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Fortum in brief

Forerunner in clean energy

64% of power generation CO₂-free - in EU 97%

Core competences in hydro and nuclear power, combined heat and power production and in operating on energy markets

Energy-related products and expert services
1.3 million electricity sales customers

Some 8,000 energy professionals
Nordic and Baltic countries, Russia, Poland

Figures: 2015

Fortum – Forerunner in clean energy

MEGATRENDS
Climate change
Urbanisation
Active customers
Digitalisation, new technologies

MISSION
We provide customers with energy solutions that improve present and future life, and we deliver excellent shareholder value.

VISION
Forerunner in clean energy

STRATEGY
Drive productivity and industry transformation
Create solutions for sustainable cities
Grow in solar and wind
Build new energy ventures

MUST-WIN-BATTLES
Put the customer in the centre
Establish a culture of speed and agility
Digitalise our business for maximum scalability
Create value from market volatility
Drive competitive markets and fair regulation
Success through a shared perspective in thermal solutions: Power Solutions/Fortum’s expert services in brief

- Fortum has extensive references in commissioning, operating, maintaining and upgrading thermal power plants in European and Asian energy markets
- Core competence in thermal, hydro and nuclear power
  - Built on Fortum’s knowledge and history as an energy producer
  - Over 300 employees delivering high quality expert services
  - Experience from projects in over 20 different countries
- Services to improve technical and economic performance of new and existing production capacity in
  - Bio-energy
  - Energy from waste
  - Combined cycle
  - Gas, coal and peat fired power plants
- Expert references cover hundreds of customers globally
- Co-operation with various partners and networks
- Combining our top technical know-how with an economic view enables us to identify opportunities and turn them into measurable results
- Independence of equipment suppliers

Value Creation with Plant Lifecycle Management

Maximum productivity during the lifecycle

Potential for value added to be assessed taking into account:
- Unexpected failures
- Unplanned corrective maintenance
- Availability degradation
- Investment costs
- Long-term planning
- Systematic approach
- Energy efficiency
- Risks

The purpose of asset lifecycle management:
To optimise the resources invested in assets to maximise the revenues during the asset lifetime
Lifecycle Management built on expertise

- Setting of objectives, collection of initial information and data
- Analysis of component criticality and planning of inspections and maintenance actions
- Inspections and measurements, analysis of the results, correct timing for action and investment plans, also follow-up and necessary updates
Asset Lifecycle Management, Fortum practices

Set-up risk management
- Feasibility studies
- Criticality analysis
- Lifetime analysis and long-term planning
- Decommissioning
- mothballing
- Demolition

Set-up Integrated Management System
- Set-up Maintenance Management (Maximo®)
- Set-up other ICT: TOP®, etc.
- Design Reviews
- Document management

Set-up and start Operation and Maintenance

Design and Design Reviews
- Investments
- Optimize lifetime (Optimize actions)

Operation and Maintenance

Performance monitoring
- Maintenance and condition monitoring for main components
- Audits, reviews, cPISP®
- Refurbishment
- Upgrading
- Reinvestments

Training
- Fuels, combustion
- Fingerprint measurement
- O&M Contract
- O&M Support Contract
- Remote monitoring
- Emission control
- Overhaul planning

Risk-based Asset Lifecycle Management Implementing RBIM and RBLM

- Optimisation of O&M and Asset Management
- Defined and acceptable risk levels in relation to:
  - Safety, Health, Environment
  - Business/production/operation/availability
- Integrity related RBI:
  - Scenarios (structural damage)
  - Failure probability & consequences → Assessed risk
- Risk-based ranking of criticality and planning for cost-effective inspections and maintenance
- Planning for sustainability

RBI – risk-based inspections
RBIM – risk-based inspections and management
RBLM – risk-based life management

Source: “Risk Based Inspection Framework” (RBIF)
Availability & Reliability Management

Combined package including separate module services such as:

**ReMaint®**: Criticality Analysis, Maintenance and Spare parts Optimisation, FMEA/RCM Analysis

**CMMS Audit and Population**

**RAM Analysis and investment decision support**

KPI’s monitoring and reporting: Feedback Analysis

Disturbance reporting Problem Solving

Support: Training

- Continuously improve your plant’s performance

Joensuu Power Plant, Finland, an example

**Ownership and personnel**

<table>
<thead>
<tr>
<th>Ownership</th>
<th>100 % Fortum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operation by</td>
<td>Fortum</td>
</tr>
<tr>
<td>Maintenance by</td>
<td>Fortum</td>
</tr>
<tr>
<td>Staff</td>
<td>54</td>
</tr>
<tr>
<td>o Operation</td>
<td>29</td>
</tr>
<tr>
<td>o Maintenance</td>
<td>22</td>
</tr>
<tr>
<td>o Asset Management etc.</td>
<td>3</td>
</tr>
</tbody>
</table>

**Production**

- Heat production capacity 130 MW
- Net electricity production capacity
  - At CHP operation mode 50 MW
  - At Condensing operation mode 70 MW

**Production units at the plant**

<table>
<thead>
<tr>
<th>Power plant</th>
<th>HOB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start-up year</td>
<td>1986</td>
</tr>
<tr>
<td>Fuel capacity (MW)</td>
<td>200 Peat/ Wood</td>
</tr>
<tr>
<td>Main fuel(s)</td>
<td>Peat/ Wood</td>
</tr>
<tr>
<td>Yearly operation hours (h)</td>
<td>7600</td>
</tr>
<tr>
<td>Boiler manufacturer</td>
<td>Ahlström</td>
</tr>
<tr>
<td>Boiler type</td>
<td>BFB</td>
</tr>
</tbody>
</table>

Pyrolysis Oil Production started 2013
Joensuu Investment planning & Lifetime Management project

**Planning**
1. Select systems and scope for lifetime assessment
2. Collect initial data and interview, utilize annual overhauls (e.g. periodic inspections)
3. Prepare preliminary inspection plan and budget

**Implementation**
4. Plan detailed inspections and allocate resources
5. Prepare and carry out inspection
6. Analyze inspection results
7. Recommend immediate improvements
8. Establish lifetime assessment for critical parts, list of necessary long term actions and investment estimates

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A practical example at Joensuu Power Plant, Finland 2014-2015

**Life assessment**

<table>
<thead>
<tr>
<th>Project</th>
<th>What was found</th>
<th>More results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collect existing data, inspection results, reports, experience, condition reports, maintenance and operational information</td>
<td>Creep damage in the main steam line (material X20CrMoV121)</td>
<td>Additional life for the main components assessed: 100 000 hours</td>
</tr>
<tr>
<td>Plan the needed inspections and measurements</td>
<td>Hanger improvements needed</td>
<td>Timing of new investments taking into account the life of the existing equipment</td>
</tr>
<tr>
<td>Implement inspections, measurements, assessments</td>
<td>Internal layer thicknesses affect life of a superheater</td>
<td>Continuous safety improvement</td>
</tr>
<tr>
<td>Analyze results</td>
<td>RBI Risk assessment needed</td>
<td>Timing of the correct investments -&gt; benefits already on the short-term</td>
</tr>
<tr>
<td>Plan and schedule actions, update earlier plans and information in systems</td>
<td>Possible safety risk, significant unavailability risk eliminated (over 220 000 operation hours)</td>
<td>Risk assessments utilized</td>
</tr>
</tbody>
</table>
Some details in the Joensuu Lifetime Management project

Creep damage in the main steam pipeline found on time
Samples examined to support decision making

Important results
- No safety hazards
- Unavailability costs avoided
- Optimum timing for investments

• Repair planned and carried out during the outage
• Work supported by laboratory studies
• Timing of superheater refurbishment supported by life assessment of tube samples
• Inside layer thickness, temperature follow-up etc.

Case 2: Eskilstuna Project, boiler plant refurbishment

Background
- Eskilstuna Energi och Miljö AB (EEM) aims to extend the lifetime of the CFB boiler
- Turn-key project
- Public procurement tendering process
- Time schedule
  - Site work 1 April – 1 July 2016
- Plant: 110 MW Biofuel CHP 57\text{th} MW Biofuel CFB (in this project)

Scope
- Modernization of the boiler and auxiliary systems including renewal of
  - CFB boiler cyclones
  - Start-up/support burners (2 pcs) with an oil pumping unit; possibility to bio-diesel firing
  - Fuel day silo bottom and the hydraulic system
  - Flue gas recirculation fan and ducts (partly)
  - Bottom ash removal system incl. a new ‘ash’ building
  - Soot blowers (6 pcs) for district heating ECO
  - Extension of the SNCR -system
- All installation work is included
Outcome of the Eskilstuna Project

Emission reduction
- Extension of the existing SNCR system to fulfill the required emission limits

Production secured
- Safe and reliable production secured
- Availability improvements

Life extension
- The goal: life of the 30 years old boiler plant could be extended by 20 years

An example/ a rough illustration: renewal of the bottom ash removal system

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Asset Management Strategy

- Management system includes policies
  - Safety
  - Environment
  - Legislation and regulations
  - Resources
  - Organisation
  - Decision making criteria
  - Long-term objectives, sustainable outcomes, stakeholder requirements

- Continuous improvement
  - Development of assets, upgrading
  - Development of the management system

In Power Generation
Asset Lifecycle Management

Asset Management system
- Data management
- Performance follow-up
- Condition report
- Long-term plans & other plans

Asset Lifecycle Management
-- Asset Integrity

Organizational strategic goals & stakeholder expectations

Investment planning, return on capital employed, risk & sustainability

System performance, cost & risk management

Manage Asset Portfolio

Manage Asset Systems

Create/ Acquire

Utilize

Maintain

Renew/ Dispose

Modified from PAS 55-1: 2008 Asset management Part 1, Specification for the optimized management of physical assets
Fortum TOPGen® O&M concept is a company specific way to set up O&M organization, management systems and selected IT tools at power plants and to operate and maintain power plants.

Make your power plant efficient!

Case
CHP-plant
60 MWe
90 MWth
6000 h/a
=>1060 GWh_{fuel}
20 €/MWh_{fuel}

1 %- Fuel saving
10600 MWh_{fuel}
=> 212 000 €/a
2 %- Fuel saving
21200 MWh_{fuel}
=> 424 000 €/a

- Optimise refurbishment costs
- Optimise operation & maintenance and management costs
- Minimise unavailability costs
- Fuel and emissions cost savings through optimum efficiencies

- Recruitment
- Training
- Continuous updating of knowhow
- Multi-skilled
- Rewarding

- Leadership

- Thermodynamics, hydrodynamics (water steam process), Water chemistry, Fortum wide support e.g. purchasing

- Use of advanced tools and techniques Fortum wide support and expertise

- Use of advanced tools and techniques Fortum wide support and expertise

- Structured operating processes

- Professional and motivated people

- Continuous improvement

- IT tools:
  - Thermodynamics, hydrodynamics (water steam process), Water chemistry, Fortum wide support e.g. purchasing
  - TOP® process information and optimisation system
  - Solvo® process modelling/simulator
  - TOP®® simulator
  - Apros® simulator
  - Maximo® asset and maintenance management
  - TOP® Logbook electronic log book
  - ProjectWise document and data management

- Value creation and predictable business performance
  - Safety
  - Availability
  - Costs
  - Fuel efficiency
  - Asset integrity

- Integrated (Site) Management System (IMS)
- How to work at site
- Continuous improvement IT tools:

- Recruitment
- Training
- Continuous updating of knowhow
- Multi-skilled
- Rewarding

- Leadership

- Thermodynamics, hydrodynamics (water steam process), Water chemistry, Fortum wide support e.g. purchasing

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- Value creation and predictable business performance
  - Safety
  - Availability
  - Costs
  - Fuel efficiency
  - Asset integrity

- Integrated (Site) Management System (IMS)
- How to work at site
- Continuous improvement IT tools:
Basis for successful Plant Lifecycle Management, Fortum

Preplanning and requirements
- Documents
- Meta-data
- Coding system
- Formats
- Archive and method of delivery
- Coding of the systems and equipments

Planning
- Main level hierarchy
- Purchasing
- Acceptance
- Cost control
- Project documentation
- Criticality classification for main components
- O&M strategy

Construction & Commissioning
- Equipment level hierarchy
- Commissioning logbook
  - Deviations
  - Failures
  - Preventive maintenance
- Acceptance of O&M documents
- Criticality classification for all components
- Preventive maintenance programmes
- Spare part management

Operational lifetime
- O&M budgeting (3 year interval)
- Strategy monitoring
- Long term planning (5 – 10 years)
- Preventive maintenance
  - Actions
  - Programmes
  - Analysis
  - Failure repairs
  - Yearly overhauls
- O&M data monitoring
- Benchmarking

Fortum approaches for condition monitoring in lifetime management

General services for production plants / Continuous Condition management
- Process thermal performance and energy efficiency monitoring
  - IT-systems, process model, analysis and remote support
- Mechanical equipment condition management
  - Vibration monitoring for rotating machines
  - Structural mechanics analysis and studies
- Electrical equipment condition management
  - Generators, high voltage motors, transformers
- Water and environmental chemistry management

In addition for power plants / Overhaul and projects
- Combustion and boiler condition and lifetime management
  - Combustion modelling (CFD) for all boiler types and Low-NOx-burners
  - Combustion, fouling and corrosion monitoring including systems
  - Boiler and main steam line inspection planning and long-term plans
- Turbine and generator condition review, inspection, overhaul and modernisation
  - Including replacement of parts as well as control and protection systems
Maintenance development process, ReMaint®

Objectives and scope
- Definition of equipment maintenance strategy for each CA class according to the production plan of the PP
- Collection and evaluation of plant and equipment data and documentation
- Classification of equipment according to ReMaint® concept
- Resources

Dimensions:
- Evaluation of current Maintenance activities
- Optimization of Maintenance programs and activities by e.g. FMEA
- Comparison of present and optimized Maintenance programs
- Estimation of savings
- Evaluation of saving potentials
- Continuous improvement process

Implementation:
- New processes and programs
- Implementation of new optimized Maintenance programs

Training:
- Resources

Criticality Analysis

Classification of equipment according to ReMaint® concept

Maintenance Strategy

Definition of equipment maintenance strategy for each CA class according to the production plan of the PP

Evaluation of current Maintenance activities

Implementation

Optimization of Maintenance programs and activities by e.g. FMEA

Continuous improvement process

Case CHP plant – ReMaint®

Maintenance development
- Criticality Analysis based on risk assessments
  - Waste-to-Energy plant 160 MW_TH
- FMECA(*) and RCM(**) analysis for the most critical system(s)
  - Fuel handling system
- Optimization of Preventive Maintenance (PM) programs and critical spare parts

Benefits for the Power Plant business
- Not anymore disturbances and unplanned shutdowns due to critical components (before c.a. 190 h / 11 y)
- Systematic, comprehensive and well-timed PM programs for critical components
- Outsourcing of routine maintenance, for example bearings lubrication
- Easy mobilization of critical spare parts, placed in site storage or near in spare pool

(*) FMECA = Failure Mode, Effect and Criticality Analysis
(**) RCM = Reliability Centered Maintenance
Systematic follow-up, performance indicators

- Performance: Performance indicators (KPIs), TOP® (process performance), CMMS
- Management system: cPIP® auditing, reviews and internal audits at planned intervals
- Predetermined condition reports at planned intervals, scheduled long-term plans

<table>
<thead>
<tr>
<th>Condition Indexes</th>
<th>Turbine</th>
<th>Generator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power plant/unit</td>
<td>Stator</td>
<td>Rotor</td>
</tr>
<tr>
<td>PL1 - G1</td>
<td>Very good</td>
<td>Very good</td>
</tr>
<tr>
<td>PL2 - G2</td>
<td>Good</td>
<td>Fair</td>
</tr>
<tr>
<td>PL3 - G1</td>
<td>Poor</td>
<td>Poor</td>
</tr>
<tr>
<td>PL4 - G1</td>
<td>Fair</td>
<td>Poor</td>
</tr>
<tr>
<td>PL5 - G2</td>
<td>Good</td>
<td>Good</td>
</tr>
</tbody>
</table>

Audit, Analyse and Develop the use of CMMS

CMMS (computerized maintenance management) in the asset lifecycle management
- Long-term planning
- Investment projects
- Daily operation and maintenance management and reports
- Condition reports
- Analysis, planning and budgeting support
Tools and methods for development
Summary

- **Assessment and auditing processes**, Safari® and cPIP®
- **Prioritization methods** – Criticality analysis (CA), RBI, analysis of production failures, condition and life cycle assessment
- **Analysis methods** – Failure Mode and Effect Analysis (FMEA), Hazard and Operability Study (HAZOP), Cause & Effect Analysis and Root Cause Analysis, Problem Solving
- **Integrated Management Systems (IMS)**, TOPGen®, Maintenance Handbook, ReMaint®
- **Applications**, Miriam RAM Studio, Availability follow-up tool, Elmas

Creating measurable value

**Asset productivity and lifecycle profits developed by:**

- Improving the performance and productivity of existing power plants
  - Availability, energy efficiency, O & M costs development and the productivity of investments
- Managing risks and the condition of main components, such as turbine, generator, boiler, etc.
- Utilizing advanced analysis and management tools
- Performing successful O & M introductions and start of the commercial operation for new power plants
- Improving both site-level O & M and asset productivity processes
Transition towards Solar Economy is ongoing

Thank you!

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