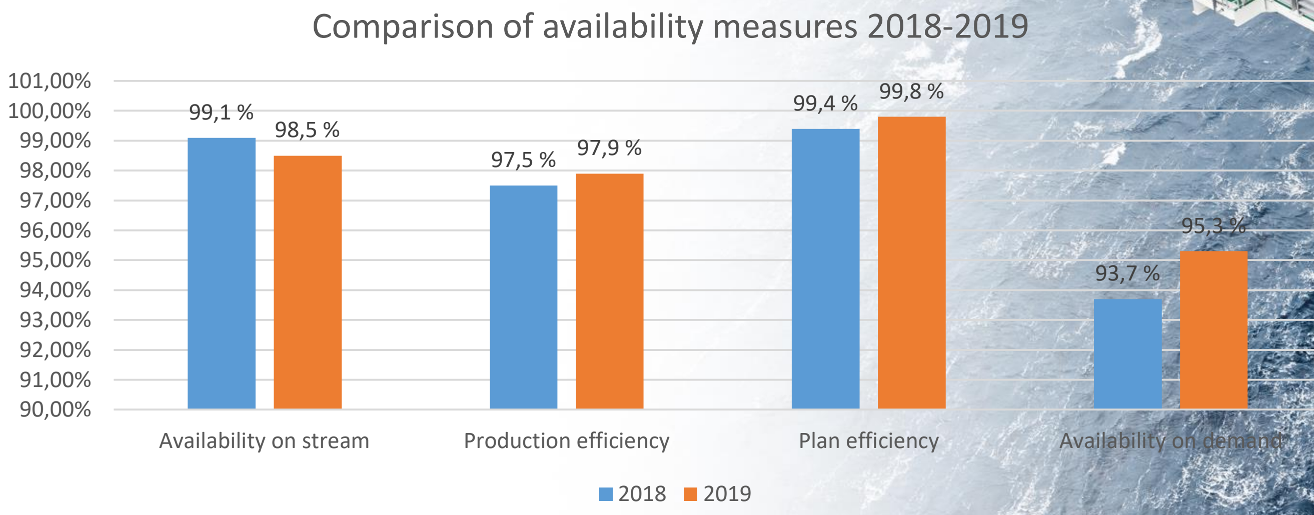
Lundin Energy Norway

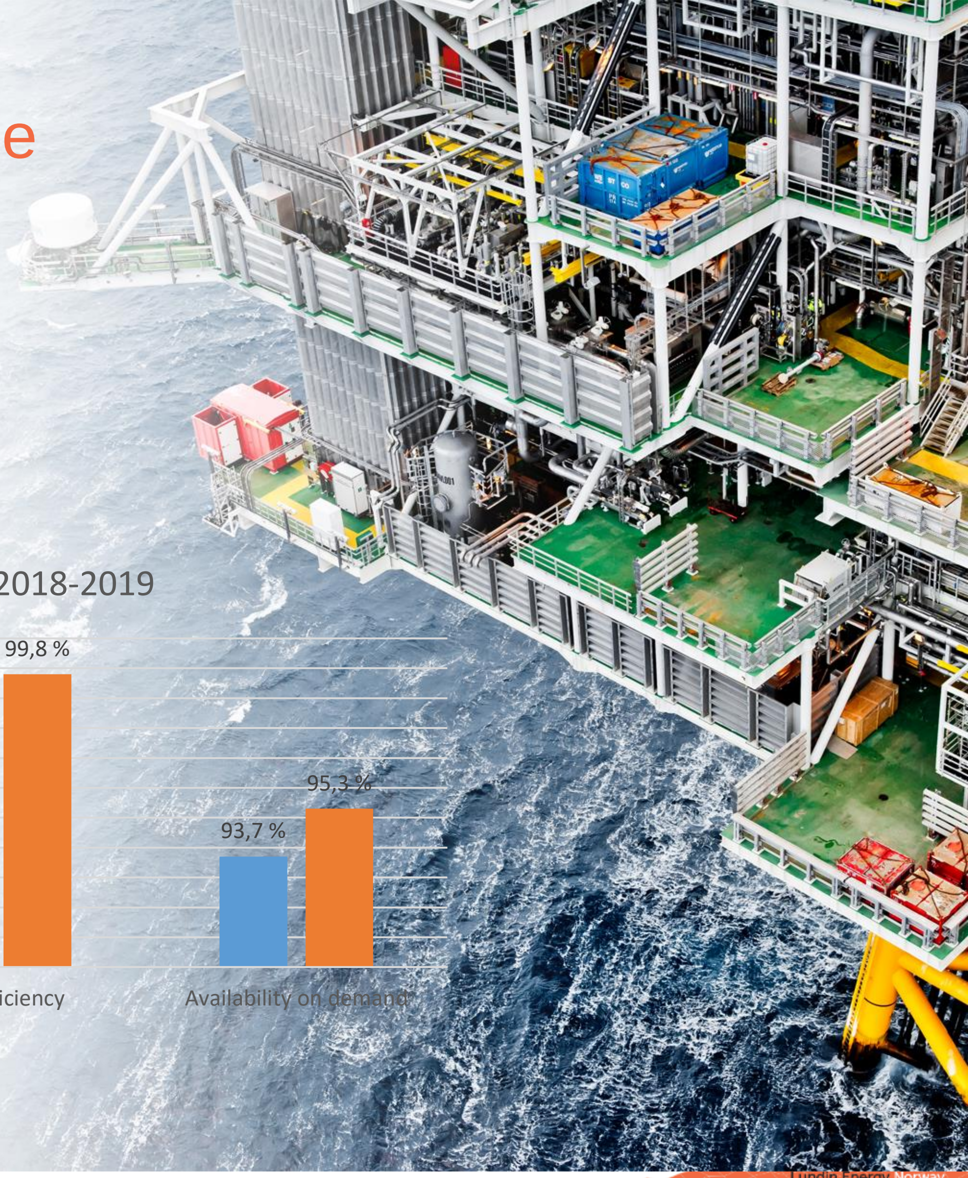
Condition Based Maintenance and Energy Management

Presentation for ESI

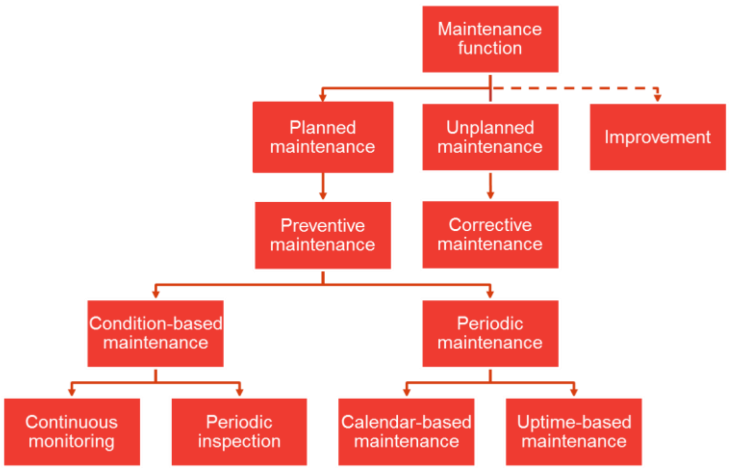
Strong Operating Performance

2020 OPEX 2.8 USD/boe

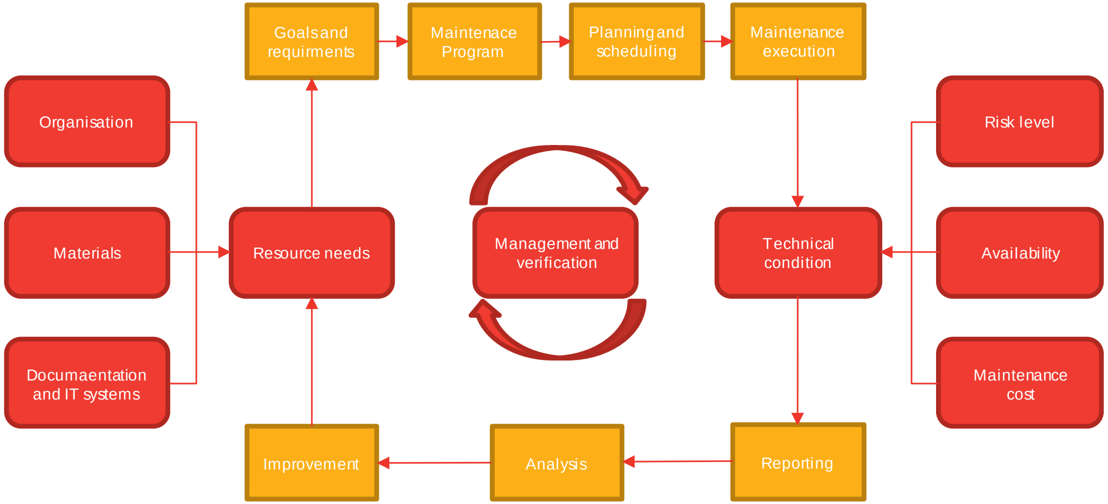




The basics

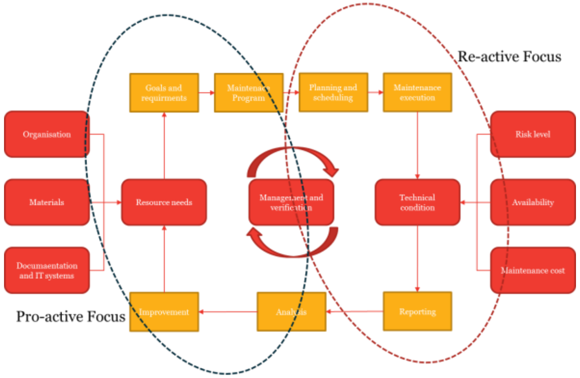


Maintenance function
Planned maintenance
Unplanned maintenance
Improvement
Preventive maintenance
Corrective maintenance
Condition-based maintenance
Periodic maintenance
Continuous monitoring
Periodic inspection
Calendar-based maintenance
Uptime-based maintenance



Goals and requirments
Maintenace Program
Planning and scheduling
Maintenance execution
Organisation
Materials
Documaentation and IT systems
Resource needs
Management and verification
Technical condition
Risk level
Availability
Maintenance cost
Improvement
Analysis
Reporting

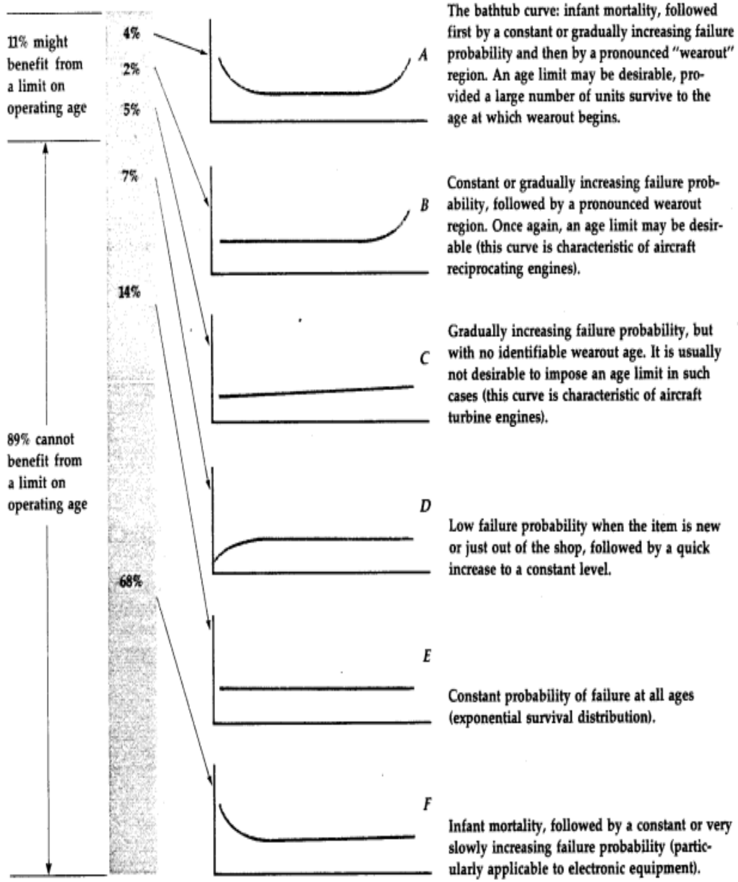
The basics cont.



Why Condition Based Maintenance?

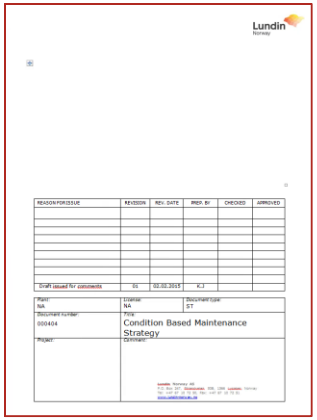
- Only about 15% to 20% of equipment failures are age related
  - The other 80% to 85% being totally time-random events
- Calendar/running hrs based maintenance will typically result in
  - Too frequent maintenance
  - Increased risk of maintenance induced failures
  - Infant mortality issues
  - Safety issues?!
- With only about 15% to 20% of your equipment failures being age related, and the other 80% to 85% being totally time-random events, how can you improve the uptime of your plant and facility?

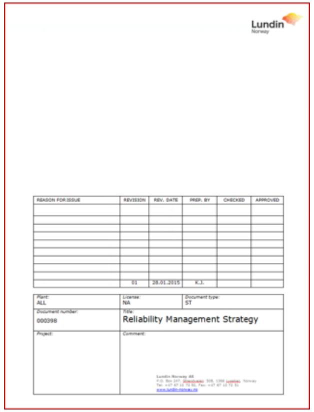
EXHIBIT 2·13 Age-reliability patterns. In each case the vertical axis represents the conditional probability of failure and the horizontal axis represents operating age since manufacture, overhaul, or repair. These six curves are derived from reliability analyses conducted over a number of years, during which all the items analyzed were found to be characterized by one or another of the age-reliability relationships shown. The percentages indicate the percentage of items studied that fell into each of the basic patterns (United Airlines)



Reliability-Centered Maintenance, F.S. Nowlan et al (1978)

What do we want to achieve??

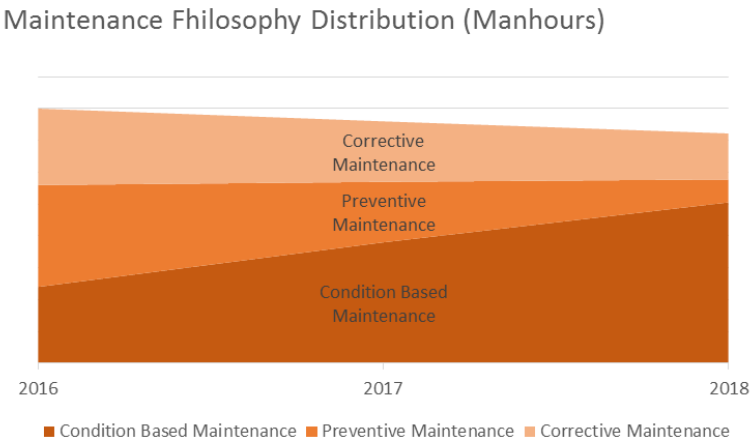




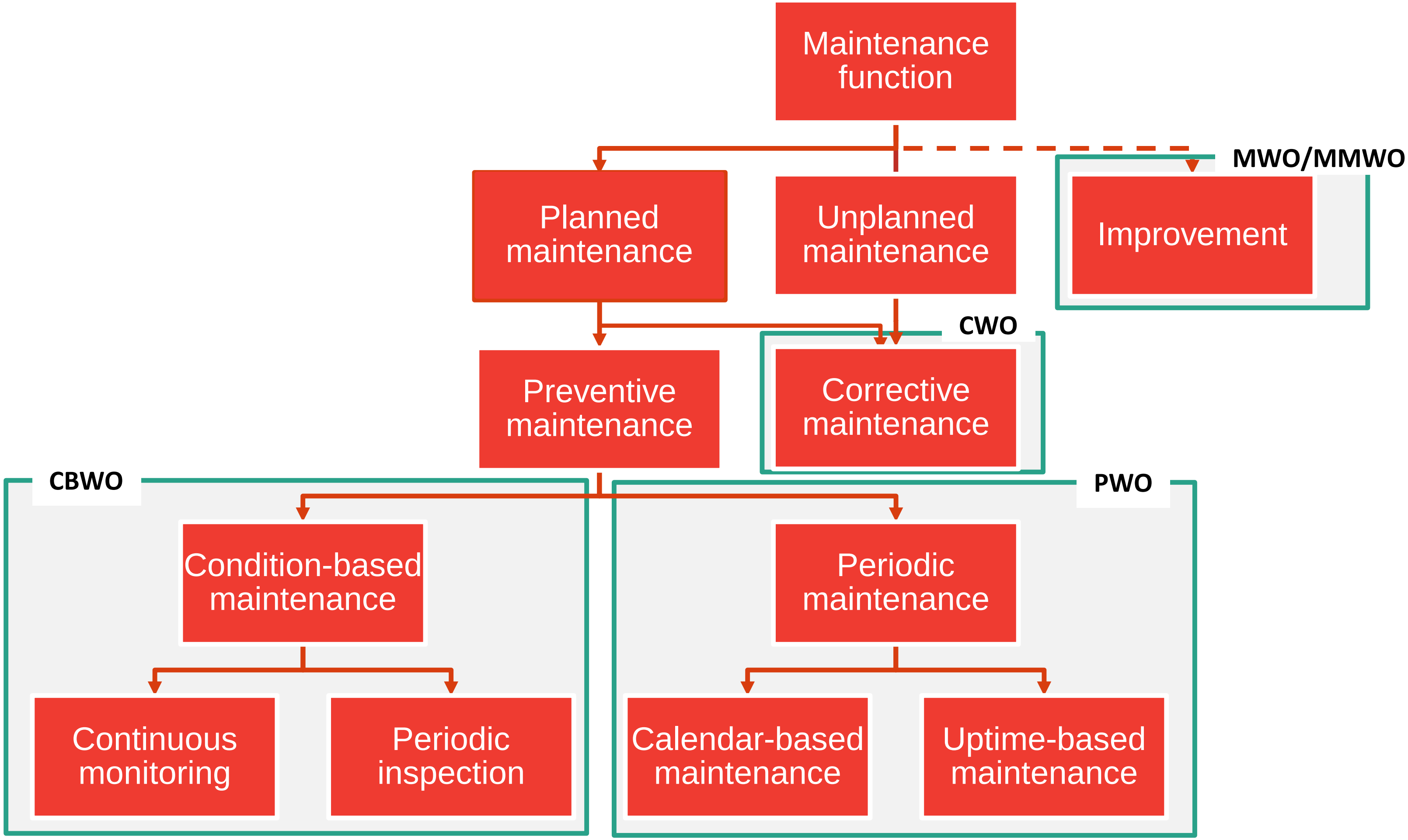
- Reliability vision: LNAS vision is to establish a reliability management process which results in **zero unplanned** equipment failures.

- CBM vision: LNAS vision is to achieve **x% deployment of condition based maintenance** as basis for realizing reliability objectives and cost objectives associated with the maintenance function.

- The objective is to:
  - Fully utilize the benefits of condition monitoring in place as well as to evaluate additional applications
  - Maximize equipment reliability and availability
  - Minimise maintenance interventions and costs



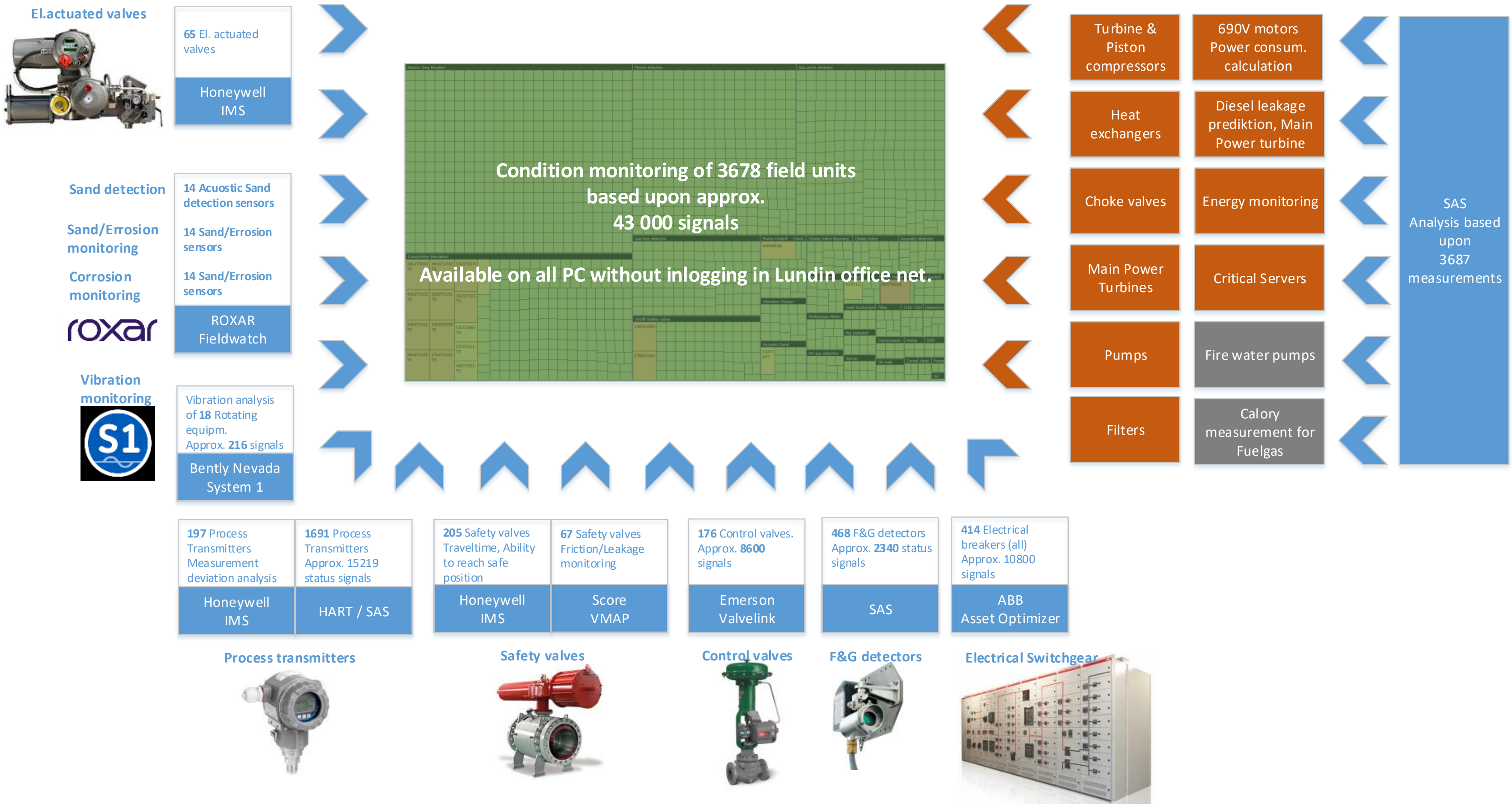
Maintenance categories with todays work order setup



Condition Monitoring on Edvard Grieg

- Gas turbines
- Diesel generators
- Pumps
- Compressors
- Power converters
- Heat exchangers
- Filters
- Valves
- Electric switches

Overview CM system

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Honeywell
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Edvard Grieg
Edvard Grieg Calculations
Edvard Grieg Energy Monito
11KV Consumers
110kV Switchgear
690V Switchboards
Energy Generation
Energy Monitoring Auxiliar
Energy Total
Main Power Gen
Asset Status | Edvard Grieg
GROUP by: Asset Type
SIZE by: Priority
COLOR by: Priority
Cell Labels: Display Name
Displaying: 2066 of 3964
Control Valve
Flame detector
Gas point detector
Transmitter Deviation
Electro Switchgear Breaker
El. Motor
Vibration Sensor
Asset Group
Pump Centrif. -
Generator
Compressor -
Oil and Gas
Acoustic
Choke Valve
OnOff Safety valve
Main Power
Sand Erosion
H2 gas
Transmitter
Server
Multiphase
Pig
Filter
Heat
Air
Pump Centrif. -
Corrosion
Diesel
Anti
UPS
Gas line detector
Area
Acoustic
Pump
Oil mist
DEMO
Search
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Active
Inactive
No Fault Recorded
Deselect All
Fault Condition
Accepted
Closed
New
No Fault Recorded
Rejected
Deselect All
Criticality
Priority
Asset Category
Calculation Assets
Equipment
Logical Group
Deselect All
Asset Class
Compressor
Computer / Data
Condition Monitoring Eq
Electro equipment
F_G Detector
Filter
Heat Exchanger
Power Generation
Deselect All
Asset Type
Seal Fluid Consumption
Server
Transmitter Deviation
Transmitter HART
Transmitter Wireless
Unit
UPS
Vibration Sensor
Deselect All
Filter Label
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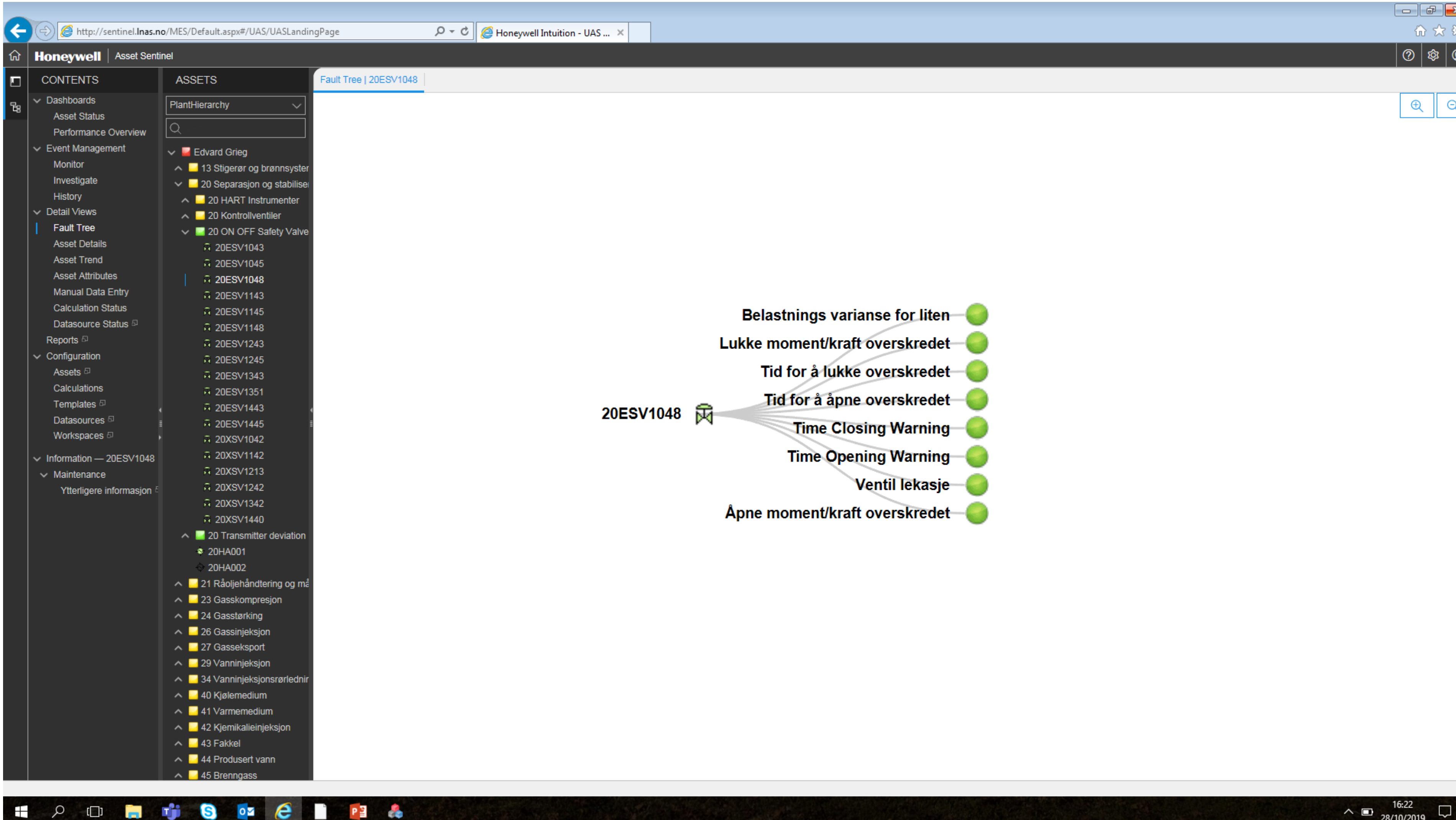
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Maintenance
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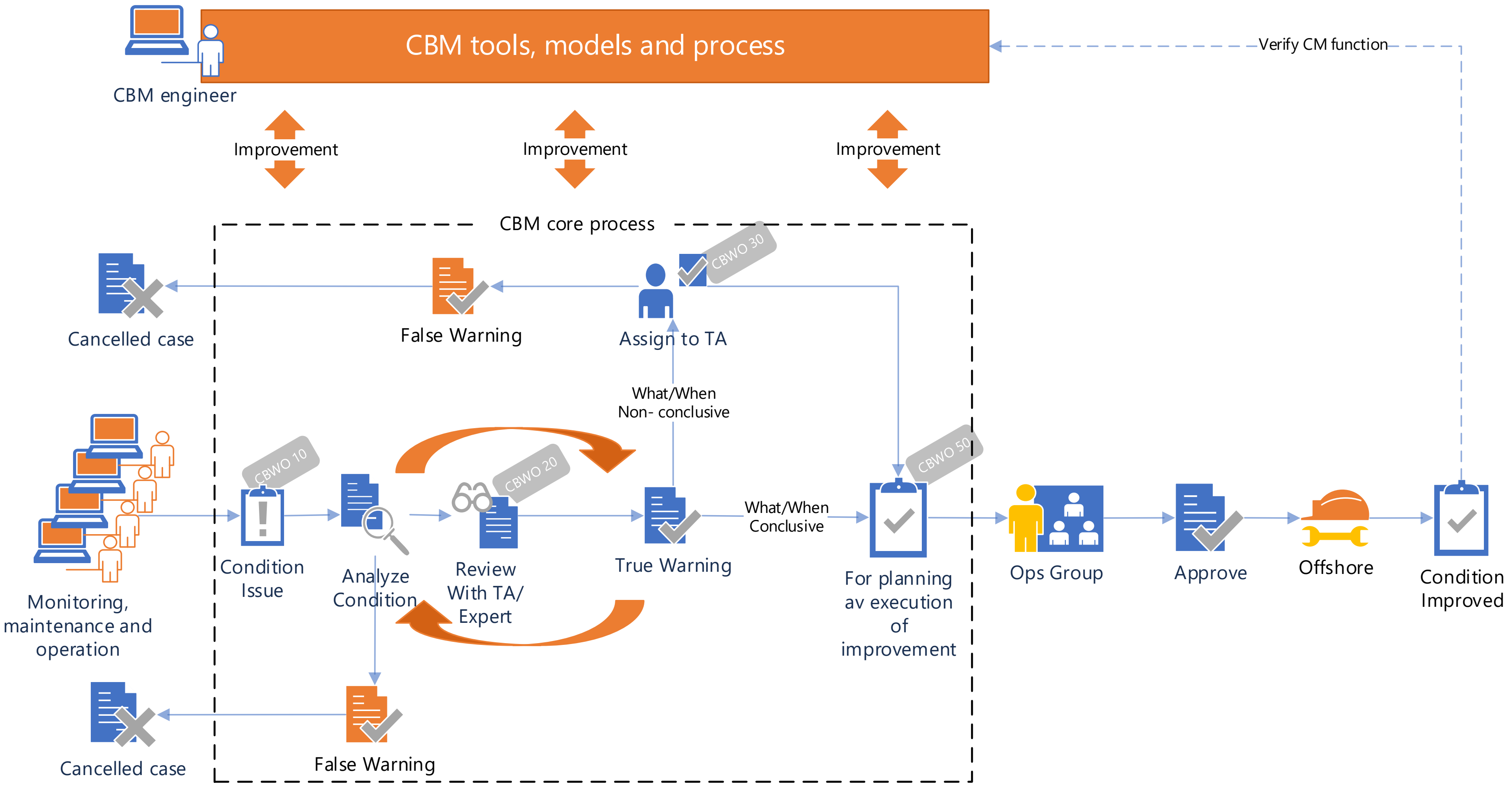
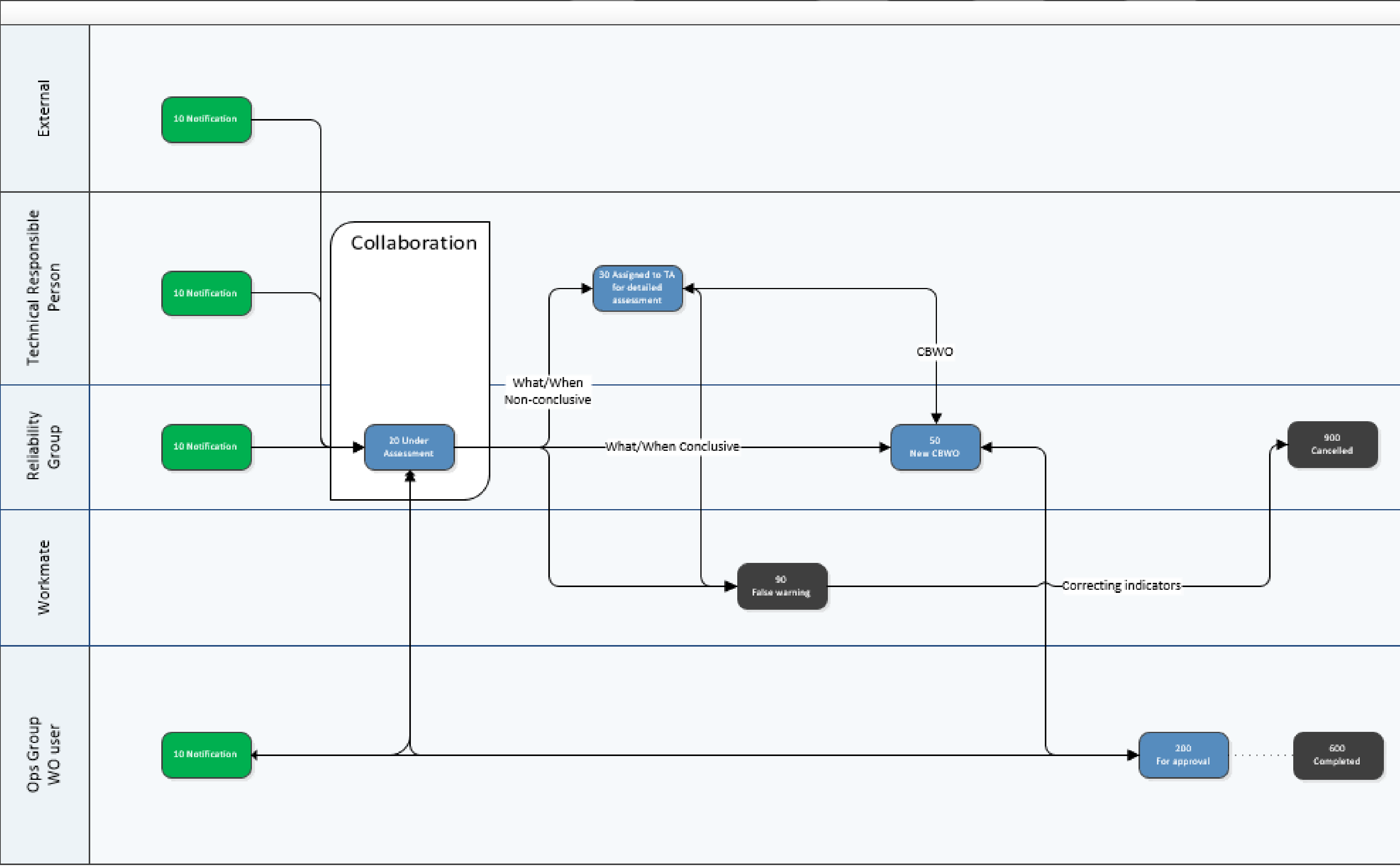
Edvard Grieg
13 Stigerør og brønnsyster
20 Separasjon og stabilise
20 HART Instrumenter
20 Kontrollventiler
20 ON OFF Safety Valve
20ESV1043
20ESV1045
20ESV1048
20ESV1143
20ESV1145
20ESV1148
20ESV1243
20ESV1245
20ESV1343
20ESV1351
20ESV1443
20ESV1445
20XSV1042
20XSV1142
20XSV1213
20XSV1242
20XSV1342
20XSV1440
20 Transmitter deviation
20HA001
20HA002
21 Råoljehåndtering og må
23 Gasskompresjon
24 Gasstørking
26 Gassinjeksjon
27 Gasseksport
29 Vanninjeksjon
34 Vanninjeksjonsrørledni
40 Kjølemedium
41 Varmemedium
42 Kjemikalieinjeksjon
43 Fakkel
44 Produsert vann
45 Brenngass
Fault Tree | 20ESV1048
20ESV1048
Belastnings varianse for liten
Lukke moment/kraft overskredet
Tid for å lukke overskredet
Tid for å åpne overskredet
Time Closing Warning
Time Opening Warning
Ventil lekasje
Åpne moment/kraft overskredet
16:22
28/10/2019

Conceptual CBM process

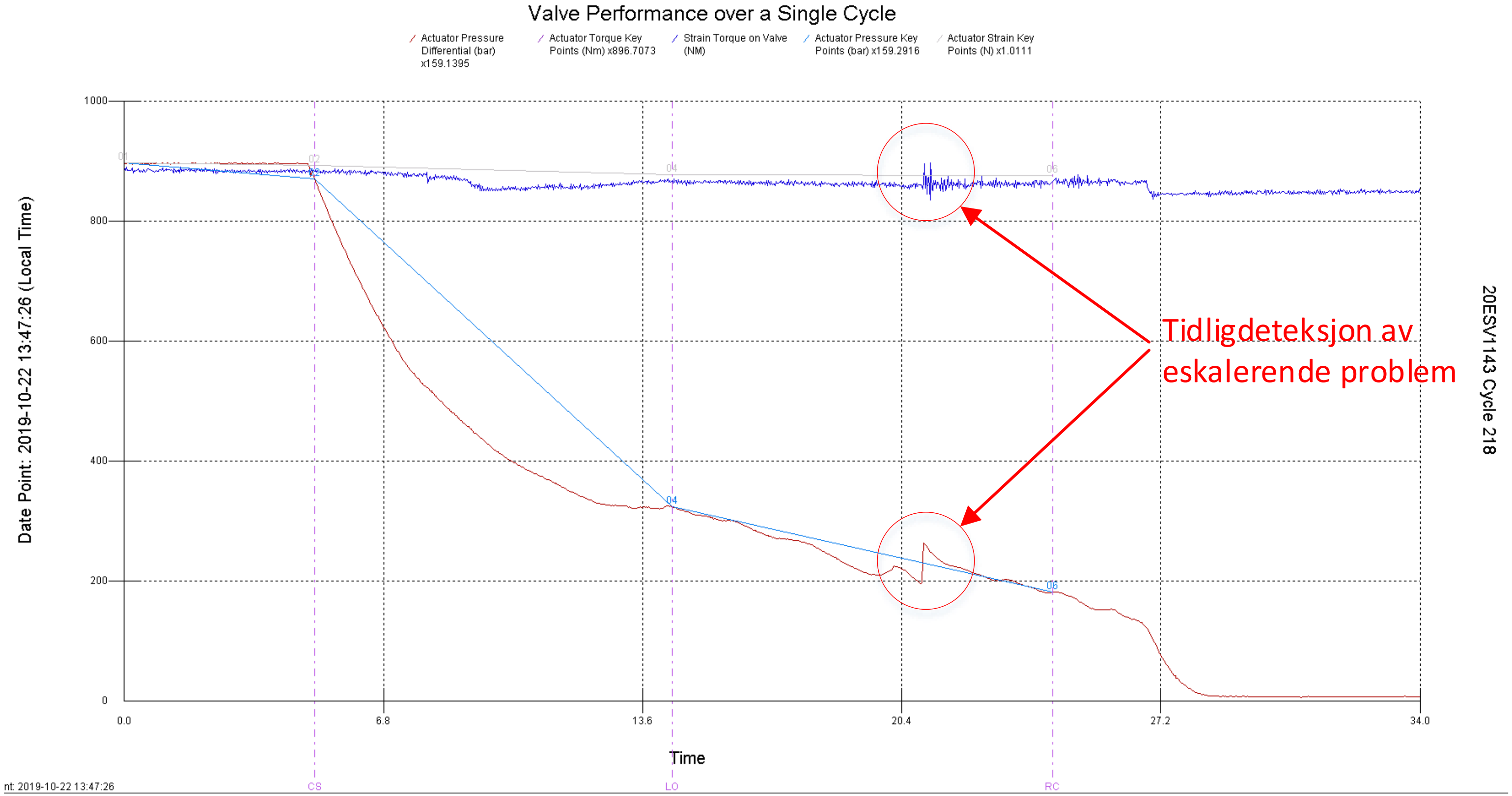


Condition Based Work Order (CBWO) process flow.



Goal for follow-up of SIL in operations

- Restore functionality before failure escalation



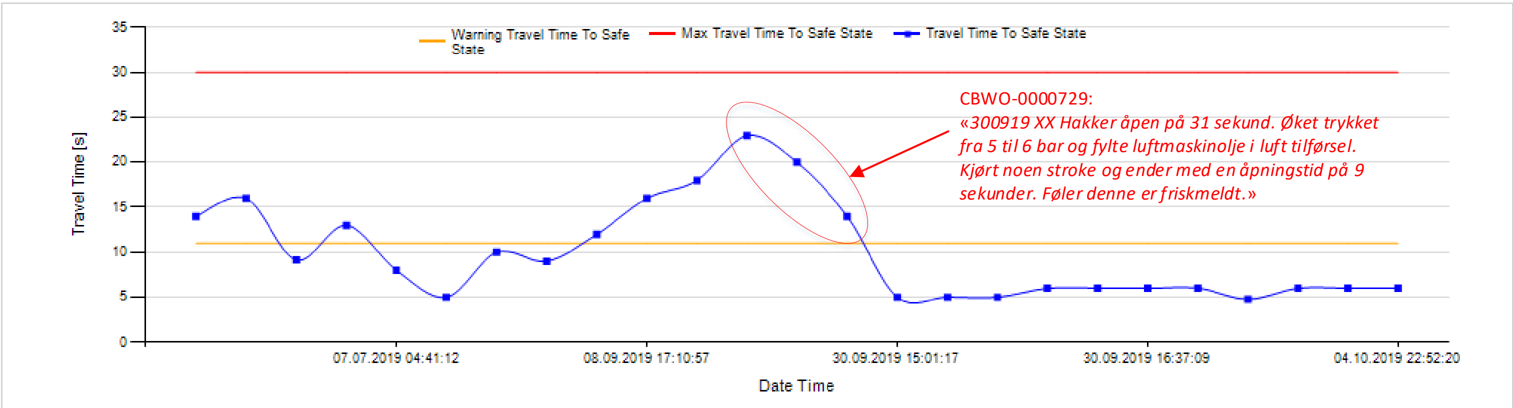
Goal for follow-up of SIL in operations

- Restore functionality before failure escalation

SIL Report

Travel Time Trend Report (to Safe State)

Start Date:	: 14.05.2019	**Generated:**	14-11-2019 09:05
End Date:	: 14.11.2019	**Valve Group:**	: ALL
Valve:	: 20ESV1047	**Valve Description:**	: Pri innlÃ¸pseparator prodvann (oml)



- Failure fixed =>«as good as new». What was root cause? Failure mode: «Other»...
- We have to become better at learning of failures. Maintenance personnel must be involved while the problem is active, and make sure observations are documented in a format and level of detail which enables analysis and learning.

Automation of workflows – integration of source systems

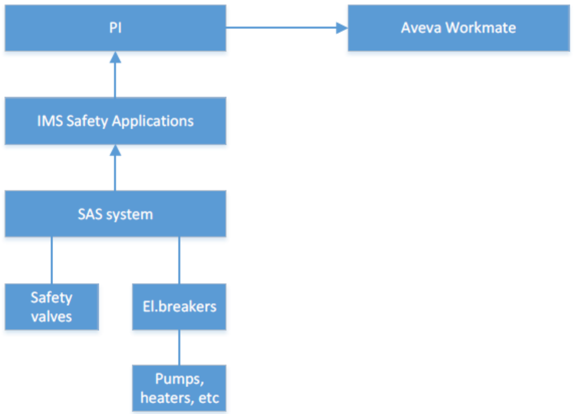
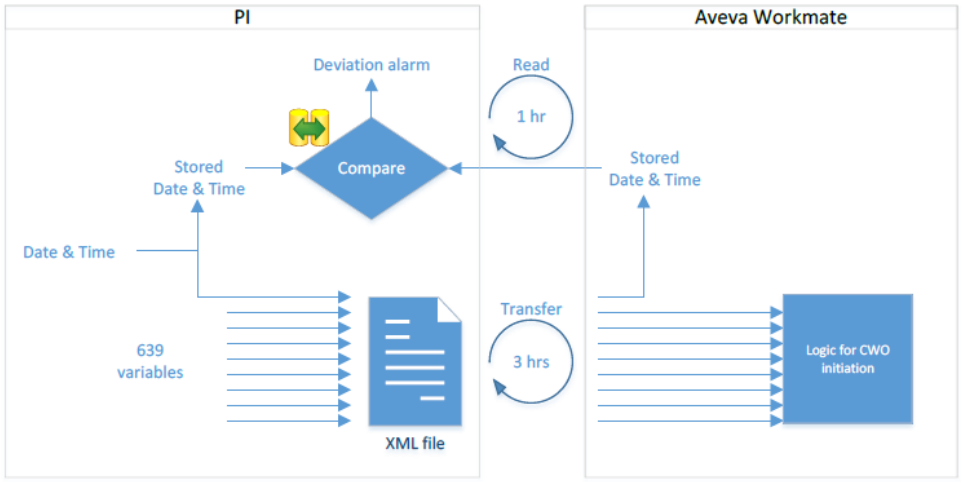
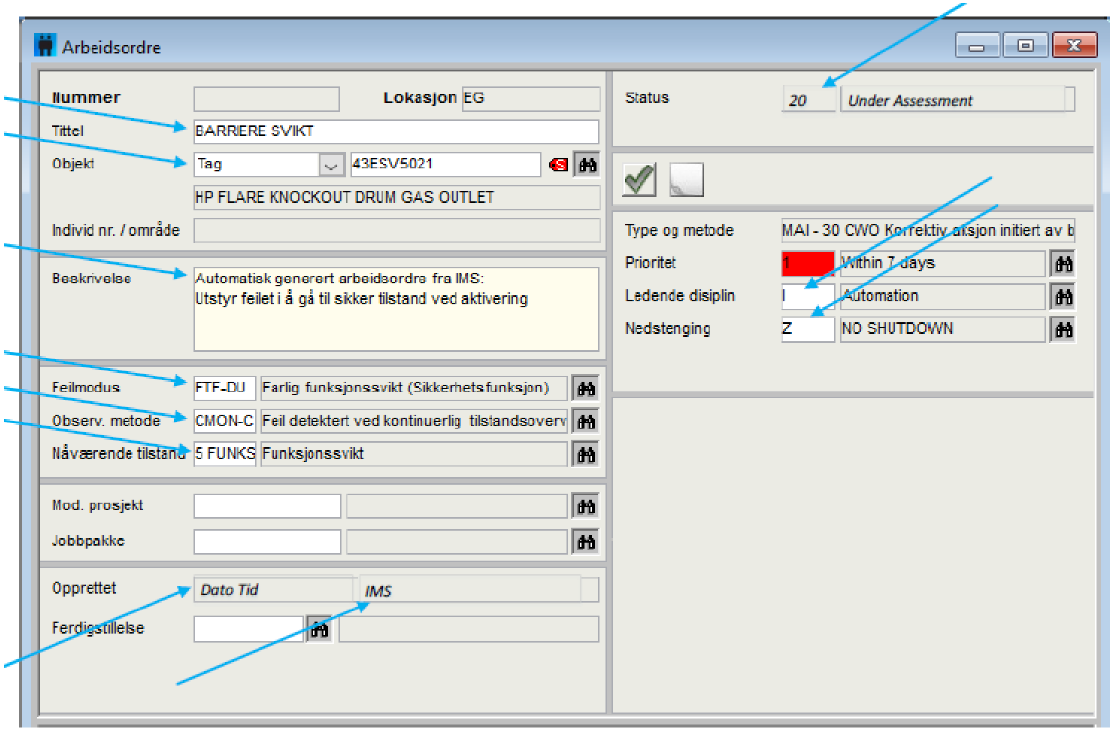


Figure 1 Overall topology

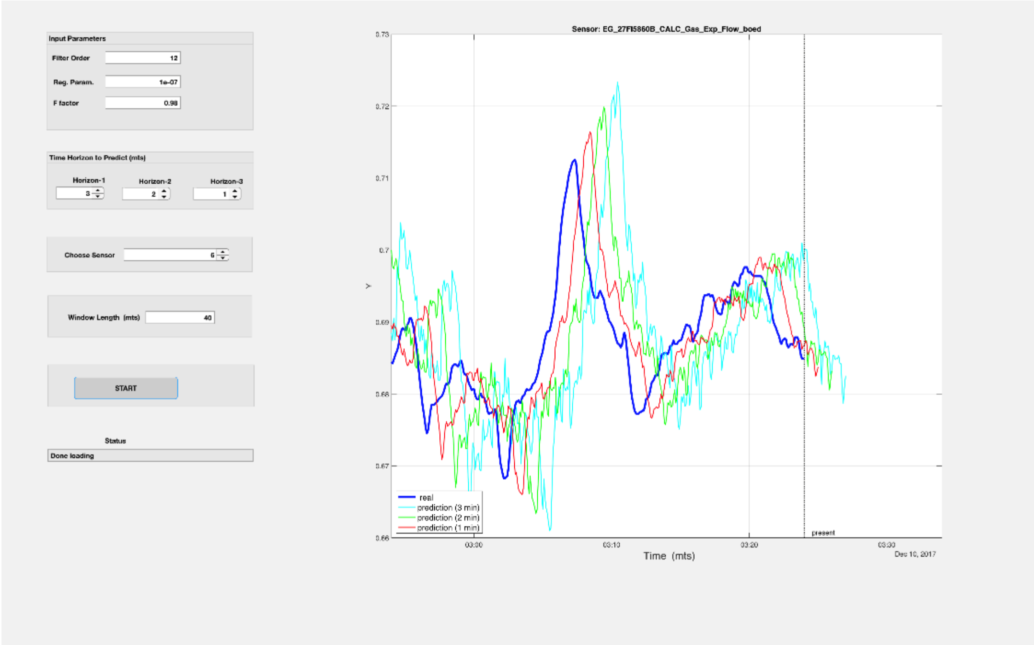


Figur 2 Data transfer sketch

Automation of workflows – integration of source systems



Outlook


Input Parameters
Filter Order
12
Reg. Param.
1e-07
F factor
0.98
Time Horizon to Predict (mts)
Horizon-1
3
Horizon-2
2
Horizon-3
1
Choose Sensor
6
Window Length (mts)
40
START
Status
Done loading
Sensor: EG_27FI5860B_CALC_Gas_Exp_Flow_boed
0.73
0.72
0.71
0.7
0.69
0.68
0.67
0.66
Y
real
prediction (3 min)
prediction (2 min)
prediction (1 min)
present
03:00
03:10
03:20
03:30
Dec 10, 2017
Time (mts)

Energy management

- A requirement from the Norwegian Environmental Agency through the Emission Permit.
- Lundin has together with Honeywell developed and implemented digital tools as basis for EM
- Online monitoring of energy generation and consumption
- Energy Loss Calculation and Optimization
- Advanced models to calculate the performed work and process energy loss

Use is part of operations working procedures

Energy loss

Design Loss

- Caused by the designed efficiency.
- Can only be reduced by replacing or modifying equipment

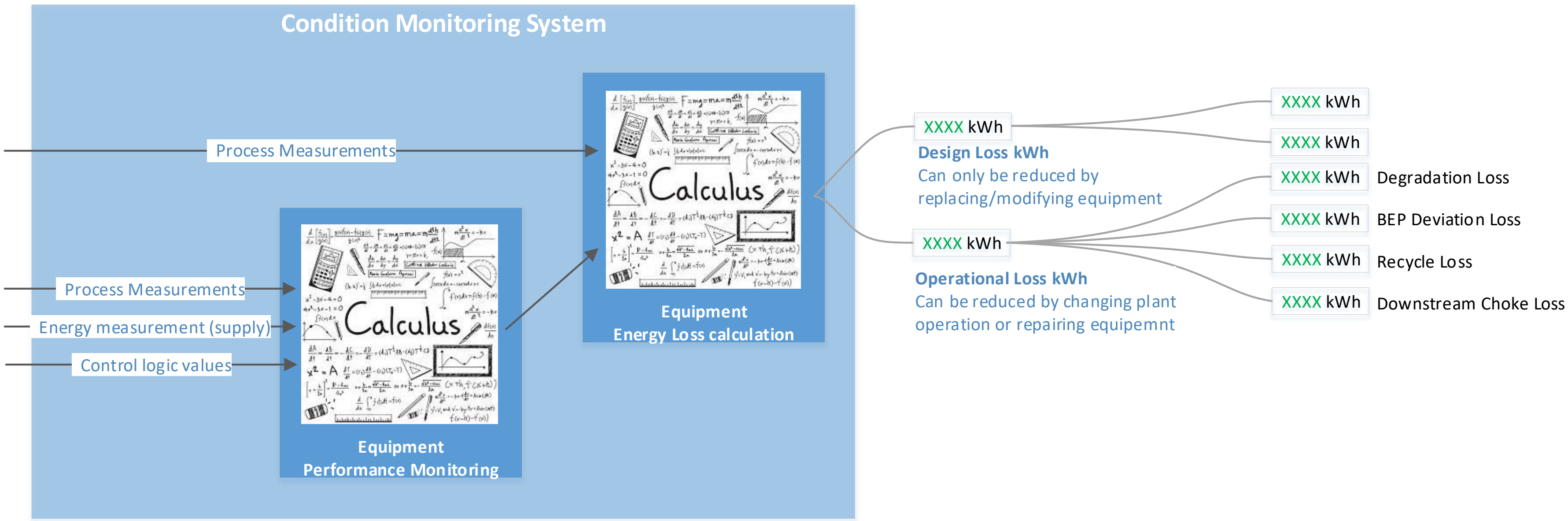
Operational Loss

- Can be reduced by repairing equipment or by changing how the equipment is operated

Energy management tools – the Lundin Way

- Development in 5 months
- Digital infrastructure present
- All calculations are performed and displayed in the Condition Monitoring System, Honeywell APM
- All calculation results available in common database for digital applications and data sharing
- Total application development cost approx. $110,000USD

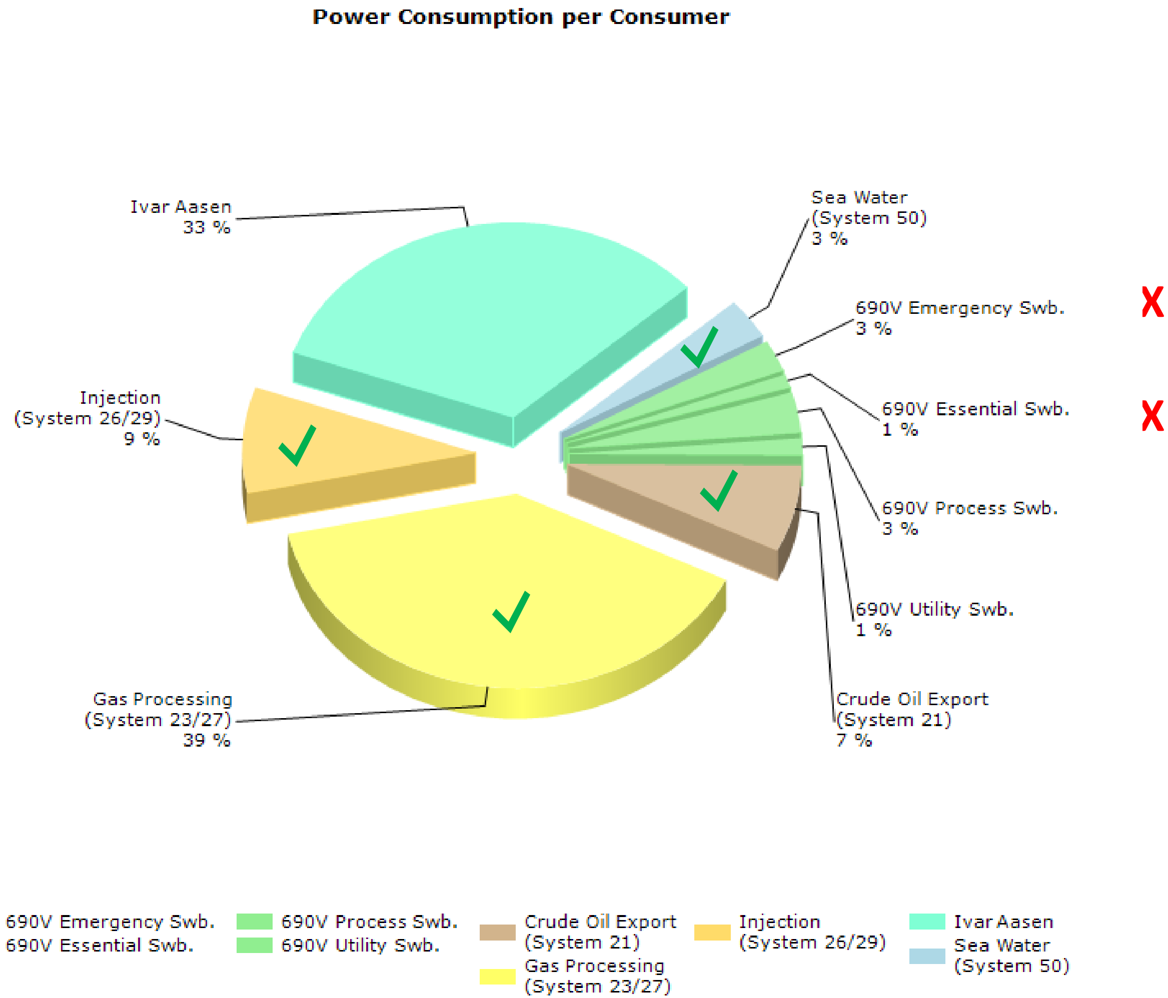
Calculation of Energy Loss, typical pump



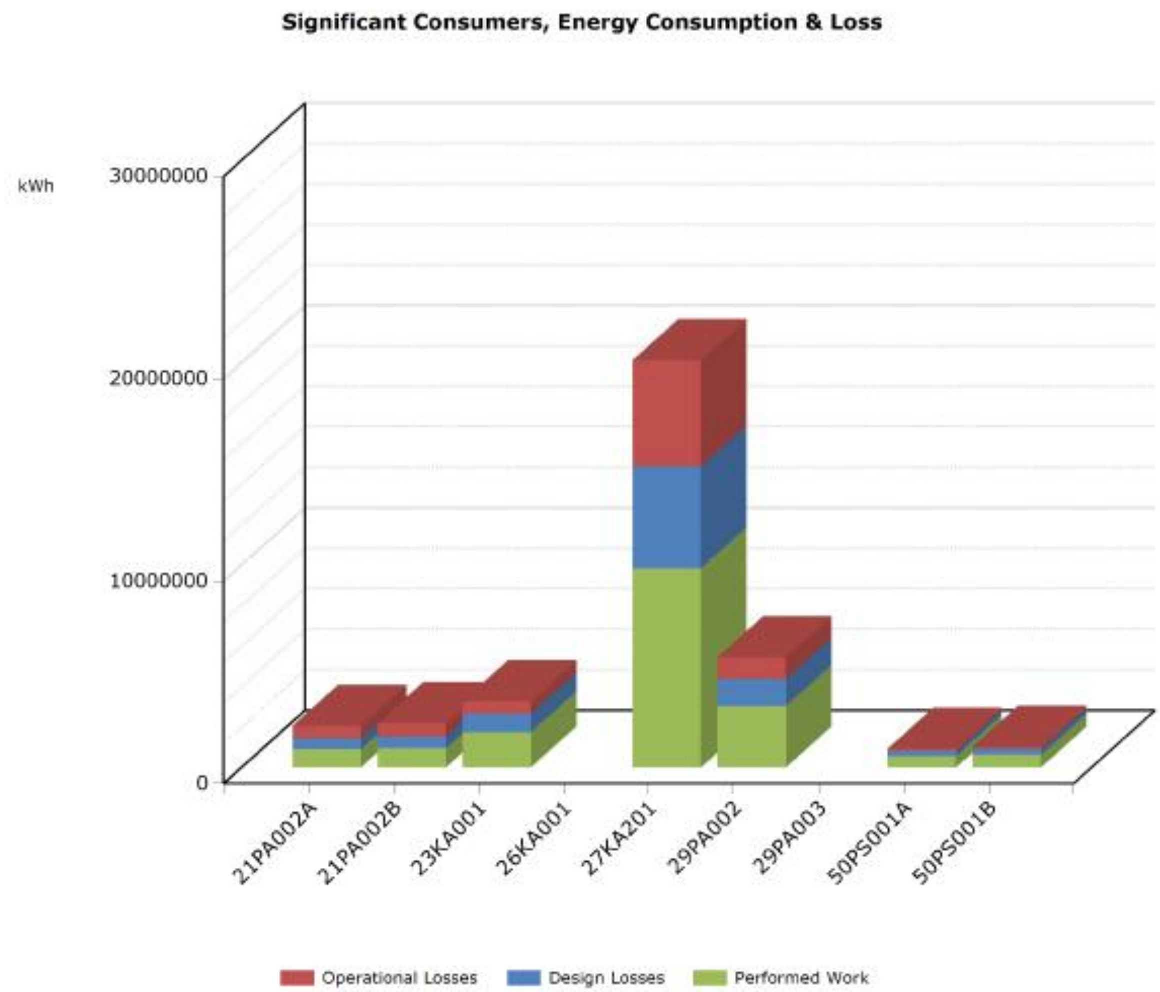
Energy Monitoring - Scope

Significant consumers (1
included in scope:

21PA002A/B	Crude Oil Export Pumps
23KA001	Recompressor
26KA001	Gas Injection Compressor
27KA101/201	Gas Export Compressor
29PA002/3	Water Injection Pumps
50PS001A/B	Sea Water lift Pumps
80EG001A/B	Main Generators

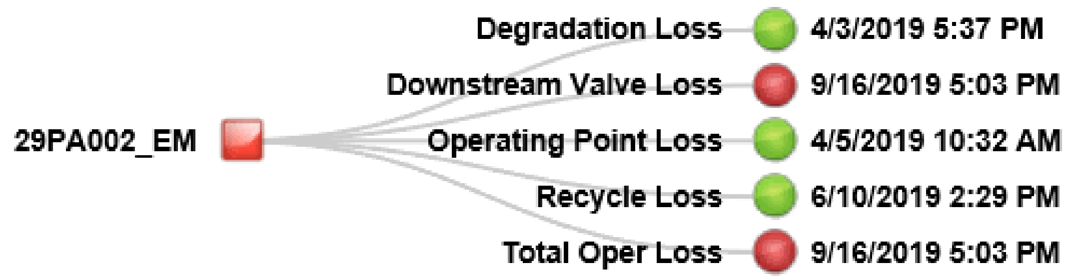


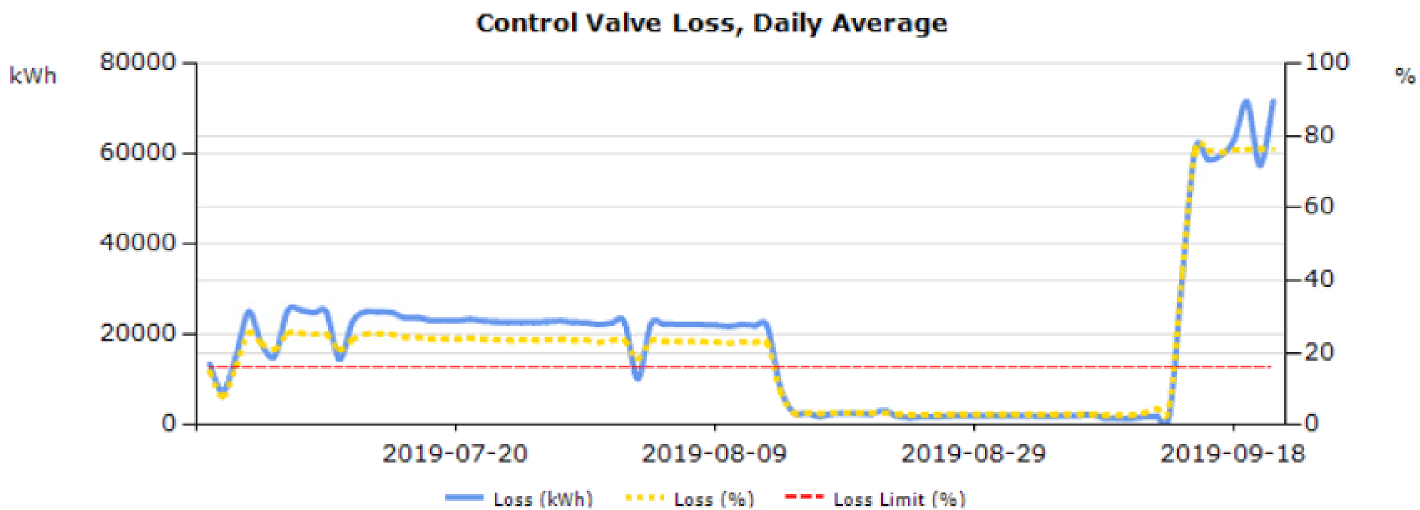
Energy management: Beginning the analysis



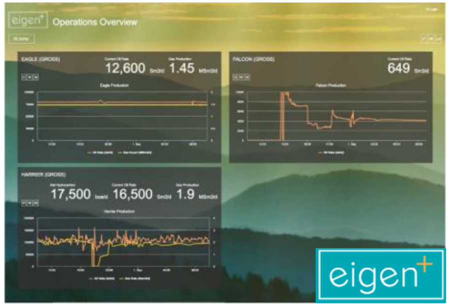
Energy monitoring application KPI & Trend

Example Water Injection Pump with downstream Choke:





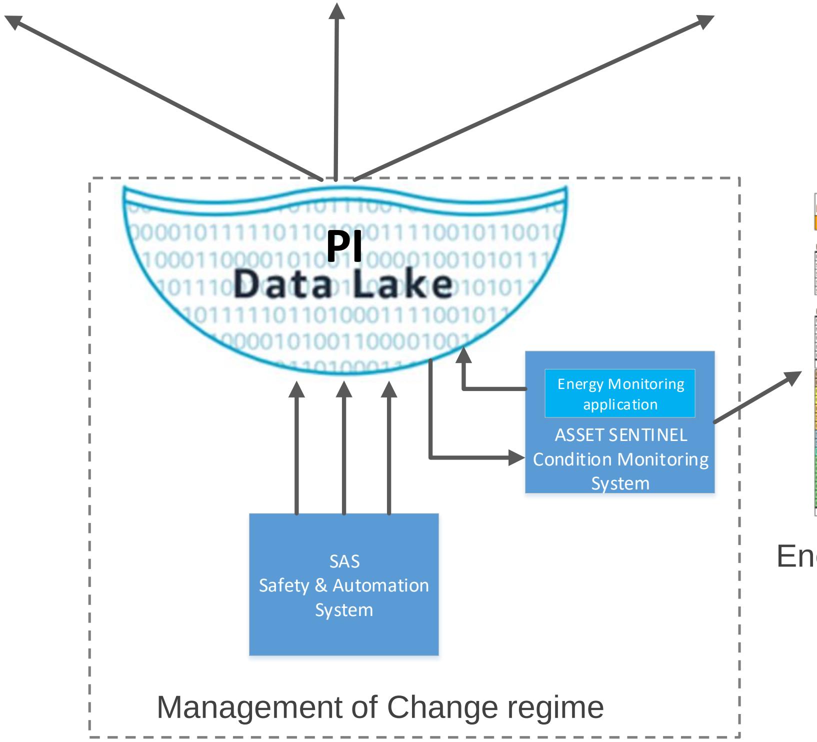
Application topology

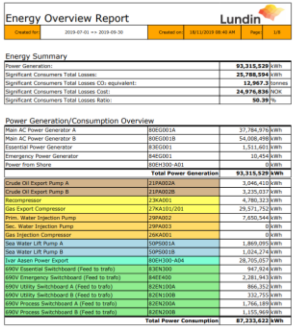


Dashboards / Reports:

All Energy monitoring data is available in PI.

Effectively, one can choose freely the tool for visualization, reporting and analysis





Energy Overview Report — Lundin

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Energy Summary

Power Generation:	93,315,529	kWh
Significant Consumers Total Losses:	25,788,594	kWh
Significant Consumers Total Losses CO₂ equivalent:	12,967.3	tonnes
Significant Consumers Total Losses Cost:	24,976,836	NOK
Significant Consumers Total Losses Ratio:	50.39	%

Power Generation/Consumption Overview

Main AC Power Generator A	80EG001A	37,784,976	kWh
Main AC Power Generator B	80EG001B	54,008,498	kWh
Essential Power Generator	83EG001	1,511,601	kWh
Emergency Power Generator	84EG001	10,454	kWh
Power from Shore	80EH300-A01	0	kWh
	Total Power Generation	93,315,529	kWh
Crude Oil Export Pump A	21PA002A	3,046,410	kWh
Crude Oil Export Pump B	21PA002B	3,235,037	kWh
Recompressor	23KA001	4,780,323	kWh
Gas Export Compressor	27KA101/201	29,571,752	kWh
Prim. Water Injection Pump	29PA002	7,650,544	kWh
Sec. Water Injection Pump	29PA003	0	kWh
Gas Injection Compressor	26KA001	0	kWh
Sea Water Lift Pump A	50PS001A	1,869,095	kWh
Sea Water Lift Pump B	50PS001B	1,024,274	kWh
Ivar Aasen Power Export	80EH300-A04	28,705,057	kWh
690V Essential Switchboard (Feed to trafo)	83EN300	947,924	kWh
690V Emergency Switchboard (Feed to trafo)	84EE400	2,281,943	kWh
690V Utility Switchboard A (Feed to trafo)	82EN100A	866,352	kWh
690V Utility Switchboard B (Feed to trafo)	82EN100B	332,755	kWh
690V Process Switchboard A (Feed to trafo)	82EN200A	1,766,189	kWh
690V Process Switchboard B (Feed to trafo)	82EN200B	1,155,969	kWh
	Total Power Consumption	87,233,622	kWh

Energy reports developed for “Proof of Concept”

Final remarks

- Data driven
- Informed decisions
- Timely
- Address the root causes and not the symptoms; calls for close integration of competences across the operational department

- Data integrity/integrations and top level applications

- Competence and capacity to exploit technology
- Operational philosophy
- Definition of roles and responsibilities
- Takes time and persistence


Lundin
Energy Norway
Thank you for your attention!