Increasing Energy Efficiency in Breweries with Gas Turbine Cogeneration

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Combined Heat and Power (CHP) increases efficiency

Source: U.S. EPA: Combined Heat and Power Partnership
Combined Heat and Power: Key Benefits

Why OP16 and CHP?

- Increase productivity
- Innovative and cheap energy
- Energy efficiency at site
- Potential to control energy prices through CHP
- Energy security → Independent energy generation
- Packaged and simple solution
- Reliable power generation

- Economic support
- Subsidies for Cogeneration projects
- Reduce emissions

Reduce production costs
Reduce energy costs
Convert waste into energy
Increase in profits

Independency, Reliability, Availability & Profitability
Breweries: Introduction

- Beer: Produced through fermentation of barley or wheat
- Energy intensive process
- Energy accounts for 3-8% of beer production costs
- Emphasis on environmental impact
  - Energy saving technologies (CHP)
  - Waste water treatment
**Breweries: Manufacturing Process**

- **Malting**
  - Malt is weighted, cleaned, stored
  - Malt is milled and treated

- **Mash tank**
  - Malt and adjuncts mixed in hot water
  - Insoluble grains are separated
  - Water is drained, wort is obtained

- **Boiling**
  - Wort is boiled with hops
  - Wort is cooled to 8-20°C, strained, filtered

- **Fermentation**
  - Yeast is added to the cold wort
  - Beer is “maturated” and stored

- **Filtration**
  - Beer contains yeast and bacteria
  - Pumped to the bright beer tank

- **Packing and CIP**
  - The beer is bottled and carbonated
  - Equipment is deeply cleaned (CIP)
Breweries: Market Distribution

- Worldwide production 200 Billion liters per year
- China is the leader in the production, followed by USA
- Germany production leader in Europe
- Both microbreweries and major breweries present in each country
Breweries: Energy Distribution

- Specific Energy Consumption:
  - Amount of energy required to produce 1hL of beer
  - Heat to Power ratio favorable for Combined Heat & Power

Utilities | Energy level
---|---
Hot Water | 70-80°C [158-176°F]
Steam | Low Pressure Saturated Steam 5-20 bar [70-290 PSI]

Cogeneration (Electrical Chillers)

- Steam 28.74%
- Electricity 7.18%
- Ref. 3.8%

Heat to Power Ratio=2.8:1

Trigeneration (Absorption Chillers)

- Steam 28.64%
- Electricity 7.16%
- Ref. 8.6, 20%

Heat to Power Ratio=5.2:1

*Assuming COP=4 for electric chillers
*Assuming COP=1.4 for absorption chillers
Breweries: Energy Consumption

The process of brewing beer involves several energy-intensive steps:

1. **Milling** - Grinding grains to create a mash.
2. **Mash Tun** - Mixing grains with water at 60°C for 0-10 hours. Electricity is used.
3. **Brewing Copper** - Heating the mixture to 100°C. Heat and electricity are used.
4. **Cooling** - Chilling the wort to 20-25°C for Ale, 7-13°C for Lager. Electricity is used.
5. **Fermentation** - In the fermentation tank and conditioning tank. Electricity is used.
6. **Filtration** - Clearing the beer of any debris. Electricity is used.
7. **Delicious Pint of Beer** - Chiller keeps the beer at the desired temperature. Electricity is used.

The process uses hot water, heat, electricity, and chilling to produce beer efficiently.
Breweries: Waste to Power

Grains disposal & waste water

CO2 Recovery plant
Breweries: Energy Consumers

- High thermal energy consumption:
  - Brewhouse

- High electricity consumption:
  - Chillers
  - Compressed air
  - Auxiliary Drives

- Anaerobic wastewater treatment
  - Biogas (Siloxanes & H2S)

- Gasification
  - Spent grains gasification
  - Syngas for OP16 gas turbines
Breweries: Feasibility Study (European Market)

- **Trigeneration calculations are including the investment cost of absorption chiller.**
- **All calculations for Cogeneration and Trigeneration includes complete turnkey costs i.e. CAPEX and OPEX.**

### Brewery Details

- **Size:** 1.3 million hL
- **Electricity Demand:** 2,500 kWe
- **OP16 Exhaust Heat:** 4,500 kWth
- **Chiller capacity:** 640 RTons
- **Sat. Steam production:** 6 tph [13,227 lb/hr] @12bar [174 Psia]
- **Natural Gas Price:** 0.028 €/kWh
- **Electricity Price:** 0.084 €/kWh

### Savings

- **High Operational Savings:** >25%
- **Quick payback:**
  - 3.6 years (Trigeneration)
  - 3.2 years (CHP)

### Cost Analysis

<table>
<thead>
<tr>
<th></th>
<th>Base Case</th>
<th>CHP</th>
<th>Trigeneration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual operating savings</td>
<td>€ 0.67</td>
<td>€ 0.74</td>
<td>€ 0.74</td>
</tr>
<tr>
<td>Annual operating expenses</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annual fuel expenses</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Annual electricity expenses</td>
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</tbody>
</table>

**Variations:**

- **Annual operating savings:** € 0.2 – € 2.0
- **Annual operating expenses:** € 0.0 – € 0.4
- **Annual fuel expenses:** € 0.0 – € 0.8
- **Annual electricity expenses:** € 0.0 – € 1.0

**Graph:**

- **25% savings**
- **28% savings**

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*Trigeneration calculations are including the investment cost of absorption chiller.*

**All calculations for Cogeneration and Trigeneration includes complete turnkey costs i.e. CAPEX and OPEX.*
# Cogeneration & Trigeneration Integration in Breweries

<table>
<thead>
<tr>
<th>Cogeneration</th>
<th>Trigeneration</th>
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<tbody>
<tr>
<td><strong>Fuel</strong></td>
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<tr>
<td><strong>8.9 kg/s at 570°C</strong></td>
<td><strong>Electricity (utilities) 1.8 MW</strong></td>
</tr>
<tr>
<td>WHRB</td>
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<tr>
<td><strong>6.5 t/h steam</strong></td>
<td><strong>8.9 kg/s at 570°C</strong></td>
</tr>
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<td><strong>Electricity (utilities) 1.8 MW</strong></td>
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**Legend**
- GT Exhaust
- Water/Steam
- Electricity
- Ambient air
- GT Fuel
- Cold air

**Notes**
- WHRB: Waste Heat Recovery Boiler
- GT: Gas Turbine
- t/h: Tons per Hour
Gas Turbines: Unique points

- High heat to power ratio (~3:1): OP16 generates 1,876 kWe with 4,500 kWth
- Utilization of **hot and clean exhaust**:
  - High pressure and temperature steam production for brewhouse
  - Drying of spent grains
  - Operation of absorption chillers
- **High combined efficiency** (~90%)
- **Continuous and reliable** power and heat
- **Low emissions** of OP16 turbines
- **Fuel Flexibility**: multiple fuel use
  - Biogas from waste water treatment
  - Syngas from spent grains gasification
- Compact and Modular: Easy integration into existing process
Introduction: OPRA Turbines

- Dual-fuel & low emissions combustors (4)
- High-efficiency (90%) radial turbine
- Bearings in cold part of engine
- 6.7:1 ratio compressor
- Reduction gear
### Introduction: Combustion Technology

<table>
<thead>
<tr>
<th>OP16-3A</th>
<th>OP16-3B</th>
<th>OP16-3C</th>
</tr>
</thead>
<tbody>
<tr>
<td>▪ Conventional diffusion type combustor</td>
<td>▪ Dry low emission combustor</td>
<td>▪ Advanced diffusion type combustor</td>
</tr>
<tr>
<td>▪ Gaseous and liquid fuels between 20-70 MJ/kg</td>
<td>▪ Gaseous fuels between 30-51 MJ/kg</td>
<td>▪ Gaseous and fuels between 5-25 MJ/kg</td>
</tr>
<tr>
<td>▪ Dual fuel operation</td>
<td>▪ Diesel as back-up fuel</td>
<td>▪ High calorific fuel as back-up</td>
</tr>
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*OPRA TURBINES*
Thank You

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