Industrial Energy Use
&
Waste Heat

Catrina Yeo
Energy Analyst
esiyklc@nus.edu.sg
Presentation Outline

• Global industry energy use
• Industry heat demand in UK and US
• Waste heat management
• Barriers to waste heat management
• Opportunities to waste heat management
• International efforts on waste heat management
Globally, industry consumes about 1/3 of total energy consumption.

Source: IEA 2006
Heat dominates final use in industry

US Manufacturing Industry, 2006

- Process Heating 32%
- Indirect Uses - Boiler Fuel 28%
- Machine Drive 19%
- Facility HVAC (g) 7%
- Others - Nonprocess 4%
- Others - Process 7%
- End Use Not Reported 3%

Source: EIA, US DOE

UK Manufacturing Industry, 2007

- Heating 72%
- Others 16%
- Motors 12%
- Space heating 11%
- High T process 18%
- Low T process 31%
- Drying/separation 12%

Source: DECC, UK
Meeting industrial heat demand by waste heat management

- **Industrial waste heat** refers to energy that is generated in industrial processes without being put to practical use.

- Waste heat losses arise both from **equipment inefficiencies** and from **thermodynamic limitations** on equipment and processes.

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*A simplified flow of energy losses*

*Source: US DOE, 2004*
Meeting industrial heat demand by waste heat management

- Waste heat management includes waste heat recycling, recovery and power generation
- It is a measure for energy efficiency improvement, which reduces:
  - Fossil fuel consumption
  - Operating costs
  - Pollutions and GHG emissions
- Estimated waste heat loss is high

Selected energy saving opportunities from waste heat recovery could total 1.6 quadrillion Btu/yr.

PNNL (2006): The chemical energy contained in exhaust gas streams totals about 1.7 quadrillion Btu/yr.

- Implies high potential
Waste heat is everywhere

Advantages

- High quality heat
- More efficient heat transfer rate

Disadvantages

- Increased chemical and thermal stress on heat exchanger materials

Combustion Exhausts
(from furnaces, cement kiln, fume incinerator, boiler)

>650°C

Process offgases
(steel electric arc furnace, aluminum reverberatory furnace)

230-650°C

Cooling water
(from furnaces, air compressors, internal combustion engines)

<230°C

Conductive, convective, and radiative losses
(from heated products & equipment)

• More compatible with heat exchanger
• Streams are dispersed

• Low efficient heat transfer rate
• Not cost-effective
• Combustion exhausts at low temperature corrodes heat exchanger
Uses of waste heat

- Preheating (of combustion air, boiler feedwater, water)
- Load preheating
- Power generation
- Steam generation (for use in power generation, mechanical power, process steam)
- Space heating
- Transfer to liquid or gaseous process streams
Common waste heat management options

- **In-process recycling**
  - Combustion air preheating
  - Load-charge preheating
  - Internal heat recycling - cascading

- **In-plant recovery**
  - Steam generation
  - Hot water heating
  - Plant or building heating
  - Absorption cooling systems
  - Cascading to lower temperature heating processes
  - Reaction heat for endothermic processes

Source: E3M Inc, 2009
Common waste heat management options – power generation

Conventional plant employing steam turbine

Organic Rankin Cycle (ORC)

Kalina Cycle

“Neo-Gen” system

Source: E3M Inc, 2009
### Matured technologies in **limited applications**

<table>
<thead>
<tr>
<th>Technology</th>
<th>Coke Oven Gas</th>
<th>Waste Gas</th>
<th>Blast Furnace Gas</th>
<th>Hot Blast Stove Exhaust</th>
<th>Basic Oxygen Furnace Gas</th>
<th>Electric Arc Furnace Offgas</th>
<th>Gasfired Melting Furnace</th>
<th>Oxyfuel Melting Furnace</th>
<th>Cement Kiln</th>
<th>Hall-Heroult Cells</th>
<th>Melting Furnaces</th>
<th>Metal Casting</th>
<th>Cross-cutting</th>
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Source: US DOE
**Barriers to waste heat management**

- Barriers may be interrelated. Some technical barriers lead to cost barriers.

### Temperature of waste streams
- High - costly materials needed to retain them
- Low - condensate cause corrosion and fouling; few viable end-use; large surface area needed
- Temperature variations in streams

### Chemical composition of waste streams
- Deposition reduces heat transfer
- Risk of contamination between streams – product/process risk
- Environmental concerns
- Material constraints
- Operational and maintenance concern

### Cost effectiveness
- Long payback period for heat recovery equipment and auxiliary systems
- Material costs
- Operation and maintenance costs
- Economics of scale

### Implementation constraints
- Process specific recovery and design
- Heat recovery complicates process
- Limited space
- Transportability
- Inaccessibility
Three components to waste heat management

Sources of waste heat
- Accessibility
- Availability
- Compatibility

Technology
- Cost effective
- Compatible

End use for recovered heat
- Viability
- Usefulness
- Compatibility
Observed trends

• Waste heat recovery systems are frequently implemented, but quantity of heat recovered is relatively low.

• Most unrecovered waste heat is at low temperatures. While low temperature waste heat has less thermal and economic value than high temperature heat, it is ubiquitous and available in large quantities.

• There are certain industrial subsectors where heat recovery of high temperature streams is less common, due to factors such as the heat source’s chemical composition and the economies of scale required for recovery. The heat sources are usually high temperature and high quality heat.

• Losses from non-traditional waste heat sources are difficult to recover, but significant.
Opportunities for Research, Development and Demonstration (RD&D)

**Recovery of low temperature waste heat**
- Develop heat exchangers for low temperatures
  - Increase heat transfer coefficients
- Identify end-use and end-use technologies for low T heat
  - Heat pumps to upgrade heat, low T power generation

**Optimising existing heat recovery system**
- Develop more cost effective materials that can withstand high heat
- Develop innovative process-specific measures

**Recovery of less commonly recovered waste heat**
- Develop more chemical resistant heat exchangers materials
- Avoid introduction of chemical contaminants into waste streams
- Adopt best practices
- Increase economies of scale

**Recovery of alternative waste heat sources**
- Requires development of novel technologies
## International efforts

### Examples from other countries

<table>
<thead>
<tr>
<th>Country</th>
<th>Description</th>
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<tbody>
<tr>
<td>Portugal</td>
<td>Project activities in pulp / paper, petrochemicals and food industries</td>
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<tr>
<td>Switzerland</td>
<td>Most ongoing activities directed towards temperatures below 120°C or lower for excess heat recovery and power; development of low cost plastic heat exchangers; direct drive; magnetic bearings; and hermetic units (no shaft seals)</td>
</tr>
<tr>
<td>Luxembourg</td>
<td>Projects in glass industry, projects focusing on using excess heat for treatment of waste water; drying of sludge using waste heat from cogeneration, projects in large hospitals – optimize polygeneration – combined heat, power and cooling etc.</td>
</tr>
<tr>
<td>Netherlands</td>
<td>Research projects aimed at upgrading the temperature level of the available heat; ongoing district heating integrated projects</td>
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Source: IEA, Draft annex 2010
International efforts –
IEA Implementing Agreement

Objectives and Goals

• Provide a global platform for sharing information and undertaking collaborative projects on the state-of-the-art, emerging technologies and research projects for recovery and utilization of excess heat in industry

• Identify knowledge, research and technology gaps and provide roadmaps to possibly reduce or close these gaps

• Identify technological & non-technological barriers to industrial excess heat recovery and offer feasible solutions to mitigate these issues

• Reduce process energy usage (specific energy consumption / energy intensity) by recycling excess heat in industry

• Create an information resource on excess heat recovery for industry

• Involve industry and communicate progress and results on excess heat recovery to and from industry, government representatives and other appropriate people
Conclusion

- Industry is a major heat consumer and heat dominates industrial energy end-use
- Waste heat management increases energy efficiency of process
- There are potential to waste heat management but barriers exist
- Opportunities for RD&D are identified to overcome barriers
- A lot of potential still exists for waste heat recovery and there are ongoing international efforts to increase waste heat recovery
Thank you!