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USERS CONFERENCE 2016

April 4-8, 2016 | San Francisco

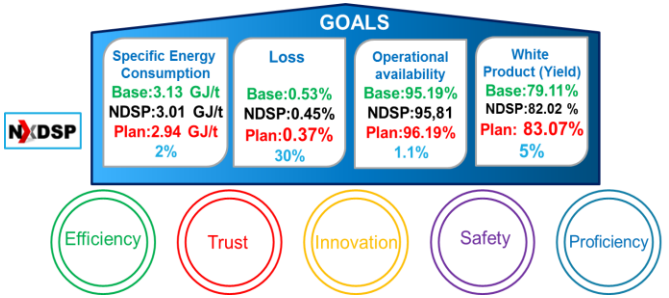
TRANSFORM YOUR WORLD

Delivering Business Value in Downstream O&G with Predictive Analytics and Machine Learning with PI AF and Microsoft Azure Machine Learning

Presented by **Tibor Komróczki**

Agenda – Delivering Business Value from the PI System

1. MOL Overview
2. Our Journey with the PI System and PI AF
3. Next Downstream Program
4. Integrity Operating Windows (IOWs)
5. Using PI AF for Forecasting & Predictive Analytics
6. Machine Learning with Microsoft Azure & the PI AF Foundation
7. Summary
8. Q&A



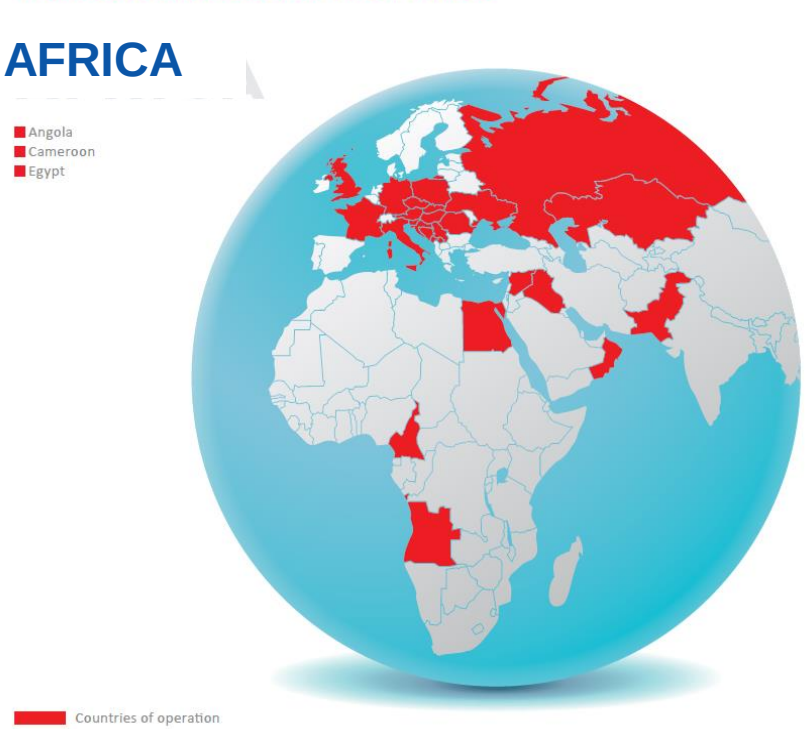
MOL Overview

MOL Group around the world

Operations in over 40 countries and employs almost 29,000 people worldwide

Production activities in 8 countries and exploration assets in 12 countries

Cultural alignment challenges - 10 time zones, 5 languages, and 3 units of measure



EUROPE

- Austria
- Bosnia & Herzegovina
- Croatia
- The Czech Republic
- France
- Germany
- Hungary
- Italy
- Montenegro
- Poland
- Romania
- Russia
- Serbia
- Slovakia
- Slovenia
- Ukraine
- United Kingdom

ASIA

- Kazakhstan
- Kurdistan Region of Iraq
- Oman
- Pakistan
- Syria

MOL Downstream

- MOL operates 4 refineries and 2 petrochemicals plants, under integrated supply chain management.

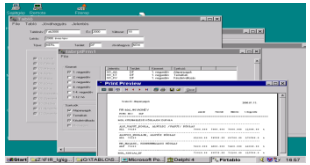
- MOL also own a network of more than 1,900 service stations under 8 brands across 13 countries in Central & South Eastern Europe.

Element Categories	133
Element Templates	301
Elements	20914
Enumeration Sets	45
Event Frames	61012
Identities	95
Mappings	96
Notification Contact Template	154
Notification Templates	31
Notifications	5908

The MOL Journey with the PI System & PI AF

Tactical to Strategic, Tags to Assets

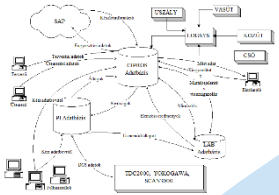
1998



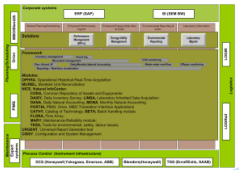
Individual

Team

2002



2006



Division

2010

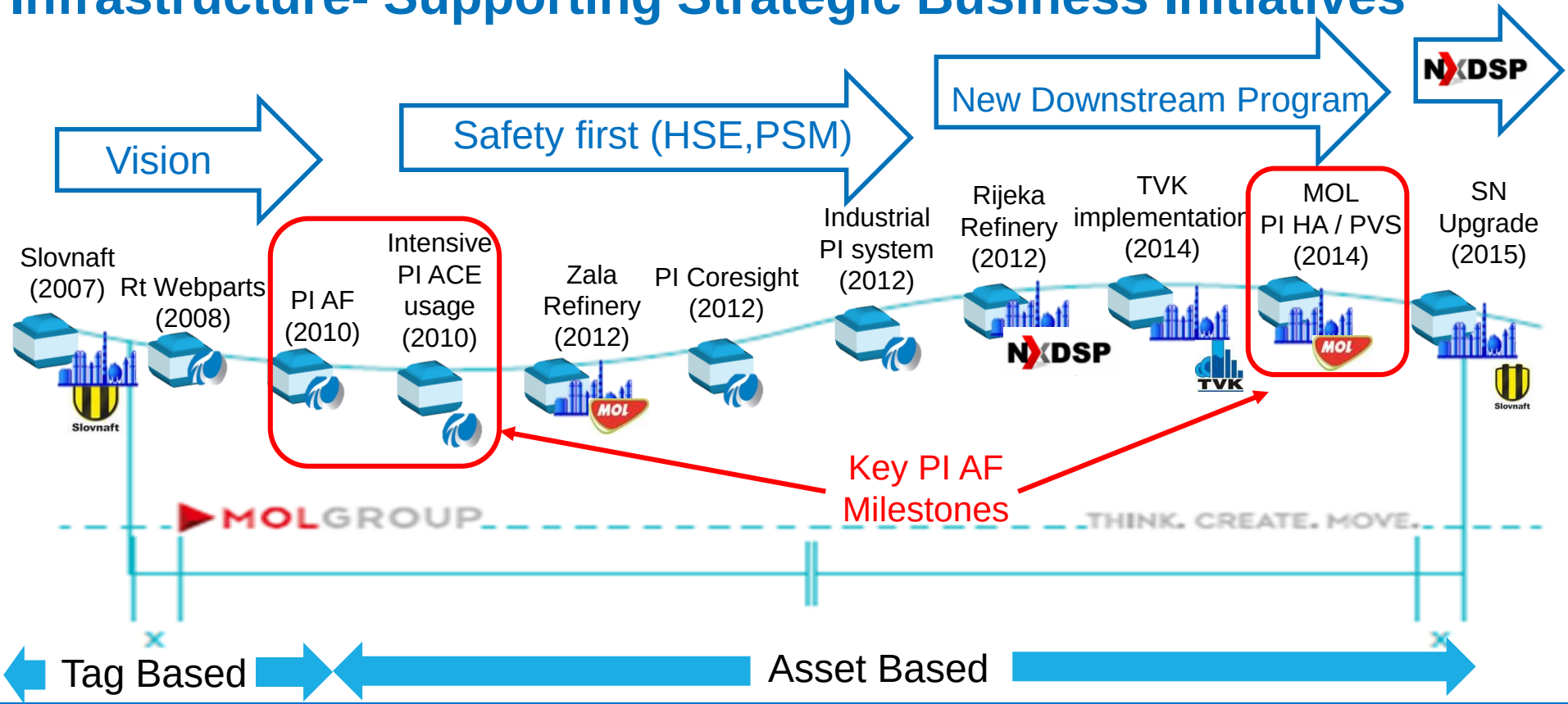
Enterprise

2016+

IoT

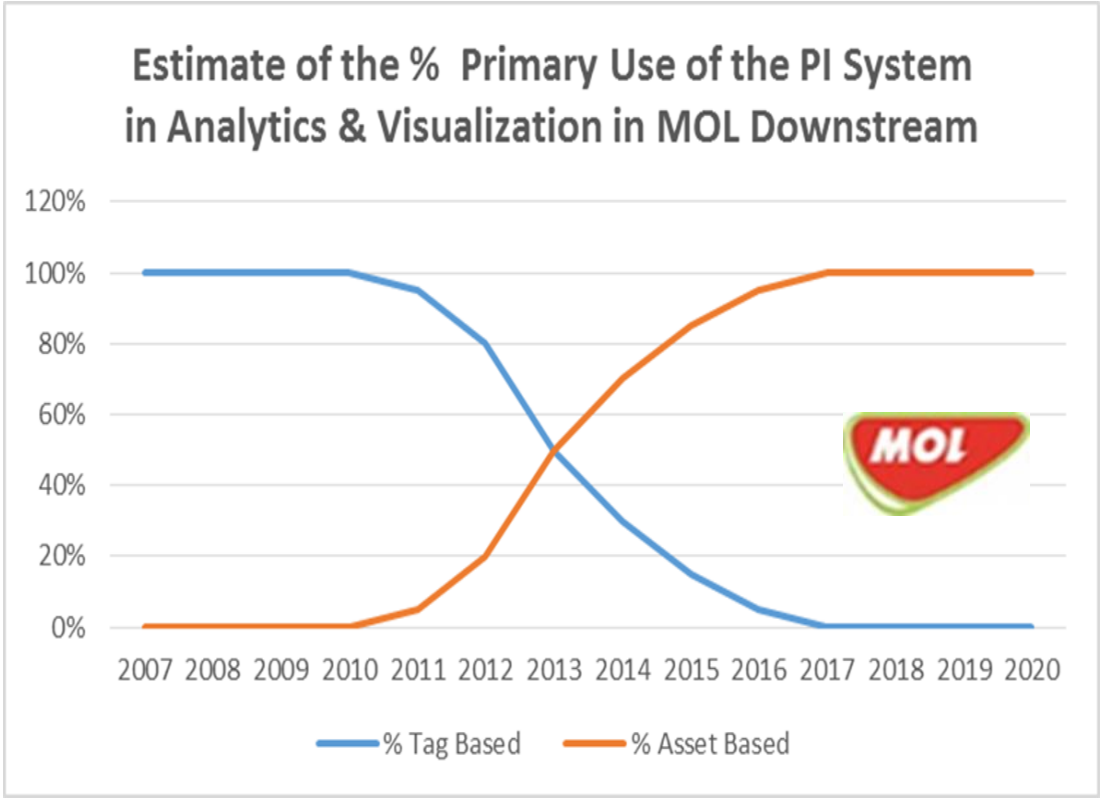
Machine learning

MOL Downstream / History II- Tactical Historian to Strategic Infrastructure- Supporting Strategic Business Initiatives

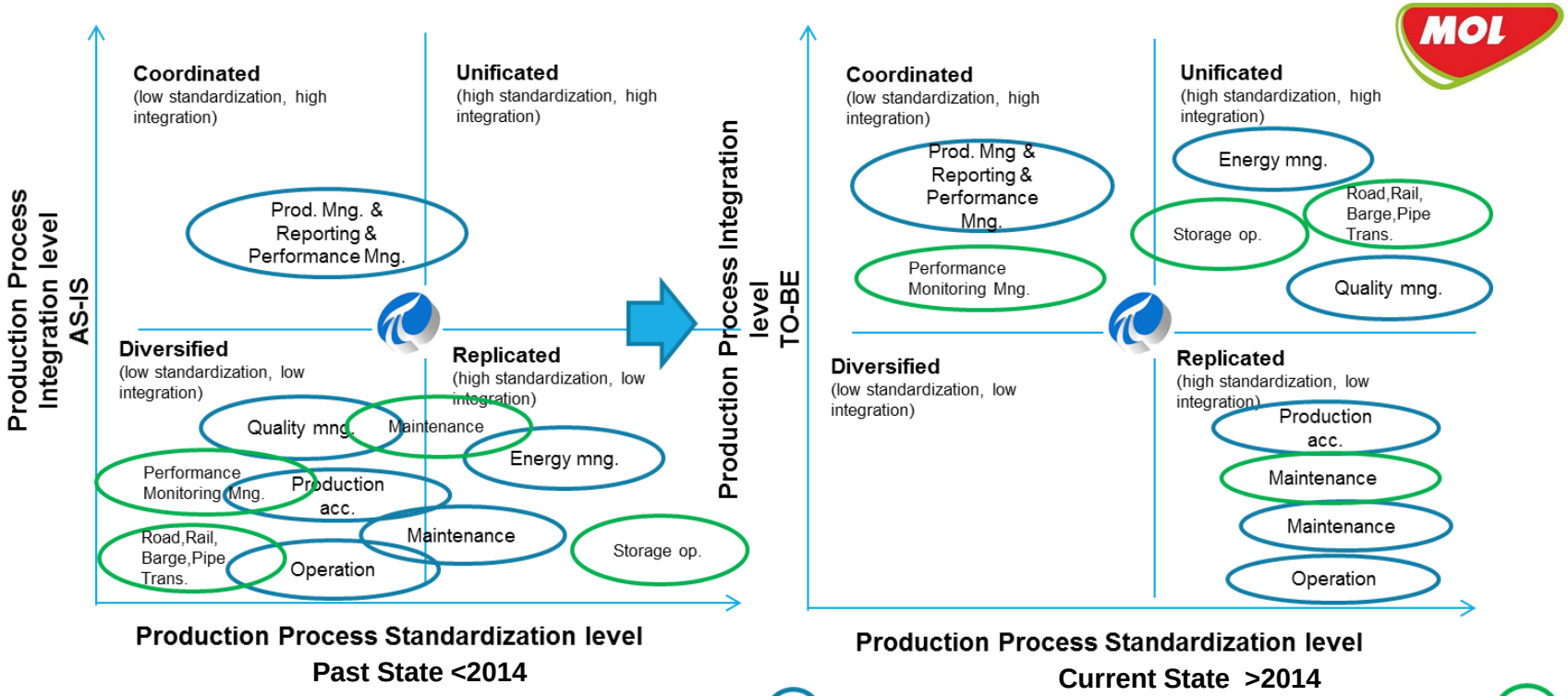


Moving to PI AF is a Vision and a Journey…..”Just do It!”

- **Start PI AF with a key business initiative** and build, capability, momentum and awareness;
- **Market PI AF vision**, capability, and value to leadership with **alignment to strategic initiatives;**
- Leverage PI AF Jumpstarts, OSIsoft consultation, PI AF templates, SIs, etc. to **lower the barriers to PI AF use**;
- **Once PI AF critical mass** is achieved, adoption will accelerate and be seen as **transformative and strategic**;
- **MOL sees PI AF as enabling** to many PI System capabilities like PI Coresight, PI Connectors, Integrators, etc.;



Leverage of the PI System as an Integration & Applications Infrastructure to Simplify & Standardize the Applications & Solutions Portfolio



Production (Refinery & Petchem) **& Logistic standardization**

MOL Downstream PI AF Based Applications

Safety and Asset Integrity

- Interlock statuses/DCS role tracking
- Operating envelopes
- Integrity Operating Windows (IOWs)
  - Corrosion control (HTHA)
- Alarm management
- Control rooms' temperature

Energy

- Energy Monitoring and Management
- Energy KPI breakdown (6 tiers)
- Column Energy Efficiency Dashboards
- Hydrogen, Utilities, and Energy balances
- Flaring

Yields

- Crude Blending Control
- Yield Optimization/Reporting
- Product Quality
- Analyser Reliability

Operational Optimization

- Plan vs Actual Analytics with Future Data
- NG and Fuel Demand gas forecasting
- Peak Electrical forecasting
- Normal mode of control loops
- APC monitoring
- PI AF and Sigmafine (PI AF) used for yield accounting & Material Movement

MOL Next Downstream Program

Next Downstream Program Goals

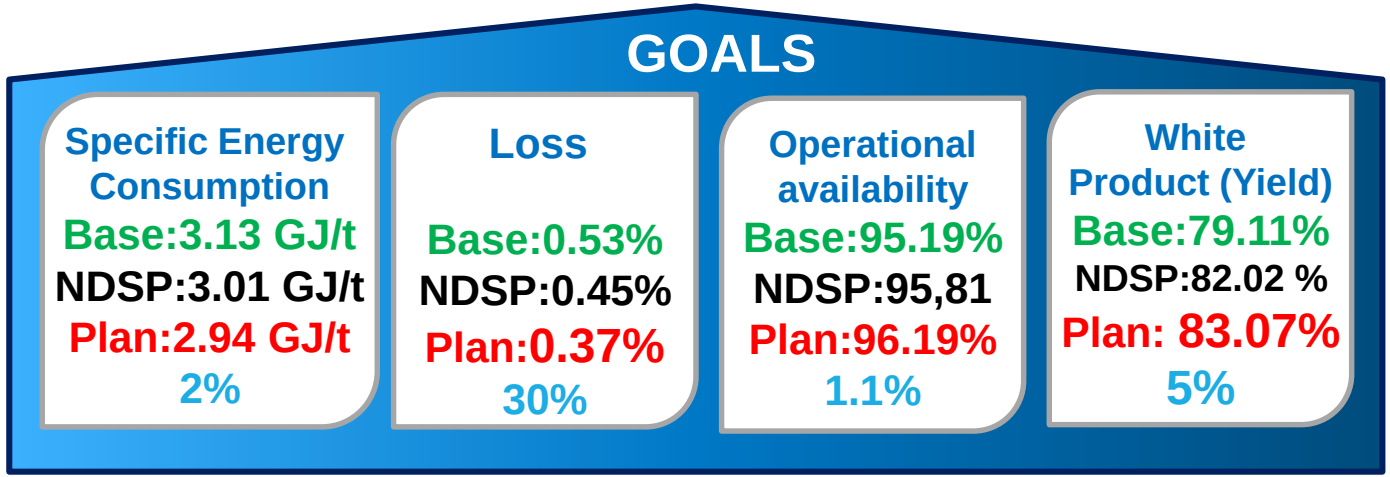
- Optimize maintenance costs and increase operational availability of MOL Group
- Move up one quartile energy intensity
- Black to white, increase of white product yield
- White yield to improve by 2.5%
- Flexibility between fuel and petchem products
- Diesel/Mogas from 2.4x to 2.76x

New DS program delivered USD 500mn Clean EBITDA improvement in 2014 vs 2011

NXDSP targets **ADDITIONAL $500M** increase by end of year 2016 vs 2014

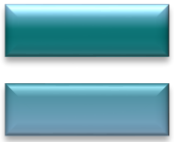
Focus areas of New Downstream Program (NDP) and Next Downstream Program

NDS is targeting $500M-550M EBITDA improvement by end of year 2016



Supporting Refining Safely Excellence with Integrity Operating Windows(IOW)

Supporting Strategic Business Initiatives – Refinery Safety Excellence



- On-line analyzers
- Interlock
- Flare
- Integrity Operating Windows (IOW)
- Operation Envelopes

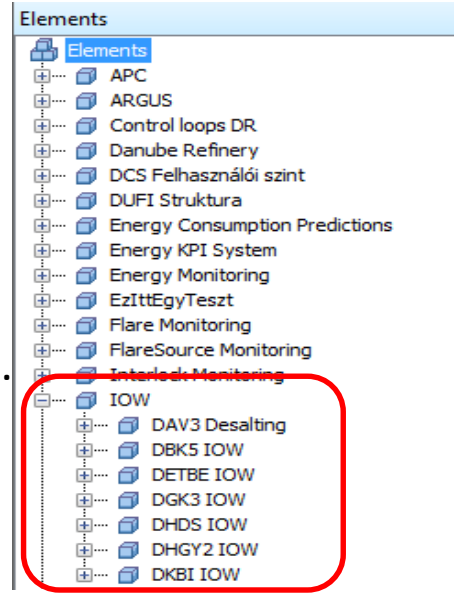
- Proactive/Predictive analytics with PI AF
- Reports – PI DataLink
- Displays PI Coresight
- Notifications Notifications

- Safe operation
- Reduced shut-downs
- Availability/Utilization
- Integrity
- Loss of containment

Integrity Operating Window- Using PI Asset Analytics

IOW - Established limits for process variables (parameters) that can affect the integrity of the equipment if the process operation deviates from the established limits for a predetermined length of time – All in PI AF

- Immediate and comprehensive reliability improvement program for key units
- Perform Failure Mode and Effect Analysis (FMEA)
- Improve investigation & upgrade corrosion control
- Define Integrity Operating Windows of Critical equipment
- Prequalification of suppliers (cover more services, review the process).
- KPIs Review & Analysis of Cycle and Duration
- Reliability awareness improvement program and people competency



IOWs - Examples

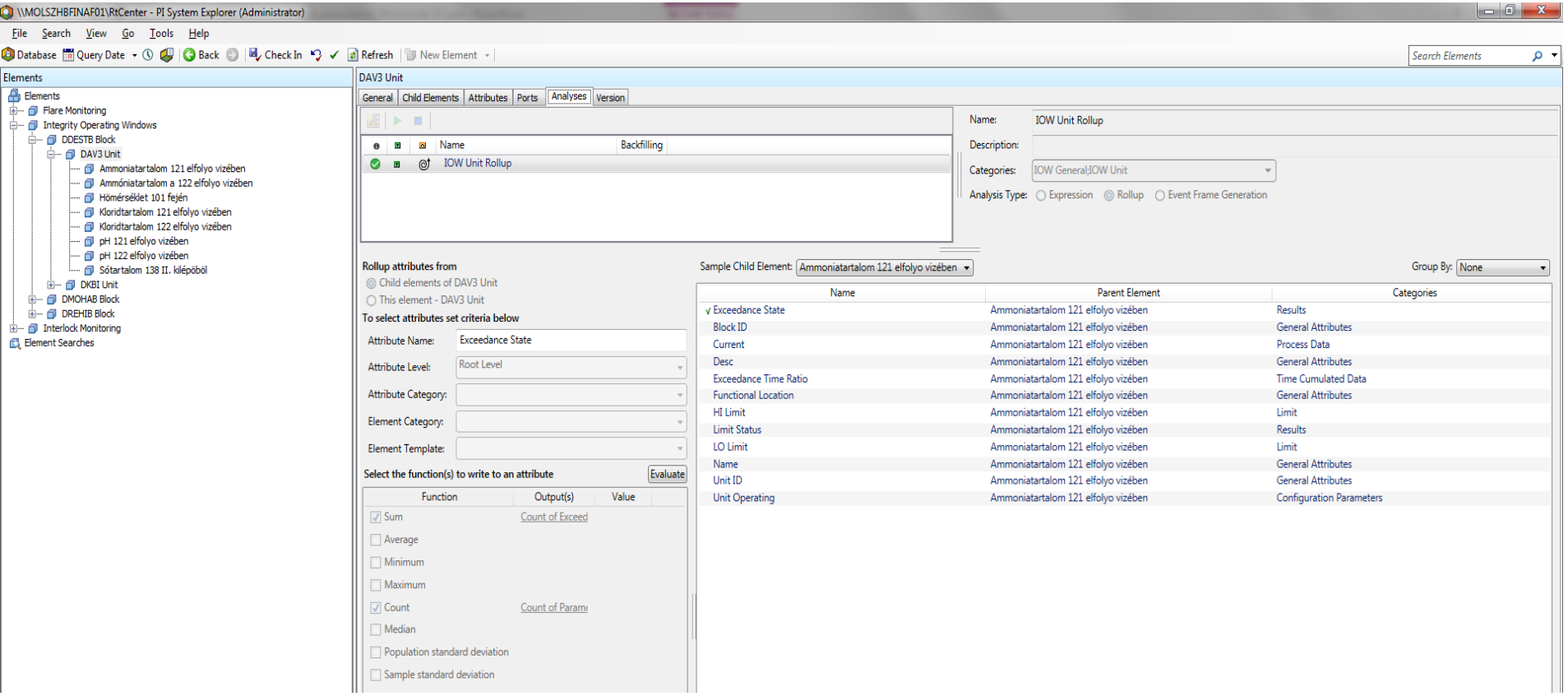
Requires attention within specified timeframe	Requires drastic and/or immediate action
Standard	**Critical**
Heater Tube Skin Temperature	Boiler Feed Water Level
Crude Fractionator Dew Point Temperature	Hydro-process Reactor Temperature
pH of Crude Tower Overhead	Heater Tube Skin Temperature
Desalter Outlet Salt Content	Sulfuric Acid Strength in Alkylation

Proactive & Predictive Rather than Reactive Maintenance Leading to Improved Asset Integrity & Utilization

OSIsoft.

COMPETENCY DEVELOPMENT	INSPECTION PROGRAM	CORROSION DATABASE	MONITORING PROGRAM	MITIGATION PROGRAM
• Expert knowledge base • Workshops • Failure reports • Laboratory background • R&I	• Advanced inspection techniques implementation • Turnaround inspection plans preparation	• Corrosion map • Develop IOWs Integrity Operating Window supported by PI client tools PI AF SDK Notifications	• Comprehensive monitoring system development • Operate monitoring system • Expert analysis PI Coresight	• Surface protection • Protection by chemicals • Cathodic protection • Material changes

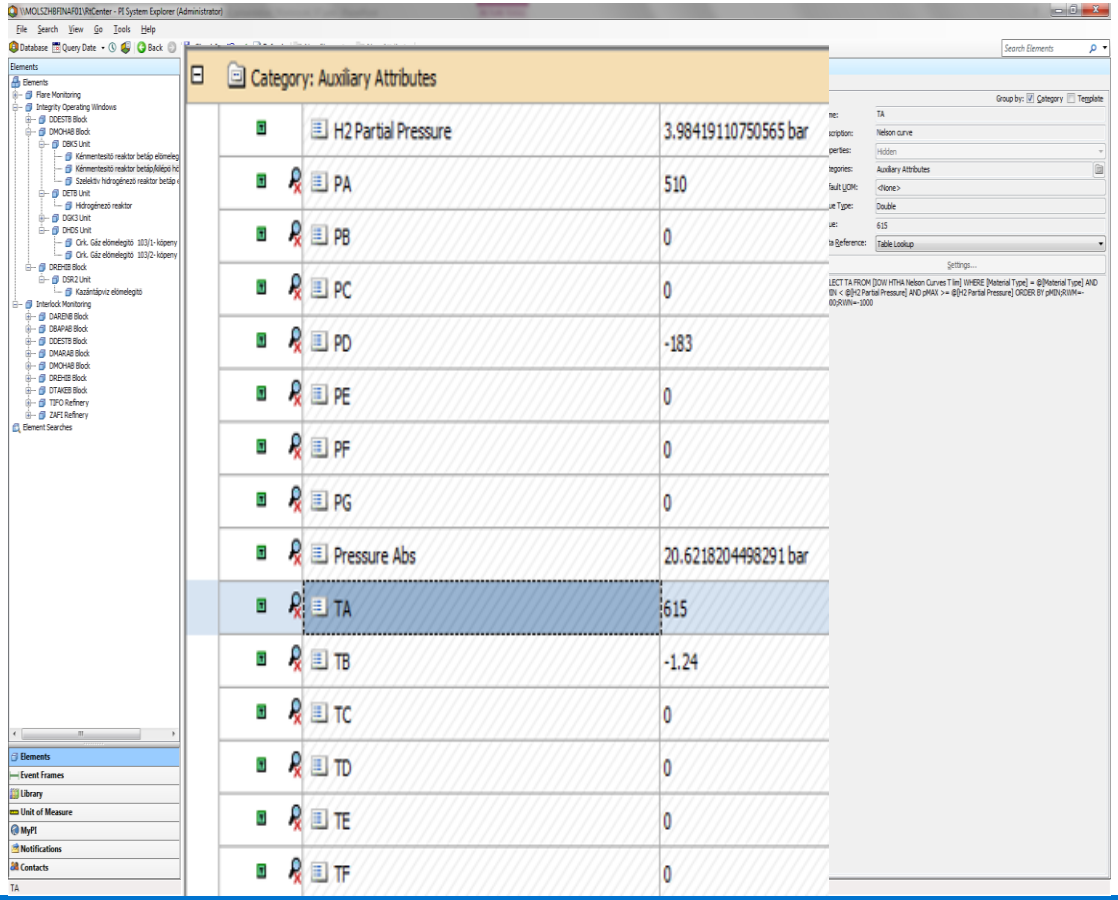
Danube Refinery Crude Distillation Unit IOW – AF Analytics



Danube Refinery Crude Distillation Unit – IOW Visualization Augmentation of Opralog

Corrosion & Integrity Predicting High Temperature Hydrogen Attack(HTHA)

Improving Asset Integrity with Advanced Corrosion Analytics

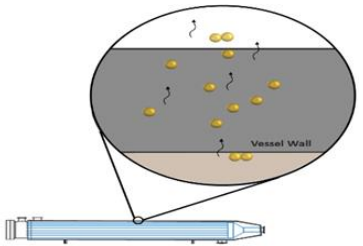


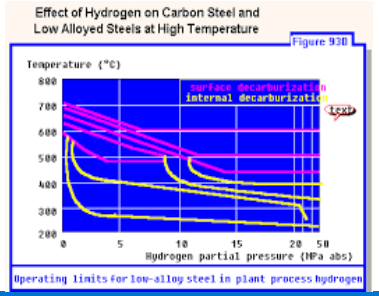
- High Temperature Hydrogen Attack (HTHA)
- f^x (metallurgy, temperature, hydrogen partial pressure(PP), length of exposure)

Developed PI AF template that:

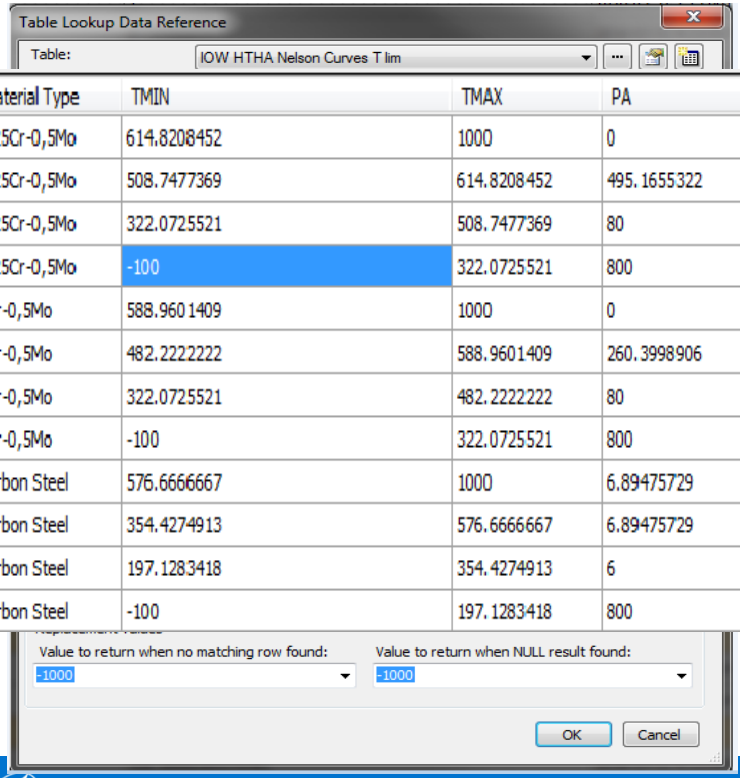
- Determine partial pressure
- Attribute of pipe class
- Temperature and length of exposure limits
- Total time above Temp and PP
- Alerts/notification/event frame

- Tested and rolled out in 6 units < 1 week
- Expanded to all plants in 2015.



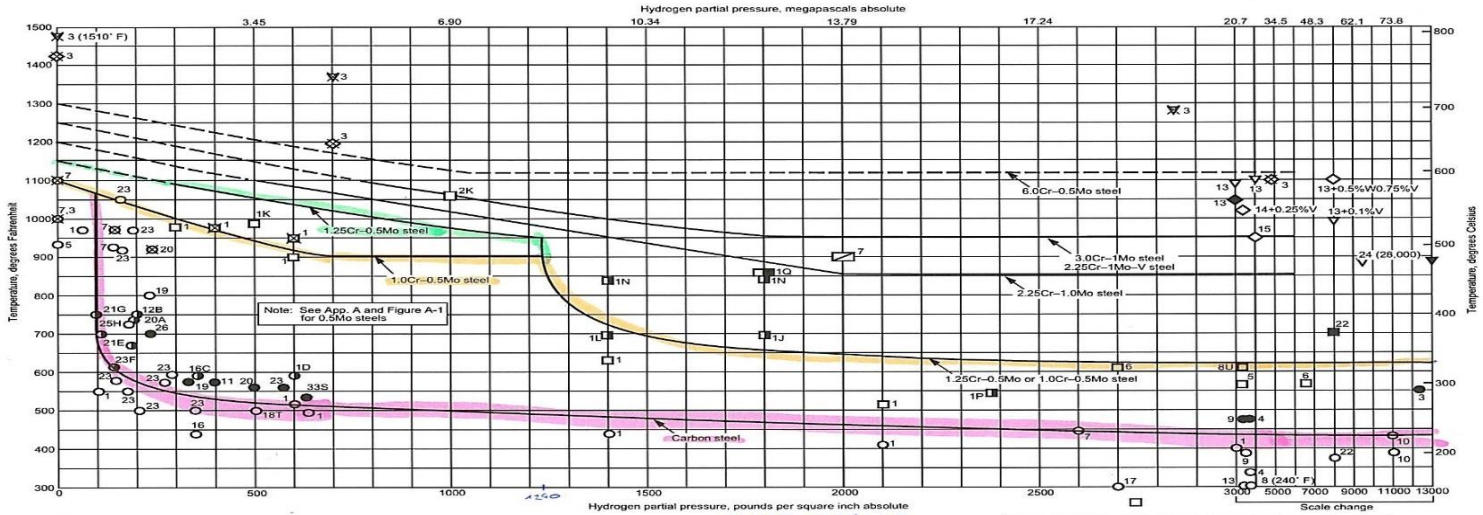


Nelson Temperature Limit LookUp Function and LookUp table



Material Type	TMIN	TMAX	PA	PB	PC	PD	PE	PF	PG
1,25Cr-0,5Mo	614.8208452	1000	0	0	0	0	0	1	0
1,25Cr-0,5Mo	508.7477369	614.8208452	495.1655322	-0.805381822	0	0	0	1	0
1,25Cr-0,5Mo	322.0725521	508.7477369	80	0	0	1	1021.226335	-320.6541822	1
1,25Cr-0,5Mo	-100	322.0725521	800	0	0	0	0	1	0
1Cr-0,5Mo	588.9601409	1000	0	0	0	0	0	1	0
1Cr-0,5Mo	482.2222222	588.9601409	260.3998906	-0.442134998	0	0	0	1	0
1Cr-0,5Mo	322.0725521	482.2222222	80	0	0	0	1021.226335	-320.6541822	0
1Cr-0,5Mo	-100	322.0725521	800	0	0	0	0	1	0
Carbon Steel	576.6666667	1000	6.89475729	0	0	0	0	1	0
Carbon Steel	354.4274913	576.6666667	6.89475729	0	0	0	0	1	0
Carbon Steel	197.1283418	354.4274913	6	0	-0.043155263	15.18420899	0	0	1
Carbon Steel	-100	197.1283418	800	0	0	0	0	1	0

Use of Excel Solver to Determine Equation from a Data Set



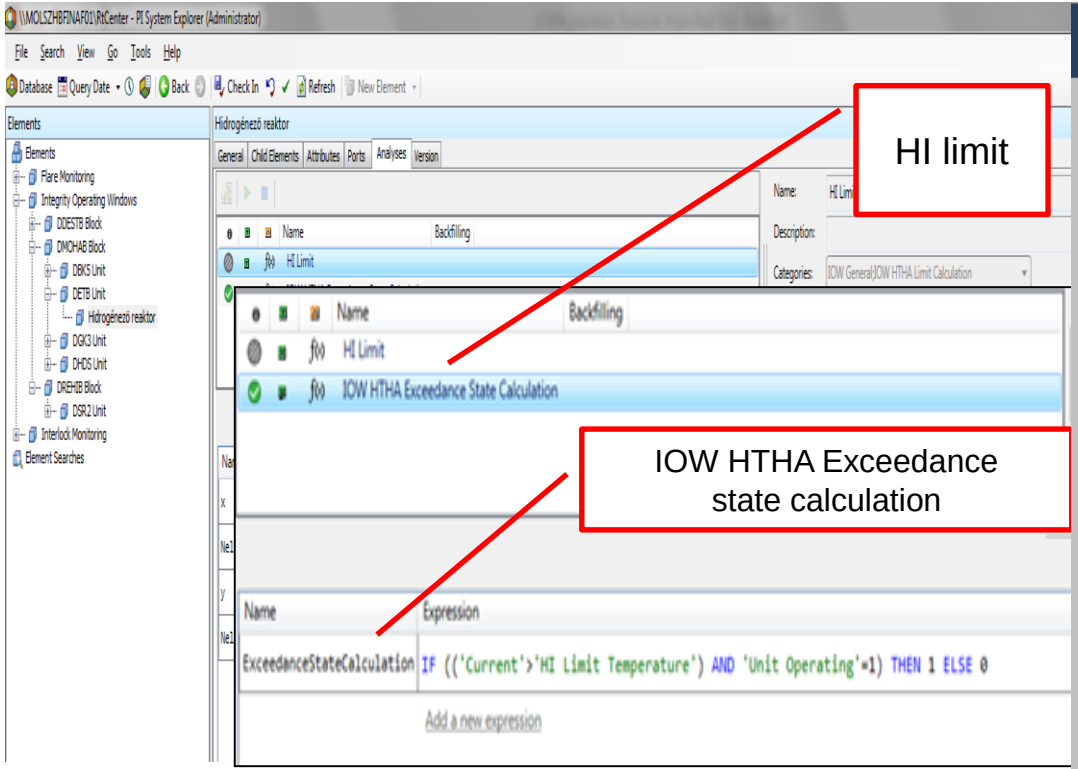
Notes:
1. The limits described by these curves are based on service experience originally collected by G.A. Nelson and on additional information gathered by or made available to API.
2. Austenitic stainless steels are generally not decarburized in hydrogen at any temperature or hydrogen pressure.
3. The limits described by these curves are based on experience with cast steel as well as annealed and normalized steels at stress levels defined by Section VIII, Division 1, of the ASME code. See 5.3 and 5.4 in text for additional information.
4. Several failures of 1-1/4Cr–1Mo steel have been reported in the satisfactory region. See Appendix B for details.
5. The inclusion of the 2.25Cr–1Mo-V class of steels is based on 10,000+hr laboratory tests where these alloys were at least equal to the 3Cr–1Mo steel. See Reference 22 listed in Section 2.2.

API 941 Fifth Edition
January 1997

Legend:	Carbon steel	1.0Cr 0.5Mo	2.25Cr 1.00Mo	3.0Cr 1.0Mo	8.0Cr 0.5Mo
Surface decarburization					
Internal decarburization					
Satisfactory	○	□	▭	◇	▽
Internal decarburization and fissuring	●	■	▬	◆	▼
Surface decarburization	⊠	⊠	▨	◈	▼
See comments	◑	◨	▬	◆	▼

Figure 1—Operating Limits for Steels in Hydrogen Service to Avoid Decarburization and Fissuring

Illustrative PI AF IOW Predictive Analytics Configuration



IOW HTHA

PI Coresight

IOW - HTHA

Area	IOW parameter / PI tag	Act	<	HI Limit	S
DBK5 IOW	Kénmentesítő reaktor betáp előmelegítő cseppfogó - Hőmérséklet DBK5RTI2017.DACA.PV	229,2	<	270	
DBK5 IOW	Kénmentesítő reaktor betáp előmelegítő cseppfogó - Nyomás DBK5RPI2038.AIA.OUT.VALUE	19,342	<	23	
DBK5 IOW	Kénmentesítő reaktor betáp/kilépő hőcserélő - Hőmérséklet DBK5RTI2015.DACA.PV	156,8	<	270	
DBK5 IOW	Kénmentesítő reaktor betáp/kilépő hőcserélő - Nyomás DBK5RPI2037.AIA.OUT.VALUE	19,6589	<	23	
DBK5 IOW	Szelektív hidrogénező reaktor betáp előmelegítő - Hőmérséklet DBK5RTI1031.DACA.PV	149,9	<	199	
DETBE IOW	Hidrogénező reaktor- Hőmérséklet DMTBTTH054.PV	89,8393	<	200	
DGK3 IOW	Cirkulációs gáz/Friss H2 dús gáz hőcserélő- cső - Hőmérséklet DGK3KT1592.PVA	142,542	<	210	
DGK3 IOW	Cirkulációs gáz/Friss H2 dús gáz hőcserélő- köpeny - Hőmérséklet DGK3KT1553.PVA	178,208	<	230	
DGK3 IOW	Cirkulációs gáz/könnyű alapanyag hőcserélő - Hőmérséklet DGK3KT1555.PVA	136,64	<	200	
DHDS IOW	Cirk. Gáz előmelegítő 103/1- köpeny- Hőmérséklet DHDSHT1179.PV	223,311	<	240	
DHDS IOW	Cirk. Gáz előmelegítő 103/2- köpeny- Hőmérséklet DHDSHT1290.PV	231,833	<	240	

Natural Gas Purchase Optimization

Business Challenge – Exceeding NG Daily Consumption Peak

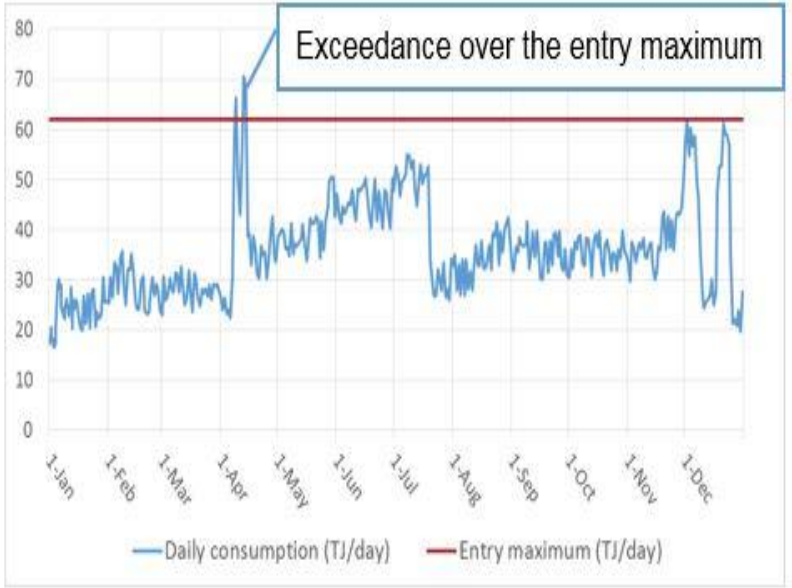
New MOL Hungary Enterprise contract

- Entry Maximum decrease → potential saving
- Entry Maximum fixed for two years
- High penalty on any exceedances
- Fluctuation in consumption

Objective

- Decrease the entry maximum
- Eliminate the chance of exceedance

- Eliminate the peaks of consumption



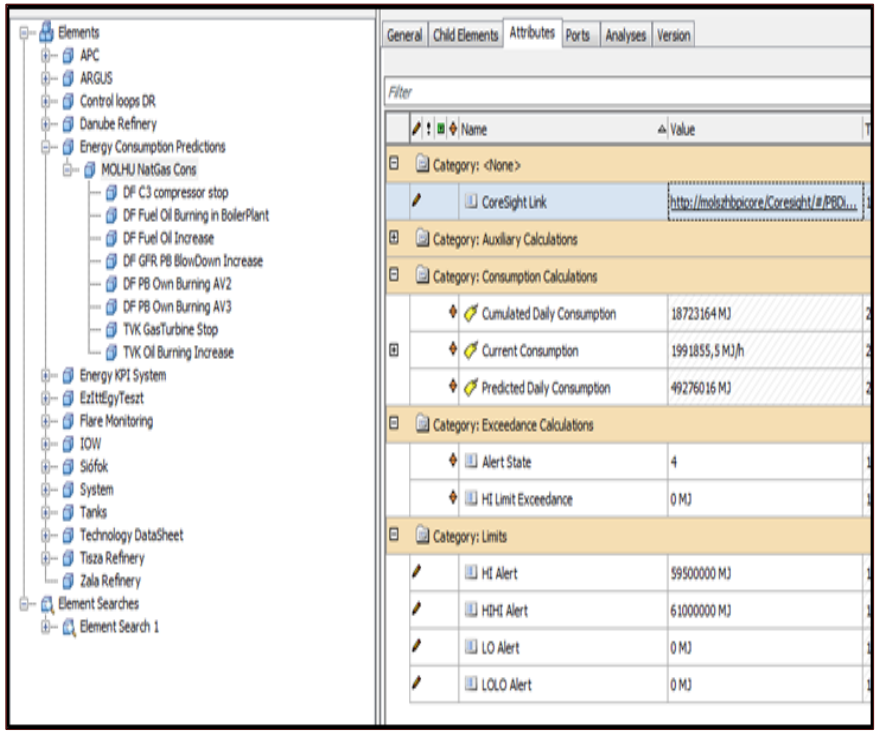
PI AF Predictive Analytics – Forecasting NG Supply/Demand

Daily & hourly forecasting system

- Continuous calculation
- Based on consumption data
- **PI Asset Analytics**

New tool to improve cooperation

- Different sites accross the country
- Alerting system
- Up-to-date, valid information
- PI Coresight



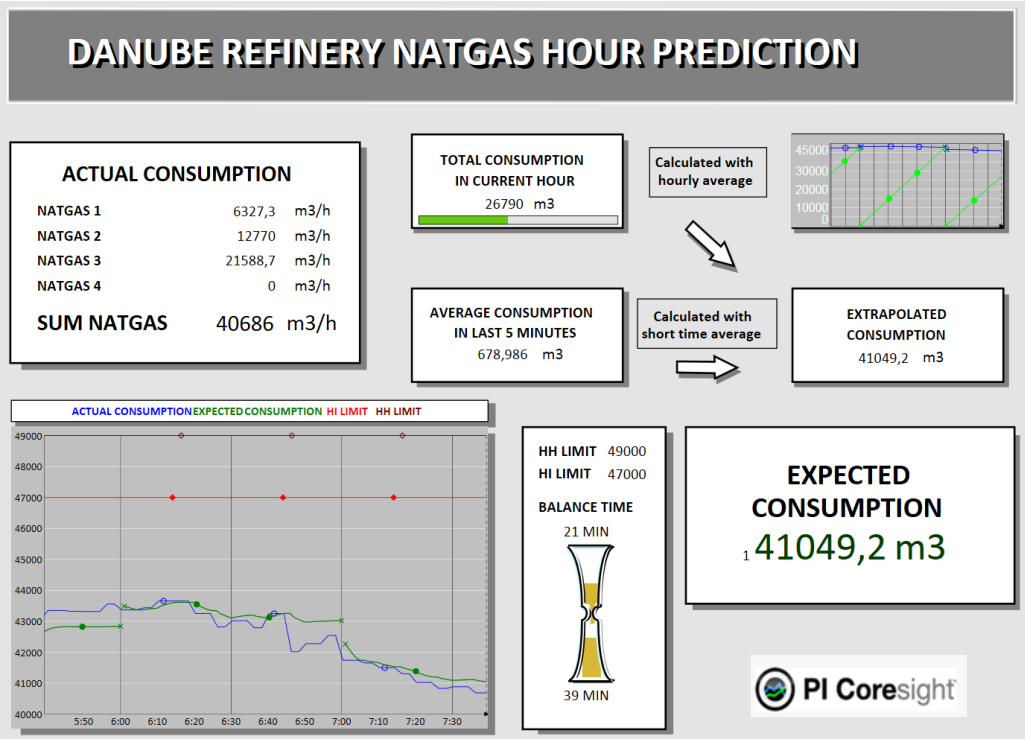
Building on Success – Daily to Hourly Natural Gas Prediction

The planned system

- Online calculation (extrapolation in every hour)
- Input:
  - online sensor data
  - static data and
  - periodically filled manual data

Tools

- PI Asset Analytics
- AF Tables and Lookup calculations avoidance of unnecessary alerts via smoothing of forecasts within the hour



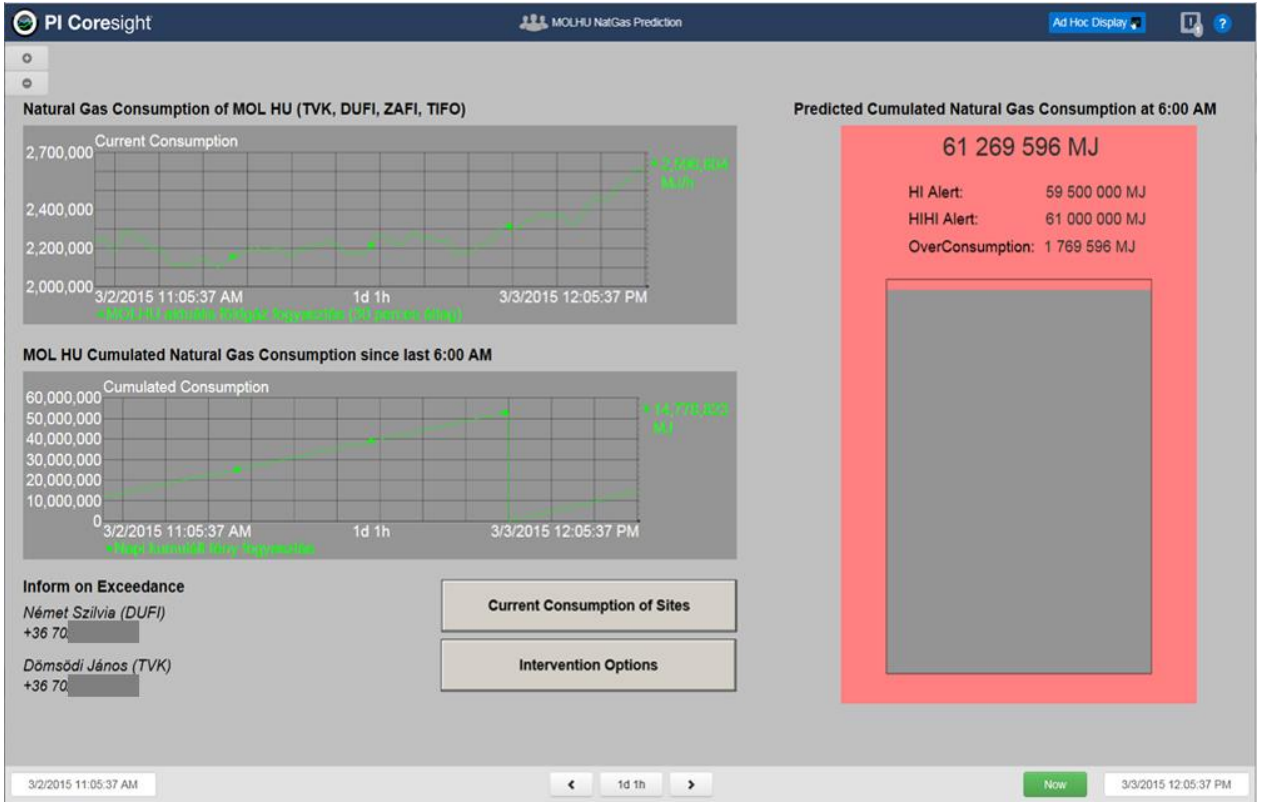
Results - The Working System

Alerting

- Conversation started immediaely after the alert
- Decision has made in around 30 minutes
- Employees were informed

Business Impact

- 2 TJ/day Entry Maximum decrease
- $230k/yr savings



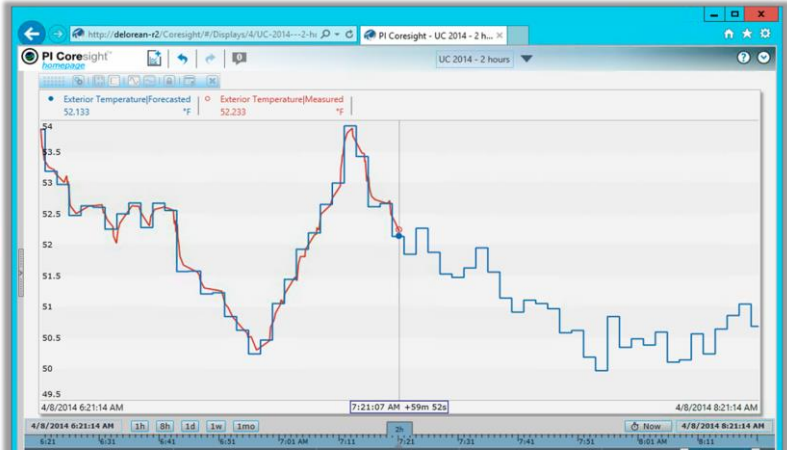
Continuing the PI AF Journey

Calculation Accuracy

- The accuracy of the forecasting calculation can be increased (Tuning)
- Involve daily scheduling data or unit operation mode
- **Use of Future Data and PvA Analytics**

Extending to Other Energy Types

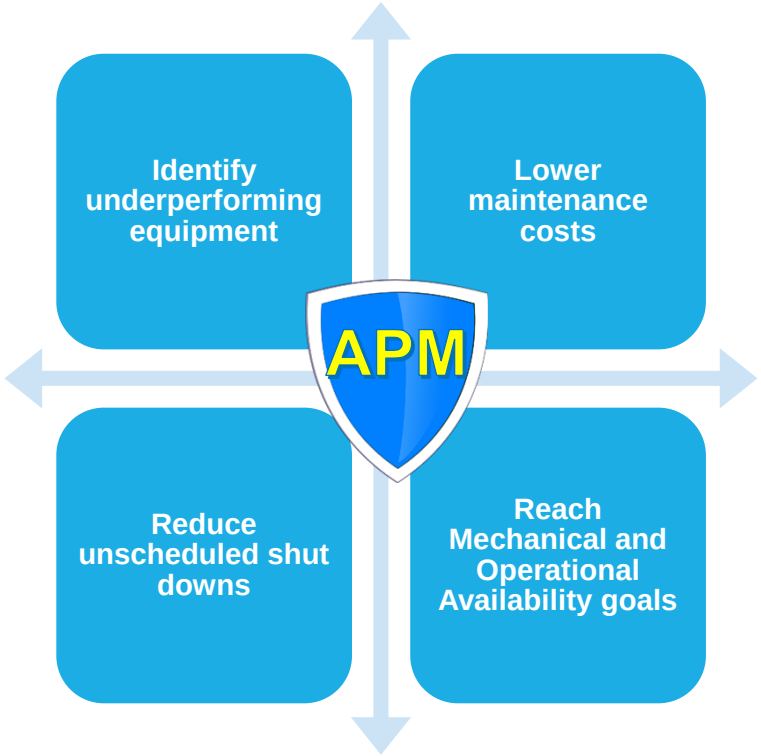
- Increase the planning accuracy in case of other energy types
- Installation is very simple and fast



Proactive/Predictive Asset Analytics

Advanced Predictive Maintenance

- No Unplanned Downtime
- Advanced maintenance strategies leveraging PI AF, EF, and SAP PM Integration
- A new project plan was initiated in 2015 to establish a condition-based maintenance system via a new Integrator for Business Analytics applied to SAP PM



PI System & SAP PM Condition Based Maintenance (CBM)

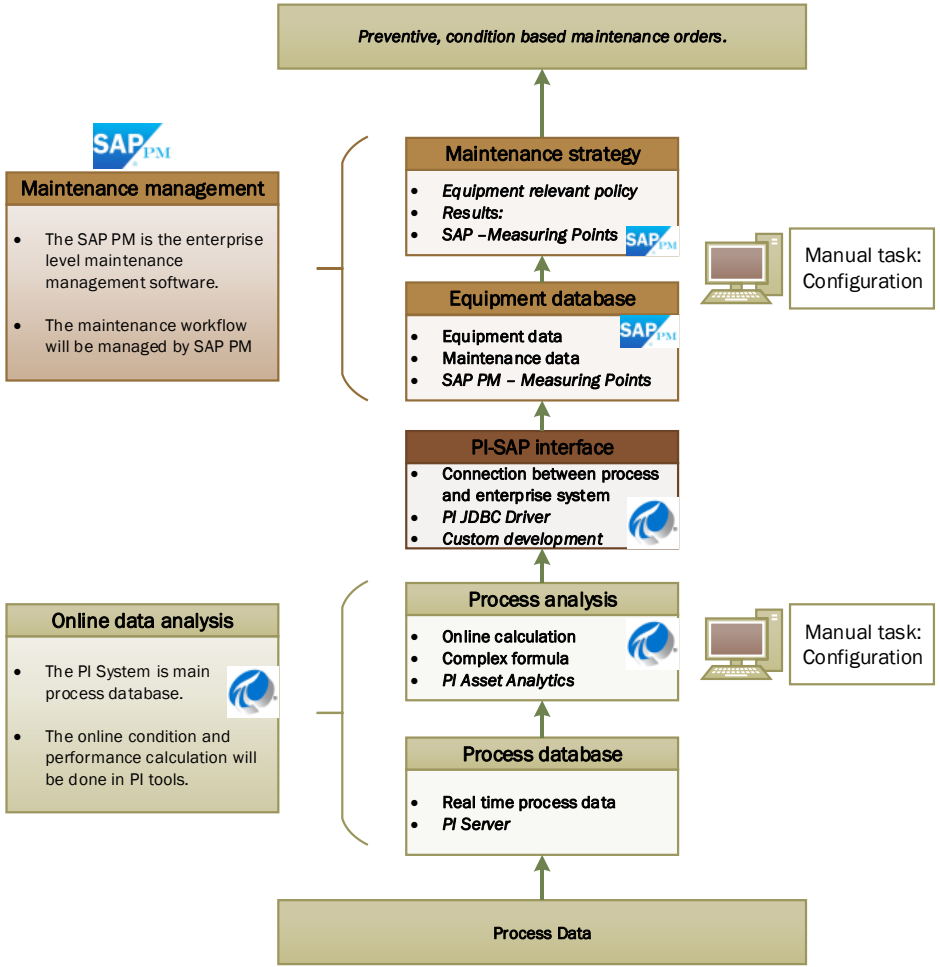
PI System - SAP PM Integration	Performance Based Maintenance Strategy	Training & Support
• SAP development • PI System access via the Integrator for Business Analytics	• PSA- Pressure swing absorbers • Chillers • Heat exchangers	• Knowledge sharing • Exploration of further possibilities • Continuous improvement

Performance or condition based strategy would fit more assets in the refinery than the time based. These calculations require process and operational data available in the PI Server.

The process data aggregation & **HealthScore calculation done in PI AF & sent to SAP PM.** Based on this result the Asset Maintenance Strategy is initiated by SAP PM.

Business Benefits

- Increased operational availability due to the installed strategies.
  (PSA - Pressure Swing Absorbers in DHPP1-2, chillers in DSDW, heat exchangers where applicable)
- A working IT solution for further condition or performance based static asset policy implementation.
- KnowHow development about advanced condition based calculations.

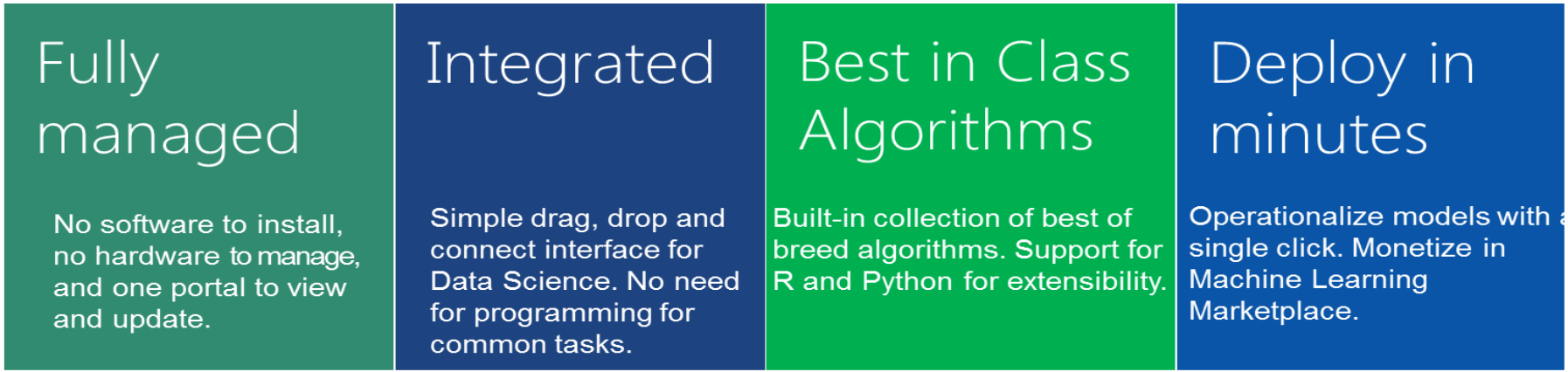


Microsoft Azure Machine Learning

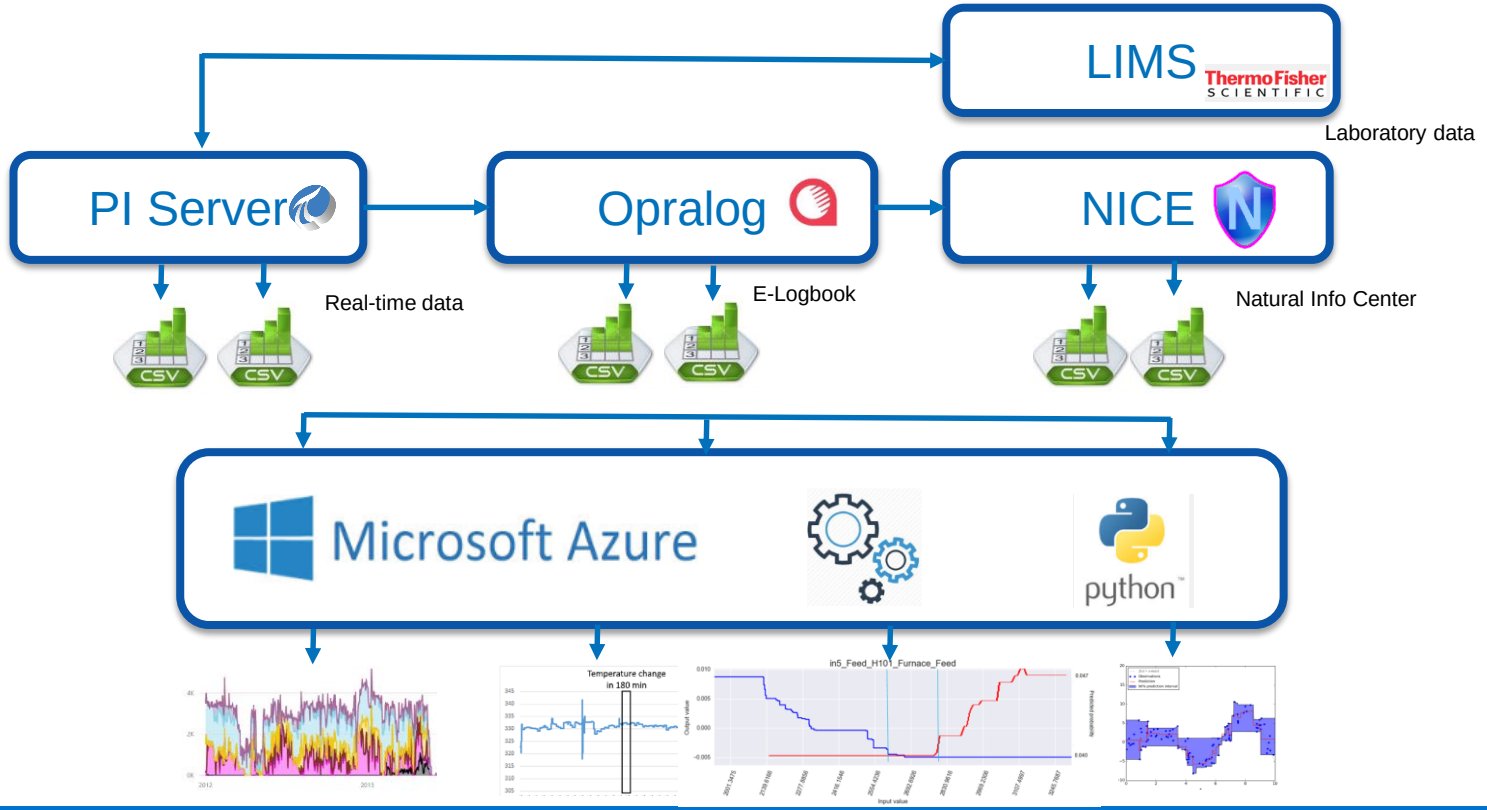
Goals and Scope

Proof of Concept project to utilize advanced analytics and machine learning in order to achieve similar results to APC in the following areas:

- Model for estimation and control of the sulfur content in diesel (Gas oil Hydrotreating unit
- Optimization of the coke yields in the Delayed Coking Unit

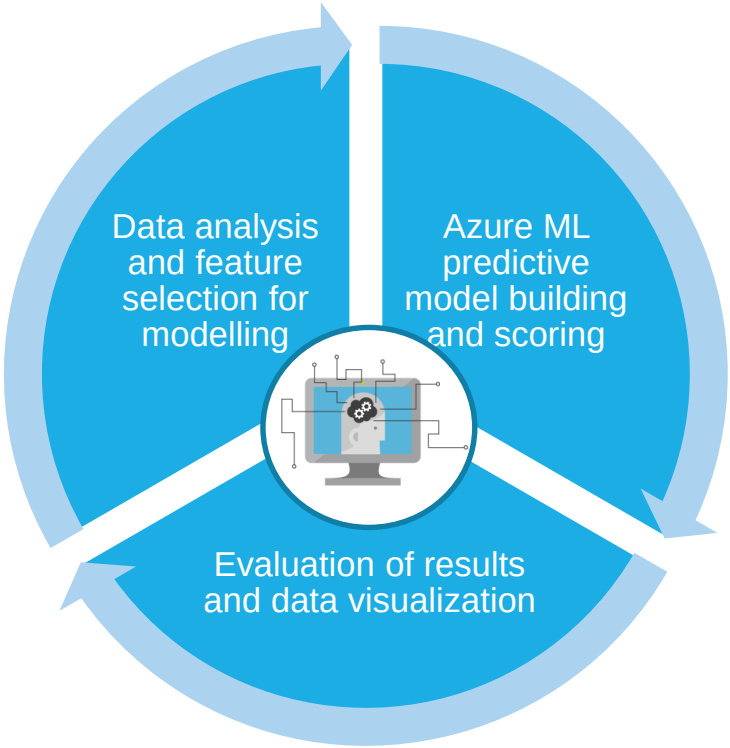


Machine Learning Architecture



Machine Learning- Use Cases

- Find the optimal mixture of different feeds into the Delayed Coking Unit (Residue Hydrocracking Unit & FCCU)
- Achieve minimal level of coke yield
- Gas Oil Hydrotreating Unit unit product sulfur content estimation based on available data
- Azure ML technology adaptation compare laboratory, online analyzer, APC and ML data



Predicting Diesel Sulfur as a in a Gas Oil Hydrotreating Unit

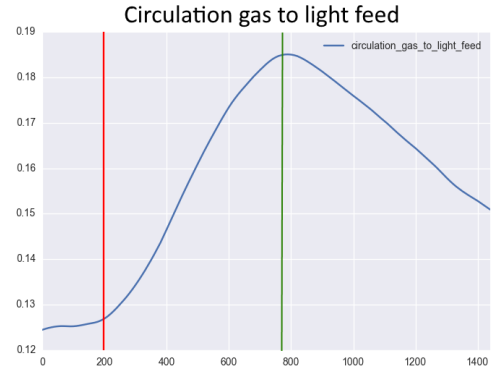
Project Scope – Rough Method to Optimize Sulfur in Diesel

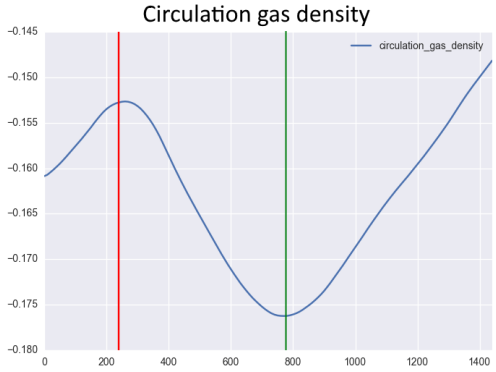
I. Analysis of data to determine the control variables which has the highest effect on sulfur content in PI AF to Machine Learning and then back to PI AF

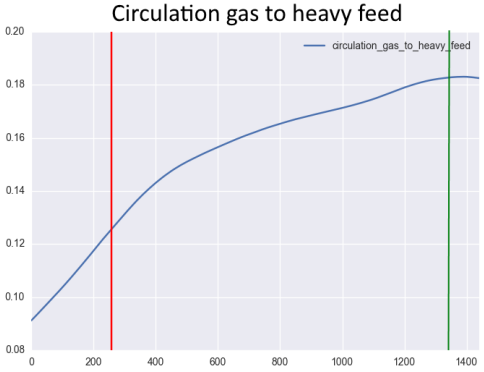
II. Determine the desired intervals for each variable to control the output sulfur content

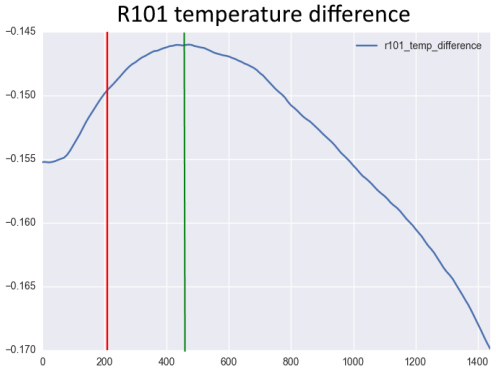
III. Advanced model to (time window based) to predict the changes of the sulfur based on the changes in the control variables

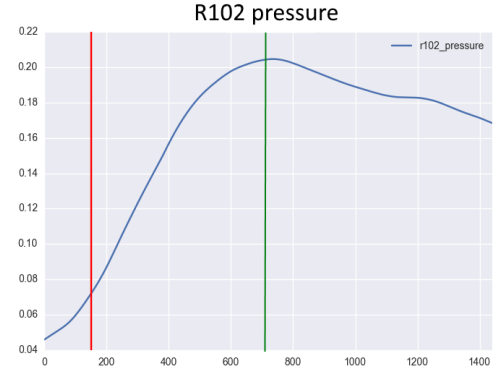
Time Shifted Correlation with Sulfur Content

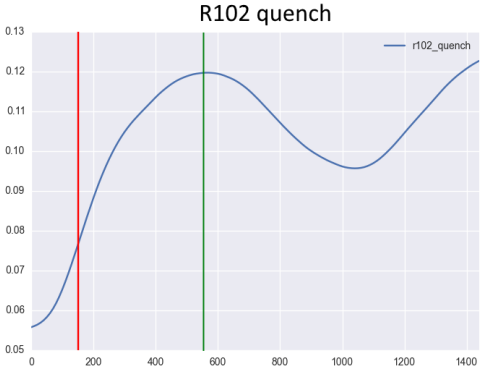




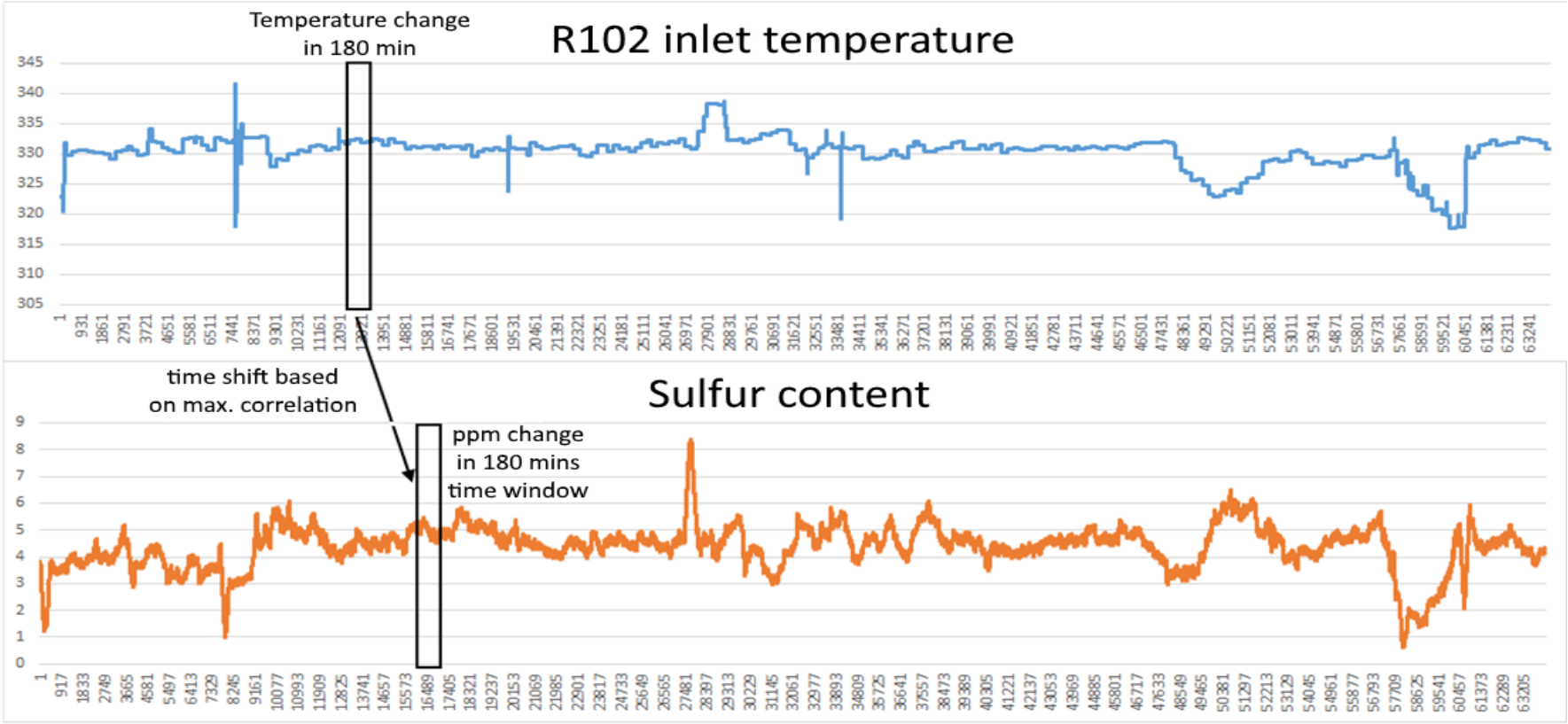




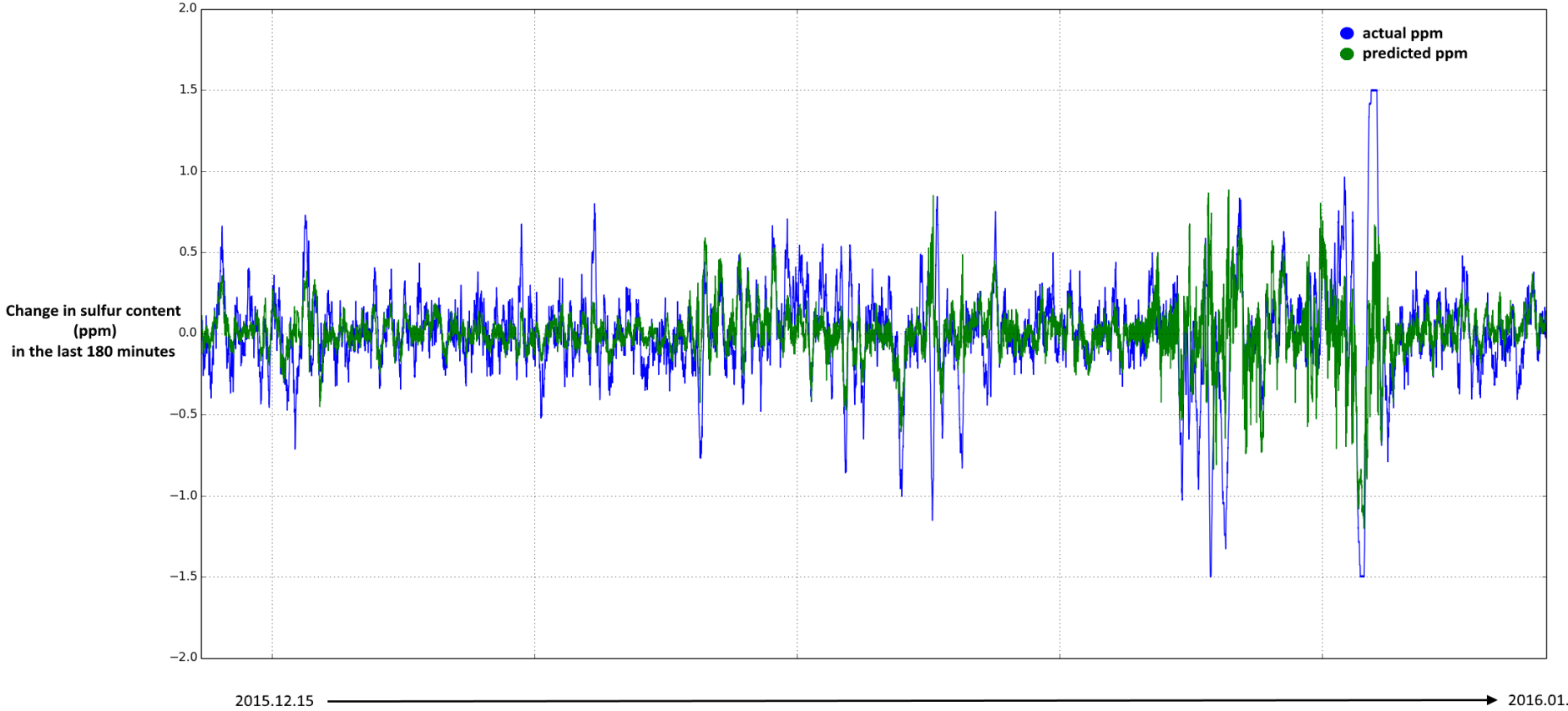




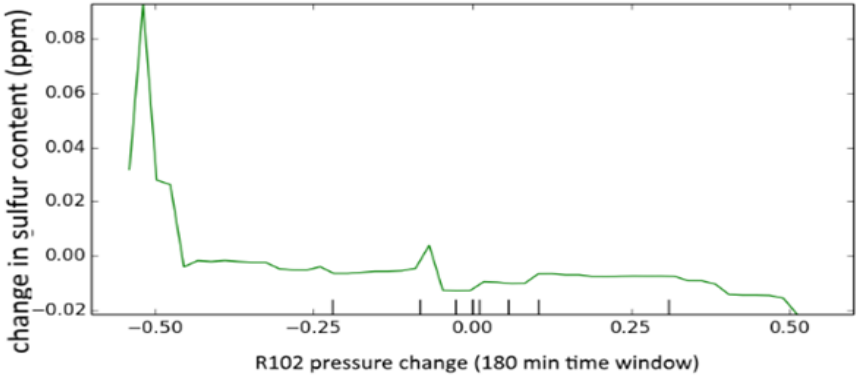
Predicting Output Based on Changes During a Time Period

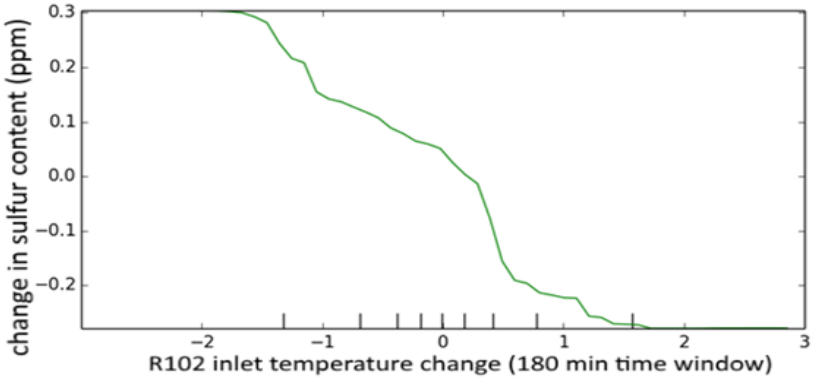


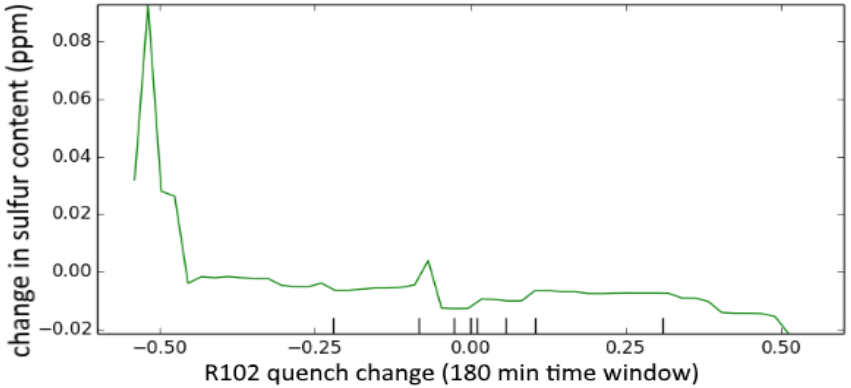
Prediction and Control Model

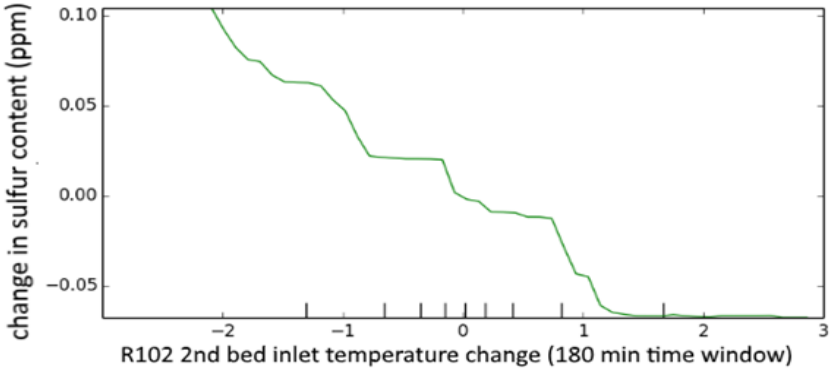


Influence of Sulfur Content



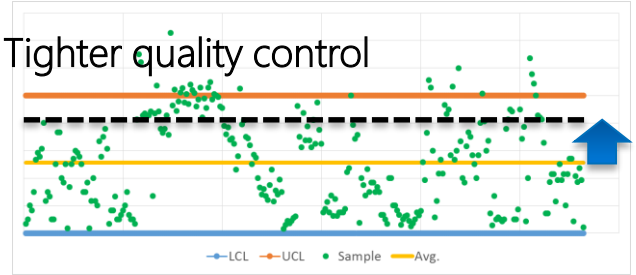






Benefits from Production Support

- Gas Oil Hydrotreater Unit #1 product sulfur content
- Tighter quality control



Quality giveaway decrease	3	ppm
Operation time (in feasible operation mode)	20	%
Fuel gas decrease	4495	GJ/Year
Benefits from decreased fuel gas consumption	47. 000	$/Year

- Effect of other empirical inferential

Maintenance of existing empirical inferential calculations (DGHT3 Sulfur content, Cloud point, Pensky Martens FP, Gasoline EBP)	28. 000	$/Year
New empirical inferential calculations (E.g. NHT, Amine systems….)	70.000	$/Year

- Sum of possible benefit ~ $140K/Year

Predicting and Optimizing Coke Yield in a DCU

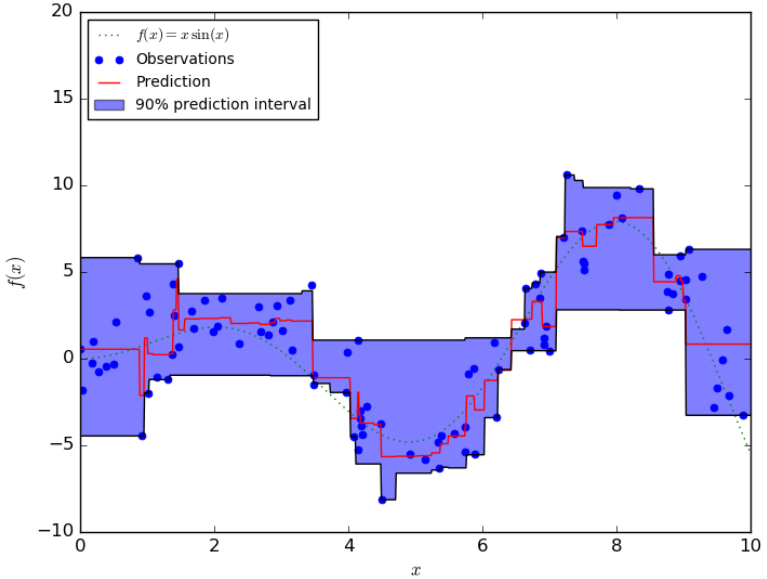
Azure Data Analysis Sample / Residue Hydrocracking Unit Flow to the Delayed Coking Unit

- We took coking cycles as the main aggregation unit (in PI AF)
- Aggregated the input hourly data to the cycles from **high fidelity operating data**
- Matched the daily coking cycle data in Machine Learning to coking cycles from PI Event Frames

Data from 2012-01-01 to 2016-03-01

Coke Yield Model

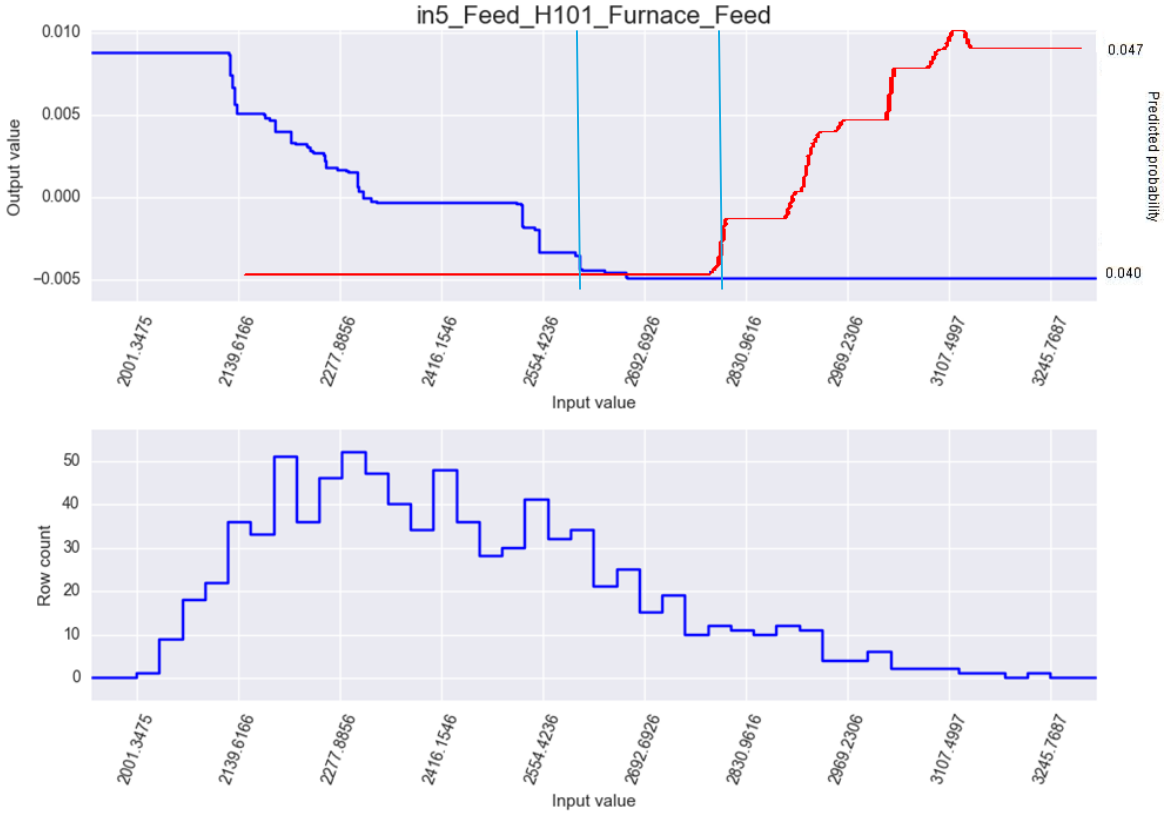
- Predicting the coke yield in percentage
- Discrete model, no time windows and time shifting
- GBR Algorithm (Gradient Boosting Regressor)



Timeline	Baseline (MSE)	Result (MSE)
2012-01-01 - 2014-12-31	0.000513	0.000363
2014-01-01 - 2016-03-03	0.000702	0.000366

MSE: mean squared error

Coke Yield & Decoking Pressure Excursion Event



Blue: coke yield (output value)
Red: coke steam/hot pocket event likelihood

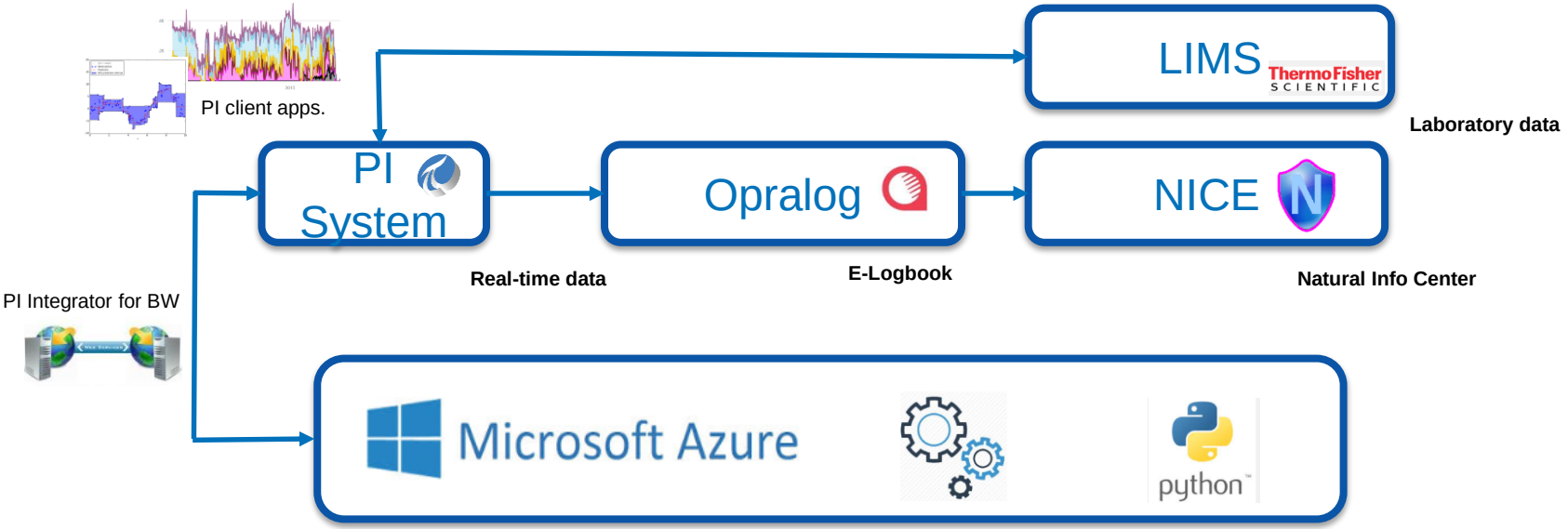
~In case of > 3100 t Furnace feed input the coke steam/hot pocket event likelihood is increasing

Blue histogram:
Row count coke cycle

Between the 2550 - 2800 t intervallic the coke yield could be decreased without coke steam/hot pocket event

Event Frames is the monitoring tool

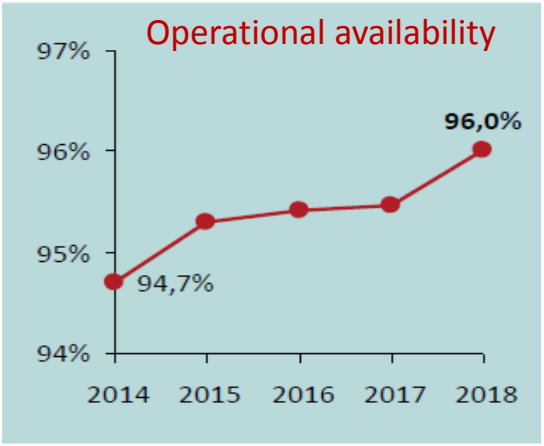
Machine Learning architecture – Future Plans



MOL IT Security approval required

Conclusion

PI AF is a Powerful Tool to Deliver Business Value from Advanced Analytics



COMPANY and GOAL

Deliver an Incremental $500M in EBITDA from the PI System & PI AF Enabled Improvement Programs Leveraging Advanced Analytics & Machine Learning to Support IOW, Forecasting, and Proactive/Preventative Maintenance

CHALLENGE

Aggressive New Downstream and NeXt Downstream Program 2018 Objectives; Limited CapX and OpX:

- Asset Reliability and Integrity
- ISO50001 Energy Forecasting
- Process Alternative crude processing and optimize results in different yield structure

SOLUTION

Continue to Leverage PI AF to perform Operating Windows, Forecasting, and Machine Learning with MS Azure:

- Standard & Critical Integrity Operating Windows
- Corrosion Advanced analytics
- Hourly NG forecasting
- DGHT3 Diesel Sulfur Prediction
- DCU Coke Make Optimization

RESULTS

Supporting $500M EBITDA New Downstream Program 2018 Goals - Examples:

- *1-2.0% reduction in PSA Pressure Swing Absorbers breakdown in Hydrogen production plant: $200K/yr*
- *Increased Mechanical and Operational availability to 96.0 worth >$100M/yr*

Contact Information

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MOL Plc.

Questions

Please wait for the **microphone** before asking your questions

State your **name & company**

Please remember to…

Complete the Online Survey for this session

http://ddut.ch/osisoft

감사합니다

谢谢

Danke

Gracias

Merci

Thank You

ありがとう

Köszönöm

Спасибо

Obrigado


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