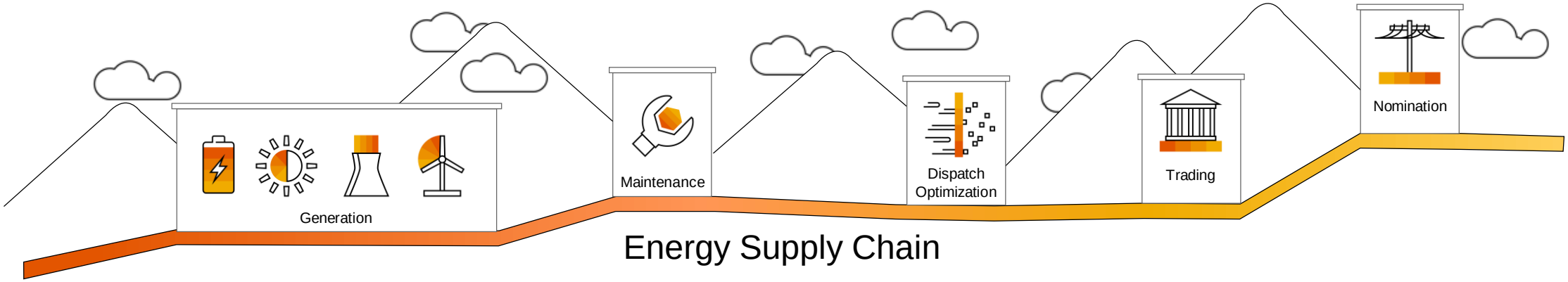

Power Generation with SAP

Michael Lutz, SAP
May, 2018

CUSTOMER

SAP Run Simple

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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

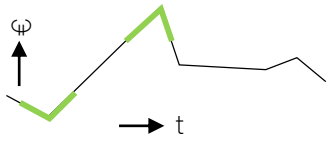
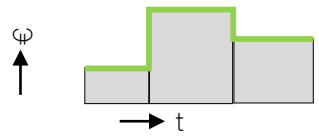
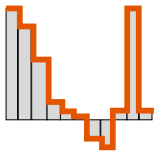
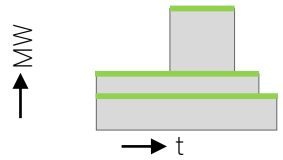
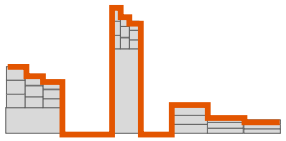
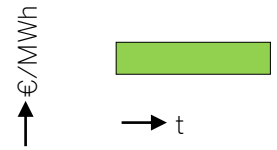
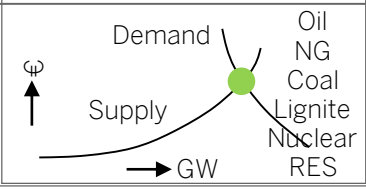
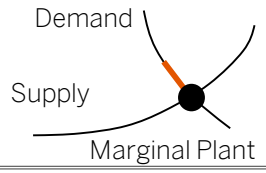
c. Reliability Performance & Schedule Operation Prototype with Procom (Merchant & Industrial Energy Hub)

d. Pump Degradation Analysis & Prediction Prototype

e. Integrated Wind Turbine Event Cost Analysis

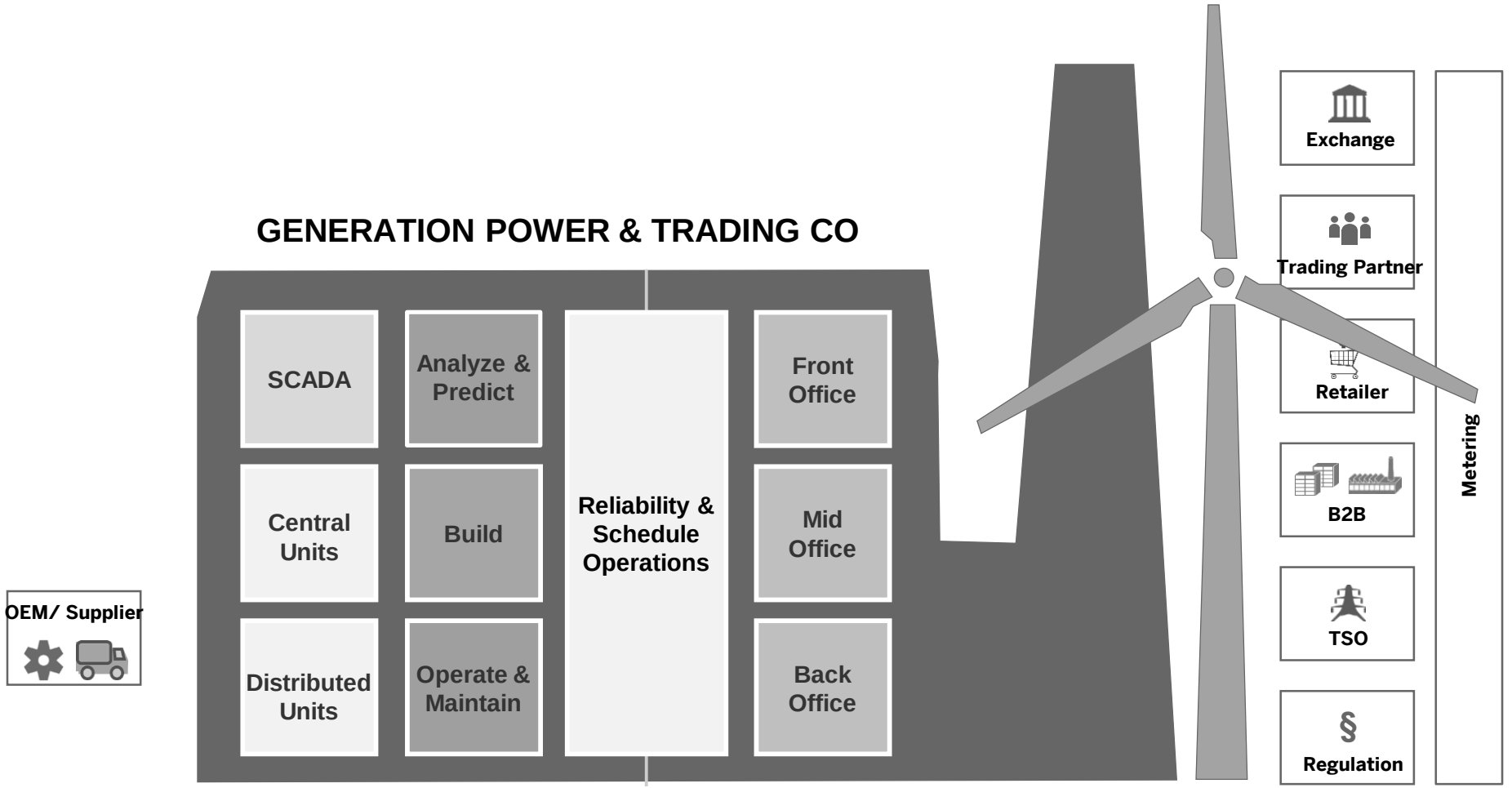
Market Observations

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 Continuous need for balancing plants Higher wear & tear of conventional plants
Balance Price			More balancing risk exposure	
Schedule			More variability	
Spread			Contribution margin does not cover capex and fixed opex	**Call for Action** Adapt portfolio strategy and operations more short-term Adapt maintenance strategy Enter new decentralized energy business models
Missing Money			Reduced market clearing price	

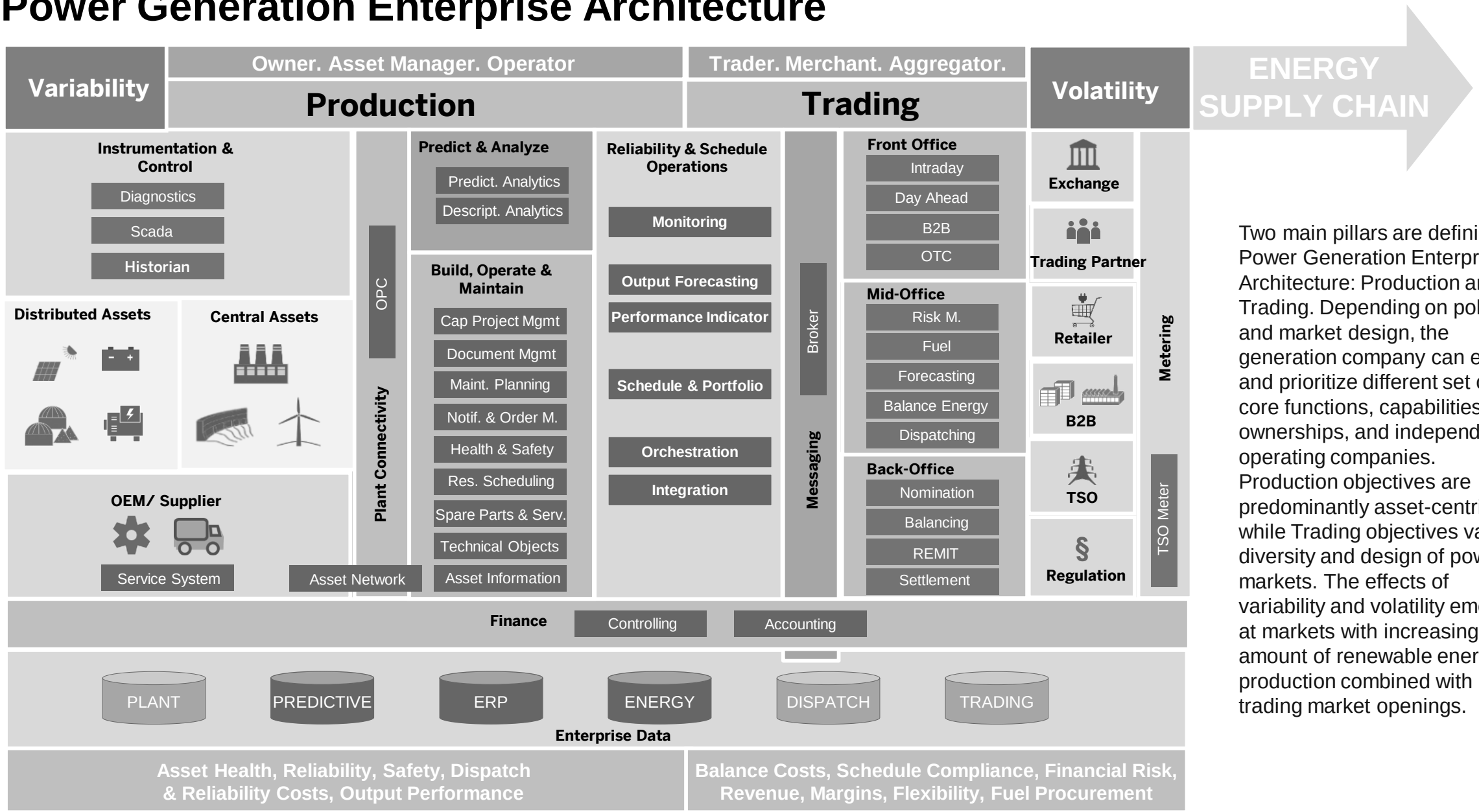
Evolution of Generation Roadmap

The Generation & Trading House



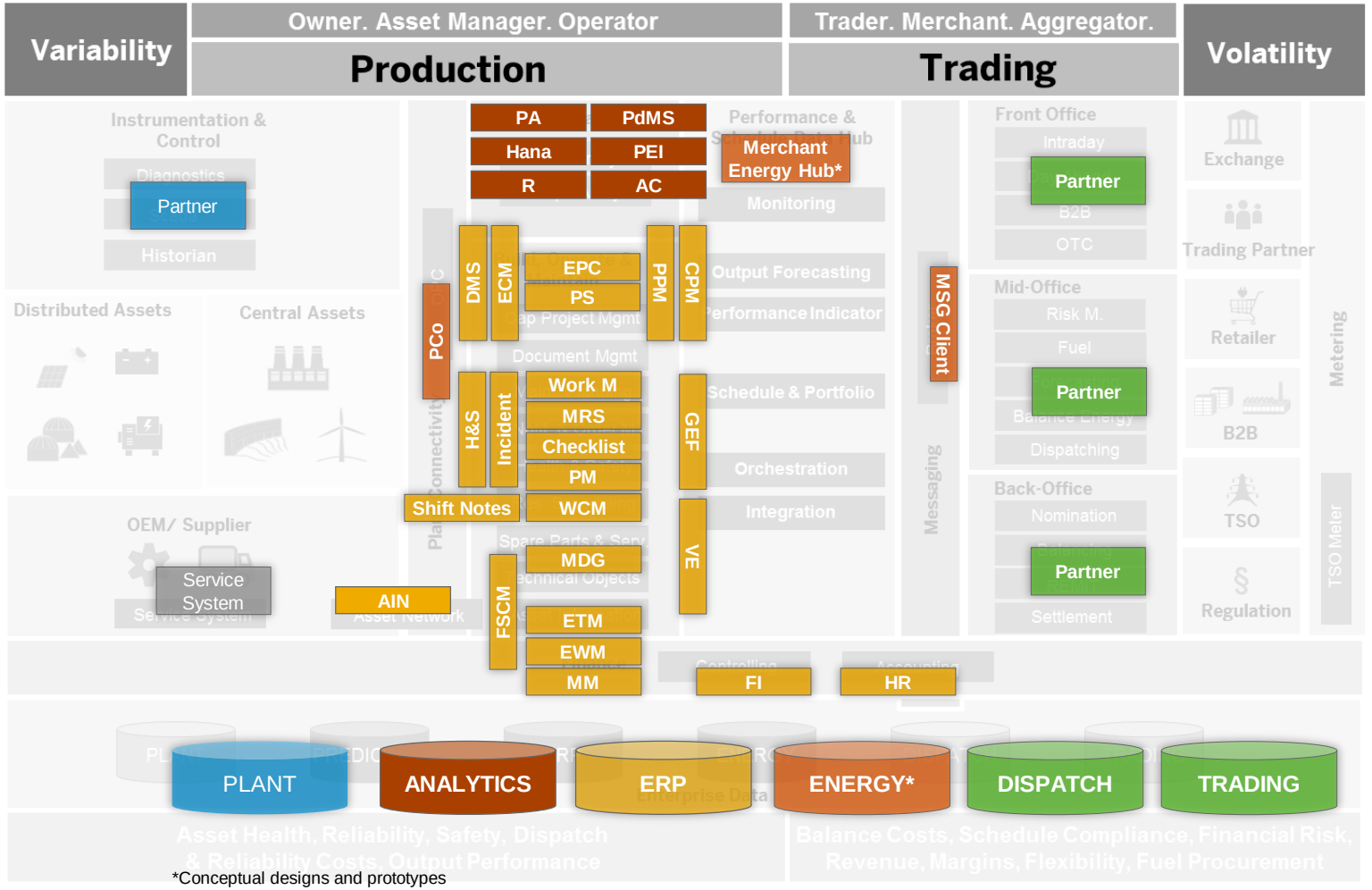
Owner. Asset Manager. Operator *Trader. Merchant. Aggregator*

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.

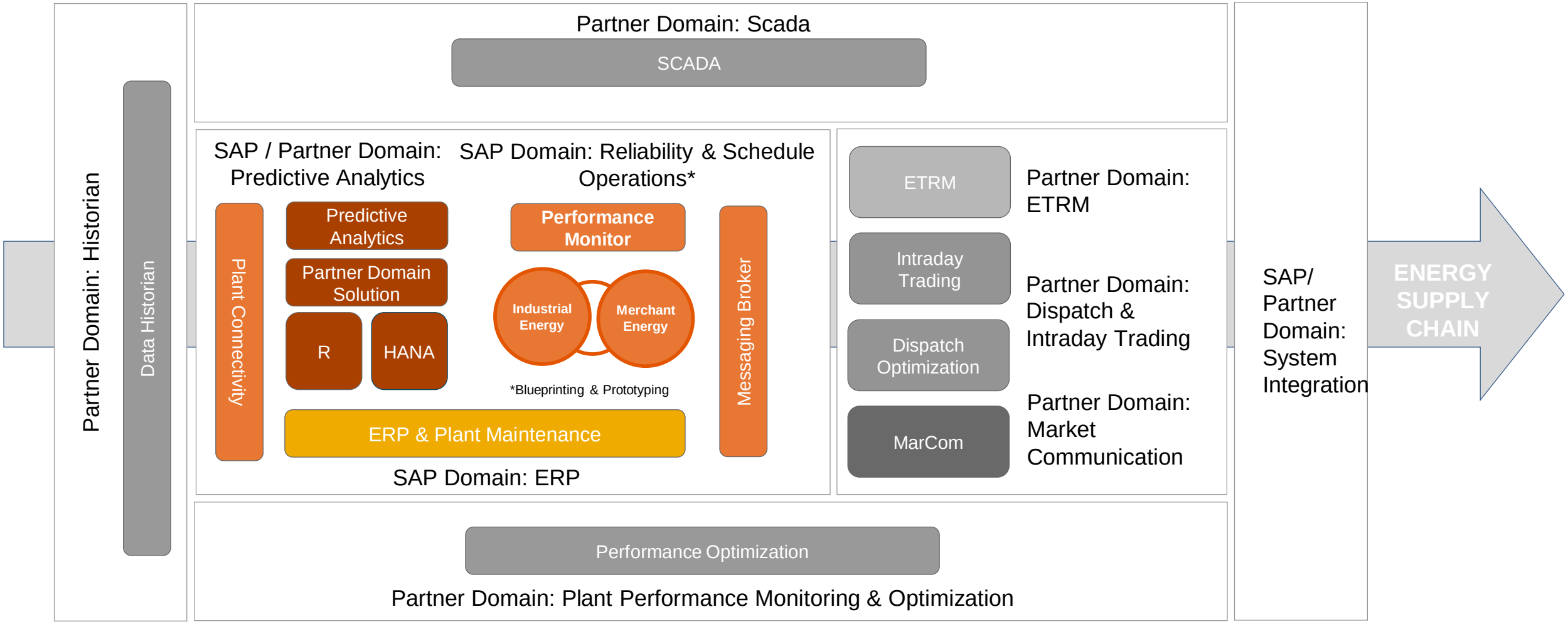
Solutions for Power Generation by SAP



*Conceptual designs and prototypes

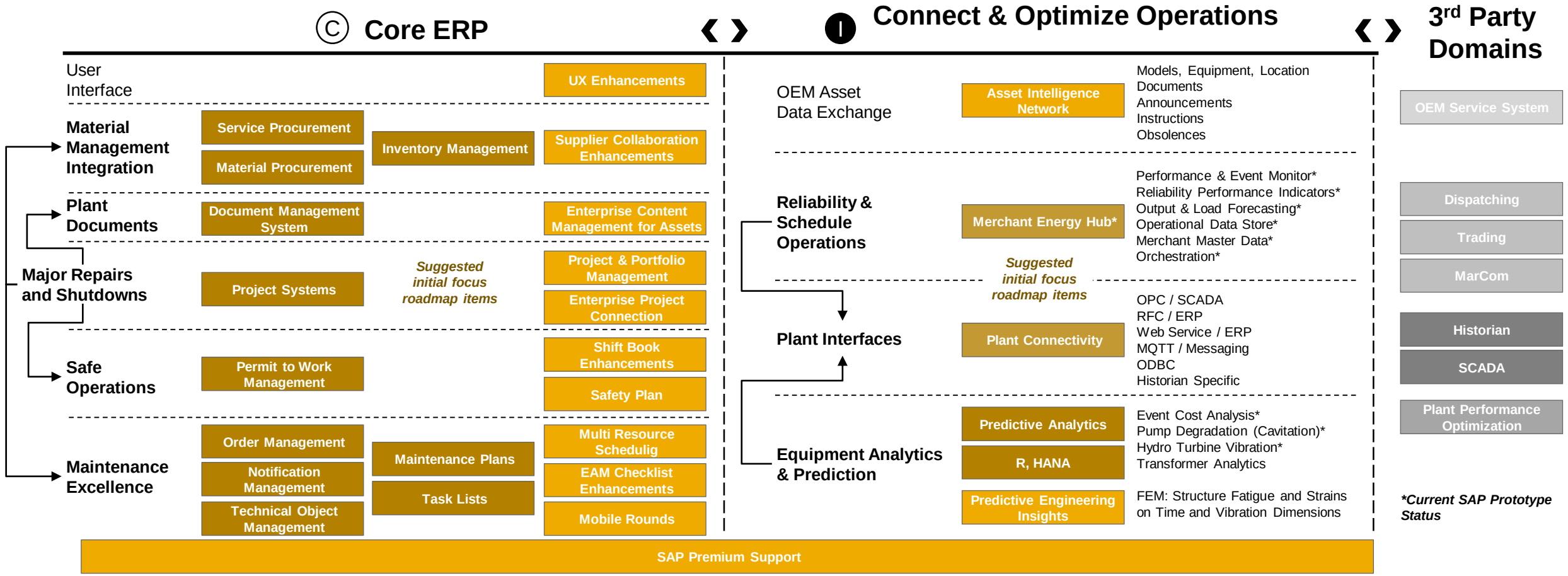
- FI (Financials), MM (Material Management), HCM (Human Resources)
- PM (Plant Maintenance), WCM (Work Clearance Management), PS (Project Systems), DMS (Document Management System)
- MRS (Multi Resource Scheduling), Work Manager (Mobile Asset Management), Mobile Checklist (Mobile Inspections)
- CPM (Commercial 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

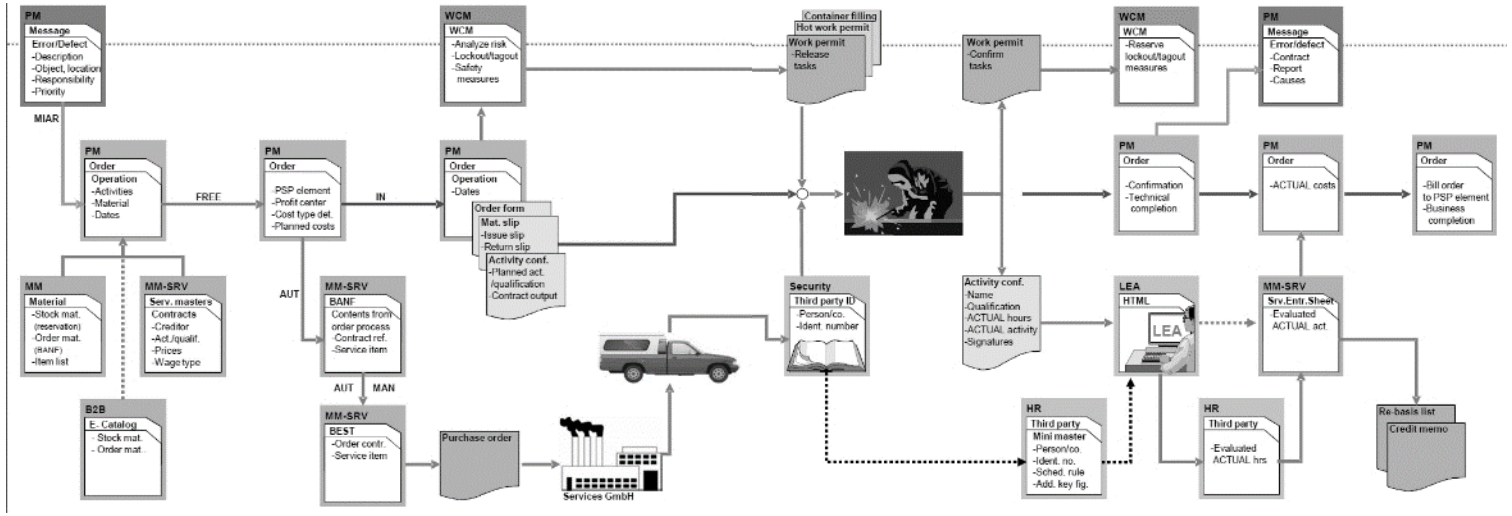
We recommend a parallel evolution of a core EAM system as well as exploring operation optimization scenarios. The core EAM implementation may be driven by an **integrated shutdown management pilot** involving requirements of 5 initiatives: project system [Major Repairs and Shutdown], order-, notification-, 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.

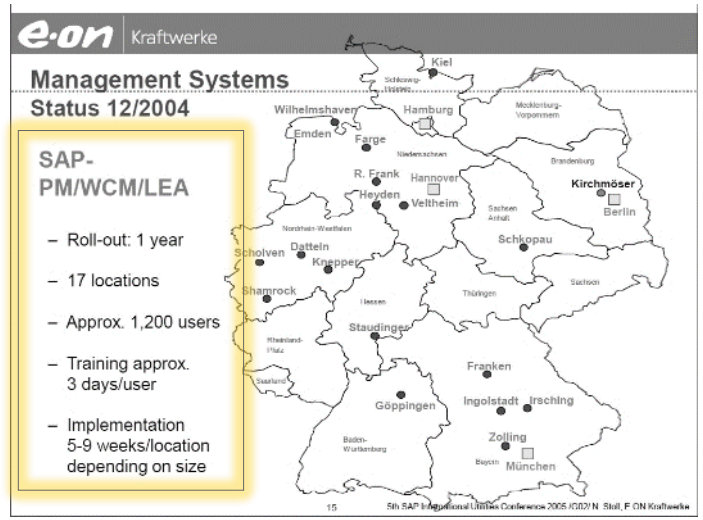


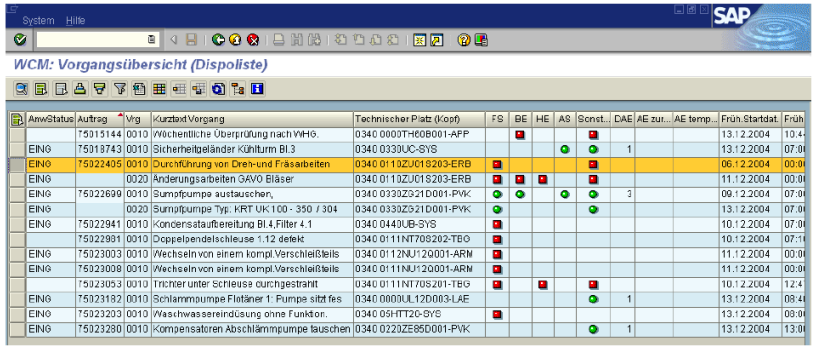
Customer Project Examples

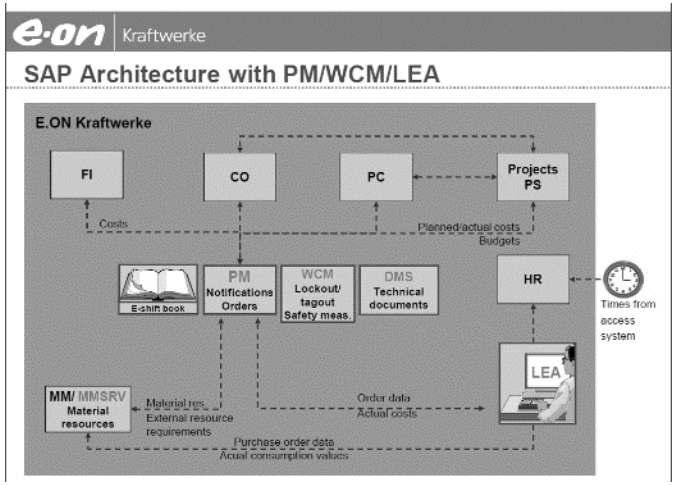
SAP EAM @ EON Thermal Generation (now Uniper), Germany

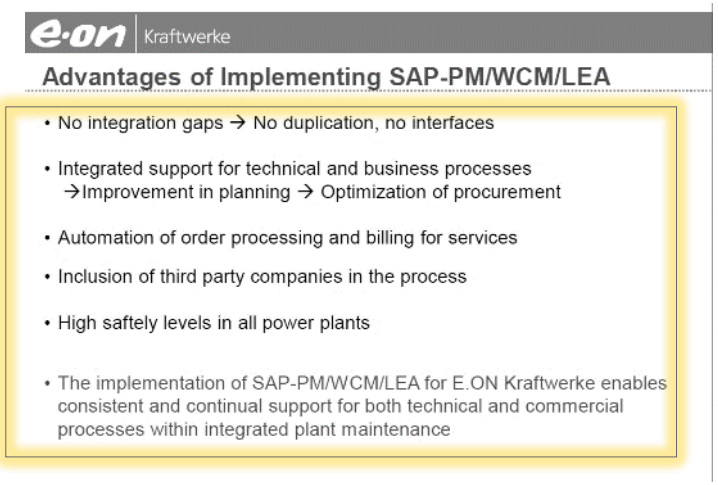
End-to-End EAM incl.
Contractor integration
17 locations in 1 year



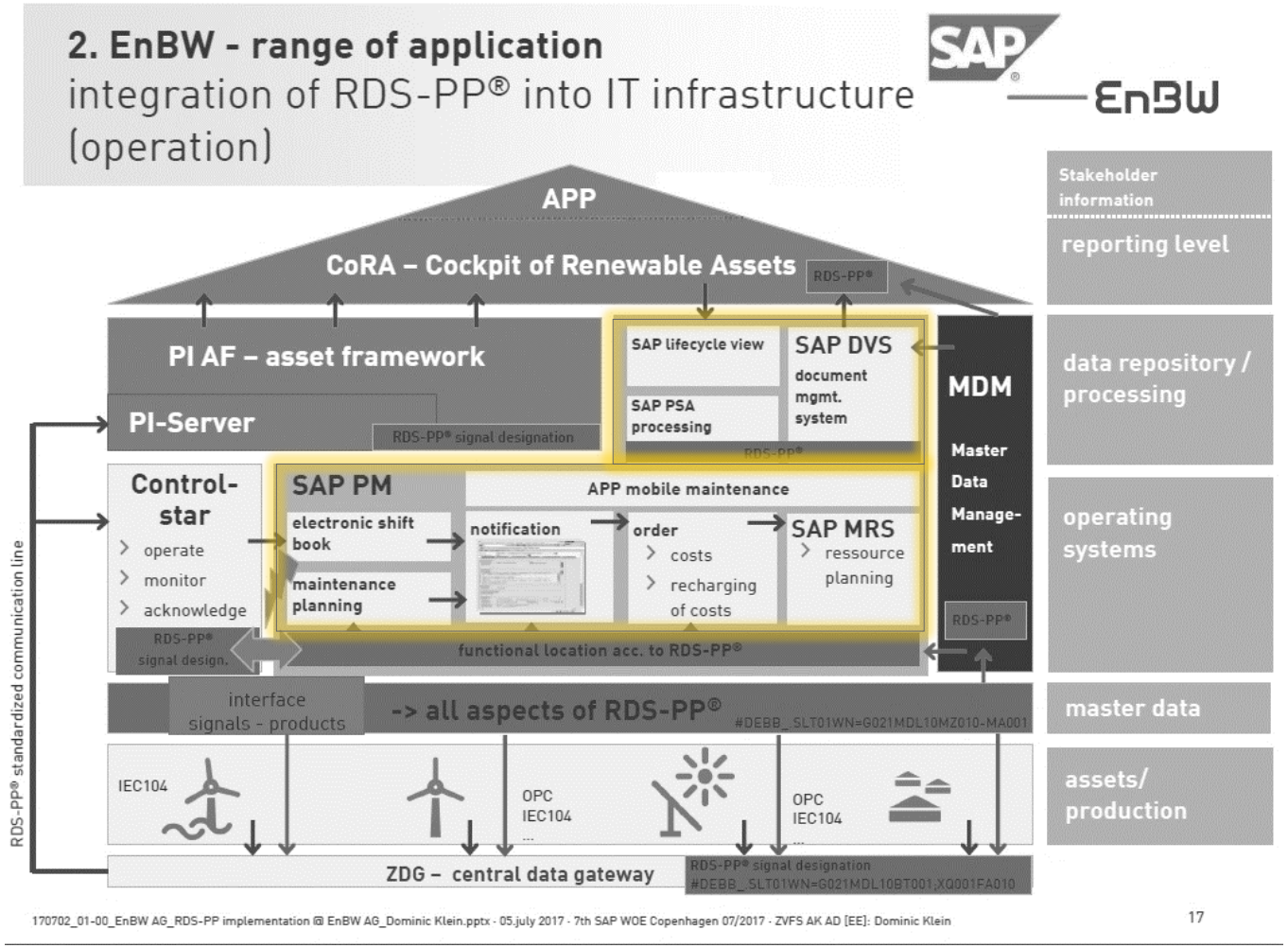




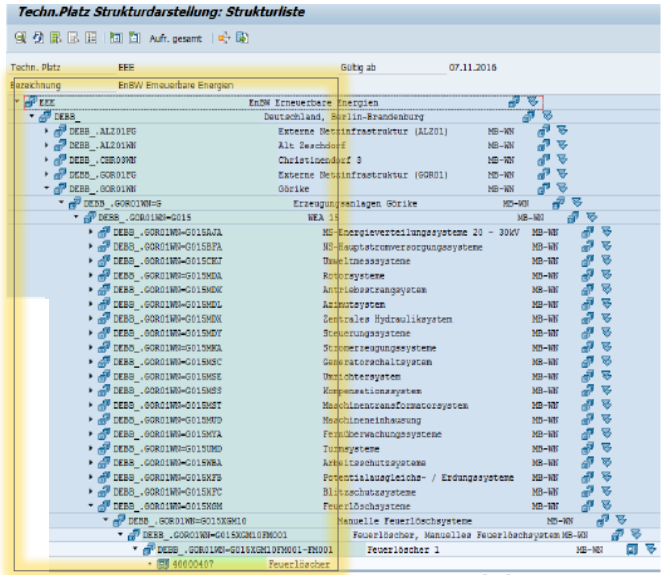




SAP EAM @ EnBW Wind Unit Generation, Germany

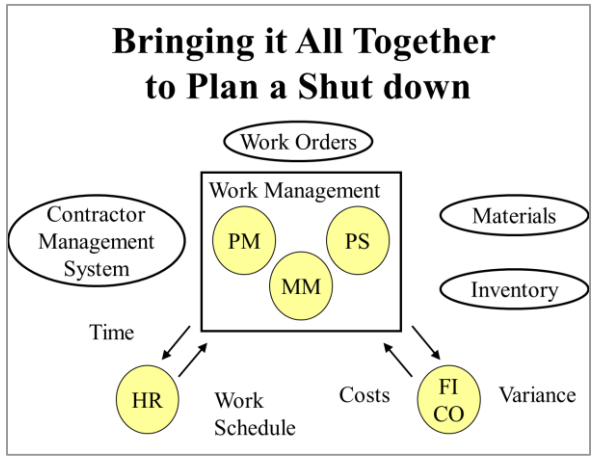


Core Maintenance & Mobile Workforce Management on industry standard RDS-PP asset structure

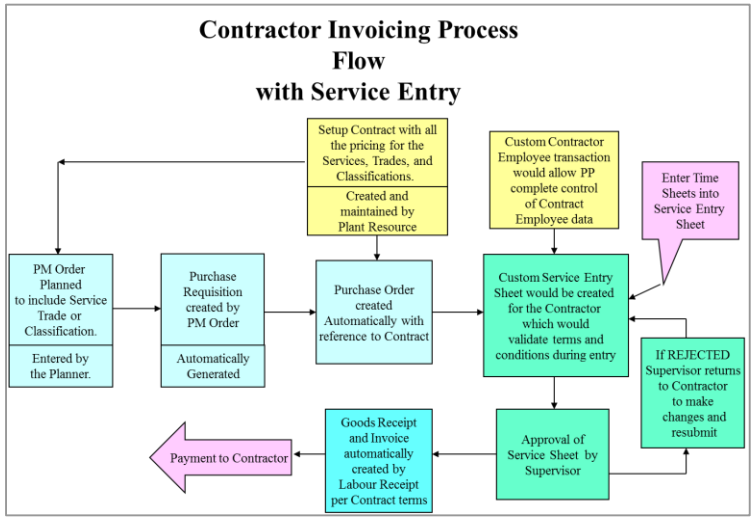


screen dump: EnBW operating machine SAP PM [EE] – technical location

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 Initiatve) 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

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

Where is Macquarie Generation?

Bayswater Power Station

- Commenced operation in 1985
- 4 x 660MW units

Liddell Power Station

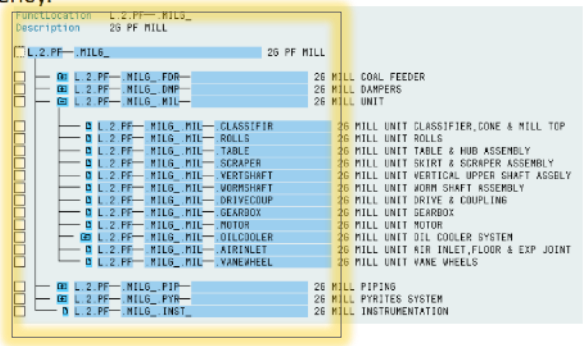
- Commenced operation in 1971
- 4 x 500MW units

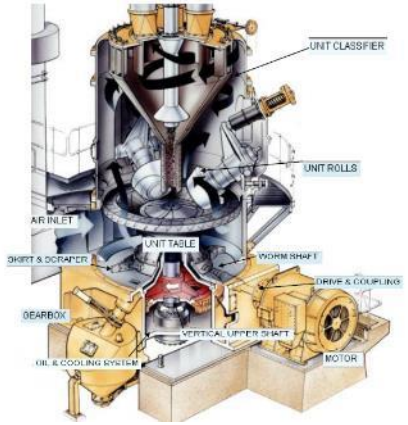
The Key Changes when using SAP

- 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.

Functional Locations updated

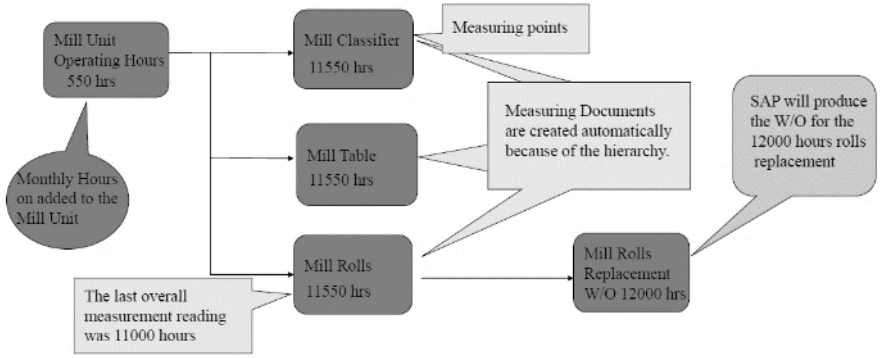
- The revised Functional Location structure allowed for improved visibility and consistency.



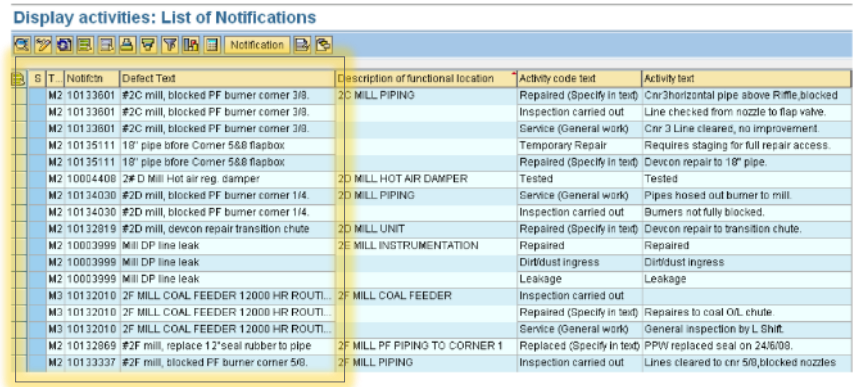


How SAP will piece it all together....

Use the scenario of a Rolls replacement @ 12000 hours



Reporting the Activities on Notifications – IW65



S	T	Notifctn	Defect Text	Description of functional location	Activity code text	Activity text
	M2	10133601	#2C mill, blocked PF burner corner 3/8.	2C MILL PIPING	Repaired (Specify in text)	Cnr3horizontal pipe above Riffle,blocked
	M2	10133601	#2C mill, blocked PF burner corner 3/8.		Inspection carried out	Line checked from nozzle to flap valve.
	M2	10133601	#2C mill, blocked PF burner corner 3/8.		Service (General work)	Cnr 3 Line cleared, no improvement
	M2	10135111	18" pipe bfore Corner 5&8 flapbox		Temporary Repair	Requires staging for full repair access.
	M2	10135111	18" pipe bfore Corner 5&8 flapbox		Repaired (Specify in text)	Devcon repair to 18" pipe.
	M2	10004408	2# D 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 hosed out burner to mill.
	M2	10134030	#2D mill, blocked PF burner corner 1/4.		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		Dirt/dust ingress	Dirt/dust ingress
	M2	10003999	Mill DP line leak		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...		Repaired (Specify in text)	Repaires to coal O/L chute
	M3	10132010	2F MILL COAL FEEDER 12000 HR ROUTI...		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 24/6/09.
	M2	10133337	#2F mill, blocked PF burner corner 5/8.	2F MILL PIPING	Inspection carried out	Lines cleared to cnr 5/8,blocked nozzles

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

SAP EAM @ CS Energy, Australia

Plant Maintenance Process

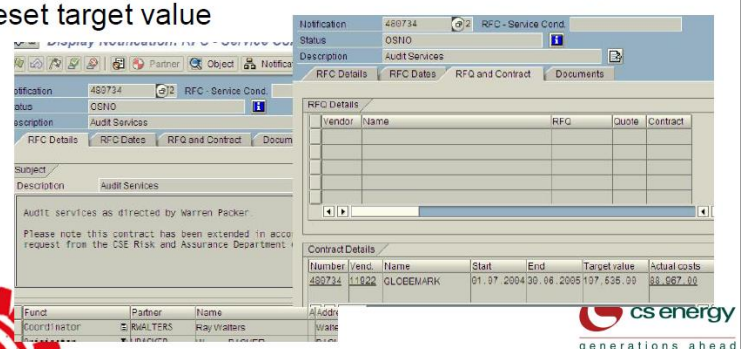
- Work Management
  - Corrective Maintenance
  - Preventive Maintenance
  - Overhaul / Outage / Opportunity Maintenanc
  - Modification Management
  - Permit to Work and JSEA
- To support work management
  - Plant Register – Predominately functional locations with few equipment
  - Bills of Materials – 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

- 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



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

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

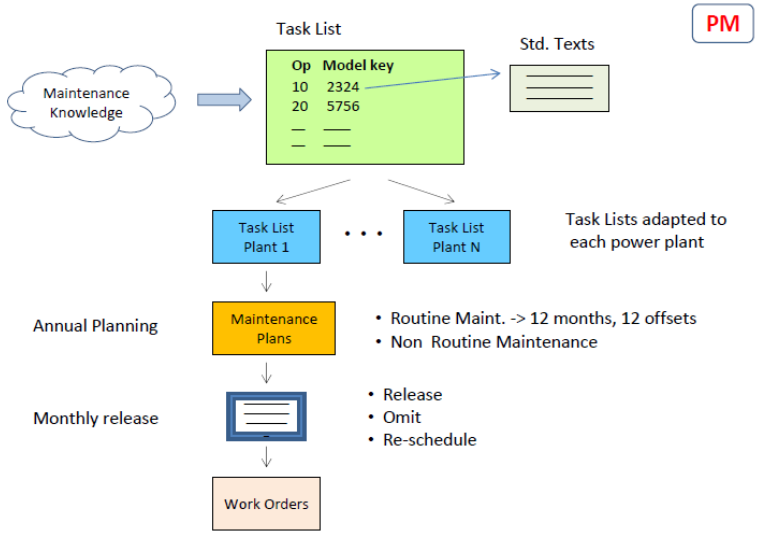
70 power stations w 170 units, 8000MW, 680 staff, 200 users, 16.000 orders per year, task list per plant, monthly schedules, planning plant per hydrographical basin

SAP EAM implementation

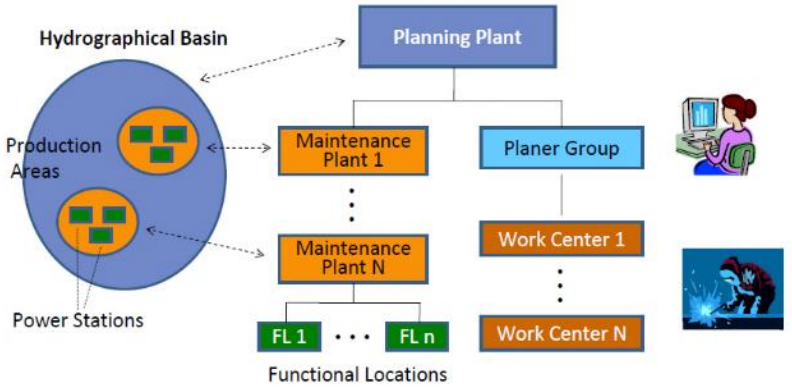
Generation type	Plants	Users	Maintenance Orders/year
Nuclear	1	300	29.200
Thermal	6	260	36.400
Combined Cycle	12	340	86.400
Spain	7		
Mexico & Brazil	5		
Hydro	73	215	15.900
≥ 100 MW	12		
≥ 10 MW < 100 MW	61		
		1.115	167.900

Planned Maintenance

PM

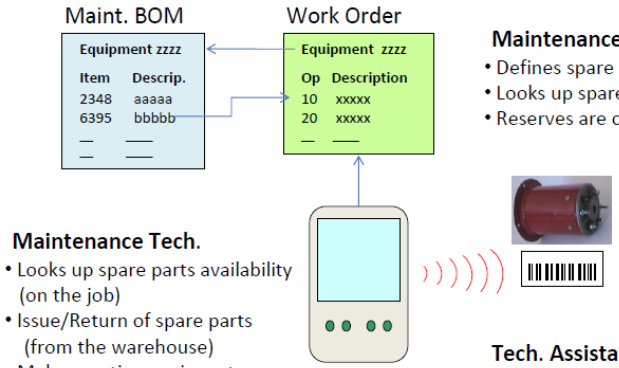


Maintenance organization with SAP EAM



Spare parts management

PM MM MI



Maintenance Tech. (at the office)
- Defines spare parts required
- Looks up spare parts availability
- Reserves are created automatically

Maintenance Tech.
- Looks up spare parts availability (on the job)
- Issue/Return of spare parts (from the warehouse)
- Makes continuous inventory

Tech. Assistant
- Manage spare parts re-supply
- Makes warehouse inventory
- Gets code bar labels from SAP and labels spare parts

SAP EAM @ West Burton CCGT EDF Energy, UK

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

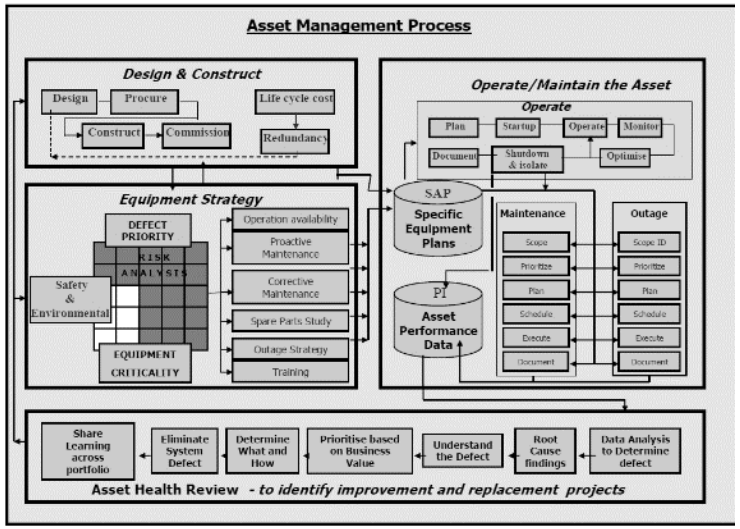
EDF Energy West Burton CCGT

Combined Cycle Gas Turbine – West Burton B

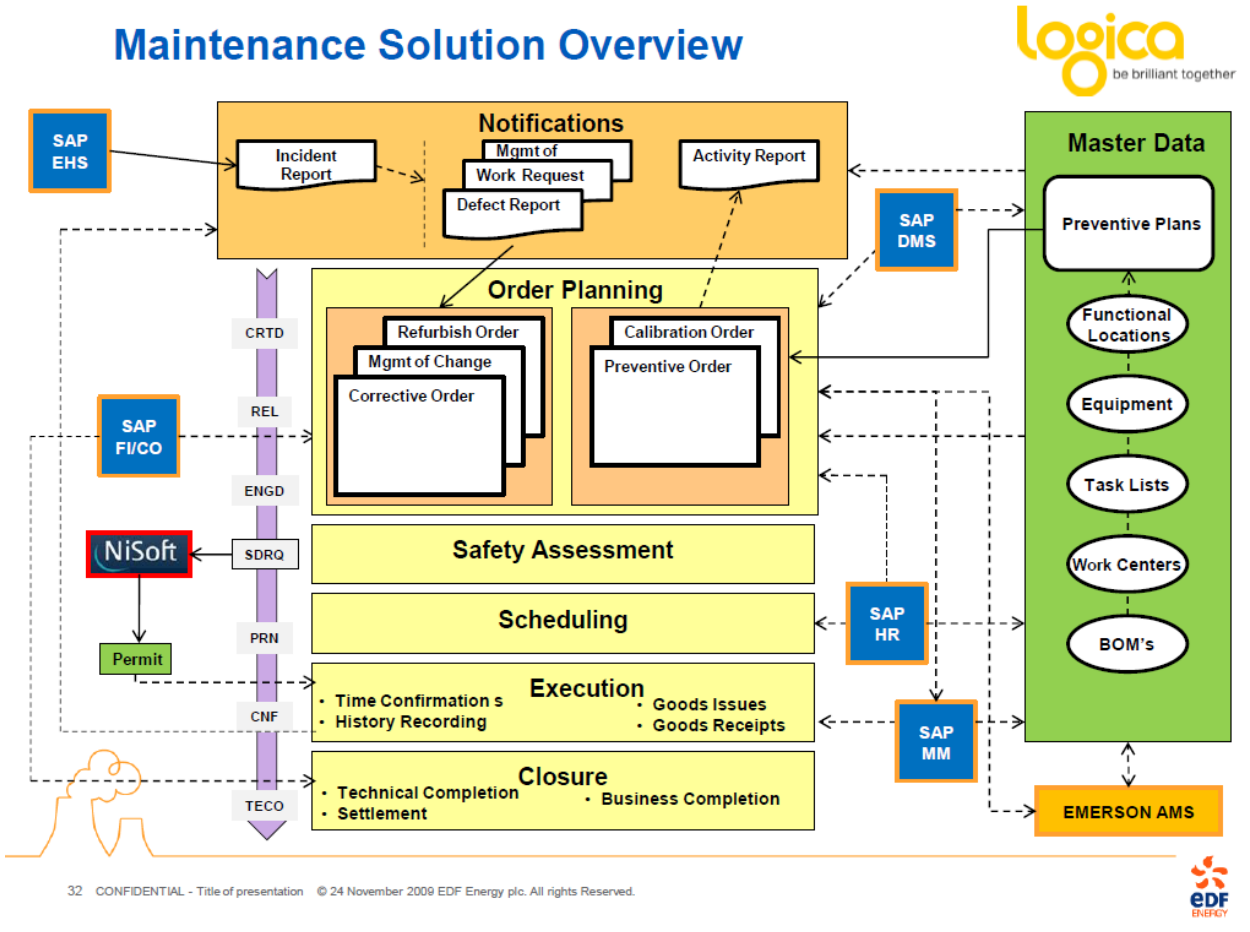
About West Burton

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

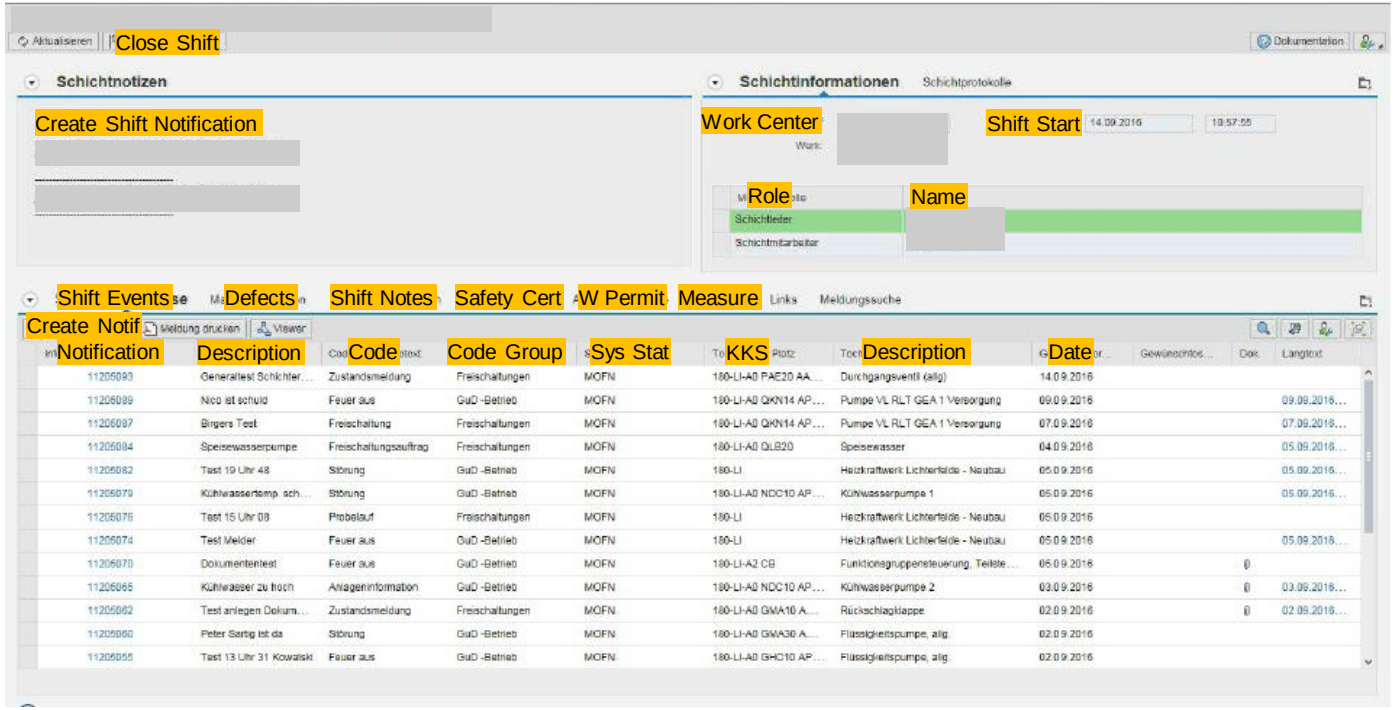
The power station is served by a 20 km gas pipeline connection to the National Grid National Transmission System (NTS) at Grayingham Lincolnshire.



Maintenance Solution Overview



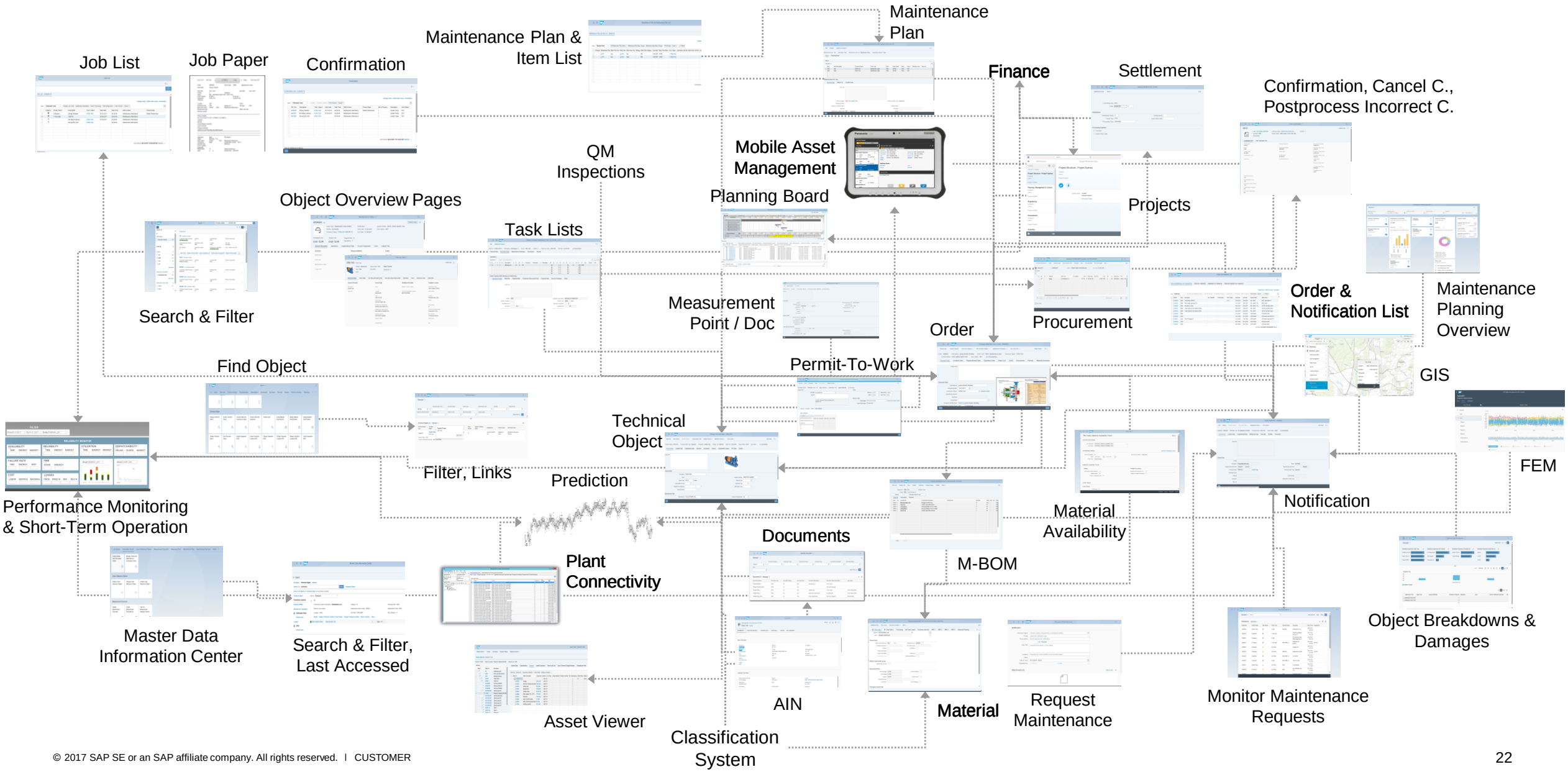
Example of Shift Book Project Implementation at Thermal Power Plant



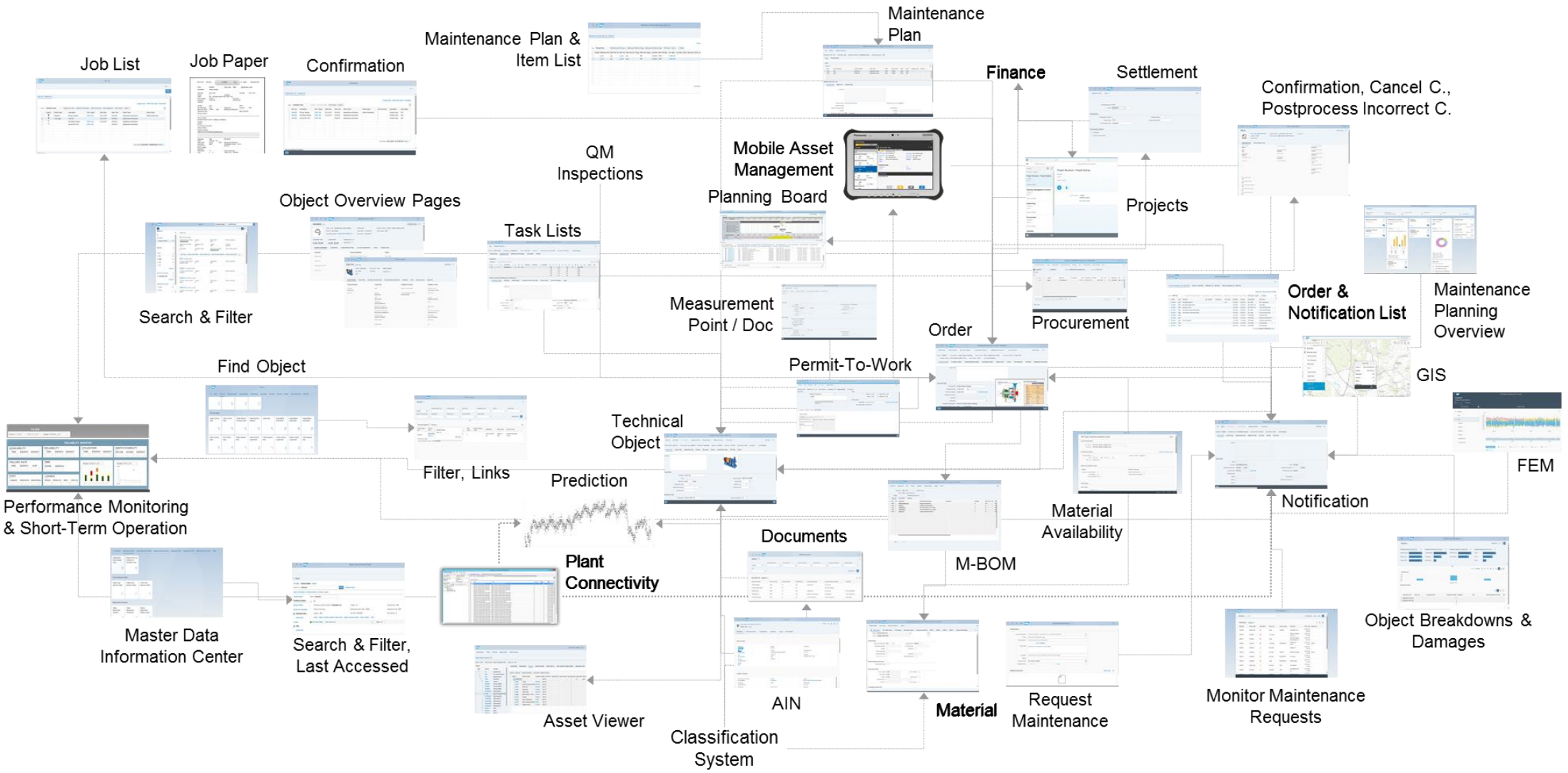
Integrated O&M Solution

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

Documentation
- DOCUMENT INFO RECORD
- ORIGINALS
- OBJECT LINK

Confirmation
- JOB LIST
- CONFIRMATION

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

Org. & Finance Integration
- CONTROLLING
- BUSINESS PARTNER
- LOCATION

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

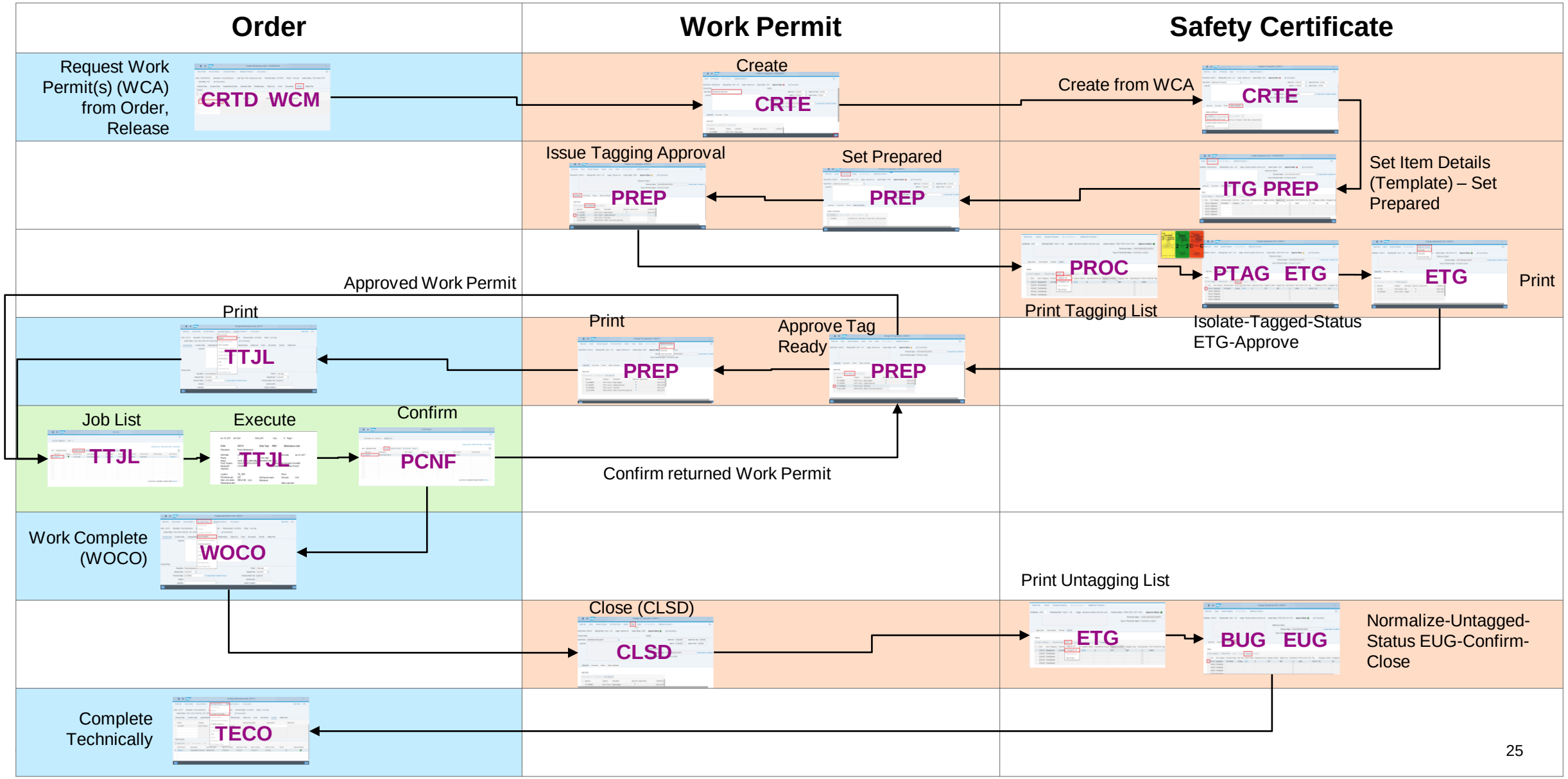
Classification
- CLASS
- CHARACTERISTICS

Notification
- ORGANIZATION
- MALFUNCTION
- TASK
- ACTIVITIES
- DOCUMENTS

Core Maintenance Processes

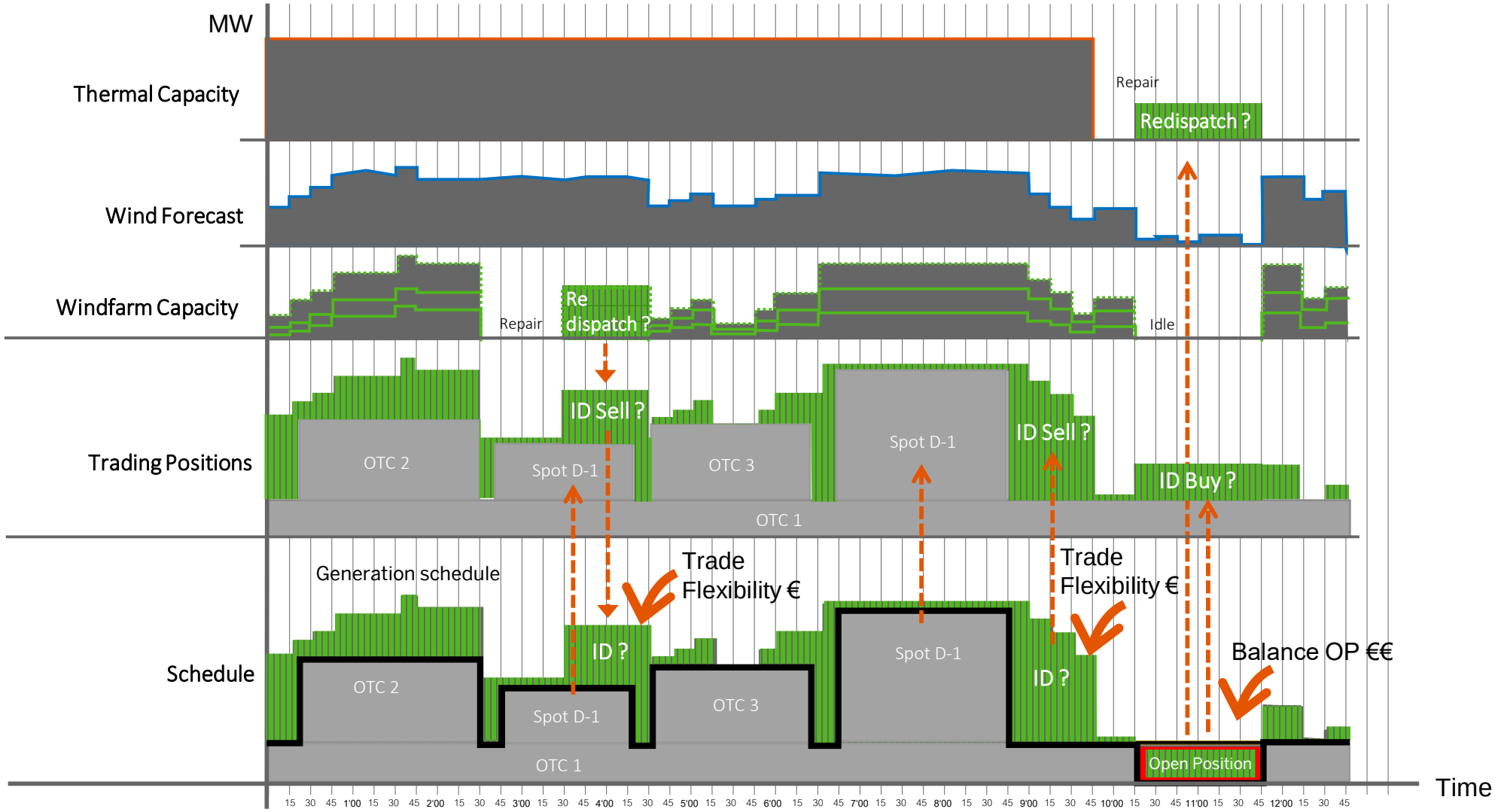
Inspection → *Reg. Maint.* → *Repair* → *Revision* → *PM, CBM* → *Procure S&P* → *Inventory* → *Document.* → *Report & Analysis* → *Asset Information*

Permit To Work Scenario

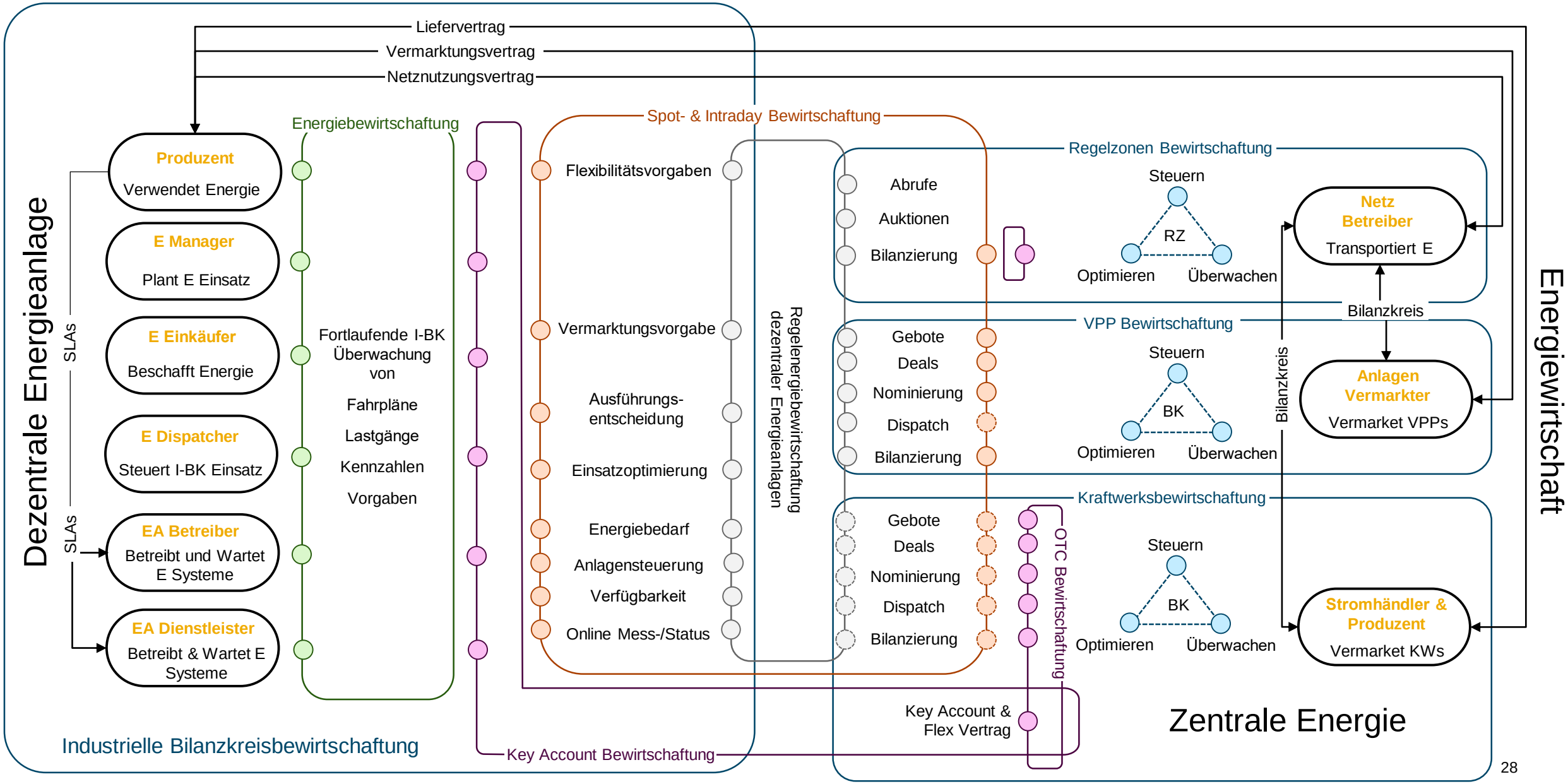


Reliability & Schedule Operations Prototype (Merchant & Industrial Energy Hub)

Illustration of Short-Term Optimization

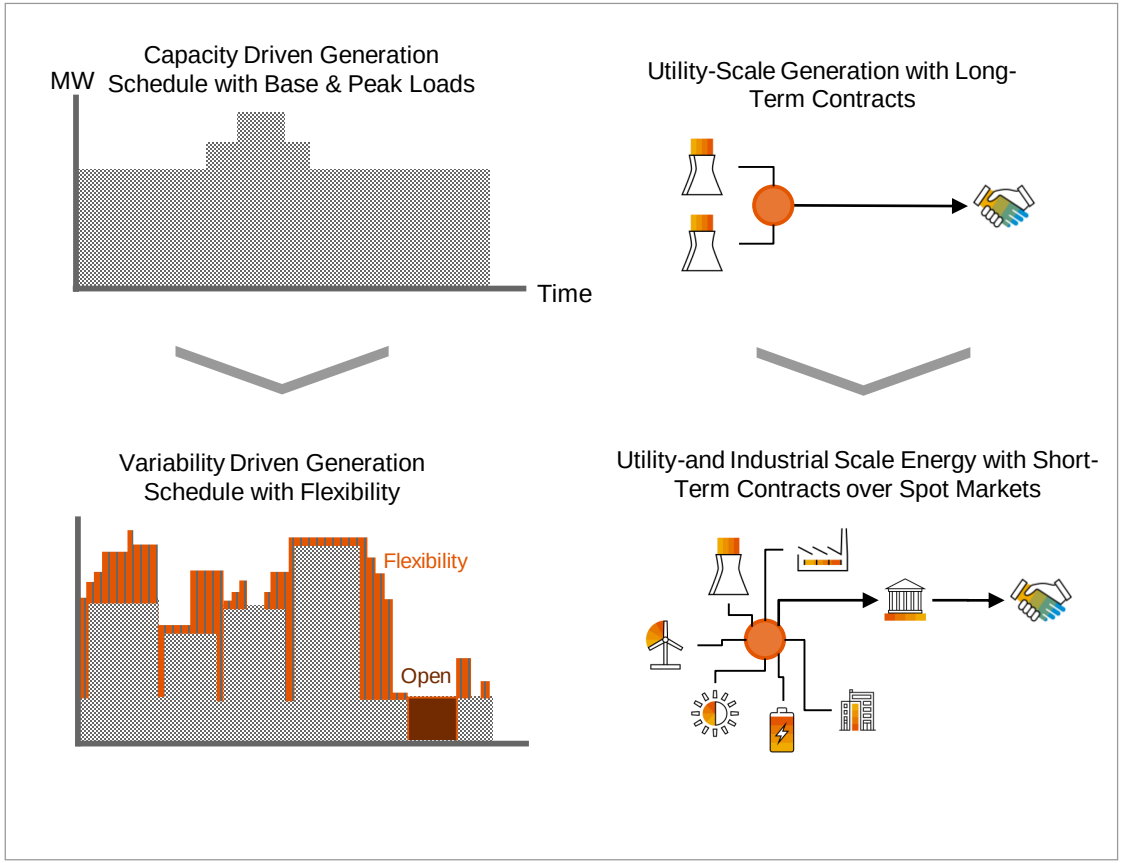


Aspects of Balance Group Management



Blueprinting & Prototyping

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.

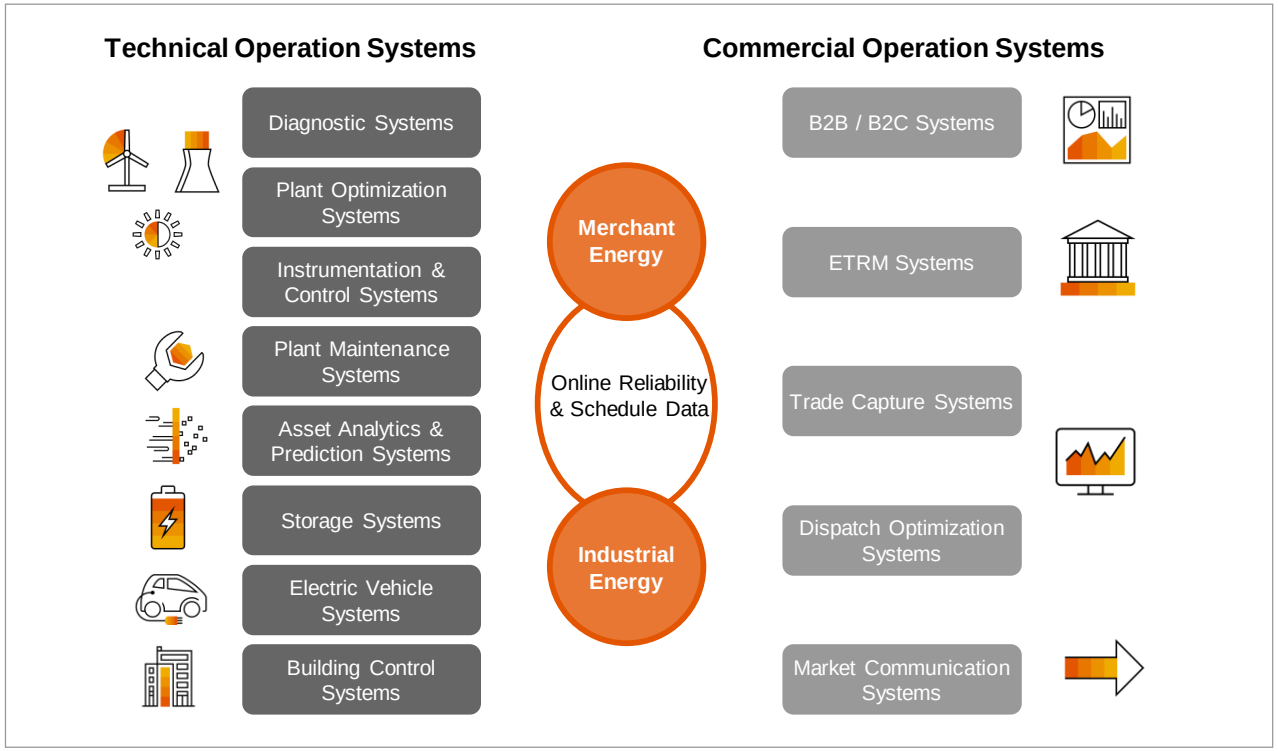
Over time, industrial-scale decentral energy resources will be integrated into energy markets and become active portfolio positions of traders and merchants – virtual power plant portfolios combined with utility-scale generation portfolios. Consequently, generation and trading schedules are transforming 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.

Supply Marginal Plant

Interfaces & Building Blocks

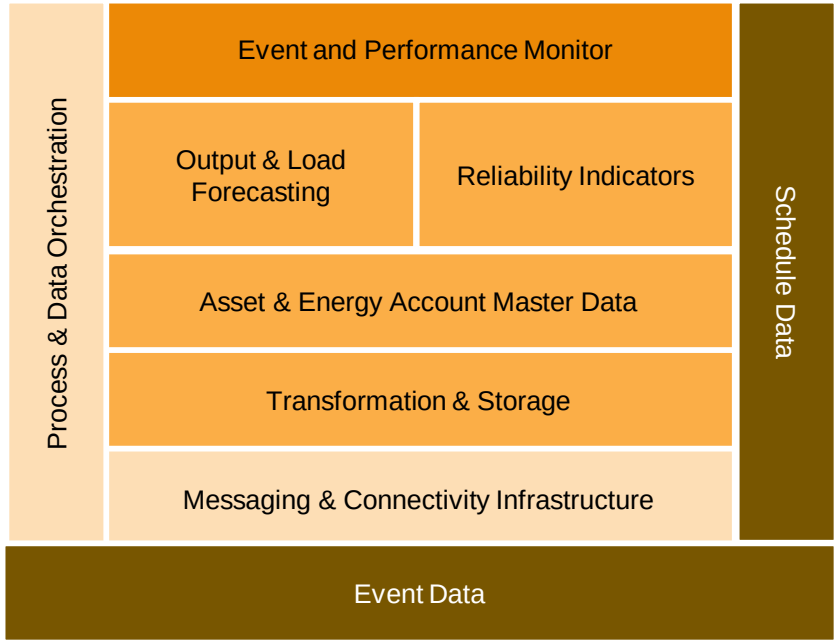
Blueprinting & Prototyping

Online Reliability & Schedule Data between Domain Expert Systems

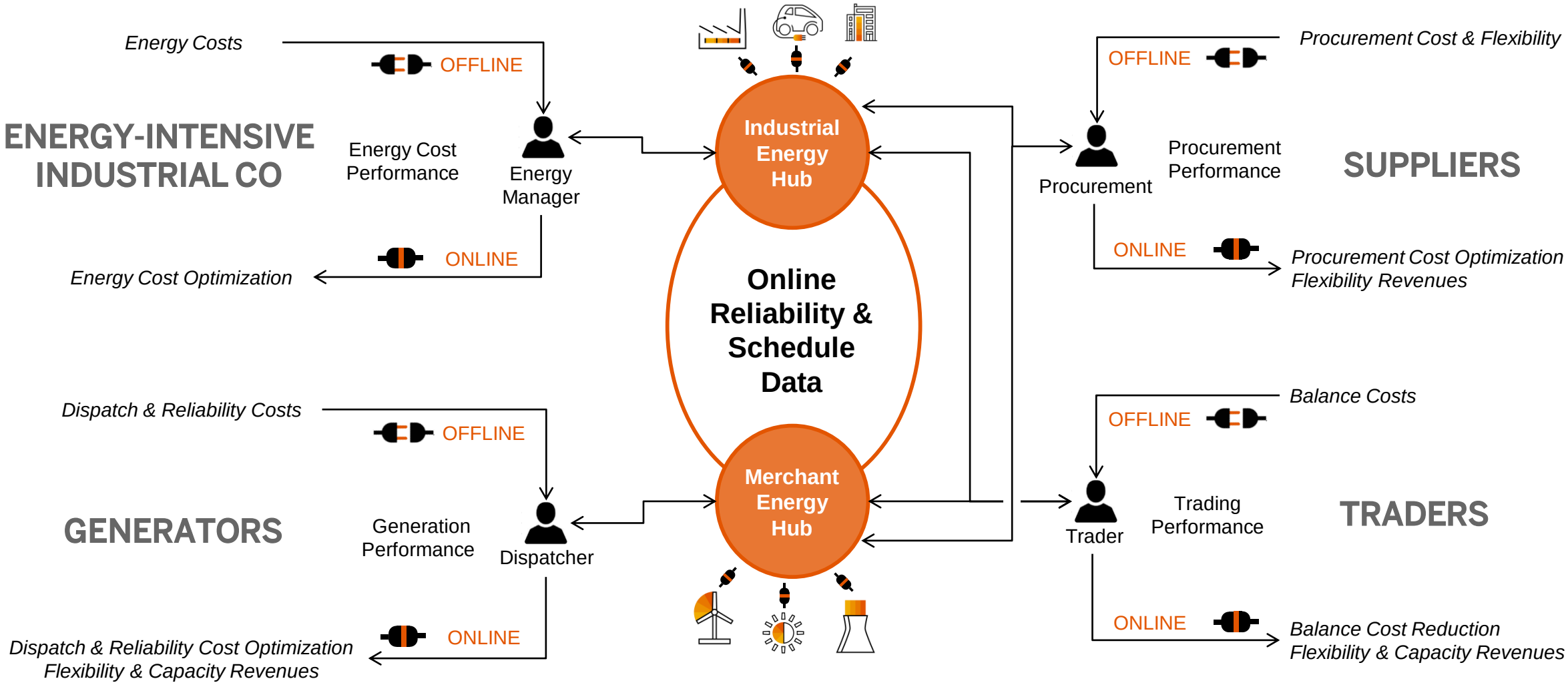


Building Blocks

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.

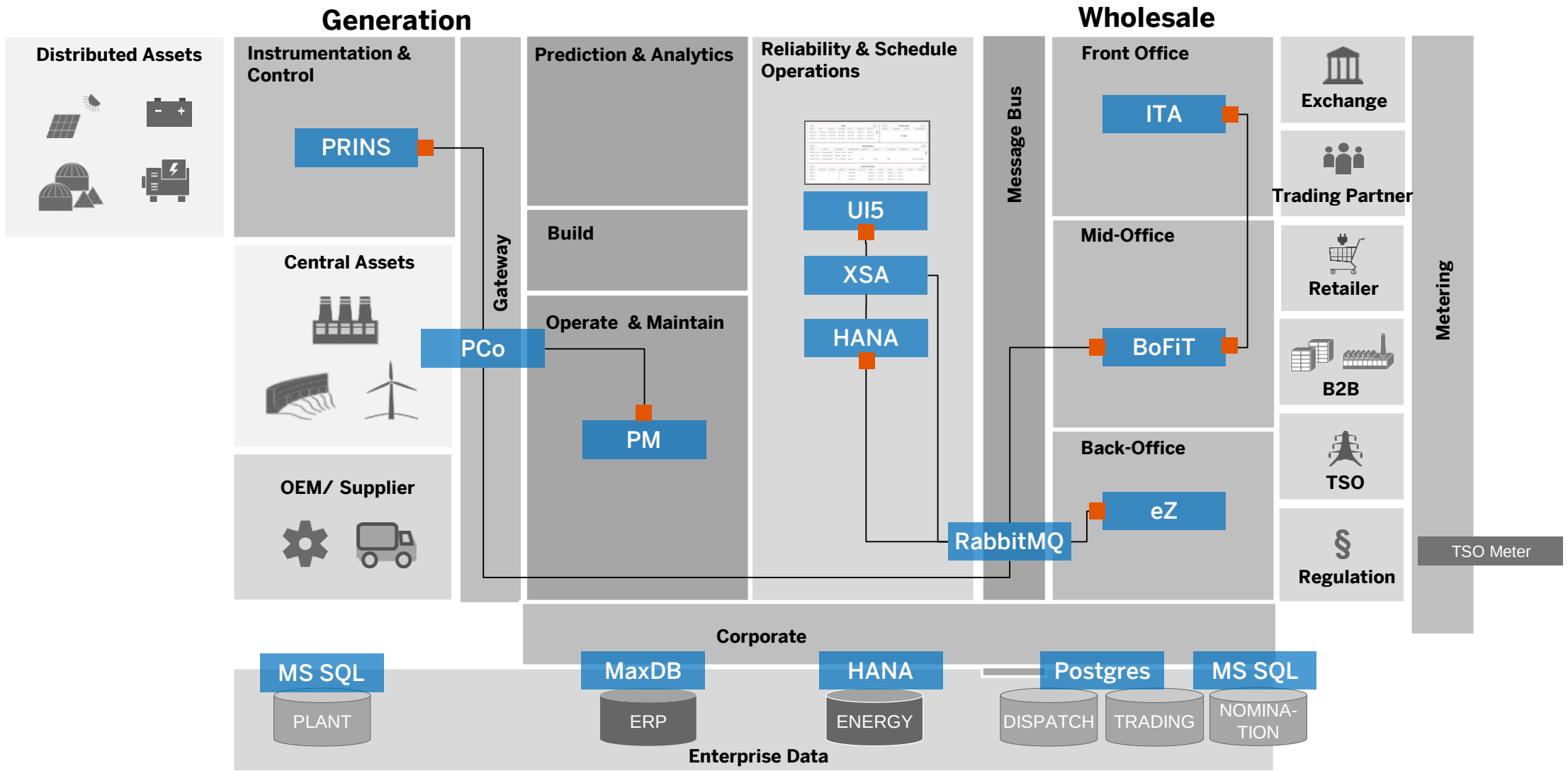


Online Reliability and Schedule Data for Economic Short-Term Operation and Market integration of Power Production and Energy Facilities



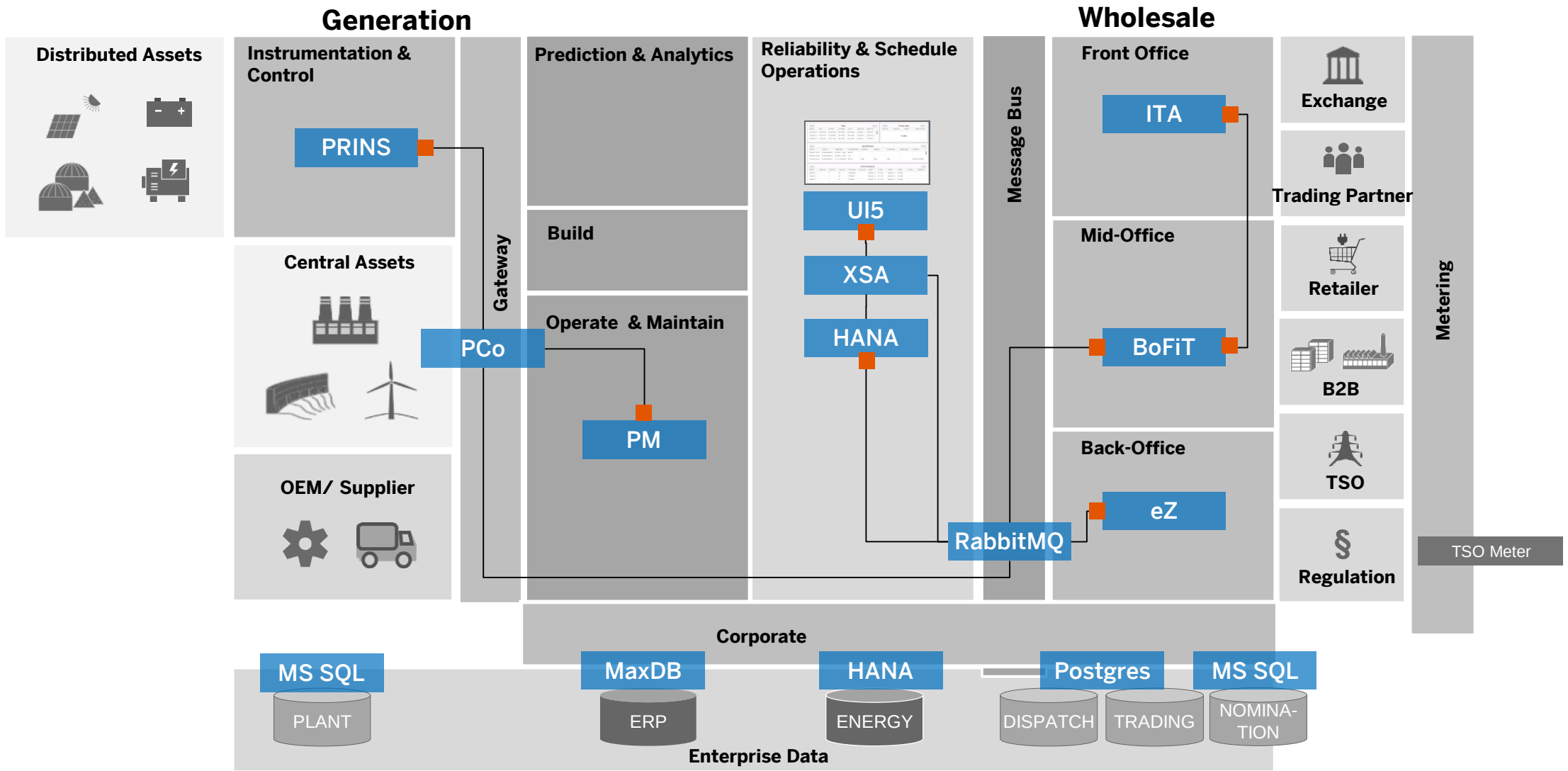
Data Flow

Blueprinting & Prototyping



Data Flow

Blueprinting & Prototyping



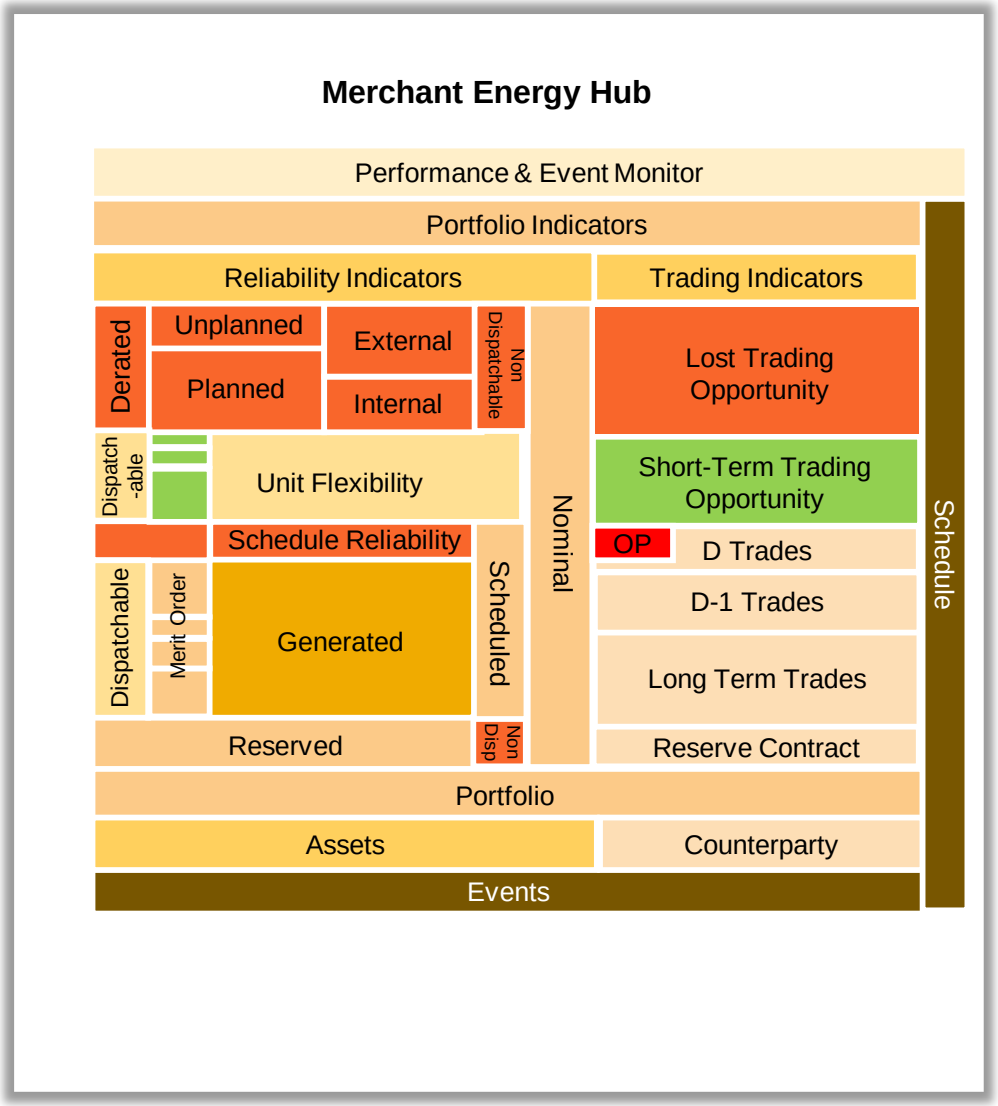
Example: VGB Indicators

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	$w_t = \frac{t_B}{t_B + t_{nv\,un}}$	t_B Operating time t_v Available time $t_{nv\,un}$ 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	$w_v = \frac{W_B}{W_B + W_{nv\,un}}$	W_B Generated energy t_v Available time $W_{nv\,un}$ 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 W_{Rd} Balancing energy
Market-assessed availability	$k_m = \frac{\sum_{i=1\ldots N}(W_{Ni} - W_{nv,i}) \cdot DB_i}{\sum_{i=1\ldots N} W_{N,i} \cdot DB_i}$	W_N Nominal energy W_{nv} Unavailable energy DB_i Contribution margin	Market-assessed reliability	$r_m = 1 - \frac{\sum \left(\lvert W_{Bi} - W_{Fpi} \rvert \right) \cdot DB_i}{\sum W_{Fpi} \cdot DB_i}$	W_{Fp} Schedule energy W_B Generated energy DB Contribution margin	Market-assessed utilization	$n_{Wm} = \frac{\sum_{i=1\ldots N}(W_{B,i})\, W_{B\_i} \cdot DB_i}{\sum_{i=1\ldots N} W_{N,i} \cdot DB_i}$	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	$p_v = \frac{W_B}{W_B + W_{nv\,un} + Wns}$	W_B Generated energy $W_{nv\,un}$ Unplanned not postponable unavailable energy W_{ns} Available unproducible 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	**Failure rate**		
			Dispatchability	$k_b = \frac{W_b}{W_N} = \frac{W_N - W_{nv} - Wns}{W_N}$	W_N Nominal energy W_b Dispatchable energy W_{nv} Unavailable energy W_{ns} Available unproducible 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	$k_{bm} = \frac{\sum_{i=1\ldots N}(W_{N,i} - W_{nv,i} - Wns_{\_i}) \cdot DB +_i}{\sum_{i=1\ldots N} W_{N,i} \cdot DB +_i}$	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	$p_l = \frac{W_{nv\,un}}{W_{nv\,un} + W_{ns} + WB}$	$W_{nv\,un}$ Unplanned not postponable unavailable energy W_{ns} Available unproducible energy (external) W_B Generated energy

Performance Indicators

Blueprinting & Prototyping

NOMINAL_POWER	Highest continuous output capability of a unit without damage at certain operating conditions. Provided by manufacturer specification
DERATED_POWER	A partial reduction in the output capability of a unit due to planned und unplanned events. Derated output value is assessed and captured in maintenance notification (independent from Live Portfolio Hub).
DISPATCHABLE_POWER_I	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.
DISPATCHABLE_POWER_II	Output capability of the unit deducting derated power captured in maintenance notification and deducting reserved power. See also Dispatchable Power I
NON_DISPATCHABLE_POWER	Amount of non-available unit output capability consisting of negative Schedule Reliability and Reserved Power (Dispatchable I) and Derated and Reserved Power (Dispatchable II).
UNIT_FLEXIBILITY_POWER	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.
SCHEDULED_POWER	Planned output capability of a unit according to trading needs (short/mid/long-term). Economically optimized for merit-order.
SCHEDULE_RELIABILITY_POWER	Difference between produced and scheduled power. Target = “0”. + more / - less power is produced than scheduled. Effect to balancing and grid connection costs.
GENERATED_ANTICIPATED_POWER	Produced (measured) and forecasted output capability of a unit. Forecast based on online event, proximity, and machine learning methods.
RESERVED_POWER	Power which is not available for open trading and economic scheduling. Reserved power are stored as Deals.



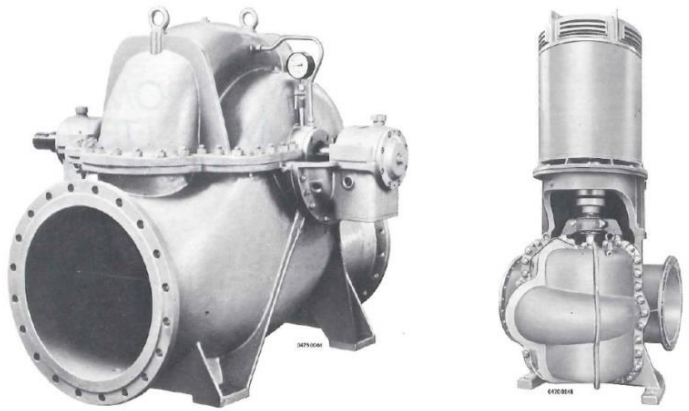
Exploring District Heating Pump Degradation & Revision Cycles

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

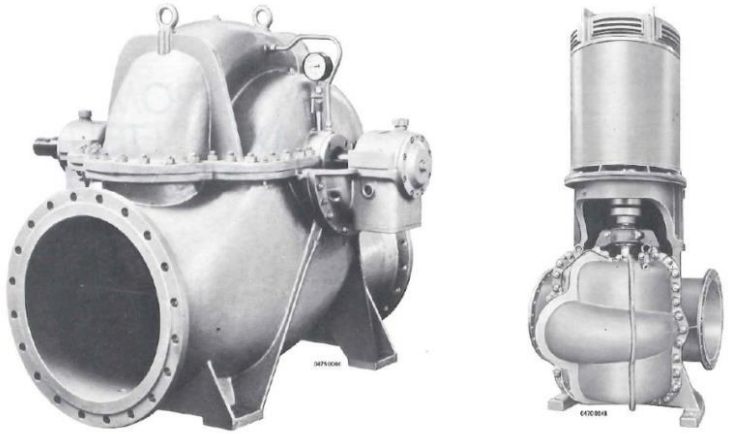
Input Parameter

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

Historic Data
At least 1 year
1 minute equidistant resolution

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

Thank you.

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Run Simple

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