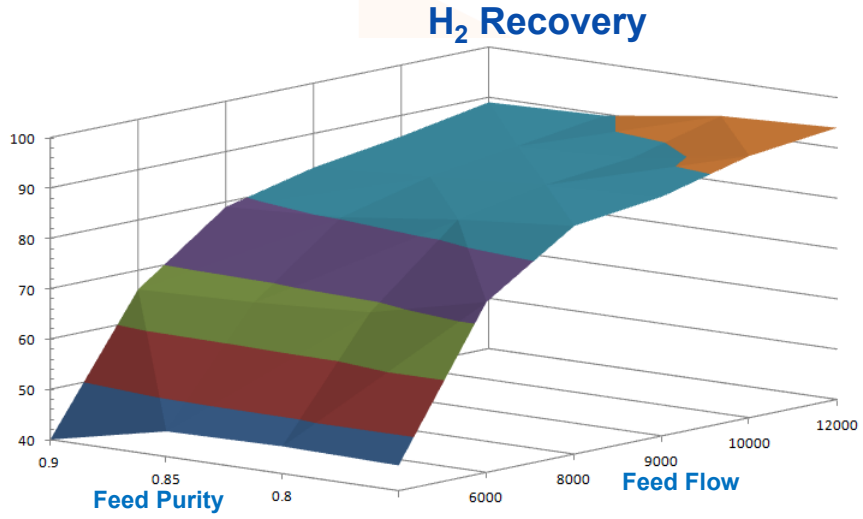
- Dynamic model of the PSA unit
  - Solves, for time and bed length, differential conservation equations for mass, heat and momentum along with Langmuir equilibrium equations developed by a University
  - Literature values for adsorbent properties
  - Fits experimental data well
- Allows rigorous evaluation of operating parameters
  - Cycle time
  - Feed flowrate
  - Feed composition

SUCCESS STORY 1 – TECHNICAL SOLUTION, PSA SIMULATION

CEPSA

- Possible operating envelope for the optimizer
  - Maximizing Recovery
  - Maximum feed flowrate, depending on feed purity

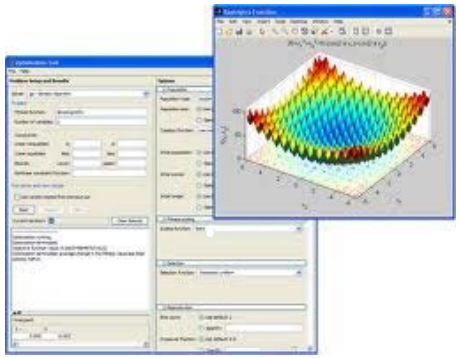




SUCCESS STORY 1: TECHNICAL SOLUTION

CEPSA

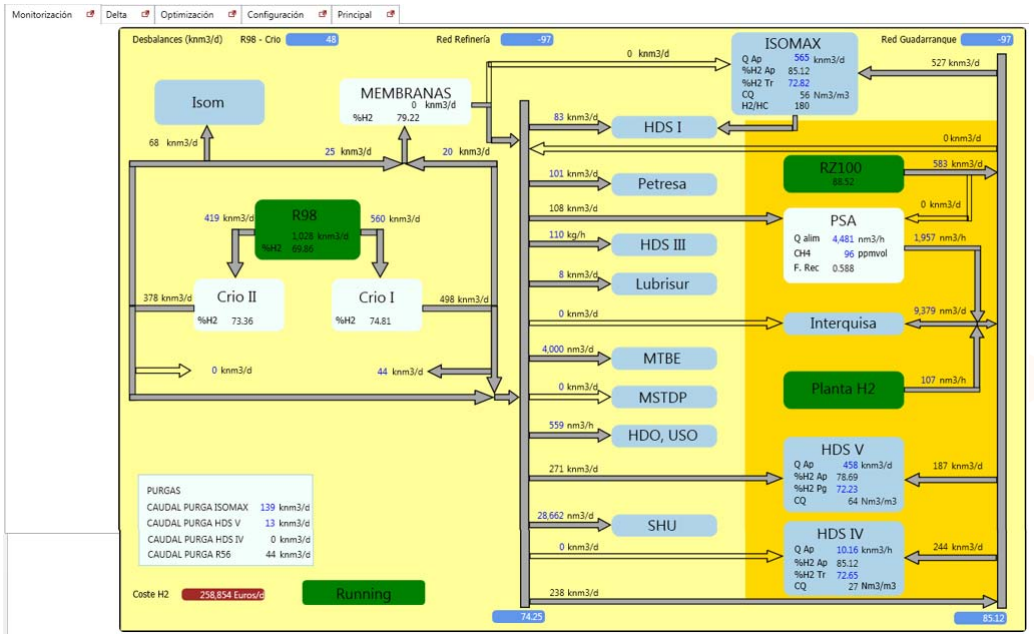
- Optimization
  - Process Variables:
    - H_2 plant load (Including shutdown)
    - Reformer #2 Load
    - Makeup flow of main hydrotreaters
    - PSA Purification unit load
  - Constraints:
    - Hydrotreater recycle purity for each unit
  - Objective function
    - Hydrogen cost when plant production allow it
    - Increased hydrotreater purities when not



SUCCESS STORY 1: USER INTERFACE

CEPSA

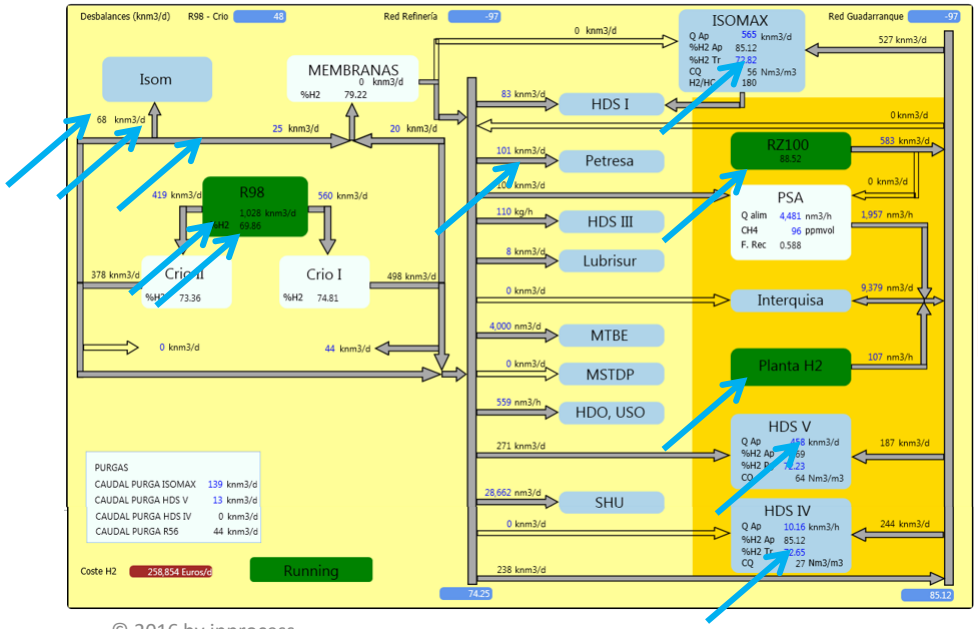
- User Interface shows current network configuration



SUCCESS STORY 1: USER INTERFACE

CEPSA

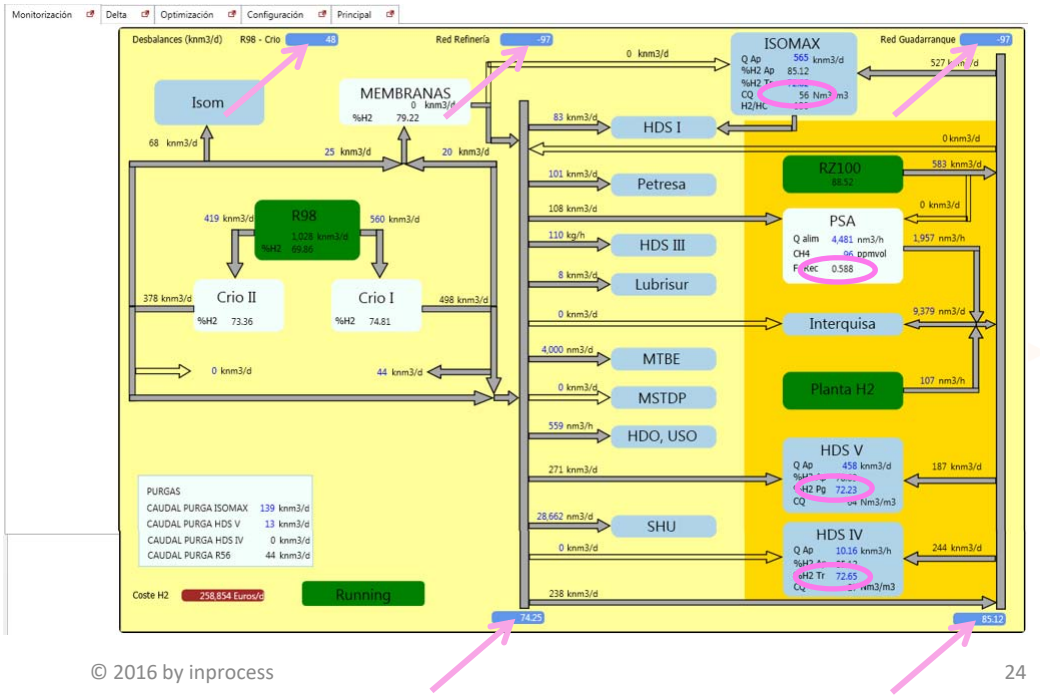
- It collects from plant data current H_2 productions, Hydrotreater make-up, purges, purities and other variables



SUCCESS STORY 1: USER INTERFACE

CEPSA

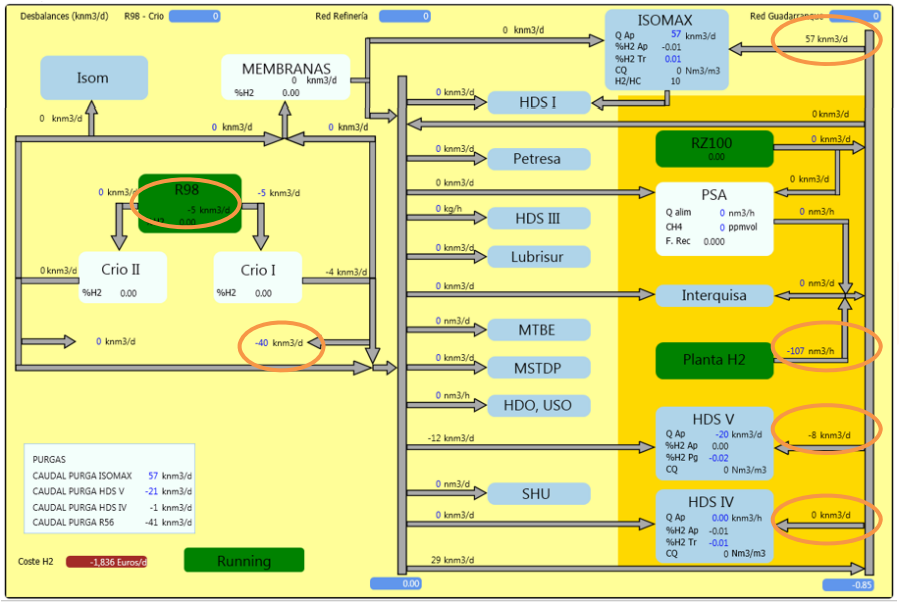
- It calculates material imbalances, network purities, H_2 consumption and other unit variables



SUCCESS STORY 1: USER INTERFACE

CEPSA

- After Calibration step, optimization is run
- Manipulated variables, constraints and objective function
- Treats results to give optimized operating suggestions



SUCCESS STORY 1: BENEFITS

CEPSA

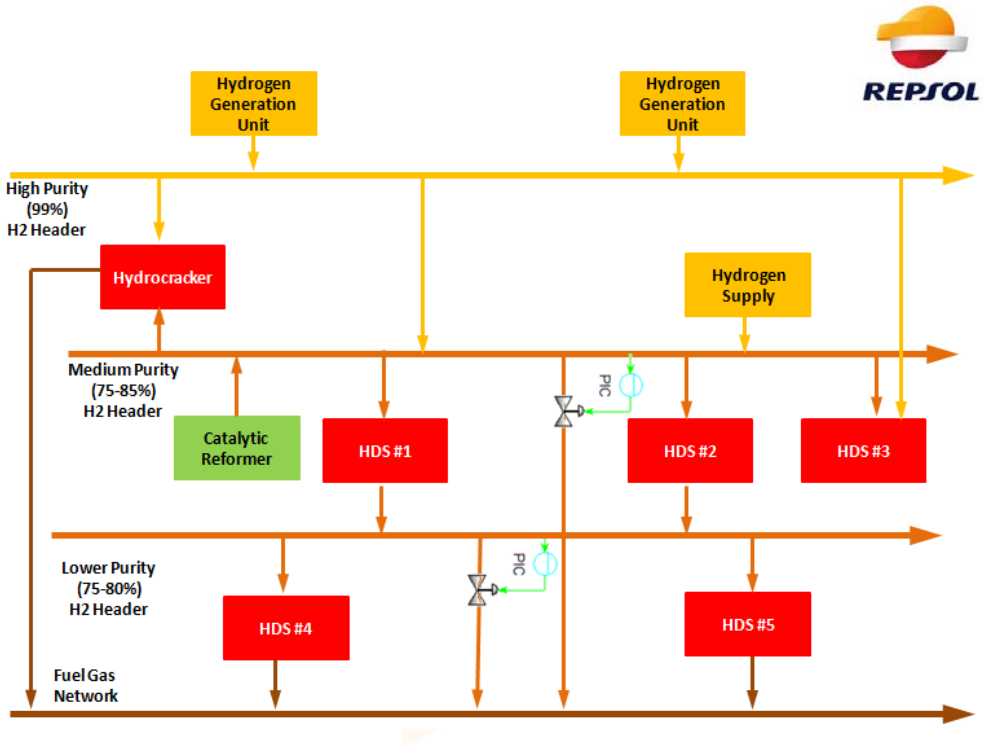
- Benefits study

Study Case	Average Daily Cost Reduction (€/day)	Benefit
I	3290	Reduce platforming load
II	0	H2 excess – increased catalyst life
III	5025	Reduce H2 plant load
IV	8568	Reduce H2 plant load
V	0	H2 excess – increased catalyst life
H2 Price 1400 €/tonne		

  - If on-line, the optimizer results must not show large benefits (otherwise, it would not have been useful)

SUCCESS STORY 2: REPSOL – PUERTOLLANO REFINERY

- Hydrogen Network Schematic

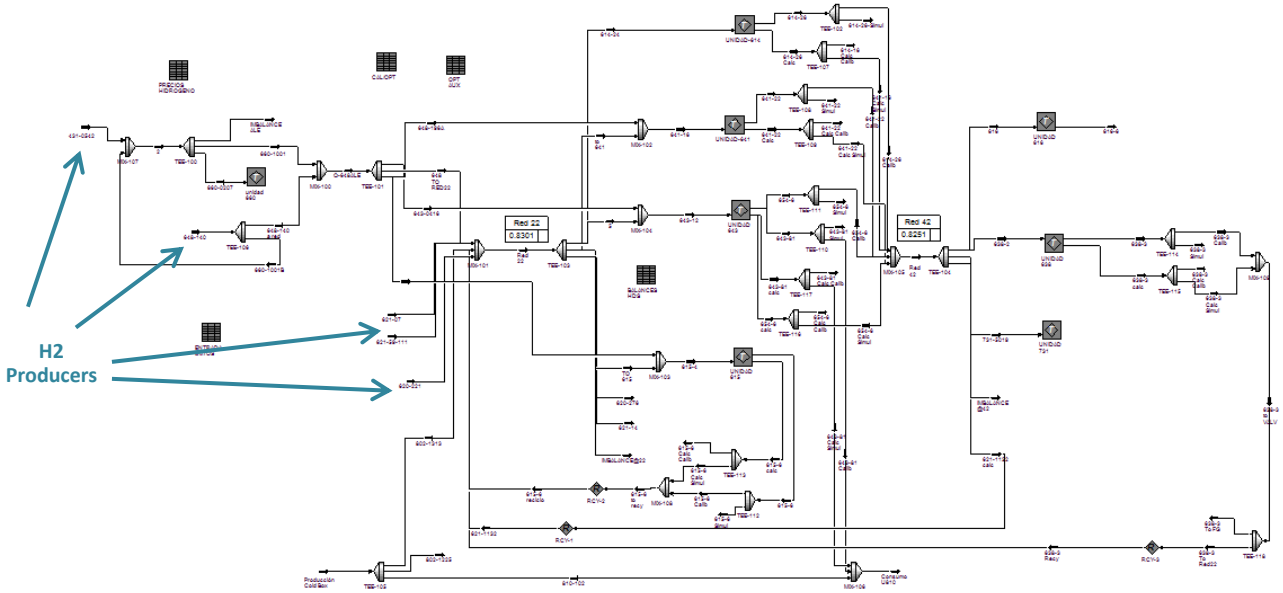


SUCCESS STORY 2: REPSOL – PUERTOLLANO REFINERY

- Challenges:
  - Collect and reconcile H_2 network related plant information
  - Minimize cost of hydrogen
    - Minimizing purges to fuel gas
    - Use lowest cost hydrogen, based on source and operating capacity
  - Evaluate imbalances in order to improve instrumentation
  - Evaluate operating scenarios

SUCCESS STORY 2: TECHNICAL SOLUTION

- Aspen HYSYS Simulation model of the H_2 network



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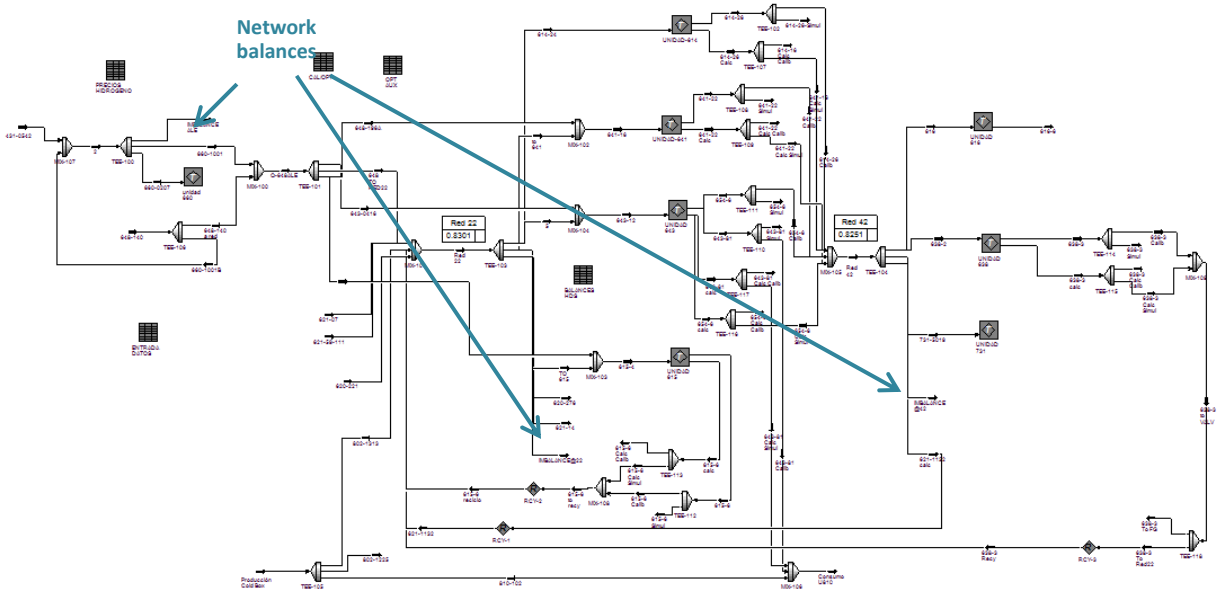

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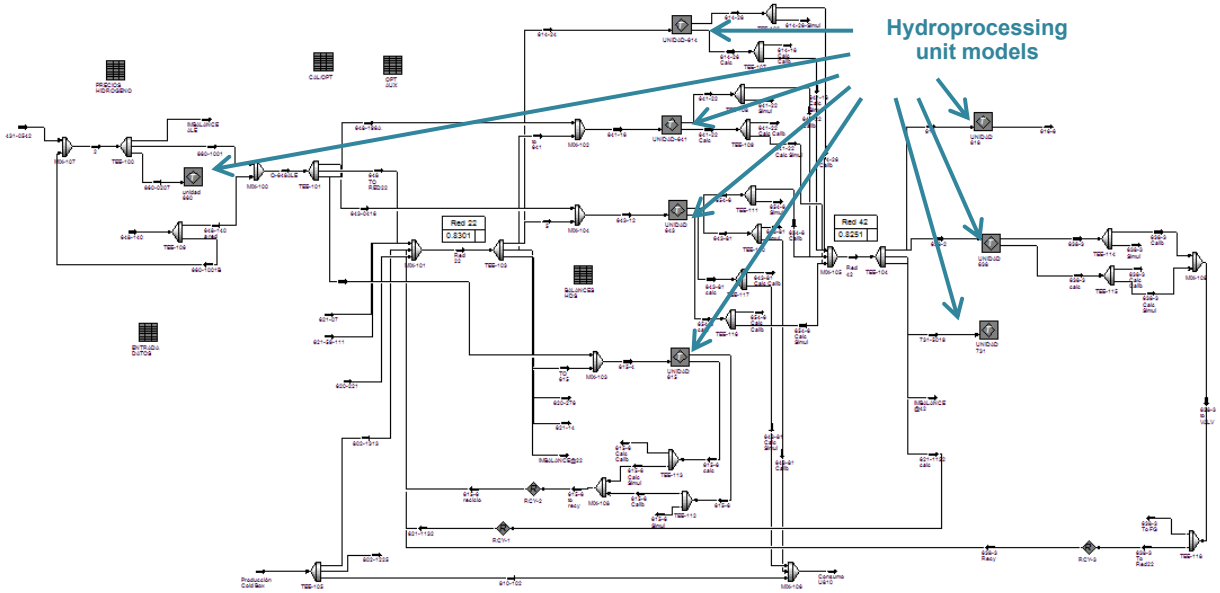
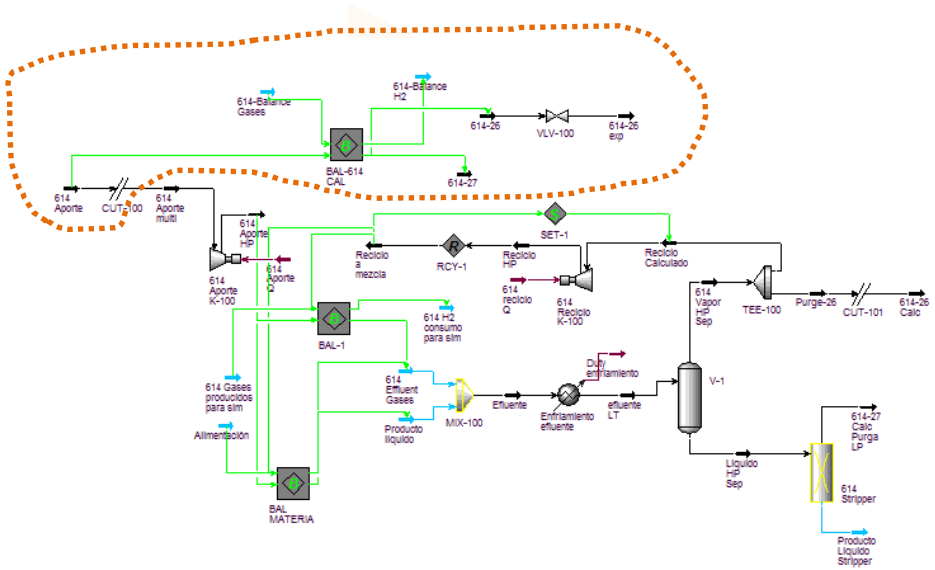


SUCCESS STORY 2: TECHNICAL SOLUTION

REPSOL

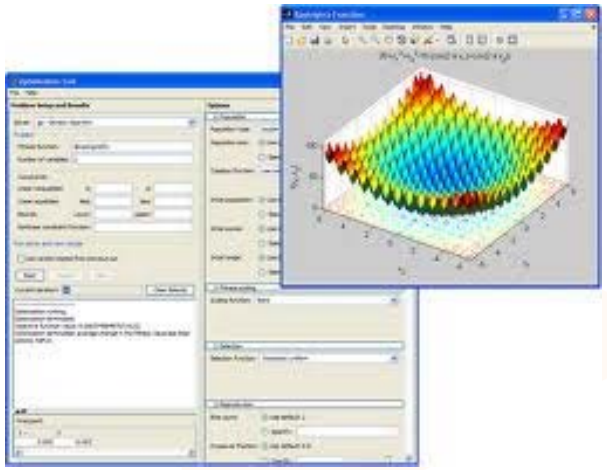
- Hydroprocessing unit models
  - Specific simulation model for each unit
    - Calibration and Simulation within the same model
    - Calculate reactor parameters by balance
    - Simulation reproduces H_2 separation



SUCCESS STORY 2: TECHNICAL SOLUTION

REPSOL

- Optimization
  - Process Variables:
    - Hydrogen production for the two units
    - Feed charge to hydrotreaters - on demand
  - Constraints:
    - Hydrotreaters recycle purity constraint
    - Additional one compressor constraint
  - Objective function
    - Price structure based on load
    - Allows for monthly update



SUCCESS STORY 2: BENEFITS

REPSOL

- Benefits Study
  - Select the optimal H_2 source based on operating plant load
  - Minimize H_2 purges to FG

Study Case	Peak Cost Reduction (€/hour)	Average Daily Cost Reduction (€/day)
I	279	2134
II	270	3442
III	538	7432
IV	256	1273
V	412	3721

  - If on-line, the optimizer results must not show large benefits (otherwise, it would not have been useful)

CONCLUSIONS

- Inprocess' H_2 Network Management Tool allows for the online optimization of a refinery hydrogen production/consumption
- Savings are achievable
- Due to the availability of a calibrated rigorous network model, connected online with Plant Instrumentation Database, additional benefits can be obtained:
  - Improvement of online monitoring instrumentation
  - Monitoring chemical hydrogen consumption,
  - Other refinery operating parameters

THANK YOU!

- Josep-Anton Feliu, Marketing Director, María-Jesús Guerra & Manel Serra (Sr. Advisors)
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JOSEP-ANTON FELIU, MARKETING DIRECTOR

- Josep Anton accumulates 25 years of experience in Process Modeling and Simulation for systems ranging from biological ones to oil & gas, refining, petrochemicals and polymers. Having taught at Universitat Autònoma de Barcelona, he joined Hyprotech as the EMEA Regional Manager for Customer Support and Training, position where he remained after Aspentech acquisition. In that role, Josep Anton helped clients, participated in modelling projects and enhanced the existing training material. Taking advantage of his lecturing experience, he did also teach countless Process Simulation courses.
- Josep Anton, at Inprocess, now manages the Marketing and Proposals Department, after having lead the Training Department since its inception, thus being responsible for the development and deployment of all Inprocess' clients educational requirements.