

# Power Generation with SAP

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CUSTOMER

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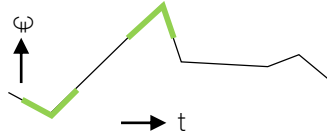
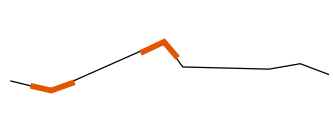
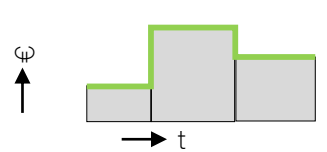
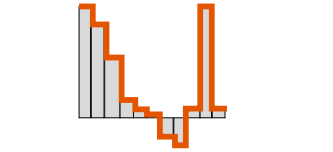
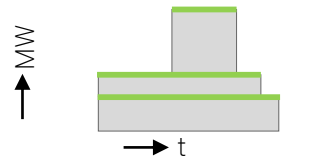
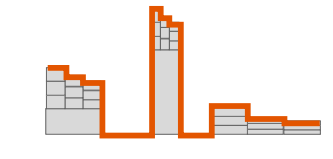
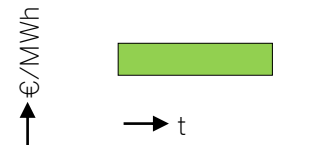
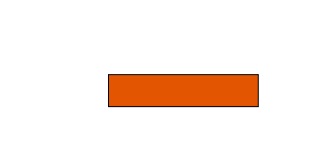
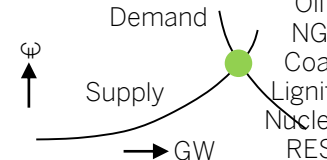
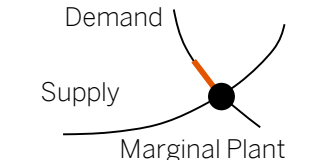
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# Agenda

- (1) Market Observations in Power Generation
- (2) Evolution of Generation Roadmap
- (3) Excursions
  - a. Customer Project Examples
  - b. Integrated O&M Solution
  - c. Reliability Performance & Schedule Operation Prototype with Procom (Merchant & Industrial Energy Hub)
  - d. Pump Degradation Analysis & Prediction Prototype
  - e. Integrated Wind Turbine Event Cost Analysis

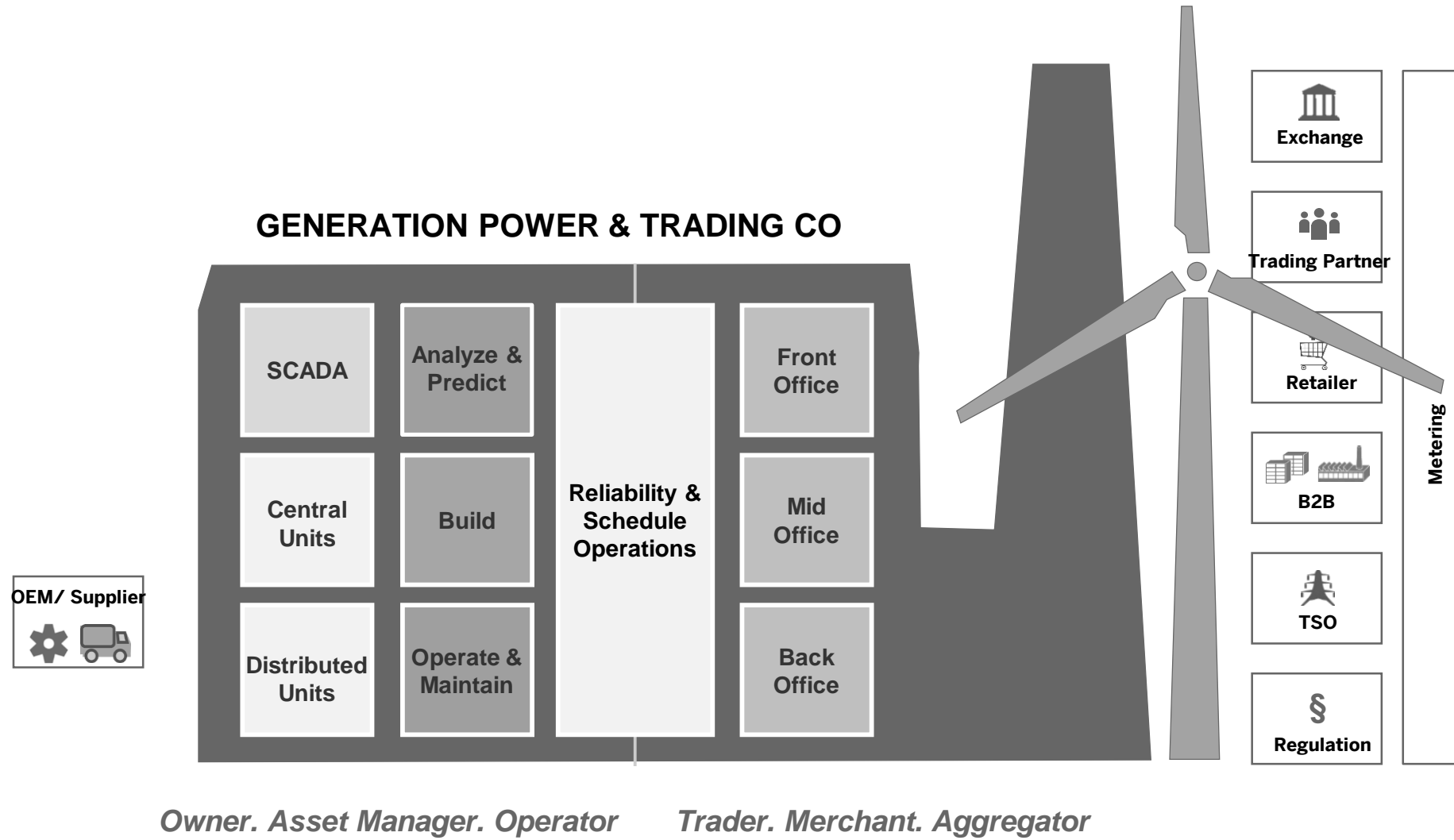
# **Market Observations**

# Change in Power Markets by Renewable Energy Additions

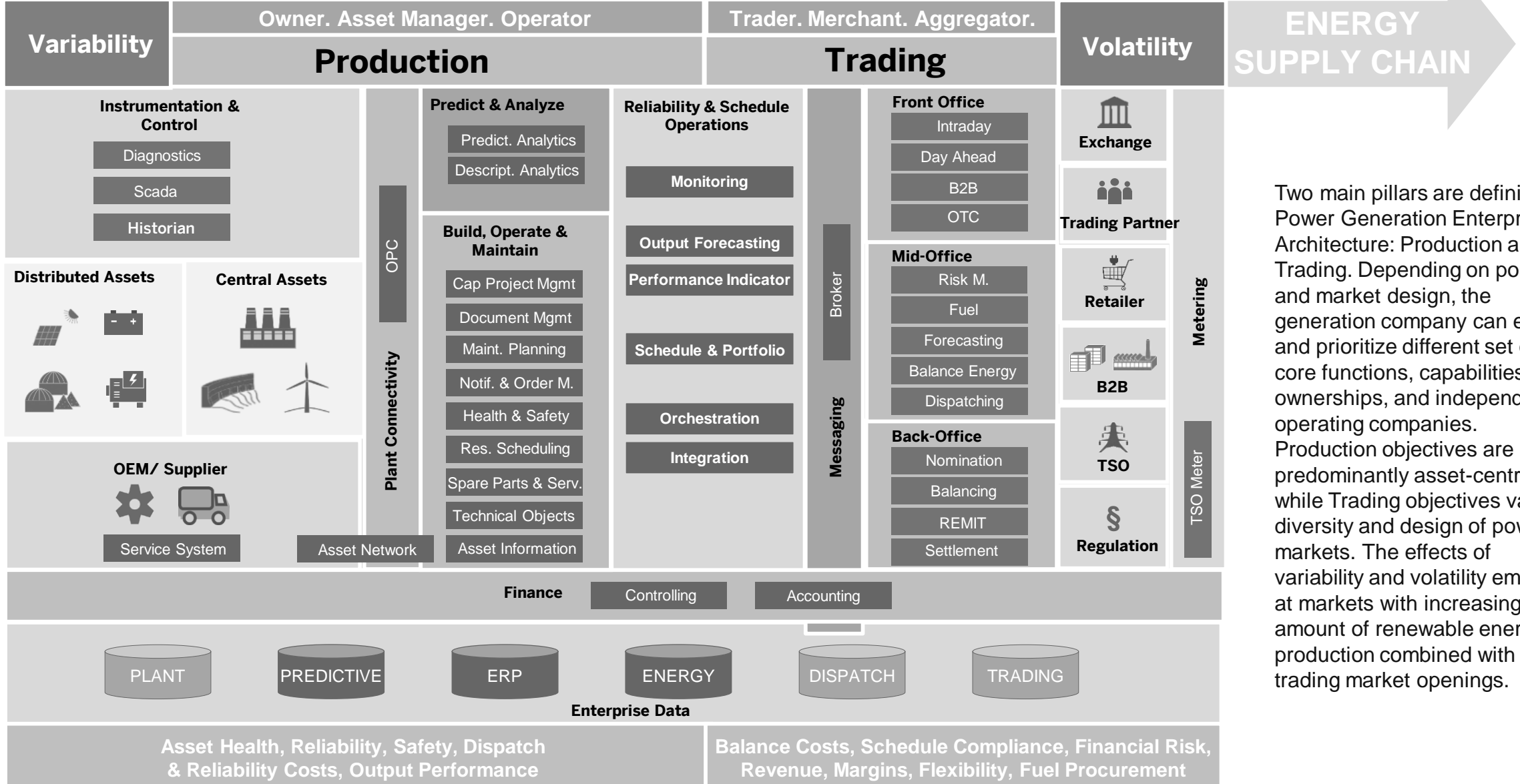
	Before	Now	Effects	Consequences	
Spot Price			No peak/off peak spread	Increasing non-economic operation of oil, gas, pumped-storage plants	
Balance Price			More balancing risk exposure		Continuous need for balancing plants
Schedule			More variability		Higher wear & tear of conventional plants
Spread			Contribution margin does not cover capex and fixed opex	<b>Call for Action</b>	
Missing Money			Reduced market clearing price	Adapt portfolio strategy and operations more short-term	
				Adapt maintenance strategy	
				Enter new decentralized energy business models	

# **Evolution of Generation Roadmap**

# The Generation & Trading House



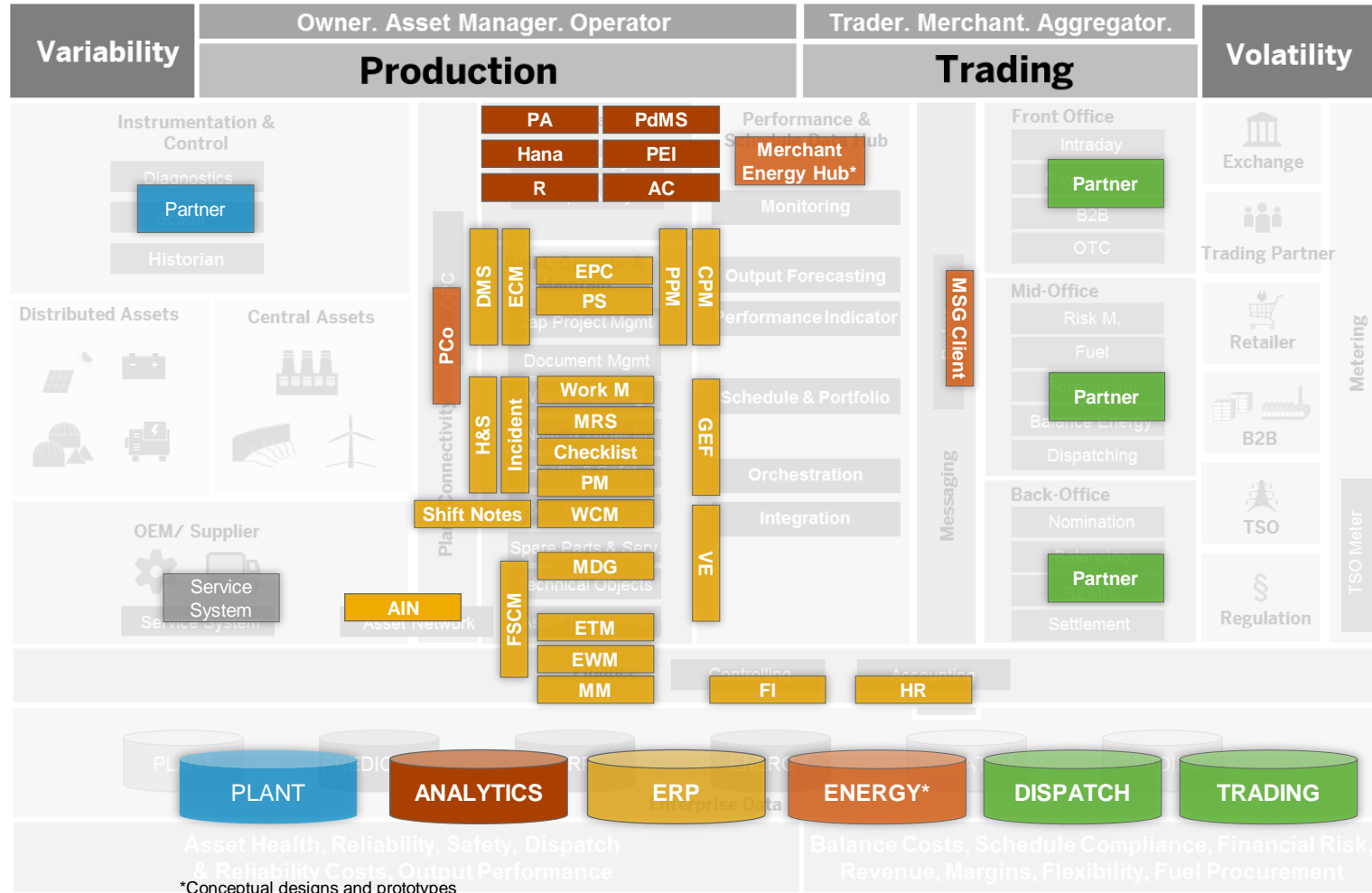
# Power Generation Enterprise Architecture



Two main pillars are defining a Power Generation Enterprise Architecture: Production and Trading. Depending on policies and market design, the generation company can evolve and prioritize different set of core functions, capabilities, ownerships, and independently operating companies. Production objectives are predominantly asset-centric while Trading objectives vary by diversity and design of power markets. The effects of variability and volatility emerge at markets with increasing amount of renewable energy production combined with trading market openings.

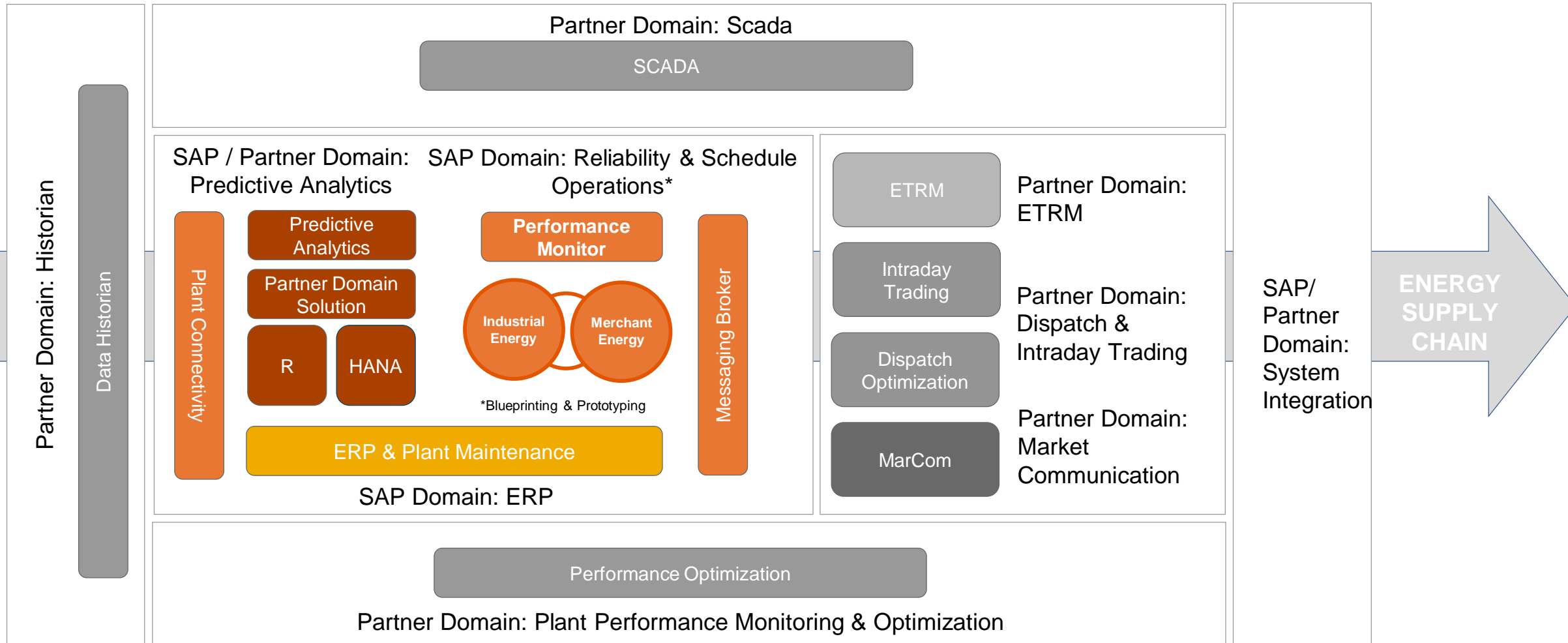


# Solutions for Power Generation by SAP



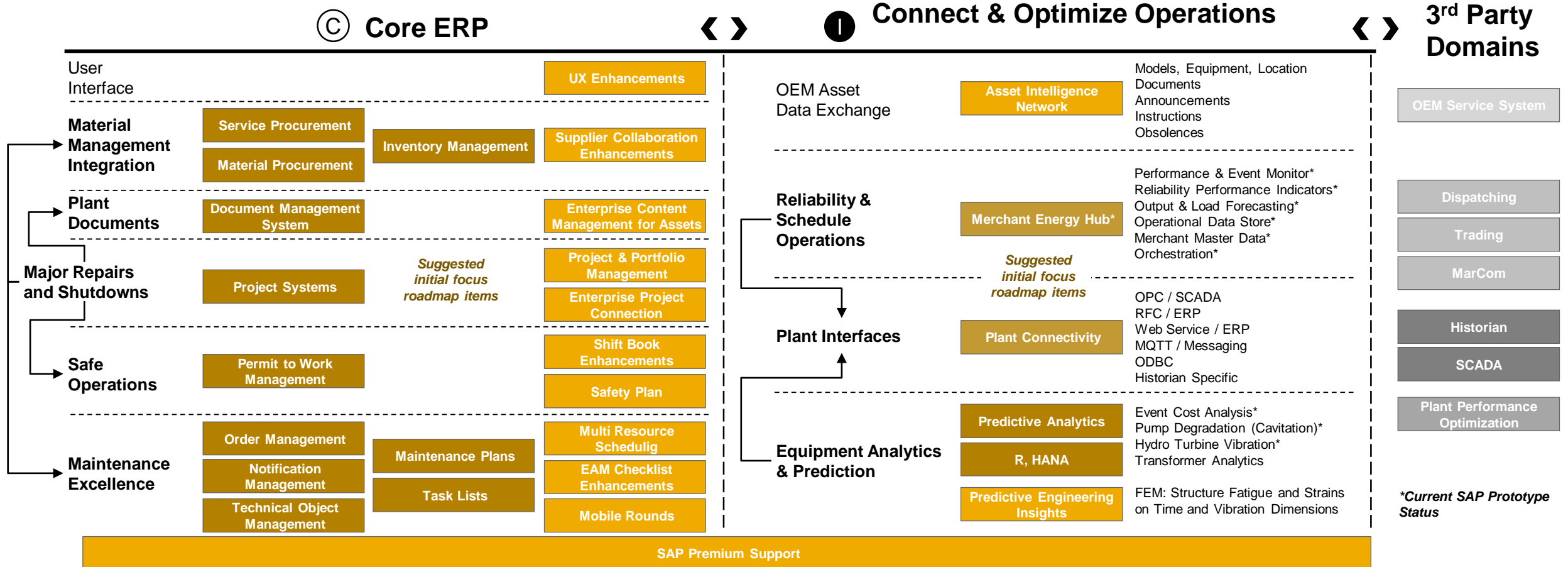
- FI (Financials), MM (Material Management), HCM (Human Resources)
- PM (Plant Maintenance), WCM (Work Clearance Management), PS (Project Systems), DMS (Document Management System)
- MRS (Multi Resource Scheduling), Work Manager (Mobile Asset Management), Mobile Checklist (Mobile Inspections)
- CPM (Commercial Project Management), EPC (Enterprise Project Connection), PPM (Project & Portfolio Management)
- H&S, Incident (Health & Safety)
- GEF (Geospatial Enablement Framework)
- MDG (Master Data Governance)
- AIN (Asset Intelligence Network)
- PCo (Plant Connectivity), MSG (Messaging Infrastructure)
- ECM (Enterprise Content Management by OpenText)
- FSCM (Fuel Supply Chain Management), ETM (Equipment & Tool Management), EWM (Extended Warehouse Management)
- Merchant Energy Hub (prototyping real time commercial operations data hub)
- Hana, PA (Predictive Analytics), R, PdMS (Predictive Maintenance & Service), PEI (Predictive Engineering Insights), AC (Analytics Cloud)

# Domain Solution Ecosystem for Power Generation Companies



# Generation Roadmap Scenario

We recommend a parallel evolution of a core EAM system as well as exploring operation optimization scenarios. The core EAM implementation may be driven by an **integrated shutdown management pilot** involving requirements of 5 initiatives: project system [Major Repairs and Shutdown], order-, notification-, technical object management, maintenance plans and task lists [Maintenance Excellence], permit to work [Safe Operations], material-, service procurement, inventory management [Material Management Integration], and document management system [Plant Documents]. Set-up would require 5 implementation project teams. Operation optimization scenarios may include prototyping of **integrated plant reliability performance indicators** [Reliability & Schedule Operations] as well testing a **pump degradation model** [Equipment Analytics & Prediction]. Both scenarios require the specification of **interfaces** [Plant Interfaces]. Set-up would require 2 PoC teams. Findings from designing, piloting, and prototyping initial focus roadmap items should lead to decisions on subsequent items including Enhancements/ Extensions for UX, Supplier Collaboration, Project Portfolio Management, Shift Book, Checklists, Mobile Rounds, Multi Resource Scheduling, as well as Reliability & Schedule Operation Hub, Equipment Prediction Models, and OEM Data Exchange. The process may discover also some yet unknown items.

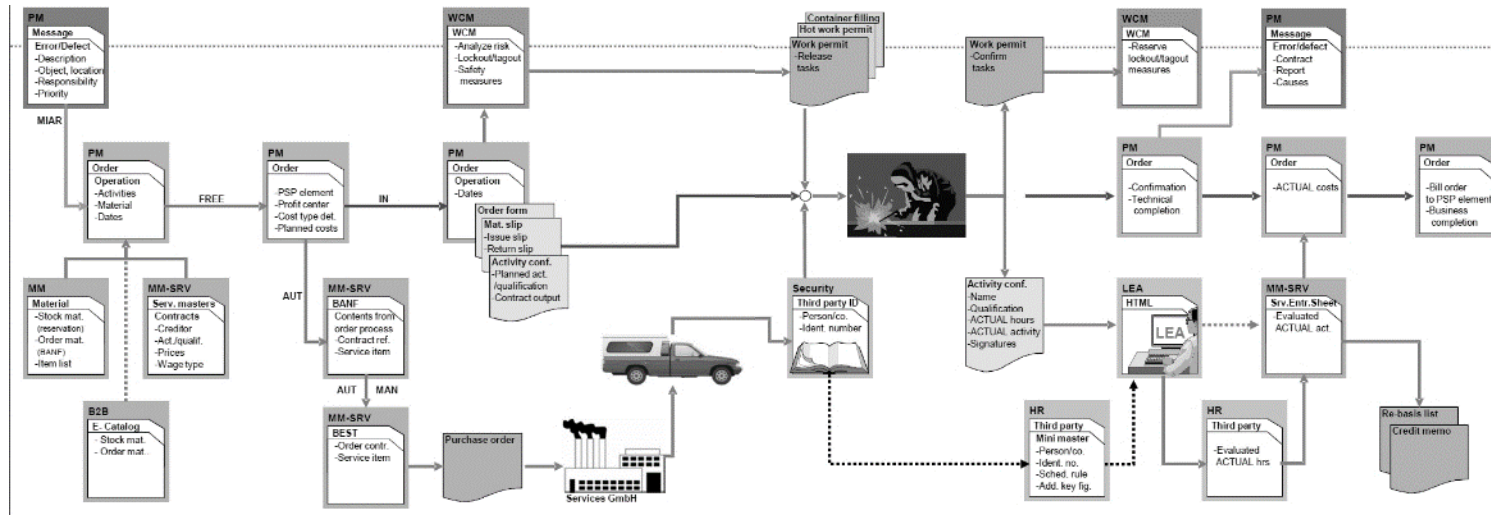


# **Customer Project Examples**

# SAP EAM @ EON Thermal Generation (now Uniper), Germany



End-to-End EAM incl. Contractor integration  
17 locations in 1 year



**e-on Kraftwerke**

**Management Systems**  
Status 12/2004

**SAP-PM/WCM/LEA**

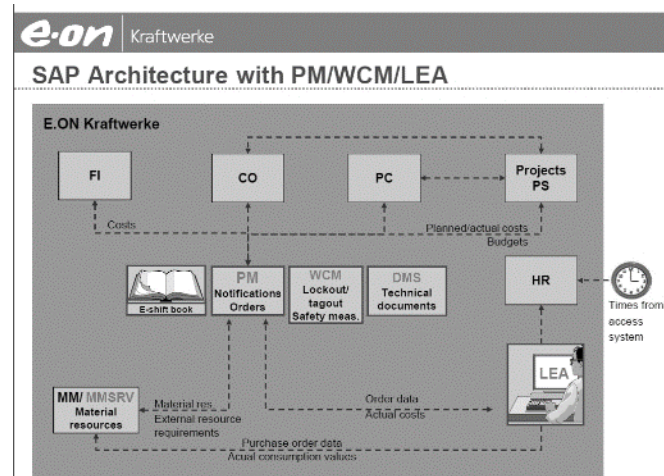
- Roll-out: 1 year
- 17 locations
- Approx. 1,200 users
- Training approx. 3 days/user
- Implementation 5-9 weeks/location depending on size

15 5th SAP International Users Conference 2005 (I02) N. Stul, F. ON Kraftwerke

System Hilfe SAP

WCM: Vorgangsübersicht (Dispoliste)

AnwStatus	Auftrag	Vrg	Kurztext Vorgang	Technischer Platz (k/obj)	FS	BE	HE	AS	Sonst.	DAE	AE zur.	AE temp.	Früh Startdat.	Früh
EN0	75015144	0010	Wöchentliche Überprüfung nach VHM5	0340 0000TH608001-APP									13.12.2004	10.4
EN0	75013743	0010	Sicherheitsgeländer Kühlturm Bl.3	0340 0330UC-SYS									13.12.2004	07.0
EN0	75022405	0010	Durchführung von Dreh- und Fräsarbeiten	0340 0110ZU01S203-ERB									06.12.2004	00.0
EN0	75022405	0010	Anderungsarbeiten GAVO Bläser	0340 0110ZU01S203-ERB									11.12.2004	00.0
EN0	75022890	0010	Sumppumpe austauschen,	0340 0330ZS210001-PVK									09.12.2004	07.0
EN0	75022890	0020	Sumppumpe Typ: KRK UK.100 - 350 / 304	0340 0330ZS210001-PVK									13.12.2004	07.0
EN0	75022941	0010	Kondensatföhrleitung Bl.4, Filter 4.1	0340 0440UB-SYS									10.12.2004	07.0
EN0	75022891	0010	Doppelendenschleife 112 dekle	0340 0111N705202-TEO									10.12.2004	07.1
EN0	75023003	0010	Wechseln von einem kompl Verschleißteils	0340 0112NUJ2001-ARN									11.12.2004	00.0
EN0	75023008	0010	Wechseln von einem kompl Verschleißteils	0340 0111NUJ2001-ARN									11.12.2004	00.0
EN0	75023053	0010	Trichter unter Schleuse durchgestrnt	0340 0111NT705201-TEG									10.12.2004	12.4
EN0	75023182	0010	Schlammpumpe Fließler 1: Pumpe sitzt fest	0340 0000UL120603-LAE									13.12.2004	08.4
EN0	75023203	0010	Waschwassereindüsung ohne Funktion.	0340 05HTT2C-GYS									13.12.2004	00.0
EN0	75023280	0010	Kompensatoren Abschlämpumpe lauschen	0340 0220ZE850001-PVK									13.12.2004	13.0



**e-on Kraftwerke**

**Advantages of Implementing SAP-PM/WCM/LEA**

- No integration gaps → No duplication, no interfaces
- Integrated support for technical and business processes → Improvement in planning → Optimization of procurement
- Automation of order processing and billing for services
- Inclusion of third party companies in the process
- High safety levels in all power plants
- The implementation of SAP-PM/WCM/LEA for E.ON Kraftwerke enables consistent and continual support for both technical and commercial processes within integrated plant maintenance

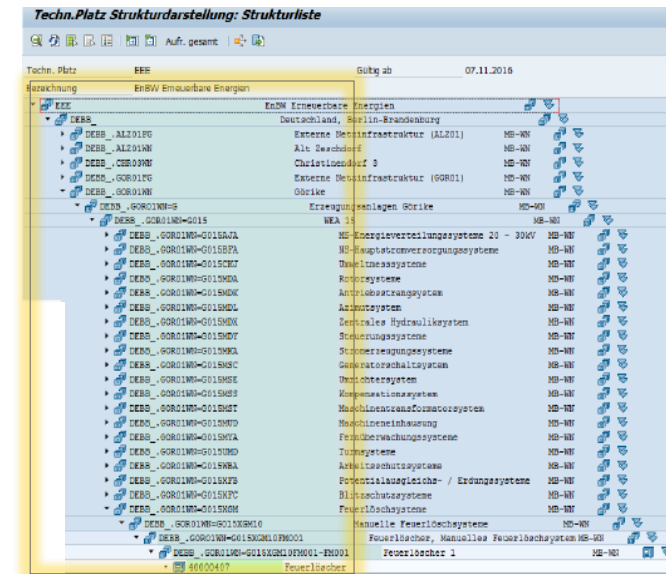
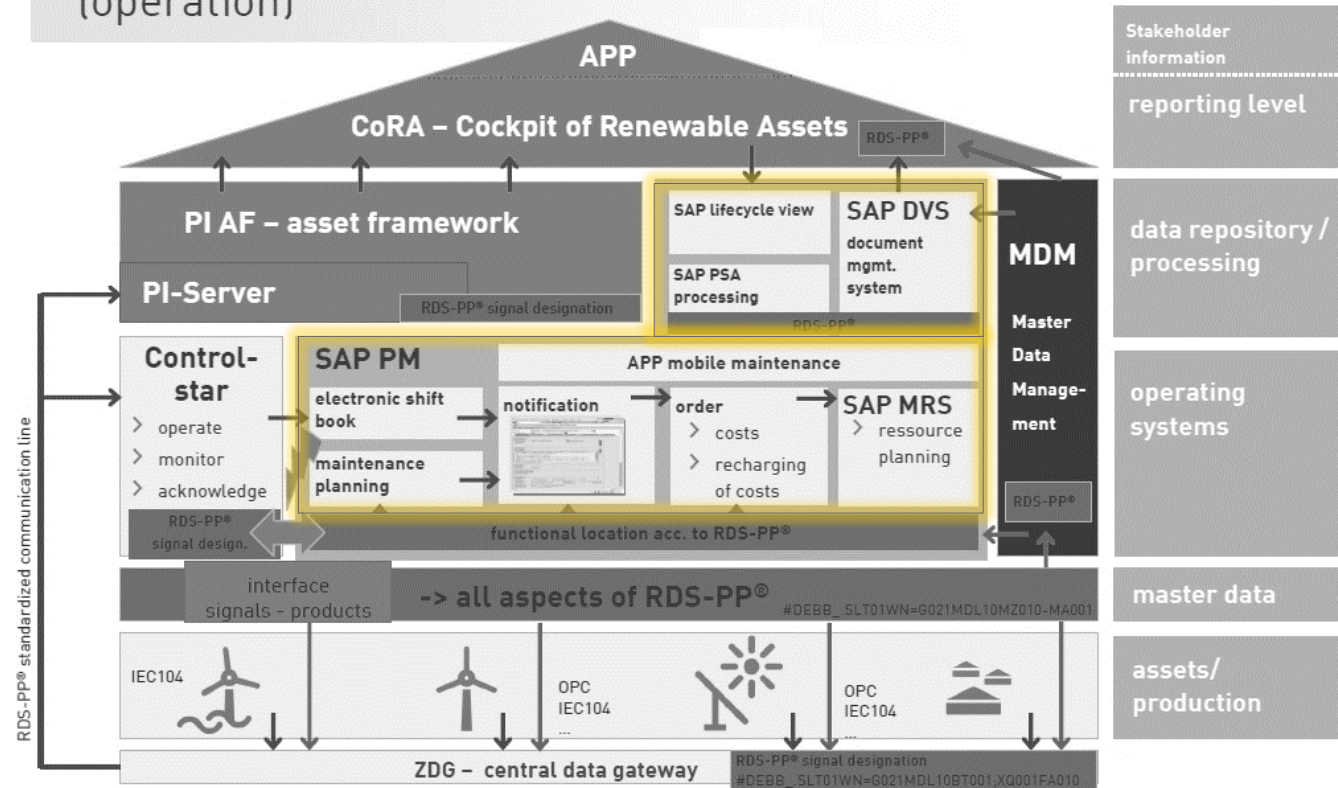
# SAP EAM @ EnBW Wind Unit Generation, Germany



2. EnBW - range of application  
integration of RDS-PP® into IT infrastructure  
(operation)

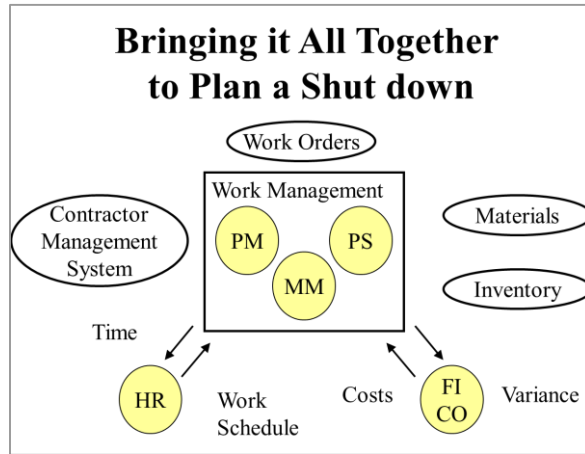


Core Maintenance & Mobile  
Workforce Management on industry  
standard RDS-PP asset structure

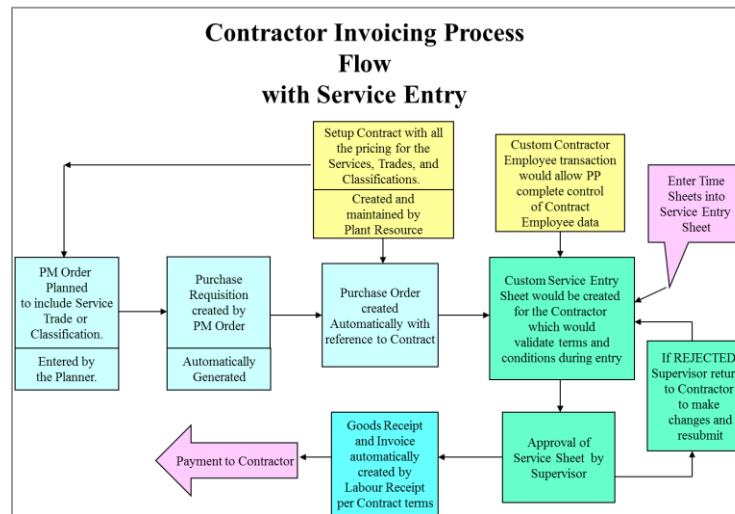


screen dump: EnBW operating machine SAP PM [EE] - technical location

# Shutdown Planning with SAP @ SASK Power, Canada



- 80% of our Overhaul work is generated from Maintenance Plans
- Work Orders are scheduled to be called to coincide with plants shutdown interval
  - during the first week of the year at Poplar River;
  - to match 18 month interval at Boundary Dam
- Shutdown Revisions are created and Work Orders are assigned to the appropriate Revision



- 2005 December
  - BDPS Sends a large contingent to a hear the results of the Poplar River pilot - most were convinced, some still skeptical
- 2006 January
  - BD Management Team commits to using PS for scheduling
  - BDPS Plant Manager establishes a 9 person project team to develop job plans and schedules for major overhauls on two identical 150 MW units
    - BD 4 Fall of '06
    - BD 3 Spring '07
  - OBJECTIVE: Deliver a completed shutdown plan and schedule to the Production Supervisor 3 months in advance of the unit coming off-line
- Plant Manager makes a strong statement of commitment
- 2006 February - Team pulled together
  - Planners, Coordinators and Supervisors. Trades people are moved up to fill the roles - training and development is a major spin-off benefit.
  - 9 full time team members
  - 6 people support the team while continue there regular duties
  - Central Process Team provides support and training
- 2006 March - Project begins
  - Process team is now in demand here and at three other sites who also liked what they saw on December 13
- PM/PS Integration Project (IT Initiative) is launched in parallel - a race to keep pace with plant work
- Check lists developed
- What do you do on every shutdown?
- What do you do every 3yrs, 5yrs, 7yrs, etc
- Existing work orders are updated
  - Operations as detailed as possible - reference written job plans if applicable
  - Job Plans Doc linked to equipment or WO
  - Materials planned (BOMs created)
  - Designate as OH, MO or xY (Overhaul, Major Overhaul or every x Years.
- Sort fields used to create calls in the future

# SAP EAM @ Macquarie, Australia

## Where is Macquarie Generation?

### Bayswater Power Station

- Commenced operation in 1985
- 4 x 660MW units



### Liddell Power Station

- Commenced operation in 1973
- 4 x 500MW units



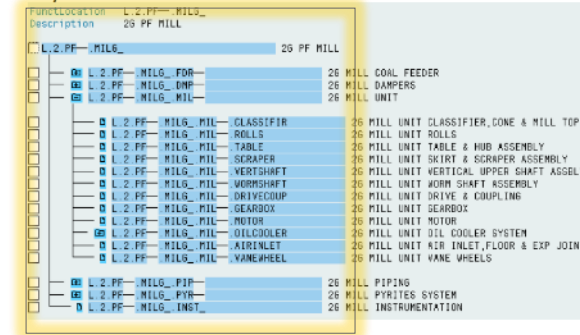
## The Key Changes when using SAP

- The operating hours no longer need to be monitored manually.
- Work orders and scheduled calls have to be monitored.
- The hours can be reported and will show operating trends.
- The monthly hours will be added to a collective entry sheet.

## Counter-Based Maintenance at Coal Mills. Automation thru asset structure. Reporting on Activity Codes.

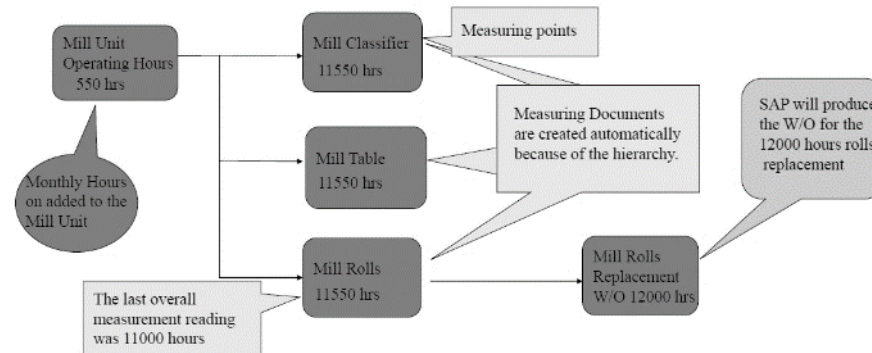
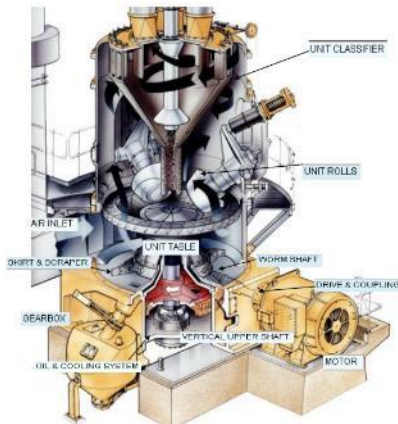
### Functional Locations updated

- The revised Functional Location structure allowed for improved visibility and consistency.



## How SAP will piece it all together...

Use the scenario of a Rolls replacement @ 12000 hours



## Reporting the Activities on Notifications – IW65

Display activities: List of Notifications

S	T	Notifzn	Defect Text	Description of functional location	Activity code text	Activity text
M2	10133601	#2C mill, blocked PF burner corner 3/B	2C MILL PIPING	Repaired (Specify in text)	Cnr3horizontal pipe above Rifle,blocked	
M2	10133601	#2C mill, blocked PF burner corner 3/B	2C MILL PIPING	Inspection carried out	Line checked from nozzle to flap valve.	
M2	10133801	#2C mill, blocked PF burner corner 3/B	2C MILL PIPING	Service (General work)	Cnr 3 Line cleared, no improvement.	
M2	10135111	18" pipe before Corner 5/8 flapbox	2C MILL PIPING	Temporary Repair	Requires staging for full repair access.	
M2	10135111	18" pipe before Corner 5/8 flapbox	2C MILL PIPING	Repaired (Specify in text)	Devcon repair to 18" pipe.	
M2	10004408	#2D Mill Hot air reg. damper	2D MILL HOT AIR DAMPER	Tested	Tested	
M2	10134030	#2D mill, blocked PF burner corner 1/4	2D MILL PIPING	Service (General work)	Pipes hoses out burner to mill.	
M2	10134030	#2D mill, blocked PF burner corner 1/4	2D MILL PIPING	Inspection carried out	Burners not fully blocked.	
M2	10132819	#2D mill, devcon repair transition chute	2D MILL UNIT	Repaired (Specify in text)	Devcon repair to transition chute.	
M2	10003999	Mill DP line leak	2E MILL INSTRUMENTATION	Repaired	Repaired	
M2	10003999	Mill DP line leak	2E MILL INSTRUMENTATION	Dirty/dust ingress	Dirty/dust ingress	
M2	10003999	Mill DP line leak	2E MILL INSTRUMENTATION	Leakage	Leakage	
M3	10132010	2F MILL COAL FEEDER 12000 HR ROUTI...	2F MILL COAL FEEDER	Inspection carried out		
M3	10132010	2F MILL COAL FEEDER 12000 HR ROUTI...	2F MILL COAL FEEDER	Repaired (Specify in text)	Repaires to coal Oil chute.	
M3	10132010	2F MILL COAL FEEDER 12000 HR ROUTI...	2F MILL COAL FEEDER	Service (General work)	General inspection by L Shift.	
M2	10132869	#2F mill, replace 12" seal rubber to pipe	2F MILL PF PIPING TO CORNER 1	Replaced (Specify in text)	PPW replaced seal on 24/6/08.	
M2	10133337	#2F mill, blocked PF burner corner 5/B	2F MILL PIPING	Inspection carried out	Lines cleared to cnr 5/B,blocked nozzles	

Other reports IW30 – Notification Multi Level list & MCI5 – Object Damage analysis



# SAP EAM @ CS Energy, Australia

## Plant Maintenance Process

- Work Management
  - Corrective Maintenance
  - Preventive Maintenance
  - Overhaul / Outage / Opportunity Maintenance
  - Modification Management
  - Permit to Work and JSEA
- To support work management
  - Plant Register – Predominately functional locations with few equipment
  - Bills of Materials – linked to the functional locations in the plant register
  - Work Centres – representing maintainers
  - Task Lists – to represent standard Jobs
  - Preventive Plans – to trigger preventive work orders

## Kogan ck Site Layout



## Interface between Plant Control system and SAP PM

Creating efficiencies through automation of functions including:

- Monitoring of Hours run information and triggering routine maintenance
- Creating PM notifications based on plant condition
- Displaying real-time and historical plant performance metrics in the portal
- Providing a Plant-centric reporting dimension to PM reporting delivered in the SAP portal

• Delivery of Maintenance Transactions via Mobile



• Device details, “ruggedised”, RF capable, Intrinsically safe

• Selected ECC6 transactions delivered on the device to increase the efficiency of the PM group

• Functions include

- Barcode functional location to ensure correct selection of plant item
- Notification, create/change
- Maintenance order, plant history and shop papers
- Confirmations



## Materials Management cont'

- The CS Energy contract register was developed and implemented to hold information on a material or service contract or agreement and monitor the spend against a preset target value

Number	Vend.	Name	Start	End	Target value	Actual costs
480734	11022	GLCEENMARK	01.07.2004	30.06.2005	107,635.00	38,687.00



# SAP EAM @ Iberdrola, Spain/LA



## Iberdrola Hydro Power



- Hydrographical basins 4
- Power stations 73
- Generating units 179
- Dams 56
- Installed capacity
  - Generating 8,230 MW
  - Pumping 2,347 MW
- Avg. Production 13,823 GWh
- Employees 682



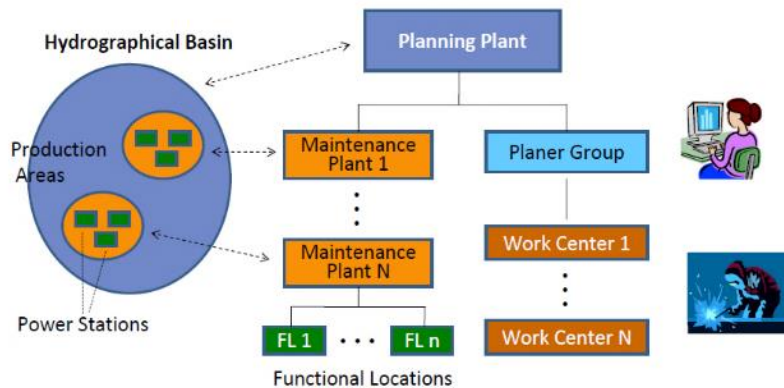
70 power stations w 170 units, 8000MW, 680 staff, 200 users, 16.000 orders per year, task list per plant, monthly schedules, planning plant per hydrographical basin

## SAP EAM implementation

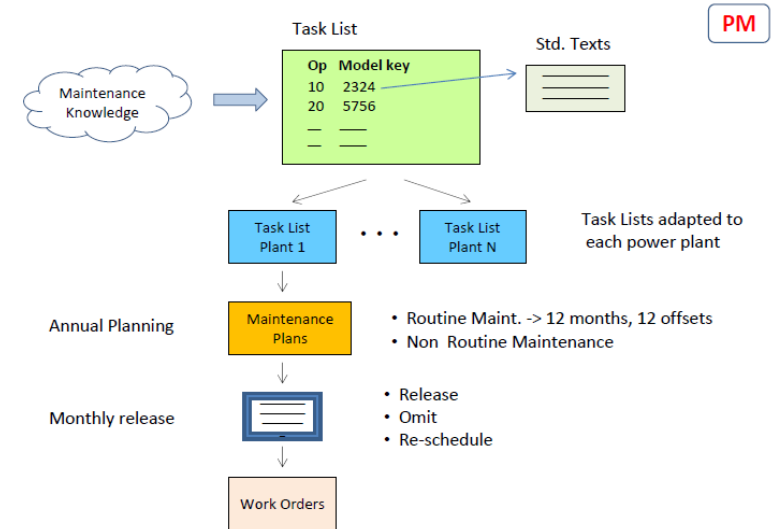


Generation type	Plants	Users	Maintenance Orders/year
Nuclear	1	300	29.200
Thermal	6	260	36.400
Combined Cycle	12	340	86.400
Spain	7		
Mexico & Brazil	5		
<b>Hydro</b>	<b>73</b>	<b>215</b>	<b>15.900</b>
≥ 100 MW	12		
≥ 10 MW < 100 MW	61		
		<b>1.115</b>	<b>167.900</b>

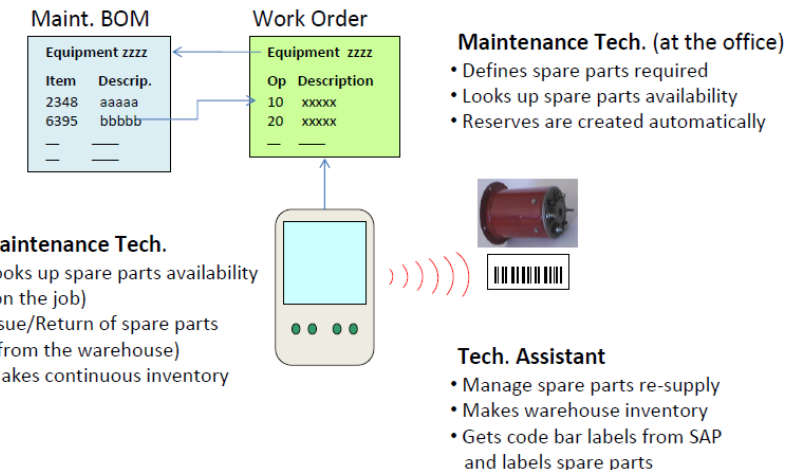
## Maintenance organization with SAP EAM



## Planned Maintenance



## Spare parts management



# SAP EAM @ West Burton CCGT EDF Energy, UK

PAS55 Asset Management Standard at CCG. Core EAM. Scada interface.

## EDF Energy West Burton CCGT



Combined Cycle Gas Turbine – West Burton B

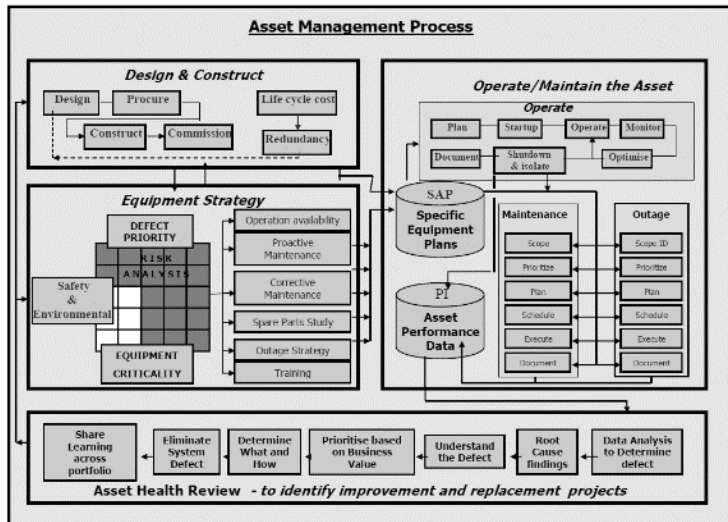
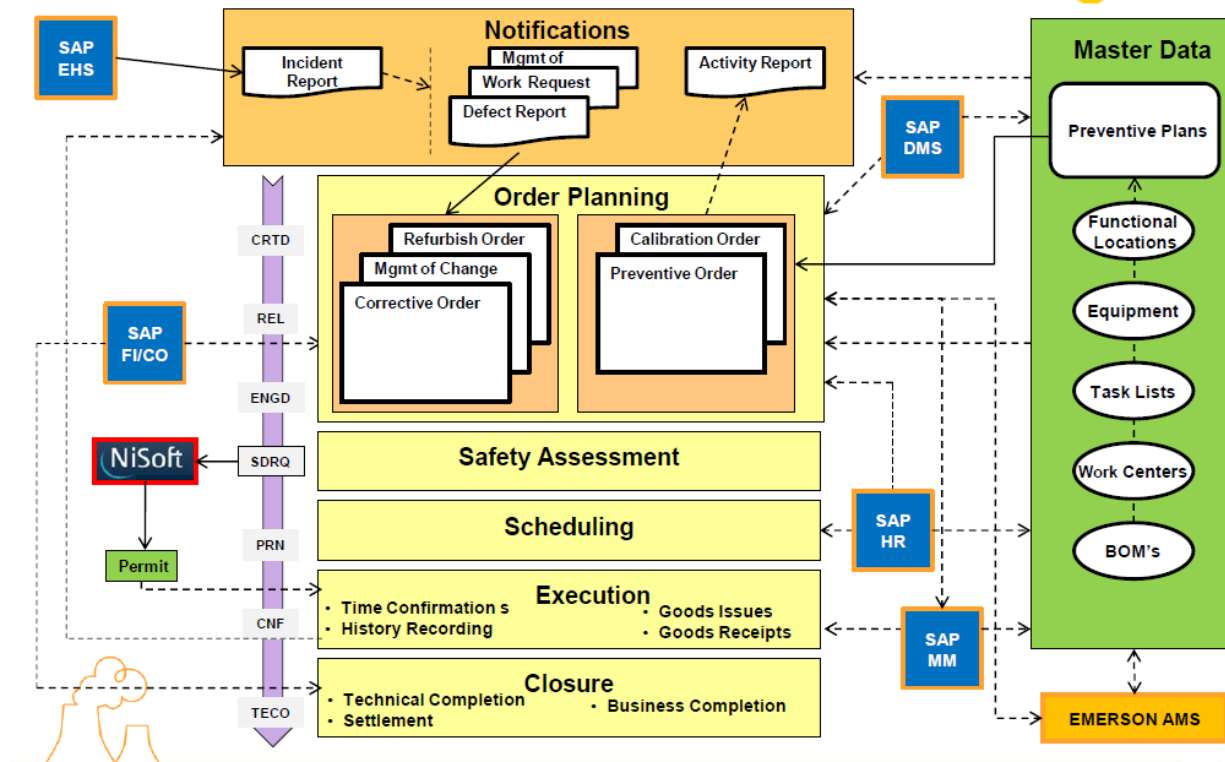


### About West Burton

A new 3 unit 1440MW Combined Cycle Gas Turbine (CCGT) plant on land next to the current West Burton coal fired power station

The power station is served by a 20 km gas pipeline connection to the National Grid National Transmission System (NTS) at Grayingham Lincolnshire.

## Maintenance Solution Overview



# Example of Shift Book Project Implementation at Thermal Power Plant

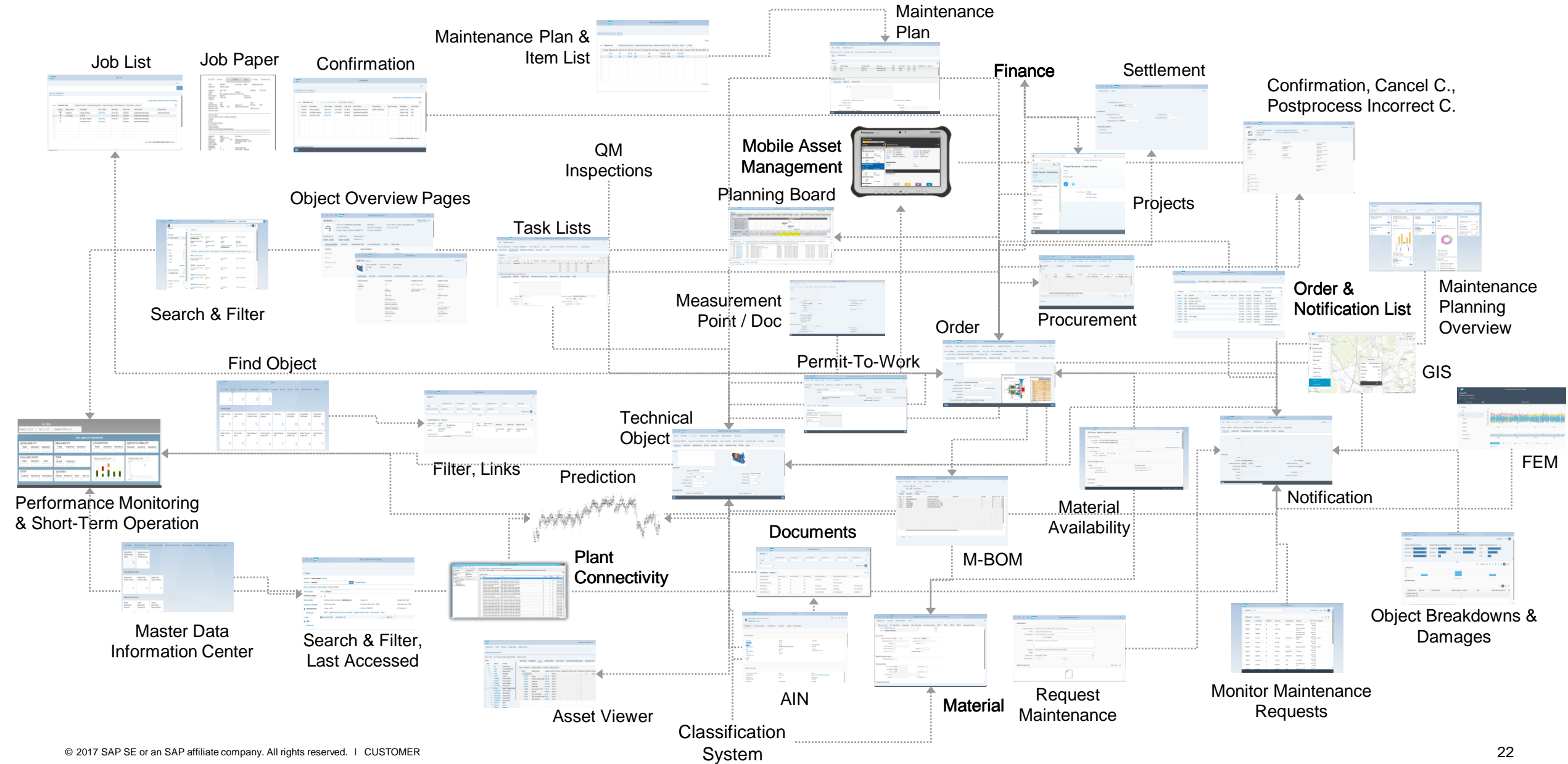
The screenshot displays the SAP Shift Book Project Implementation interface. At the top, there are buttons for 'Aktualisieren' and 'Close Shift', and a 'Dokumentation' icon. The main area is divided into two panels: 'Schichtnotizen' (Shift Notes) on the left and 'Schichtinformationen' (Shift Information) on the right. The 'Schichtinformationen' panel includes fields for 'Work Center', 'Shift Start' (14.09.2016, 19:57:25), and a table for 'Role' and 'Name' with entries for 'Schichtleiter' and 'Schichtmitarbeiter'. Below these panels is a navigation bar with tabs for 'Shift Events', 'Defects', 'Shift Notes', 'Safety Cert', 'W Permit', and 'Measure'. The 'Shift Events' tab is active, showing a table of shift events with columns for Notification, Description, Code, Code Group, Sys Stat, KKS, Plotz, Description, and Date.

Notification	Description	Code	Code Group	sSys Stat	KKS	Plotz	Description	Date
11205083	Generaltest Schichtler...	Zustandsmeldung	Freischaltungen	MOFN	180-LI-A0 PAE20 AA...		Durchgangsventil (allg)	14.09.2016
11205089	Nico ist schuld	Feuer aus	GuD-Betrieb	MOFN	180-LI-A0 QKN14 AP...		Pumpe VL RLT GEA 1 Versorgung	09.09.2016...
11205097	Bingers Test	Freischaltung	Freischaltungen	MOFN	180-LI-A0 QKN14 AP...		Pumpe VL RLT GEA 1 Versorgung	07.09.2016...
11205084	Speisewasserpumpe	Freischaltungsauftrag	Freischaltungen	MOFN	180-LI-A0 QL820		Speisewasser	04.09.2016...
11205082	Test 19 Uhr 48	Störung	GuD-Betrieb	MOFN	180-LI		Heizkraftwerk Lichterfelde - Neubau	05.09.2016...
11205079	Kühlwassertemp. sch...	Störung	GuD-Betrieb	MOFN	180-LI-A0 NDC10 AP...		Kühlwasserpumpe 1	05.09.2016...
11205076	Test 15 Uhr 08	Probelauf	Freischaltungen	MOFN	180-LI		Heizkraftwerk Lichterfelde - Neubau	05.09.2016...
11205074	Test Melder	Feuer aus	GuD-Betrieb	MOFN	180-LI		Heizkraftwerk Lichterfelde - Neubau	05.09.2016...
11205070	Dokumententest	Feuer aus	GuD-Betrieb	MOFN	180-LI-A2 CB		Funktionsgruppensteuerung, Teilst...	05.09.2016
11205065	Kühlwasser zu hoch	Anlageninformation	GuD-Betrieb	MOFN	180-LI-A0 NDC10 AP...		Kühlwasserpumpe 2	03.09.2016
11205082	Test anlegen Dokum...	Zustandsmeldung	Freischaltungen	MOFN	180-LI-A0 GMA10 A...		Rückschlagklappe	02.09.2016
11205060	Peter Sarrig ist da	Störung	GuD-Betrieb	MOFN	180-LI-A0 GMA30 A...		Filtsigelspumpe, allg.	02.09.2016
11205055	Test 13 Uhr 31 Kowalski	Feuer aus	GuD-Betrieb	MOFN	180-LI-A0 GH010 AP...		Filtsigelspumpe, allg.	02.09.2016

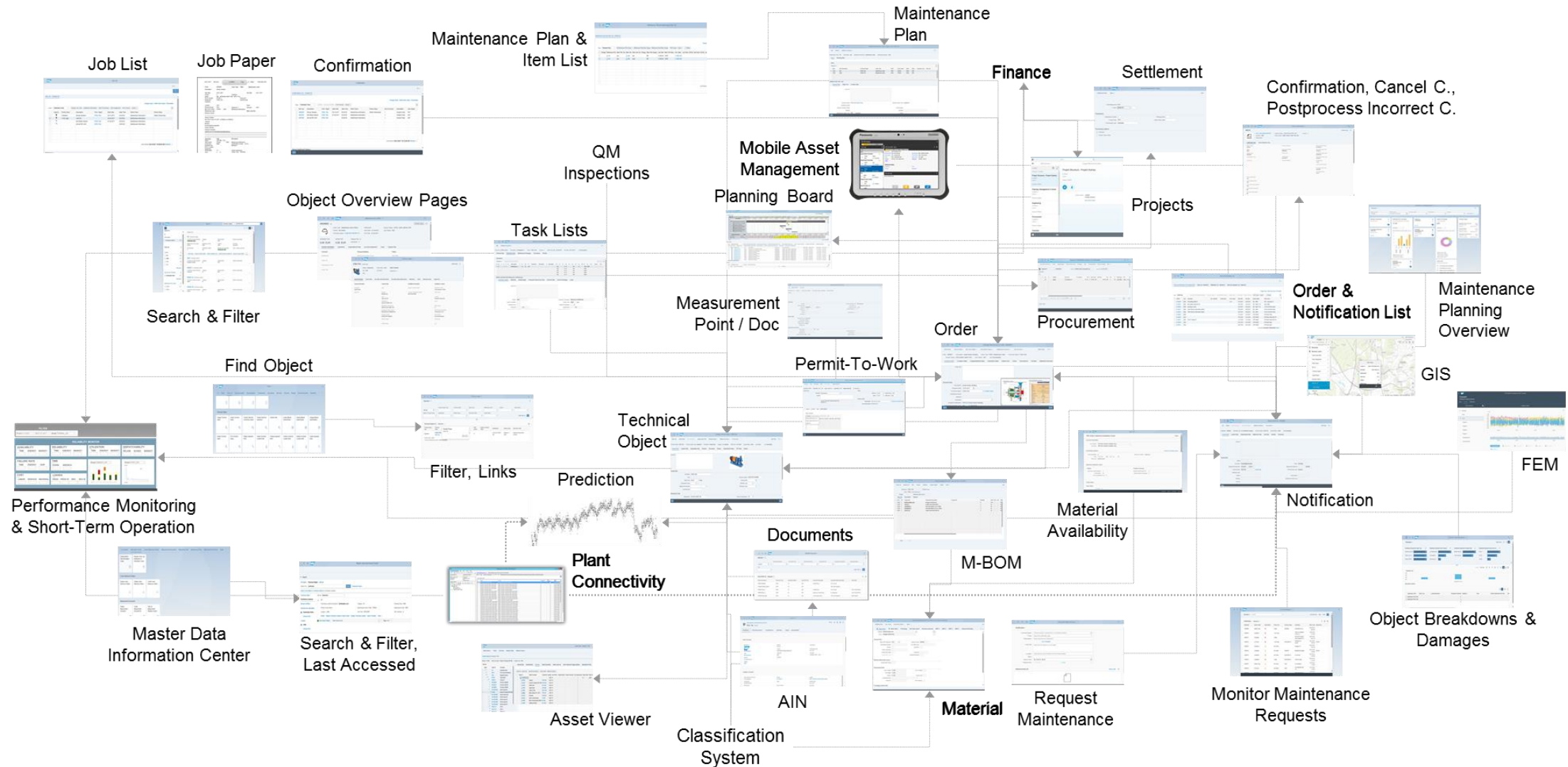
# **Integrated O&M Solution**

# An Integrated O&M System for Power Generation Companies

Animated



# An Integrated O&M System for Power Generation Companies



# Core EAM with SAP

## Major Repairs and Shutdowns

- PROJECT
- WBS
- NETWORK

## Work Safety

- SAFETY PLAN
- PERMITS
- SAFETY CERTIFICATES

## Shift Book

- SHIFT NOTES
- SHIFT REPORT

## Maintenance Planning

- REVISIONS
- TASK LISTS
- MAINTENANCE ITEM
- MAINTENANCE PLAN
- MAINTENANCE STRATEGY

## Technical Object

- FUNCTIONAL LOCATION
- EQUIPMENT
- MEASUREMENT POINT

## Tools / QM

- INSPECTION LOT

## Order

- ORGANIZATION
- OPERATION
- OBJECTS
- COSTS
- DOCUMENTS
- PERMITS

## Procurement Integration

- AGREEMENT
- PURCHASE ORDER
- SERVICE MASTER
- SERVICE ENTRY SHEET

## HCM Integration

- CAPACITY PLANNING
- QUALIFICATIONS
- RESPONSIBILITIES

## Search & Information Centers

- ORDERS
- NOTIFICATIONS
- TECHNICAL OBJECTS

## Reports

- ORDER HISTORY
- LOCATION ANALYSIS
- MAINTENANCE ITEM SIM
- SIDE PANEL CONTENT
- PROJECT STRUCTURE

## Documentation

- DOCUMENT INFO RECORD
- ORIGINALS
- OBJECT LINK

## Classification

- CLASS
- CHARACTERISTICS

## Confirmation

- JOB LIST
- CONFIRMATION

## Notification

- ORGANIZATION
- MALFUNCTION
- TASK
- ACTIVITIES
- DOCUMENTS

## Materials Integration Org. & Finance Integration

- COMPONENTS
- MAINT BOM
- SERIAL NO
- MATERIAL MASTER
- MRP
- INVENTORY
- PRT

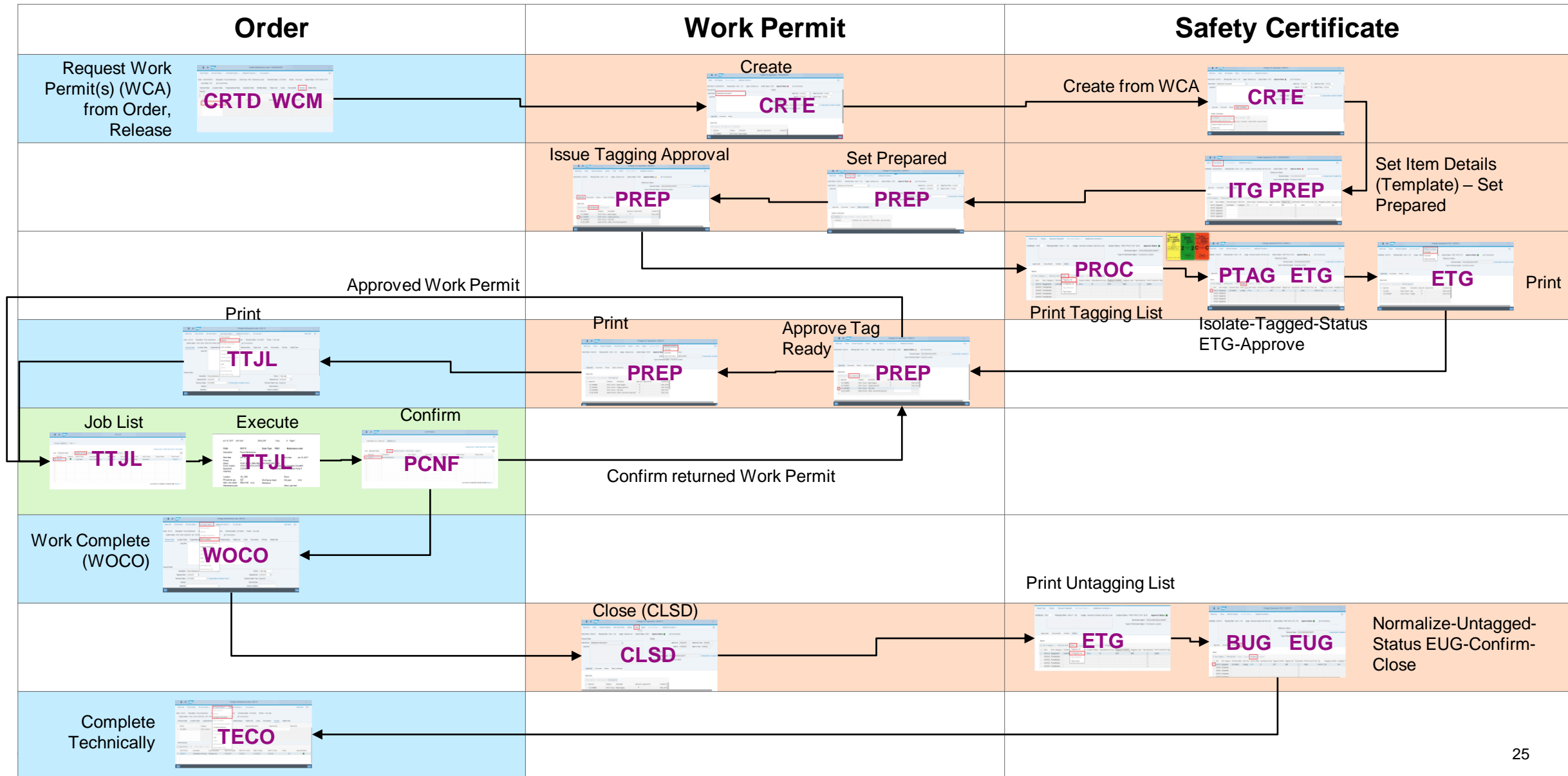
- CONTROLLING
- BUSINESS PARTNER
- LOCATION

## Core Maintenance Processes



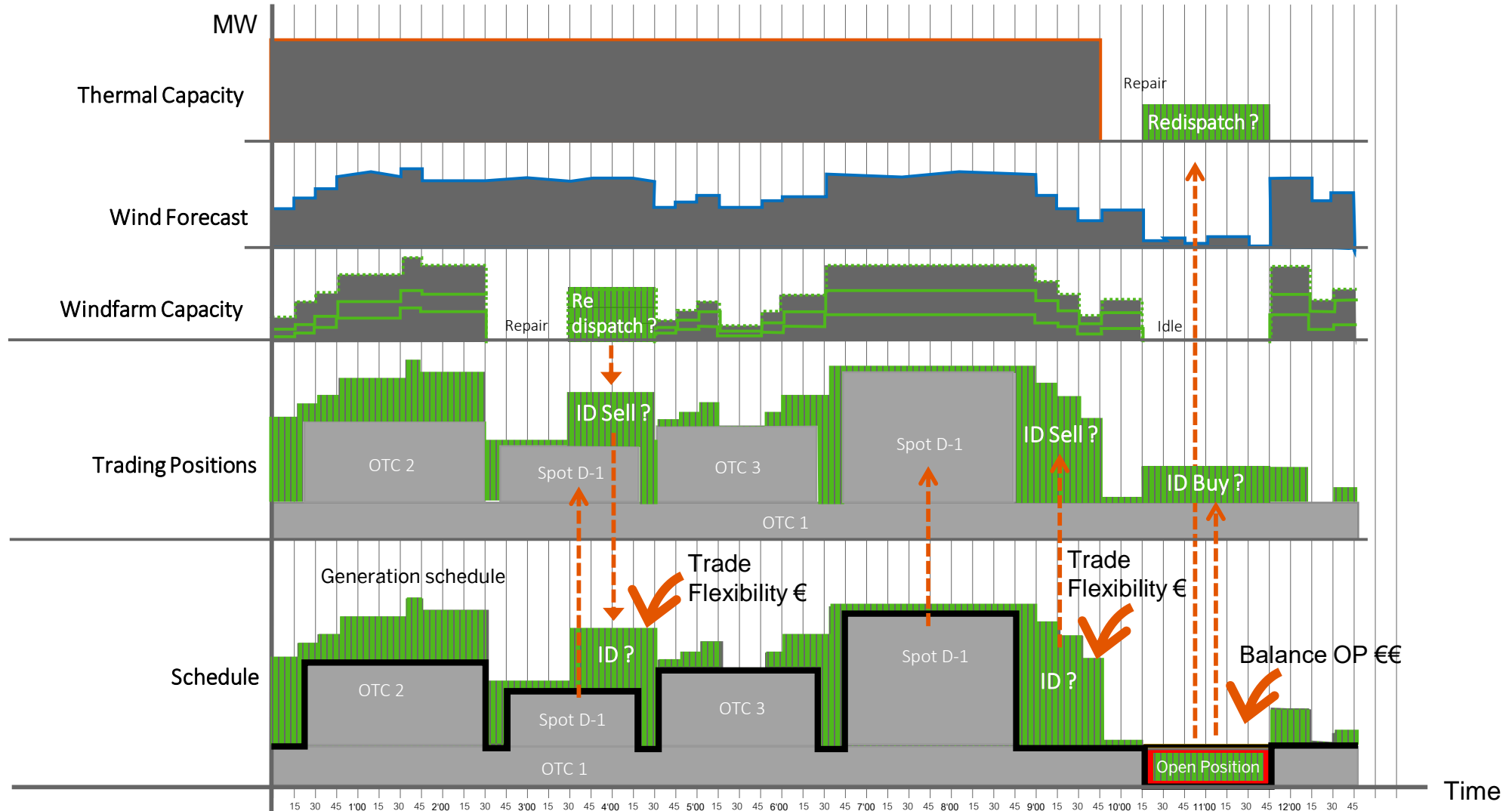


# Permit To Work Scenario

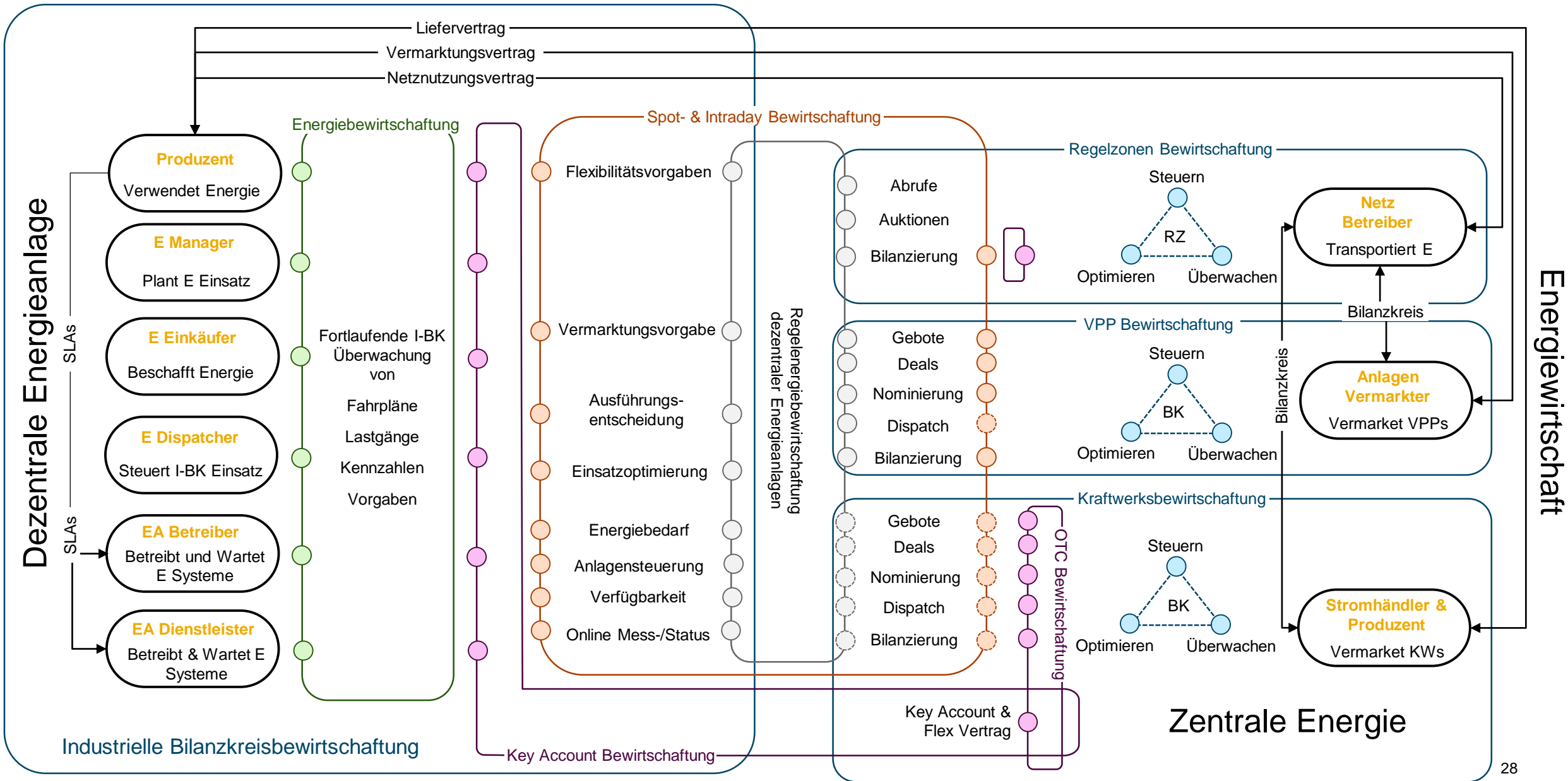


# **Reliability & Schedule Operations Prototype (Merchant & Industrial Energy Hub)**

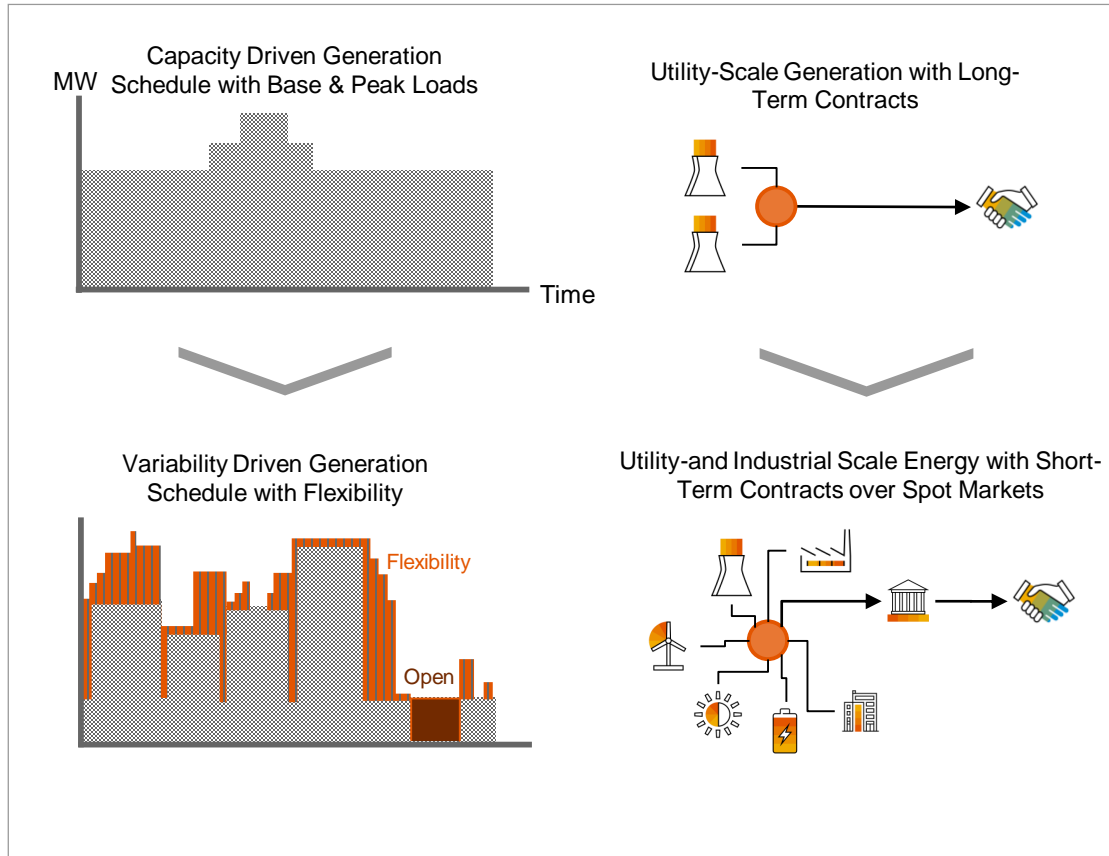
# Illustration of Short-Term Optimization



# Aspects of Balance Group Management



# Economic Short-Term Operation and Market Integration of Utility- and Industrial Scale Energy Resources



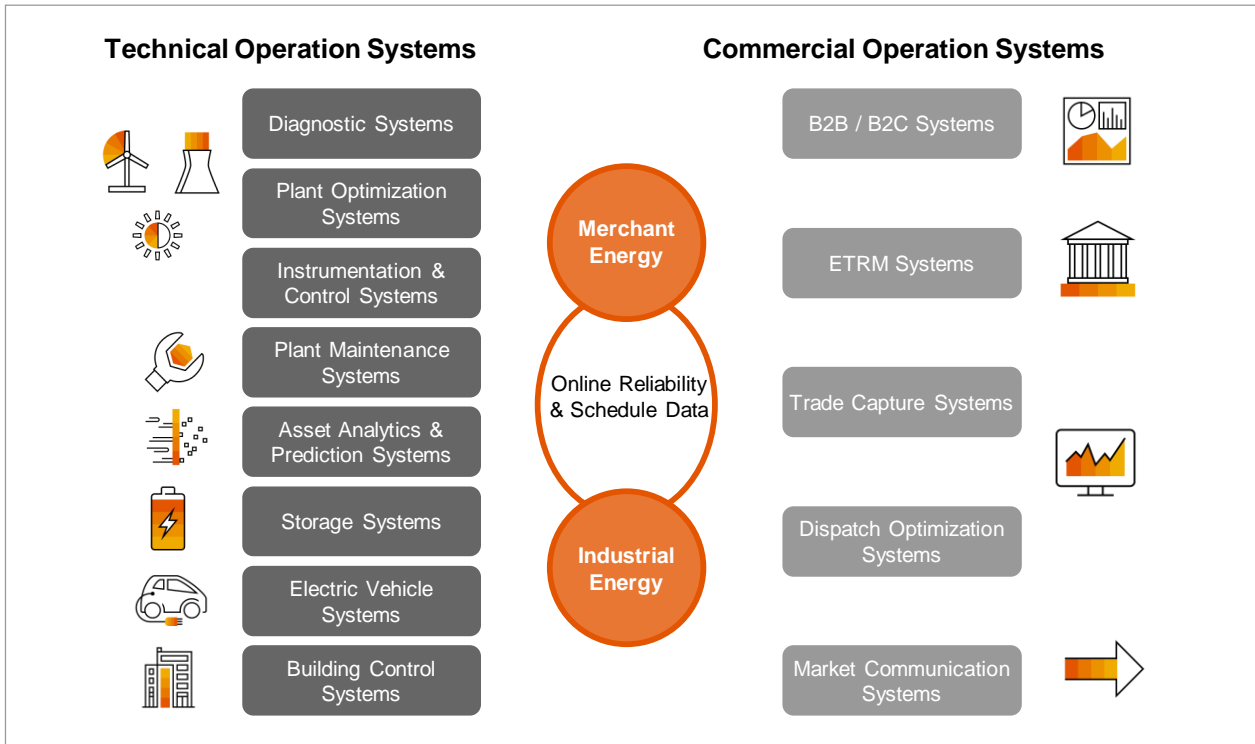
## Continuous balancing of reliability, schedule and trading data in order to commercially integrate and operate utility- and industrial scale energy resources

Decarbonization is the main driver for renewable support policies. Large-scale wind and solar additions are changing the economics and mechanisms of power markets. Same time as they add new market capacity, they are also adding generation variability and price volatility, and due to policy-support achieve favorable margins. This is leaving capacity-designed generation units with insufficient full load hours moving them beyond the merit order clearing price.

Over time, industrial-scale decentral energy resources will be integrated into energy markets and become active portfolio positions of traders and merchants – virtual power plant portfolios combined with utility-scale generation portfolios. Consequently, generation and trading schedules are transforming from simple base-peak load shapes into highly variable curves with flexibilities and open positions. As response, short-term operation and market integration strategies need to be put in place. They require a continuous balancing of reliability, schedule and trading data in order to commercially integrate and operate utility- and industrial scale energy resources.

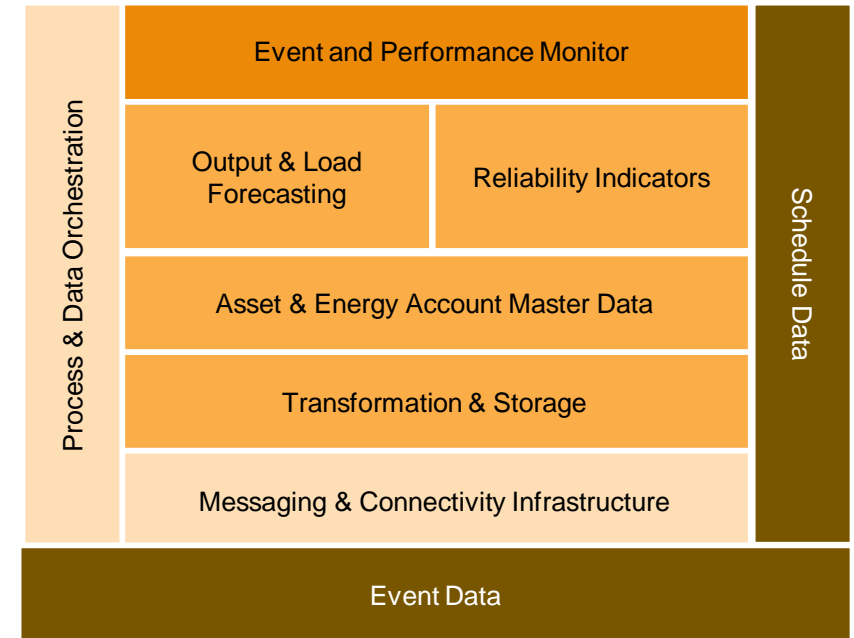
# Interfaces & Building Blocks

## Online Reliability & Schedule Data between Domain Expert Systems

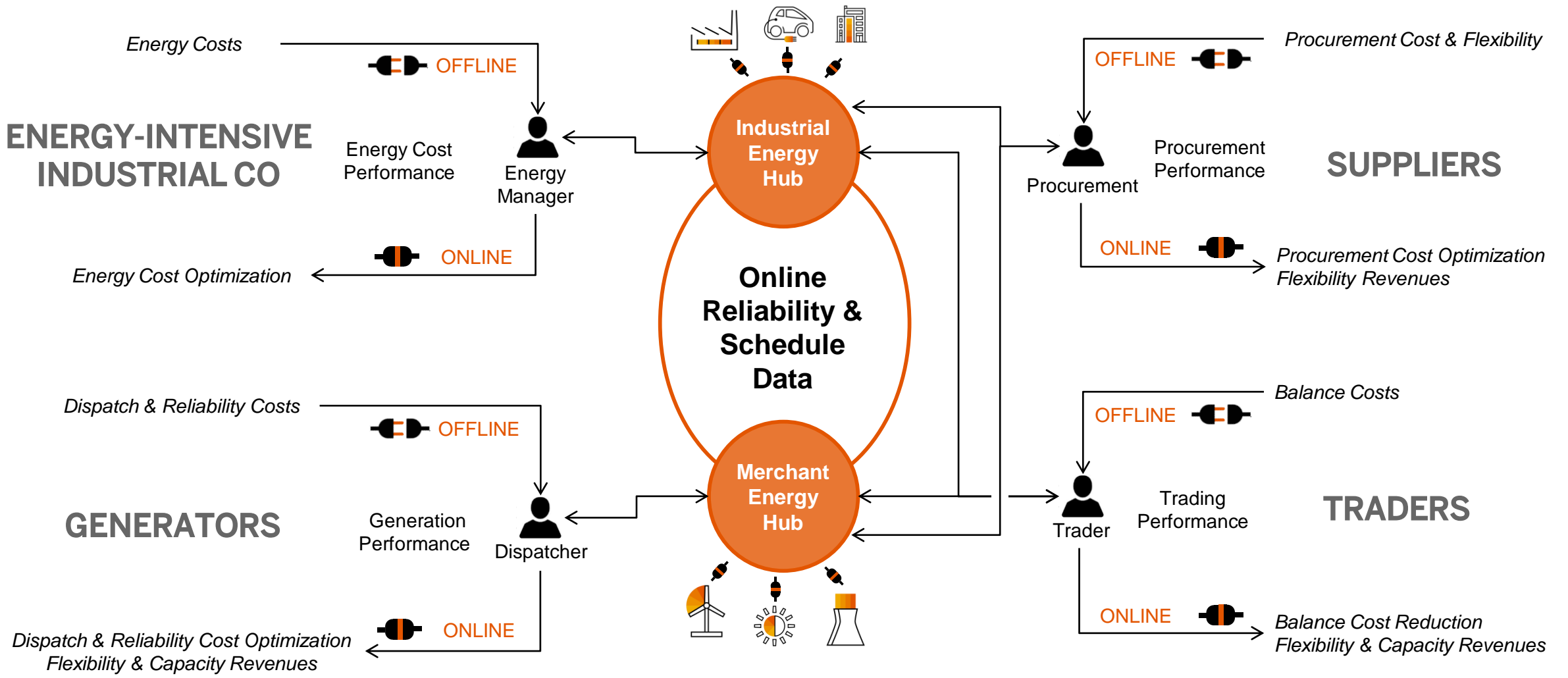


## Building Blocks

Key ONLINE capabilities include a messaging enabled display of event and performance data, calculation of reliability indicators from event to portfolio level, short-term output and load forecasting on machine and maintenance data using predictive technologies, matching of asset with energy account domains, transformation of control, maintenance, weather, plant, deal, and energy data into reliability and schedule time series, messaging and connectivity to technical and commercial domain expert systems, as well as an overall process and data orchestration.

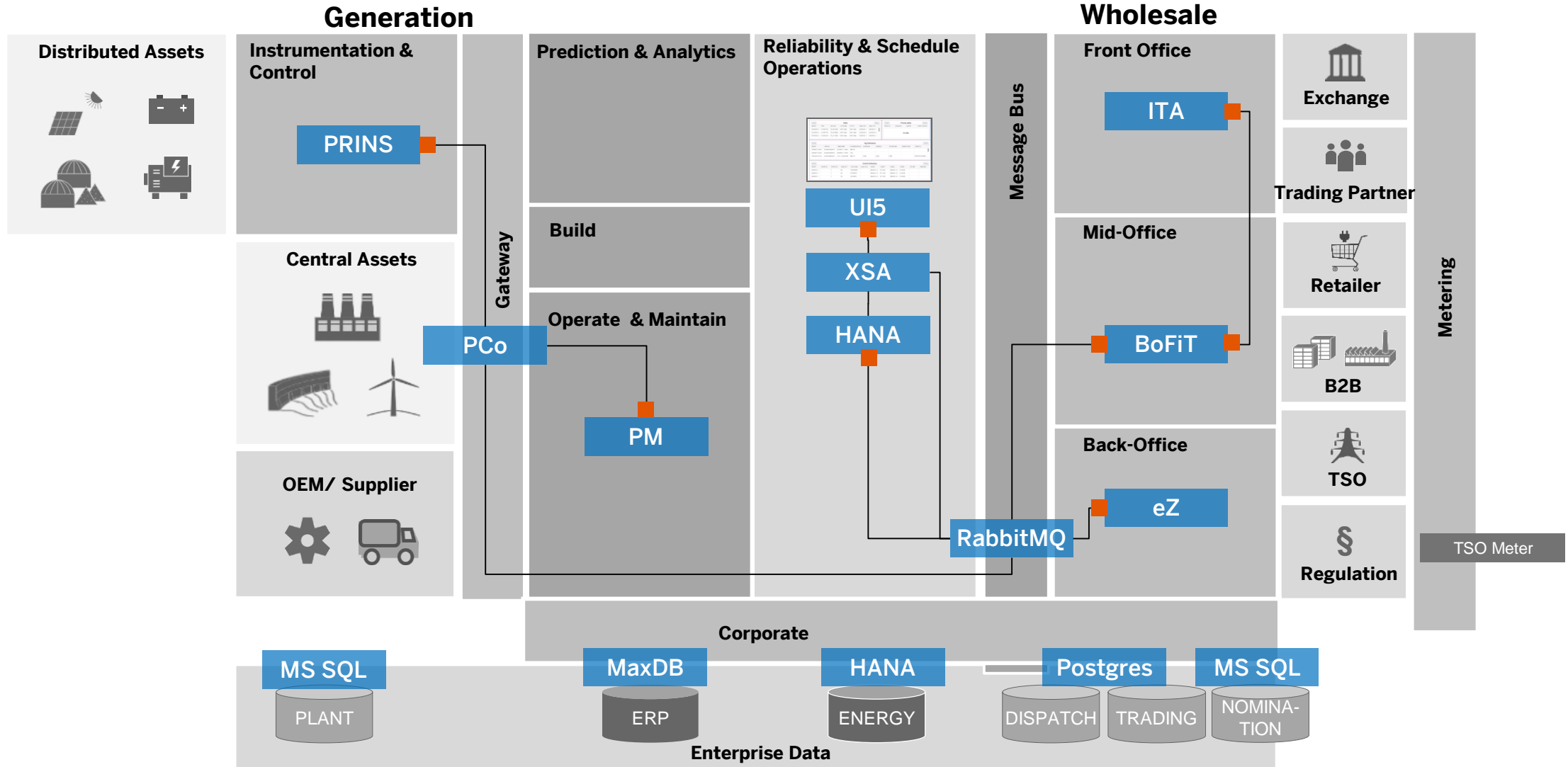


# Online Reliability and Schedule Data for Economic Short-Term Operation and Market integration of Power Production and Energy Facilities



# Data Flow

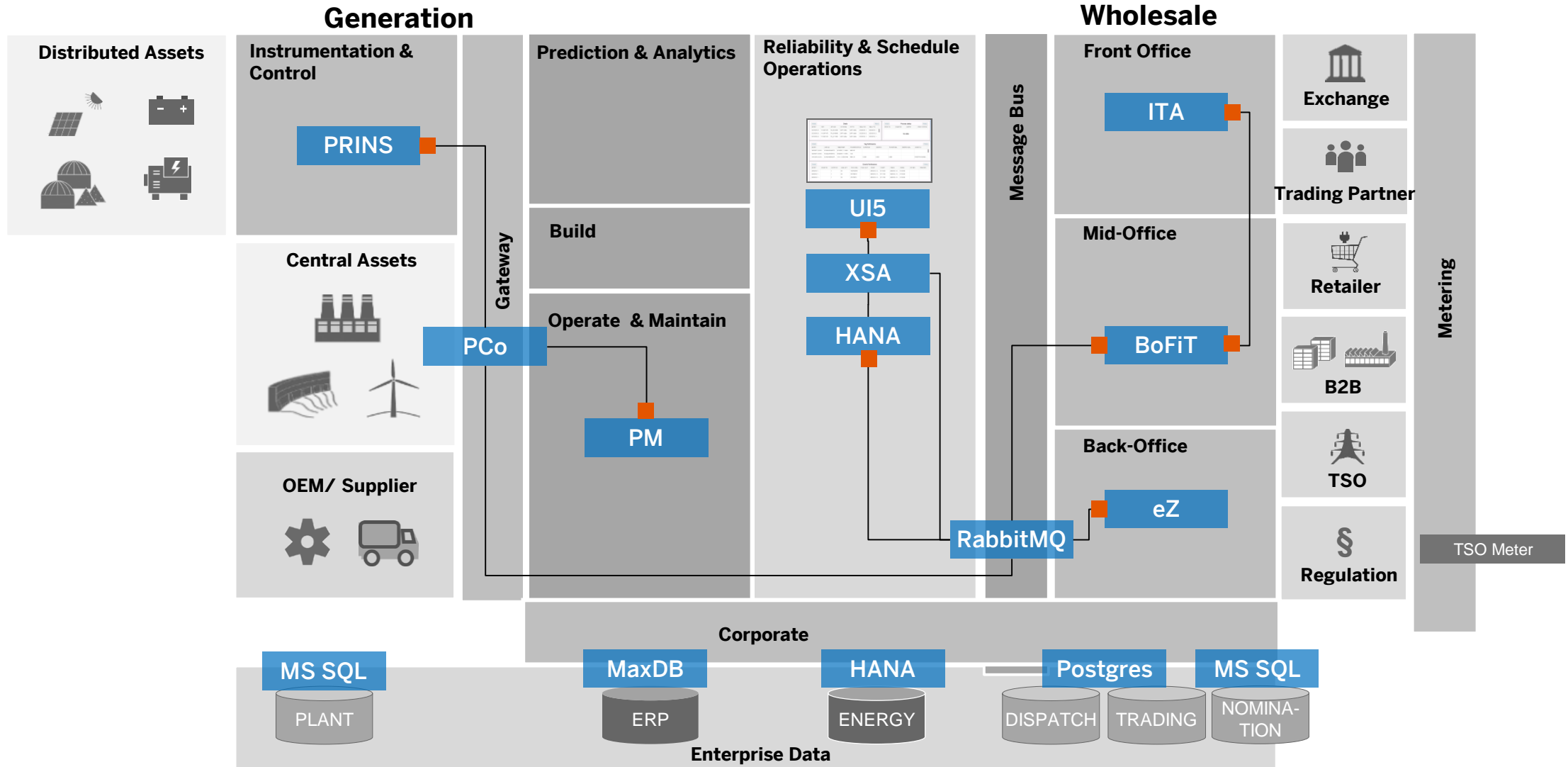
Blueprinting & Prototyping





# Data Flow

Blueprinting & Prototyping



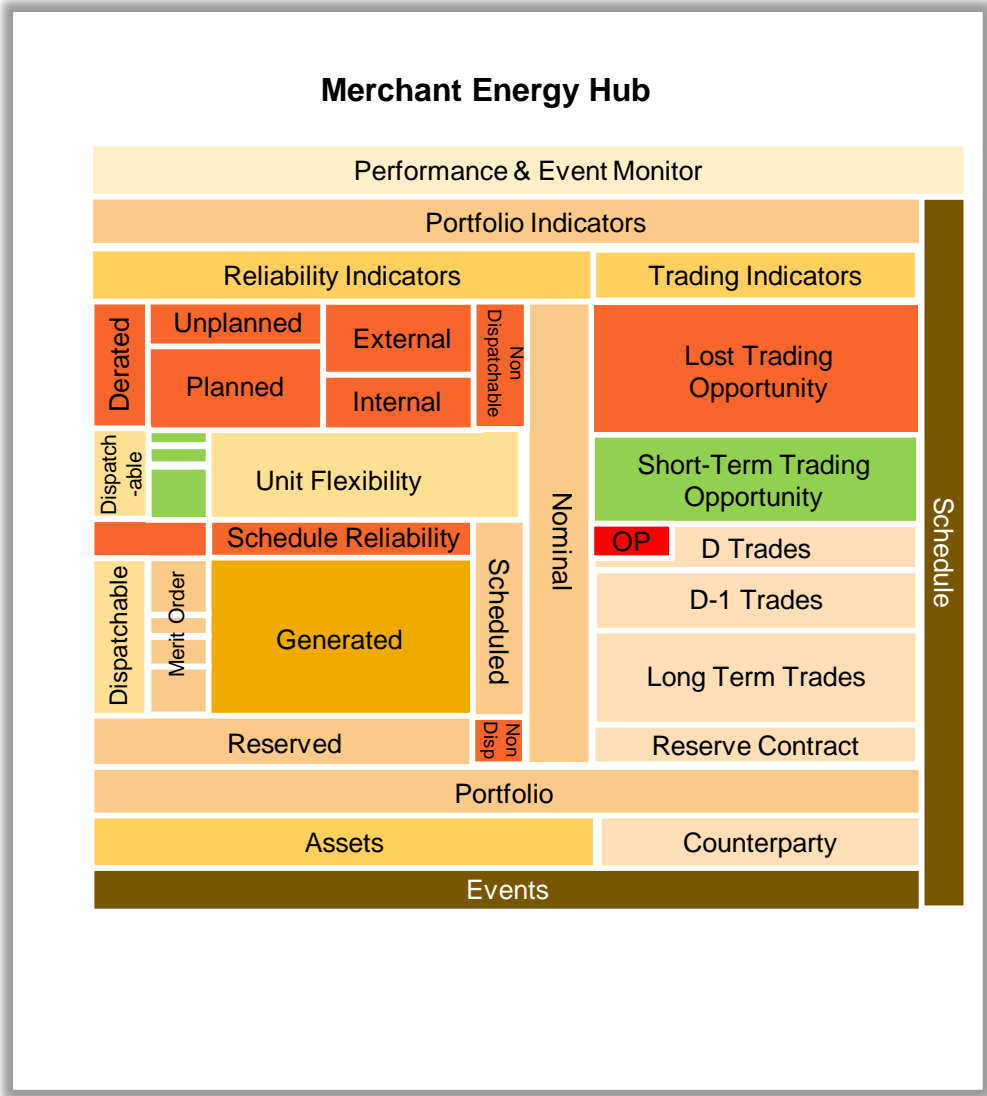
# Example: VGB Indicators

Availability indicators		Reliability & dispatchability indicators		Utilization	
Time availability	$k_t = \frac{t_v}{t_N} = \frac{t_N - t_{nv}}{t_N}$ $t_N$ Reference period $t_v$ Available time $t_{nv}$ Unavailable time	Time reliability	$w_t = \frac{t_B}{t_B + t_{nvun}}$ $t_B$ Operating time $t_v$ Available time $t_{nvun}$ Unplanned not postponable unavailable time	Time utilization	$n_t = \frac{t_B}{t_N}$ $t_B$ Operating time $t_N$ Reference period
Time availability peak times	$k_{tPe} = \frac{t_{vPe}}{t_{NPe}} = \frac{t_{NPe} - t_{nvPe}}{t_{NPe}}$ $t_{NPe}$ Peak time ref. per. $t_{vPe}$ Avail. peak time $t_{nvPe}$ Unavail. peak time				
Energy availability	$k_W = \frac{W_v}{W_N} = \frac{W_N - W_{nv}}{P_N \cdot t_N}$ $W_N$ Nominal energy $W_v$ Available energy $W_{nv}$ Unavailable energy $P_N$ Nominal capacity	Energy reliability	$w_v = \frac{W_B}{W_B + W_{nvun}}$ $W_B$ Generated energy $t_v$ Available time $W_{nvun}$ Unplanned not postponable unavailable energy	Energy utilization/ w neg. balancing energy	$n_W = \frac{W_B}{W_N} = \frac{W_B}{P_N \cdot t_N}$ $n_W = \frac{W_B + WRd}{W_N} = \frac{W_B + WRd}{P_N \cdot t_N}$ $W_B$ Generated energy $W_N$ Nominal energy $t_N$ Reference period $P_N$ Nominal capacity $WRd$ Balancing energy
Market-assessed availability	$k_m = \frac{\sum_{i=1...N} (W_{Ni} - W_{nv,i}) \cdot DB_i}{\sum_{i=1...N} W_{Ni} \cdot DB_i}$ $W_N$ Nominal energy $W_{nv}$ Unavailable energy $DB_i$ Contribution margin	Market-assessed reliability	$r_m = 1 - \frac{\sum ( W_{Bi} - W_{Fpi} ) \cdot DB_i}{\sum W_{Fpi} \cdot DB_i}$ $W_{Fp}$ Schedule energy $W_B$ Generated energy $DB$ Contribution margin	Market-assessed utilization	$n_{Wm} = \frac{\sum_{i=1...N} (W_{B,i}) W_{B,i} \cdot DB_i}{\sum_{i=1...N} W_{N,i} \cdot DB_i}$ $W_B$ Generated energy $W_N$ Nominal energy $DB$ Contribution margin
Time UA Base/peak	$k_{tn} = 1 - k_t$ $(k_{tnPe} = 1 - k_{tPe})$ $k_t$ Time availability $k_{WPe}$ Time avail peak	Dispatch reliability	$p_v = \frac{W_B}{W_B + W_{nvun} + W_{ns}}$ $W_B$ Generated energy $W_{nvun}$ Unplanned not postponable unavailable energy $W_{ns}$ Available unproductive energy (external)		
Energy UA Base/peak	$k_{Wn} = 1 - k_W$ $(k_{WnPe} = 1 - k_{WPe})$ $k_W$ Energy availability $k_{WPe}$ Energy avail peak	Schedule constancy	$f_{Fp} = \frac{W_B}{W_{Fp}}$ $W_B$ Generated energy $W_{Fp}$ Schedule energy	<b>Failure rate</b>	
		Dispatchability	$k_b = \frac{W_b}{W_N} = \frac{W_N - W_{nv} - W_{ns}}{W_N}$ $W_N$ Nominal energy $W_b$ Dispatchable energy $W_{nv}$ Unavailable energy $W_{ns}$ Available unproductive energy (external)	Time failure rate	$p_t = \frac{t_{nvu}}{t_{nvu} + t_B}$ $t_B$ Operating time $t_{nvu}$ Unplanned unavailable time
		Market-assessed dispatchability	$k_{bm} = \frac{\sum_{i=1...N} (W_{N,i} - W_{nv,i} - W_{ns,i}) \cdot DB + i}{\sum_{i=1...N} W_{N,i} \cdot DB + i}$ Contribution margin, only positive, otherwise 0	Energy failure rate	$p_w = \frac{W_{nvu}}{W_{nvu} + W_B}$ $W_{nvu}$ Unplanned unavailable energy $W_B$ Generated energy
		Start-up reliability	$z = \frac{s_e}{s_e + s_n}$ $s_e$ # successful starts $s_n$ # unsuccessful starts	Dispatching (energy) failure rate	$p_l = \frac{W_{nvun}}{W_{nvun} + W_{ns} + W_B}$ $W_{nvun}$ Unplanned not postponable unavailable energy $W_{ns}$ Available unproductive energy (external) $W_B$ Generated energy

# Performance Indicators

Blueprinting & Prototyping

<b>NOMINAL POWER</b>	Highest continuous output capability of a unit without damage at certain operating conditions. Provided by manufacturer specification
<b>DERATED POWER</b>	A partial reduction in the output capability of a unit due to planned and unplanned events. Derated output value is assessed and captured in maintenance notification (independent from Live Portfolio Hub).
<b>DISPATCHABLE_POWER_I</b>	Output capability of the unit considering calculated schedule deviations from produced power (+/-) and deducting reserved power. Online model "agnostic" of derated power values captured in maintenance notification. Deviations includes derating events. Difference between Dispatchable Power I and II expresses the unit capability to follow the schedule.
<b>DISPATCHABLE_POWER_II</b>	Output capability of the unit deducting derated power captured in maintenance notification and deducting reserved power. See also Dispatchable Power I
<b>NON_DISPATCHABLE_POWER</b>	Amount of non-available unit output capability consisting of negative Schedule Reliability and Reserved Power (Dispatchable I) and Derated and Reserved Power (Dispatchable II).
<b>UNIT_FLEXIBILITY_POWER</b>	Amount of available unit output capability not yet scheduled, non-available, and reserved. View depending on Dispatchable I and II. May represent short-term trading opportunity.
<b>SCHEDULED_POWER</b>	Planned output capability of a unit according to trading needs (short/mid/long-term). Economically optimized for merit-order.
<b>SCHEDULE_RELIABILITY_POWER</b>	Difference between produced and scheduled power. Target = "0". + more / - less power is produced than scheduled. Effect to balancing and grid connection costs.
<b>GENERATED_ANTICIPATED_POWER</b>	Produced (measured) and forecasted output capability of a unit. Forecast based on online event, proximity, and machine learning methods.
<b>RESERVED_POWER</b>	Power which is not available for open trading and economic scheduling. Reserved power are stored as Deals.



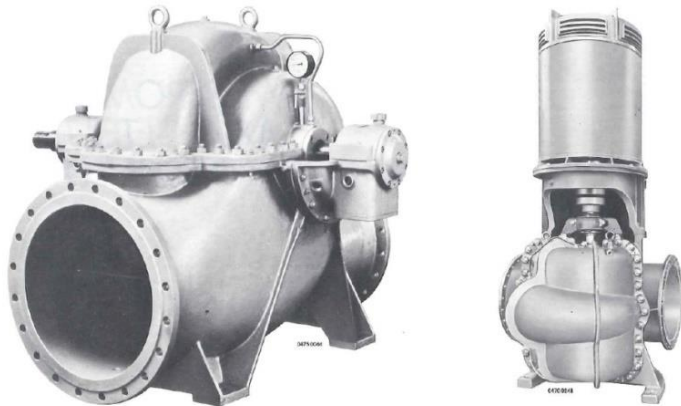
# **Exploring District Heating Pump Degradation & Revision Cycles**

# Plant Analytics & Prediction: Exploring District Heating Pump Degradation and Revision Cycles

PoC /  
Exploration

SAP is currently exploring data-driven analytics and prediction for a heating pump scenario in order to evaluate degradation and revision cycle related useful life hours.

## Parallel Operation of Dual Stream Axially Split Casing Pump



### Customer Business Case

- Optimize Number of Major Revisions over Pump Lifetime
- Reduce Pump Degradation Occurrences
- Minimize Costs for Infrastructure Extension and External Services
- Capture Pump Operation Knowledge

### 10 Min Schema

Expressing pump sensor values and physical pump formulas over 10 minute timestamps

### Q Schema

Expressing 10 Min Schema over volume flow sections on daily values

### Heat Map

Expressing useful life hours over volume flow sections and years

### Targets

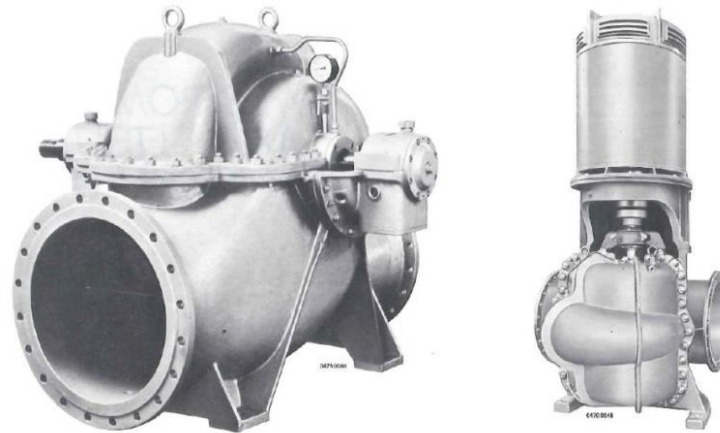
- Revision Cycle on Useful Life Hours
- Degradation Factor per Volume Flow Section
- Gap Loss Factor

# Input Parameter

PoC / Exploration

Sensors	UoM
Volume Flow	m3/h
Revolutions	1/min
Inlet Flow Temperature Water	°C
Return Flow Temperature Water	°C
Pressure In Front	bar
Pressure After	bar
Vibration (e.g. bearing)	m/s
Operation Hours	h

Formulas	UoM	
$NPSH_{REQ}$	Regression on Pump Curve $NPSH = f(Q)$	m
$NPSH_{AVAIL}$	Pressure suction, Density, Gravity	m
$Q_{IDEAL}$	Regression on Pump Curve $H = f(Q)$	m3/h
Density	Regression on Density Curve	kg/m3



## Pump Specifications

$NPSH = f(Q)$
$H = f(Q)$

## Maintenance Events

Revision
Repairs
Regular
Inspection

## Historic Data

At least 1 year
1 minute equidistant resolution

# Thank you.

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