Coal to Biomass Conversion

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19th February 2019
Summary
Coal to Biomass Conversion

- Transformation Timeline
- Drax Overview
- Project Overview
- Plant Modifications/Adjustments
- Technical Challenges
- Next Steps
## Biomass Transformation Timeline

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
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<tbody>
<tr>
<td>2003</td>
<td>• Started cofiring biomass, small % through the mill</td>
</tr>
<tr>
<td>2005</td>
<td>• Installation of pilot direct injection (DI) plant</td>
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<tr>
<td>2006</td>
<td>• Installation of 2\textsuperscript{nd} phase DI plant</td>
</tr>
<tr>
<td>2010</td>
<td>• Single mill trials on 100% biomass • Completion of 400MWe (10%) cofiring plant</td>
</tr>
<tr>
<td>2011</td>
<td>• Full unit test 50% biomass, short term 100% test</td>
</tr>
<tr>
<td>2012</td>
<td>• Large scale project execution</td>
</tr>
<tr>
<td>2013</td>
<td>• Unit 2 conversion to 100% biomass</td>
</tr>
<tr>
<td>2014</td>
<td>• Unit 3 conversion to 100% biomass</td>
</tr>
<tr>
<td>2015</td>
<td>• Unit 1 conversion to enhanced cofiring</td>
</tr>
<tr>
<td>2016</td>
<td>• Unit 1 conversion to 100% biomass</td>
</tr>
<tr>
<td>2017</td>
<td>• Unit 4 trial conversion</td>
</tr>
<tr>
<td>2018</td>
<td>• Units 4 conversion to 100% biomass</td>
</tr>
</tbody>
</table>
Integration Throughout Supply Chain

- Fibre contracts for Drax Biomass International
- Delivered at Port (DAP)
- Free on Board (FOB)$^{(1)}$
- Cost Insurance Freight (CIF)$^{(2)}$
- Delivered to Drax

- Forest  
- Harvesting  
- Transport  
- Processing  
- Transport  
- Port storage and handling  
- Ocean freight  
- Port storage and handling  
- Rail  
- Furnace

Drax pellet plants  
Drax US port facility  
Drax UK port facilities

Moving back up the supply chain to secure the supply portfolio
Project challenges

Scale of conversion
• No similar sized plant operating at same output, reference sites

Technical Advice
• No single EPC contractor with necessary expertise
• Limited experience of conversion with similar technology
• Conflicting information/advice from 3rd parties

Timescales
• 1st April 2013 deadline for first conversion.
• Alignment to outage programmes.

Budget
• Forecasting for trial and full conversions
• Challenge to budget throughout process
Drax Biomass Plant – Site Overview

Diagram showing the flow of biomass from storage, through co-firing, operational plant for conversion, and finally to the boiler and ash co-products.

Key components:
- Unloading & Storage
- Hammer Mills
- Coal
- Stockpile & Reclamation
- Pulverising Mills
- Co-firing
- Operational Plant for Conversion
- Ecostore
- Rail Unloading
- Large Scale Storage
- BDS
- Pneumatic Conveying
- Ash Co-products
- Burners
- Boiler
Drax Site – 2006
Materials Handling Plant
Ecostore construction
Drax Site Development

Rail Unloading and Storage

Fuel Distribution

Combustion

[Images of construction sites and diagrams related to Drax Site Development]
## Coal vs Biomass

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Coal</th>
<th>Biomass</th>
<th>Impact</th>
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</thead>
<tbody>
<tr>
<td>CV</td>
<td>~24 MJ/kg</td>
<td>↘ 16.5-18.5 MJ/kg</td>
<td>More volume required into boiler</td>
</tr>
<tr>
<td>Bulk density</td>
<td>~900 kg/m³</td>
<td>↘ 650 kg/m³</td>
<td>Transport, storage, handling</td>
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<tr>
<td>Sulphur content</td>
<td>1.4%</td>
<td>↘ 0.02</td>
<td>FGD not required</td>
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<tr>
<td>Volatile Matter</td>
<td>32.9%</td>
<td>↗ 80%</td>
<td>Processing controls</td>
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<tr>
<td>Oxygen</td>
<td>7%</td>
<td>↗ 50%</td>
<td>Self heating, reactivity</td>
</tr>
<tr>
<td>Moisture</td>
<td>10-20%</td>
<td>↘ 4-6%</td>
<td>Safety, combustion</td>
</tr>
<tr>
<td>Chlorine</td>
<td>0.40</td>
<td>↘ 0.02</td>
<td>Agricultural residues</td>
</tr>
<tr>
<td>Particle size</td>
<td>75% &lt; 75µm</td>
<td>99.5% &lt; 4.15mm</td>
<td>Larger particle size, burnout, emissions</td>
</tr>
<tr>
<td>Ash</td>
<td>~10-20%</td>
<td>0.85%</td>
<td>Lower dust emissions</td>
</tr>
</tbody>
</table>
Drax Boiler Overview
Unit 1-3

- Main steam conditions (stop valve outlet):
  - Pressure - 165 bar
  - Temp - 568°C
  - Evaporation - 565kg/s

- 645MWso
- Stable export limit 300MWso
- Frequency response

- Dimensions
  - ~20m(w) x 10m (d) x 65m (h)

- 48off axial swirl PF burners

- 10off vertical spindle ball mills
  - Throughput - 21-50t/hr per mill
  - 8 mills required for full load

- Full load ~ 320t/hr biomass burn

- Net efficiency ~ 40%
Boiler

Combustion

Burners

Mills
Boiler

- Furnace Bottom Ash
- Gas Outlet Temp
- Emissions
Boiler

Fouling
Boiler

Corrosion, Heat Flux
Boiler Conversion Requirements

Mill conversions
• Throughput optimisation

Burner modifications
• Design changes
• Flame detection

PF distribution improvements
• Balancing equipment
• Measurement & analysis

Mill inlet temperature reduction
• PA Cooler

Mitigant injection system

Operational performance
• Efficiency
• Flexibility
• Emissions
• Forced outage rate

Fan performance improvements
• Throughput increase
• Temperature control

Combustion controls
• Boiler response

Fuel flexibility
• Slagging
• Fouling
• Corrosion – boiler, ductwork, airheaters

Dust handling plant
• ESP performance
• Dust transfer

Ash handling plant
• Ash hopper temperature control

Recovery of unburned fuel
Project Development Process

- Information search
- Contact with other operators
  - Avedore, Burger, Hasselby, OPG, Lynemouth and others
- 3rd Party studies
  - KEMA, Nalco Mobotec, Doosan Babcock
- Identification of bottlenecks/unknowns
- Proposal for improvements
- Engineering calcs/design
- Testing of theories and analysis of outcomes
- Full work scope planning and development
- Full scale modification
- Optimisation
**Burners**

**Key Information**
- Heat input – 40MWth or 61MWth per burner
- Fuel flow – 3.5t/hr → 12.5t/hr (each burner)
- Higher Volatile matter content
- Lower CV – higher fuel volume required
- Coarser Particle size

**Flame Detection**
- Provides safety function as part of boiler management system
- Reliable flame detection is very important
- Flame discrimination between oil/biomass necessary
- Opposed wall firing boiler provide additional challenge
**MK3 Burner**

Preliminary modifications

**Issues**
- Flame detachment – flame monitoring reliability
- Particles projecting into opposing windbox
- Incomplete combustion
- High ash hopper fall out
- Insufficient mixing of air/fuel in near burner region
- NOx/CO production

**Initial Solution**
- Removal of coal concentrators in burner
- Removal of secondary air barrel
- Combined secondary/tertiary swirler with high angle
- Minimisation of primary air velocity
- Adjustment of flame monitor settings/location
- Improve burner deslagging
- Improve fuel distribution
- Improve secondary air distribution
Modified Coal Burner Design
Doosan MK3 Low Nox burner (biomass modification)

- Sec Air Swirler
- Wind box
- Core air tube
- Furnace Quarl
- Primary Air/Fuel Mix
- PA Fan
New Burner Design
Hitachi DS Burner (40/60MWth)
Long Term Installation
Hitachi biomass burners

• All boilers now upgraded to Hitachi DSW burners
• Improved flame stability
• Reduction in NOx/CO emissions (stoichiometry)
• Improved burner integrity
Furnace Flow Vortex Analysis

- CFD modelling carried out
- Identify optimised swirl configuration
- Predict furnace CO creation
- Allow adjustment of operating parameters
  - Furnace staging
  - BOFA operation

Rev.4
$\lambda_0=0.90$
MOFA Level A
typ. Sec. Air
# Burner Set-up and Swirl Patterns

## Units 1-3

**Front Wall**  
(view from outside furnace)

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<th>A6</th>
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<th>A4</th>
<th>A3</th>
<th>A2</th>
<th>A1</th>
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<td>Short</td>
<td>Short</td>
<td>Short</td>
<td>Short</td>
<td>Long</td>
<td>ACW</td>
<td>CW</td>
<td>ACW</td>
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<td>Short</td>
<td>Short</td>
<td>Short</td>
<td>CW</td>
<td>ACW</td>
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## Rear Wall

(view from outside furnace)

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<th>A3</th>
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<td>CW</td>
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<td>Short</td>
<td>Short</td>
<td>Short</td>
<td>Long</td>
<td>ACW</td>
</tr>
</tbody>
</table>

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**CW** - Clockwise Swirl  
**ACW** - Anti-Clockwise Swirl
Mill Modifications
Doosan 10E10 Vertical Spindle Pulverising Mill
Mill Modifications

Coal Milling
• 43t/hr processing – coal is ground to fine powder (75% thro’ 75micron)
• Coal CV ~24MJ/kg
• Brittle material
• Mill inlet temp ~ 260-300°C
• Outlet temp target 90°C

Biomass Milling
• 50t/hr target throughput (giving similar heat input to coal)
• Wood pellets are broken back to constituent particles
• Further grinding is beneficial to combustion
• Fibrous material
• Mill inlet temp max ~ 170°C
• Outlet temp target 90 °C
Mill Modifications
Primary Air Cooler

Issue
• High tempering air requirement into mill to achieve 170°C inlet temp
• Tempering air ductwork size inadequate
• High tempering air leads to airheater bypassing
• Increased gas exit temperatures – exceeding downstream component design

Solution – Install PA Cooler
• Heat exchanger cools hot air to mills
• Recovered heat is used to preheat boiler feed water
• Mill hot air now comes from PA cooler outlet duct ~ 165-170°C
• Temperature adjusted to minimise tempering air use
• Reduces gas exit temperature
• Provides small efficiency improvement
Mill Modification

- Adjustable classifier inlet
- Classifier swirl removed
- Primary return baffles
- Extended inlet cone
- Fuel distribution paddle
- Throat modifications
- Firefighting injection point
- Mill Modification
Mill Grinding Performance

- **Milled Fuel**
  - >2.36mm
  - 0.6% to 3.7%

- **Sieved Fuel**
  - 0.0% to 1.0%
  - 2.7% to 3.7%

- **Raw Pellets**
PF Pipe Blockages

**Issue**
- PF falling out of suspension and building up in PF lines
- No time to react to blockages occurring
- Blockages lead to loss of availability of plant
- Increased safety risk due to overheating components
- Line clearing adds additional risk

**Solution**
- Adjust mill operating load lines
- Improve air/fuel balance across PF lines
- Install instrumentation to provide early warning of blockages
- Provide operator additional information – fuel characteristics
PF Distribution - HVARBs

- Rope breakers lift fuel rope from pipe wall
- Improves effectiveness of bi/tri-furcators
- Control gates provide additional fine tuning of PF split
PF Distribution
Equipment development

- Sampling undertaken using isokinetic Roto-probe sampling
  - Modified nozzle size leads to reduced blockages
  - Repeatability is inconsistent due to transient flow characteristics
- Performance dissimilar across sister mills.
- Mill outlet imbalance cannot be overcome by downstream equipment.
- Focus made to improve balance of fuel at mill exit.
- Mill modelling and improved internal design implementation
- Online PF flow monitors fitted to allow quick reaction to developing issues.
Mill Modifications – 2nd Generation

- Improved aerodynamics through mill
- Reduction in mill pressure drop
- Lower pressure drop across mill throat
- Reduced internal baffling, change of direction
- Simplified classification
- Increased throughput
- Improved mill outlet fuel flow balance
- Adjustable internals
- Reduced maintenance requirements
- Improved internal access

- Currently installed on 10 of 40 mills
- Optimisation programme ongoing
Furnace Corrosion

Potential to occur at any location around the boiler
Accelerated by gas temperature
Localised gas chemistry variations

Permanent Corrosion Measurement
- Corrosion probe array (340 locations)
- Coverage of vulnerable sections of side wall
- Separate probes at specified locations – in gas pass
- Indicates corrosion rate, wall loss, heat flux

Manual testing
- Short term test coupon insertion and analysis
- Evaluation of corrosion rates, build up rate, build adhesion

Outage inspection and analysis
- NDT findings cross checked against predictions and online measurements
- Inspection based assessment carried out at other locations in boilers
Lower Furnace Corrosion
Sidewall monitoring system

Data Analysis

- Analysis and reporting carried out remotely by 3rd party
- Identifies areas of concern
- Actions taken to rectify
- Determination of expected outage workscope
- Short term analysis can be overlaid onto test periods
Furnace Corrosion
Manual corrosion probe measurement

Test Equipment
• Test ring inserted into furnace gas flow
• Temperature controlled to match metal temperatures of boiler components
• Collection period of ~2hrs

Post-retraction analysis allows evaluation of:
• Build up rate
• Metal Loss
• Adhesion strength of deposit
• Chemistry of deposit (SEM/EDAX analysis)

Benefits
• Short test periods can be undertaken
• Provides indication of corrosion and expected deposits

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Deposit probe with detachable ring.

Deposit probe after exposure.
Furnace Slagging

**Issues caused**
- Reduced heat transfer rate
- Boiler access restricted
- Corrosion of components
- Slope damage due to slag falls

**Reducing impact of slagging**
- Sootblower optimisation
- CCTV monitoring
- Mitigant injection
- Visual inspections on periodic basis
- Fuel spec understanding
- Fuel blending – boiler fuel specification
- Superheater element design – coatings, membranes
Furnace Cleaning
Online explosive cleaning

Cleaning techniques used for slag removal
• Pre-outage cleaning – on load
• Off load cleaning

Access improvements
• Boiler modifications – access doors
• High pressure tank cleaning head use
• Internal manual cleaning
Boiler Fouling

Boiler fouling model
• Observes operating temperatures to determine fouling throughout the gas path
• Allows sootblower optimisation – saving works power, efficiency

Operational parameters – heat distribution
• Economiser boiling margin monitored

Build up on tube reduces heat transfer to water/steam
• Higher gas temps at economiser
• Reflectivity of furnace walls reduces heat transfer in furnace zone
• CO emissions – increases with higher furnace temps

Internal inspections
• Periodic visual inspections
• Fouling samples analysed for ash components

Cleaning access
• Breakdown outage cleaning – for access to carry out repairs
• Outage access – widespread cleaning required to allow full safe access
Mitigant Injection

- Investigation and test work showed that injection of mitigant controls slagging, fouling and corrosion
- Mitigant material must have undergone specific conditions during combustion
- UK Patent secured for mitigant addition
- Mitigant material introduced into furnace
  - Pneumatic direct injection
  - Slurry mix through mills
- **Primary function**
  - Collection of corrosive components of flue gas and transport through boiler
  - Cleans elements of boiler via mild erosion
  - Reduce slag formation – more friable
- **Secondary benefits**
  - CO reduction
  - Improved heat transfer within furnace zone
  - Improves performance of ESPs
**Mitigant Injection**

**Corrosion ring evaluation**

<table>
<thead>
<tr>
<th>Fuel</th>
<th>No Mitigant Injection</th>
<th>With Mitigant Injection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wood Only</td>
<td>![Image of Wood Only (No Mitigant Injection)]</td>
<td>![Image of Wood Only (With Mitigant Injection)]</td>
</tr>
<tr>
<td></td>
<td><strong>Two tests show variability within fuel</strong></td>
<td><strong>Lower build up rate, less firm and less corrosive</strong></td>
</tr>
<tr>
<td>Wood + Agri Fuel</td>
<td>![Image of Wood + Agri Fuel (No Mitigant Injection)]</td>
<td>![Image of Wood + Agri Fuel (With Mitigant Injection)]</td>
</tr>
</tbody>
</table>

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Siemens P3000

- Laser array provides combustion zone information
  - In-furnace monitoring of NOx, CO, O_{2}, H_{2}O
- Live feedback of combustion outputs
- Reduction in O_{2} levels
- Improved plant reliability required
- NOx reduction of >10% achieved
- Maintain operation within tolerable maximum CO limits
  - Improved efficiency – lower CinA
  - Reduction in unburned material reaching ESPs
- Further tuning necessary to provide sustained performance across transient operating modes.
Future Challenges

• **Optimisation of current systems**
  • Reduce CinA
  • Improve unit flexibility
  • Higher load output

• **Tightening emissions limits**
  • Overall reduction – NOx, sulphur, particulates

• **Broadening fuel basket to more challenging fuels**
  • Higher slagging, fouling and corrosivity
  • Lower CV
  • Processing and handleability
Visit in person

• **Weekday tours**
  Monday to Friday
  9am – 4pm

• **Weekend tours**
  Saturdays between February and November
  10am

[www.drax.com/visit-us](http://www.drax.com/visit-us)
Thank you

Adam Nicholson CEng FI MechE
19\textsuperscript{th} February 2019