Offshore Energy Efficiency Technologies

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Why Energy Efficiency?

- Increasing focus on CO$_2$ emissions
- Energy intensive operations
  - Oil and gas production
  - On-board processing
  - Export (compressors)
  - Drilling
- Ageing fields

Photo: Kristin Hommedal, Statoil
CO₂ Emissions

Source Distribution

- Turbine: 78.9%
- Flaring: 11.0%
- Engine: 6.8%
- Well Test: 1.2%
- Other: 1.2%
- Boiler: 0.9%

Source:
2010 Data From Norwegian Department of Oil and Energy, Facts, 2011
Goal

- Develop energy efficient technologies
- Promote implementation

Means not covered:
- Reduced flaring
- Electrification
- CCS

Reduced energy use & CO$_2$ emissions
EFFORT Objectives

- Tailor energy efficiency technology to offshore conditions
  - Compact bottoming cycles
  - Power production from surplus heat sources
- Enable implementation → focus on offshore-specific requirements
  - Low weight
  - Compact size
- Identify demonstration opportunities
Energy Sources and Demands

Sources
- Gas turbine exhaust heat
- Diesel engine exhaust heat
- Gas compressor export gas intercooling/aftercooling
- Well stream energy
- Gas expansion

Demands
- Product export
- Gas compression
- Water/Oil/Gas separation
- Gas lift and Gas/water injection
- TEG regeneration
- Amine regeneration
- Refrigeration
- Fresh water production and daily life
EFFORT Case Studies

Case Group 1: Newer Installations
Case Group 2: Brown Field Installations
Gase Group 3: Future Installations and FPSO

Working Fluids/Cycles
- Steam
- CO₂
- Hydrocarbons

Integration Principle
- Heat integration
- All electric
- Compact Bottoming Cycles
- Compact Surplus Heat Utilization

Heat Capture and Utilization
Power Production from Waste Heat

Gas turbine
- Natural gas in
- Combustion chamber
- Generator
- Compressor
- Air in

Bottoming cycle
- Hot exhaust warms CO₂/steam
- Condenser
- Pump
- Heat exchange with seawater
- Turbine and generator
- Power

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Bottoming Cycle

- GT nominal power: 32MW
- Combined cycle: 42 MW
- Increase in plant efficiency: 38.6 -> 50.0%
Working Fluids for Bottoming Cycles

**Steam**
- Conventional technology
- Challenges:
  - Land-based systems too bulky
  - Reliability
- Opportunities
  - Once-through technology
  - Reduce water treatment issues

**CO₂**
- Under development
- Challenges:
  - Full scale demo necessary
- Opportunities:
  - Potentially more compact
  - Suited for Arctic areas
Power Production from Surplus Heat Sources: Compressed Gas

- Low temperature heat source
- High pressure -> compact HX
- Rankine Cycle
  - Subcritical hydrocarbon
  - Transcritical CO₂ or hydrocarbon

Export gas compressor

Aftercooler

Generator

Turbine

Pump

Condenser

Cooling water
## Bottoming Cycle Performance

<table>
<thead>
<tr>
<th></th>
<th>Simple Cycle</th>
<th>Combined Cycle Steam OTSG</th>
<th>Combined Cycle CO2 Single Stage</th>
<th>Combined Cycle CO2 dual stage</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gas Turbine</strong></td>
<td>GE LM2500+G4</td>
<td>GE LM2500+G4</td>
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</tr>
<tr>
<td><strong>Net plant power output (MWe)</strong></td>
<td>32.2</td>
<td>42.9</td>
<td>41.1</td>
<td>42.0</td>
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<tr>
<td><strong>GT Gross Power output (MWe)</strong></td>
<td>32.5</td>
<td>32.1</td>
<td>32.1</td>
<td>32.1</td>
</tr>
<tr>
<td><strong>Bott Cycle Gross Power output (Mwe)</strong></td>
<td>-</td>
<td>11.3</td>
<td>9.5</td>
<td>10.4</td>
</tr>
<tr>
<td><strong>Plant Efficiency(%)</strong></td>
<td>38.6</td>
<td>51.0</td>
<td>48.9</td>
<td>50.0</td>
</tr>
</tbody>
</table>
CO₂ Emissions from Gas Turbine with Steam and CO₂ Bottoming Cycles

GT LM 2500+G4

w/OTSG W/CO2 CC single stage w CO2 CC dual stage

CO₂ emitted (g/kWhr)

517 388 406 397

-25% -23% -24%

GT LM2500+G4 Turbine with bottoming cycles
Scenarios for Improving Offshore Energy Efficiency

Efficiency of gas turbine very dependent on load

- LM2500+ RD(G4)
- LM2500PJ
- LM1800 e HP
Scenario 1:
Reduce Size of Turbines to Operate at Higher Effective Load

- More than half of offshore gas turbines on the NCS run at 50-60% load, a few at 70-80%
- Beneficial to replace with smaller turbines where possible
  - Run at higher load and higher efficiency
  - Up to 5% reduction in CO₂ release
- Even greater effect towards the end of the life of the platform
  - Power demand is reduced.
  - At low loads a less efficient turbine may become relatively more efficient than the larger turbine
- Reducing CO₂ emissions without taking up precious space and weight
- Important factor in design of future- and during remodeling/maintenance of current platforms.
Scenario 1: Reduce Turbine Size
Scenario 2: Remove Turbine and Install Bottoming Cycle on Other Turbine

Internal electrification of platform.

- Share power generated by many turbines to run more effectively
- Install bottoming cycle on one turbine and make other turbine redundant
  - No effect on platform's heat demand as WHRU is installed on a different gas turbine
  - Minimal weight addition as weight of gas turbine is ~ 200 tonnes and weight of bottoming cycle ~ 350 tonnes
Scenario 2: Replace 4\textsuperscript{th} Turbine with a Bottoming Cycle
Adding Bottoming Cycle Can Reduce CO₂ Emissions by 63 000 tonnes/year

- CO₂ Reduction of 1.1 M tonnes CO₂ over the remaining life of the platform
- 22% reduction
Cost Savings from Reduced Fuel Consumption and Tax (Norway)

- Scenario 0: "As is"
- Scenario 2: "Replace turbine with Bott. Cycle"

Annual Costs (Million US$)

- CO₂ tax
- Fuel Cost

Scenarios:
- Scenario 0: Norway
- Scenario 2: Norway
- Scenario 0: US
- Scenario 2: US

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Development and Implementation

- Several spin-off projects planned
- Several opportunities in Norway for DEMO projects suitable for these technologies
  - DEMO 2000, Research Council of Norway
  - ENOVA

[Diagram: VENDOR and EFFORT arrows leading to Innovation! and Implementation!]
Conclusions

- "Low hanging fruit"
  - Internal electrification of platform to improve efficiency
  - Replace turbines running at low load with smaller turbines running at higher load—particularly towards end of life of platform—part of maintenance schedule
- "Gas turbine replaced with a bottoming cycle"
  - 22% CO$_2$ reductions of 1,1 M tonnes over the remaining life of the platform or 63 000 tonnes/year for the 18 years investigated
  - Annual savings in operational costs would be US $17 Million if on the NCS
- CO$_2$ release on the NCS was 10.2 Million tonnes in 2010
  - Potential max CO$_2$ reduction: 2.65 Million tonnes annually!
- Implementation—technical and political factors

Highly effective and not overly costly path towards reducing emissions of climate gases
Acknowledgements
The author(s) acknowledge the partners: Statoil, TOTAL E&P Norway, Shell Technology Norway, PETROBRAS, NTNU and the Research Council of Norway, strategic Norwegian research program PETROMAKS (203310/S60) for their support.
Thanks to Daniel Rohde, SINTEF Energy for design of animations.

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