Cogeneration for Metal Industry
- Utilization of Furnace Off - gases for power generation

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Product Line Manager
GE Energy
Austria
Jenbacher Manufacturing

Jenbach, Austria
HQ for Sales, Service, Manufacturing & R&D

Veresegyház, Hungary
Container manufacturing

Hangzhou, China
Packaging for Asia
Four types of gas engines

**Type 2**
- Electrical output: from 250 to 330KW
- 8 cylinder
- 1,500 rpm (50Hz) / 1,800 rpm (60Hz)
- Delivered engines: more than 850
- Since 1976 in the product program

**Type 3**
- Electrical output: from 500 to 1,100KW
- V12, V16 and V20 cylinder
- 1,500 rpm (50Hz) / 1,800 rpm (60Hz)
- Delivered engines: more than 5,000
- Since 1988 in the product program

**Type 4**
- Electrical output: from 800 to 1,500KW
- V12, V16 and V20 cylinder
- 1,500 rpm (50Hz) / 1,800 rpm (60Hz)
- Delivered engines: more than 750
- Since 1989 in the product program

**Type 6**
- Electrical output: from 1.5 to 4MW
- V12, V16, V20 and V24 cylinder
- 1,500 rpm (50Hz, 60Hz with gearbox)
- Delivered engines: more than 2,200
- Since 2002 in the product program
Integrated steel plant - process gases

- Coke oven gas
- BF gas
- BOF gas
- Ladle metallurgy
- LD converter

Alloy melting Industry

- SAF (Sub Merged Arc Furnaces)

<table>
<thead>
<tr>
<th>J620</th>
<th>COG</th>
<th>BFG</th>
<th>BOF</th>
<th>FOF</th>
</tr>
</thead>
<tbody>
<tr>
<td>engine version</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>electrical output Pel (potential)</td>
<td>[kWe]</td>
<td>1970</td>
<td>1970</td>
<td>1700</td>
</tr>
<tr>
<td>electrical efficiency [%]</td>
<td>[%]</td>
<td>40,2%</td>
<td>37,4%</td>
<td>37,2%</td>
</tr>
<tr>
<td>total efficiency hot water [%]</td>
<td>[%]</td>
<td>79,6%</td>
<td>82,9%</td>
<td>81,6%</td>
</tr>
<tr>
<td>total efficiency steam (10 barg) [%]</td>
<td>[%]</td>
<td>54,2%</td>
<td>63,1%</td>
<td>62,4%</td>
</tr>
</tbody>
</table>
Integrated steel plant - process gases

- Coke oven gas
- BF gas
- BOF gas
- FOF gas

Alloy melting Industry

SAF (Submerged Arc Furnaces)
Coke Gas Utilization

Profusa / Spain
12 x JMS 316 GS-S/N.L

Plant Output
7,164 kWel
8,950 kWth

Coke gas:
H₂  55%
CH₄  30%
CO   5%
CO₂  5%
N₂   5%
LHV = 4.8 kWh/m³

More than 1.3 Mio. cumulated oph (12/2010)
Converter Gas from LD-Steel Process:

**Aceralia / Spain - Pilot**

Pilot engine „Acerpruebas“
1 x JMS 620 GS-S/N.L
approx. 3000 oh

**LD Converter gas:**
- CO 60-75%
- H₂ 1%
- N₂ 13%
- CO₂ 13,5%
- **LHV = 2.4 kWh/m³_N**

About 3,000 operating hours resulting in optimized solution
Converter Gas from LD-Steel Process:

Aceralia / Spain

12 x JMS 620 GS-S/N.L
Plant Output
20,400 kWel
12,140 kWth

LD Converter gas:
CO  60-75%
H₂  1%
N₂  13%
CO₂ 13.5%
LHV = 2.4 kWh/m³

More than 400,000 cumulated operating hours (10/2010)
Converter Gas – Aceralia:

Gas Engines: Electricity and Heat (Feed water for Boiler)

Steam boiler

Gas

Electrical Energy and Steam

Plant Aceralia

Steam boiler
Converter Gas from LD-Steel Process

12 x JMS 620 GS-S/N.L  20.4 MWel

More than 300,000 cumulated operating hours (10/2008)
Combustion development at single cylinder engine test bench (LEC Graz) with artificial BFG & Furnace Off gases

- Various test runs with different combustion concepts
- Three different configurations selected for “siderurgical gases”
Converter Gas – Furnace Off gases

Power Output vs. H2 Content vs. CO Content

- E53
- E55
- E 57
- E58

H2 [Vol%]

CO [Vol%]

1 2 3 4

10 20 30 40 50 60 70 80 90

0 5 10 15 20 25 30 35 40 45 50 55
## Converter Gas – Furnace Off gases

### Output Overview

<table>
<thead>
<tr>
<th>1</th>
<th>J 620GS - E53</th>
<th>2</th>
<th>J 620 GS- E55</th>
<th>3</th>
<th>J 620 GS - E57</th>
<th>4</th>
<th>J 620 GS - E58</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Potential</strong></td>
<td><strong>Guaranteed</strong></td>
<td><strong>Potential</strong></td>
<td><strong>Guaranteed</strong></td>
<td><strong>Potential</strong></td>
<td><strong>Guaranteed</strong></td>
<td><strong>Potential</strong></td>
<td><strong>Guaranteed</strong></td>
</tr>
<tr>
<td>BMEP</td>
<td>11.22 bar</td>
<td>11.22 bar</td>
<td>11.22 bar</td>
<td>10 bar</td>
<td>13 bar</td>
<td>11.22 bar</td>
<td>13 bar</td>
</tr>
<tr>
<td><strong>Electrical Output</strong></td>
<td><strong>Electrical Efficiency</strong></td>
<td><strong>Steam@10bars</strong></td>
<td><strong>Th. Efficiency Water &amp; Steam</strong></td>
<td></td>
<td></td>
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<tr>
<td>1,698 kW</td>
<td>37.0 %</td>
<td>1,515 kg/h</td>
<td>41.2 %</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1,698 kW</td>
<td>37.0 %</td>
<td>1,564 kg/h</td>
<td>41.4 %</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1,511 kW</td>
<td>36.6 %</td>
<td>1,437 kg/h</td>
<td>41.4 %</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1,968 kW</td>
<td>35.9 %</td>
<td>1,713 kg/h</td>
<td>40.7 %</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1,698 kW</td>
<td>37.4 %</td>
<td>1,517 kg/h</td>
<td>38.8 %</td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>1,511 kW</td>
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<td>1,317 kg/h</td>
<td>37.5 %</td>
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</table>
Furnace Off gas plant

Power Output vs. H2 Content vs. CO Content

<table>
<thead>
<tr>
<th></th>
<th>plan</th>
<th>actual</th>
</tr>
</thead>
<tbody>
<tr>
<td>H₂</td>
<td>3-7 Vol%</td>
<td>9-18 Vol%</td>
</tr>
<tr>
<td>C</td>
<td>70-80 Vol%</td>
<td>62-80 Vol%</td>
</tr>
<tr>
<td>Pe</td>
<td>1.5 - 1.7 MWe</td>
<td>1.4 - 1.5 MWe</td>
</tr>
</tbody>
</table>
Steel gas – ArcelorMittal – BFG Pilot plant

Pilot plant built on site in ~1 week
High flexibility of modular containerized Solutions
Reliable and Efficient power production

✓ High Redundancy, reliable power

- SINGLE POWER PLANT
- n INDEPENDENT UNITS

40 MW

✓ Constant Efficiency at varying loads

- Small scale Gas turbine (single cycle)
- Multiple gas engine plant
Cost of Electricity CoE – Blast Furnace Gas

### Quantitative

<table>
<thead>
<tr>
<th></th>
<th>Steam Cycle</th>
<th>Gas Turbine</th>
<th>Gas Engine</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAPEX / MWe</td>
<td>1.500 k€</td>
<td>1.750 k€</td>
<td>1.200 k€</td>
</tr>
<tr>
<td>OPEX / MWhe</td>
<td>4 €</td>
<td>5 €</td>
<td>12 €</td>
</tr>
</tbody>
</table>

Source: Assessment ArcelorMittal

### CAPEX/OPEX

- Based on case study ArcelorMittal
- European standard/labor cost
- No additional cost for fuel
  - BF-gas treatment
  - COG enrichment

Gas engine CoE competitive with gas turbine or steam turbine

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60,000 oph Financing:
- interest rate 5%
- 100% outside financing
- 10 years repayment
## CoE Steel gas – Cost base Europe

<table>
<thead>
<tr>
<th>Quantitative</th>
<th>Steam Cycle</th>
<th>Gas Turbine</th>
<th>Gas engine</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>BFG Engine</td>
</tr>
<tr>
<td>CAPEX / MWe</td>
<td>1.500 k€</td>
<td>1.750 k€</td>
<td>1.200 k€</td>
</tr>
<tr>
<td>OPEX / MWhe</td>
<td>~4 €</td>
<td>~5 €</td>
<td>~12 €</td>
</tr>
</tbody>
</table>

**Assessment**

- **Arcelor Mittal**
  - CAPEX and OPEX estimates for different engines.
  - Gas engine CAPEX: 1.500 k€, OPEX: ~4 €
  - Steam turbine CAPEX: 1.750 k€, OPEX: ~5 €
  - Gas turbine SC CAPEX: 1.200 k€, OPEX: ~12 €

**GE Jenbacher**

- CAPEX and OPEX estimates for different engines.
  - BFG engine CAPEX: 1.500 k€, OPEX: ~4 €
  - COG engine CAPEX: 1.200 k€, OPEX: ~12 €
  - LDG engine CAPEX: 1.100 k€, OPEX: ~12 €

- Financing details:
  - Interest rate 5%
  - 100% outside financing
  - 10 years repayment
Product requirements/Costumer benefit

- Flexibility towards variable off-gases offer (flow & LHV)
- Adaptable capacity to variable steel production (modularity)
- Short project lead time
- Minimal need for long term vision - limitation of risks
- High fuel efficiency (~37+%) even at small scale plants
- Higher electrical output than with steam turbine
- Competitive CoE
- Deconsolidated financing possible
Thank You!

GE imagination at work