Project Promoting Application of Low Carbon Technologies to Small and Medium-Size Companies in India

Report of Effects of Adopting GHPs (Gas Heat Pumps)

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1. What is a GHP? Comparison with Electric HPs (EHPs)

GHP (Gas Heat Pump Air-conditioner)
- Compressor is driven by a gas engine.

* Indoor unit is the same as an EHP.

EHP (Electric Heat Pump Air-conditioner)
* Compressor is driven by an electric motor.
2. Characteristics of GHP Comparisons with Electric HP (EHP)

1) Drives gas engine with natural gas ⇒ Saves energy

2) Heater heat source = Outside air+engine waste heat
   ⇒ Large heating capability when outside air is low

3) Control of cooling/heating capability = Control of engine speed
   ⇒ Improves efficiency during partial capacity (inverter effects)

4) Periodic inspection cycle: Engine running time = Every 10,000 hours
   (Equivalent to approx. every 300,000 km traveled by car ⇒ Covers weaknesses of engine type)
3. Yanmar’s GHP

### Units delivered by facility type

- **Schools**: 21%
- **Shops/dept. stores/supermarkets**: 20%
- **Companies/offices**: 18%
- **Medical facilities**: 9%
- **Factories**: 9%
- **Recreational facilities/exhibition halls**: 7%
- **Other**: 16%

### Change in No. of GHP Units Sold

(Based on outdoor units)

<table>
<thead>
<tr>
<th>Year</th>
<th>Annual total</th>
<th>Cumulative total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1988</td>
<td>250,000 units</td>
<td></td>
</tr>
</tbody>
</table>

#### GHP manufacturers

<table>
<thead>
<tr>
<th>GHP manufacturer</th>
<th>Mounted engine</th>
<th>Indoor unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yanmar Energy System</td>
<td>Yanmar</td>
<td>Daikin/Hitachi</td>
</tr>
<tr>
<td>Panasonic (former Sanyo)</td>
<td>Nissan/Mazda</td>
<td>Sanyo</td>
</tr>
<tr>
<td>Aisin Seiki</td>
<td>Toyota/Daihatsu</td>
<td>Daikin</td>
</tr>
<tr>
<td>Mitsubishi Heavy Industries</td>
<td>OEM by Aisin</td>
<td>Mitsubishi Heavy Industries</td>
</tr>
<tr>
<td>Hitachi Appliances</td>
<td>OEM by Yanmar</td>
<td>Hitachi</td>
</tr>
<tr>
<td>Daikin Industries</td>
<td>OEM by Aisin</td>
<td>Daikin</td>
</tr>
</tbody>
</table>
### 4. GHP Technology Application Promotion Project Schedule

<table>
<thead>
<tr>
<th>Event</th>
<th>FY2011</th>
<th>FY2012</th>
<th>FY2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>Selection of demonstration test site</td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Conclusion of memorandum on demonstration test</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equipment procurement and production</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shipment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Commencement at site</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GHP operation project</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Data measurement</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Discussion with test site and capacity building</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Evaluation and proposal</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1: Evaluation of candidate demonstration test sites: 5 companies  
2: Discussion on GHP construction guidelines  
3: Guidance on construction and test operations  
5: Change of specifications of custom-made air filter of indoor unit (increased front surface)  
5: Change of GHP operation control software: Standard (energy saving) software -> Software focusing on cooling/heating capability  
6: Change of GHP operation control software: Software focusing on cooling/heating capability -> Standard (energy saving) software  
7: GHP service training for demonstration test sites
5. Demonstration test sites

1) Location: Rajkot (Gujarat)

<table>
<thead>
<tr>
<th></th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Avg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rajkot Monthly avg. highest temperature (°C)</td>
<td>28</td>
<td>31</td>
<td>35</td>
<td>39</td>
<td><strong>40</strong></td>
<td>37</td>
<td>33</td>
<td>32</td>
<td>34</td>
<td>36</td>
<td>33</td>
<td>30</td>
<td>34.0</td>
</tr>
<tr>
<td>Rajkot Monthly avg. lowest temperature (°C)</td>
<td>13</td>
<td>15</td>
<td>19</td>
<td>23</td>
<td>25</td>
<td>27</td>
<td>26</td>
<td>24</td>
<td>24</td>
<td>22</td>
<td>19</td>
<td>15</td>
<td>21.0</td>
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<tr>
<td>Osaka Monthly avg. highest temperature (°C)</td>
<td>10</td>
<td>10</td>
<td>14</td>
<td>20</td>
<td>25</td>
<td>28</td>
<td><strong>33</strong></td>
<td>29</td>
<td>23</td>
<td>18</td>
<td>12</td>
<td>18</td>
<td>28.3</td>
</tr>
<tr>
<td>Osaka Monthly avg. lowest temperature (°C)</td>
<td>3</td>
<td>3</td>
<td>6</td>
<td>11</td>
<td>16</td>
<td>20</td>
<td>24</td>
<td>25</td>
<td>22</td>
<td>16</td>
<td>0</td>
<td>5</td>
<td>20.4</td>
</tr>
</tbody>
</table>

2) Business type: Casting plant (Lost wax casting) 2 companies (Companies A and B)
3) Air-conditioner (cooling/heating) used in: (1) Wax injection work room
   (2) Mold drying room  (3) Office (1 company only)

4) Switching to GHP: Select same cooling/heating capability and indoor unit model as existing electric air-conditioner
6. Installed State of Equipment (Company B)

- **Wax injection room**

- **Drying room**

~ Part of existing electric air-conditioner is continuously used for GHP backup
7. Measurement Items and Measurement Points (Company A)

- Measurement work:
  Panasonic Eco Solutions
  Souken

- Measurement interval
  - Power consumption: 60 min
  - Temperature and humidity: 30 min
8. Measurement Results (Monthly Power and Gas Consumption) (Company A)

- Measurement time of electric air-conditioner is short, so to compare both, cooling/heating load is calculated.
9. Measurement Data Classification Procedure

1) Horizontal axis

- Temperature during cooling/heating period
- Room temperature during cooling/heating period
- Cooled/heated floor area
- Cumulative temperature difference
- Production amount
- Building structure cooled/heated
- Representative value for cooling/heating load (heat quantity)

2) Vertical axis

- Power and gas consumption is corrected to equivalent of 35°C according to monthly average outside air temperature (GHP power consumption cannot be corrected due to fan power.)

\[ \text{Cumulative temperature difference} = \sum (\text{Outside air temperature} - \text{Indoor temperature}) \]
10. Effects of Adopting GHP (1)  Company A

- **Calculation conditions**

<table>
<thead>
<tr>
<th>Gas</th>
<th>Heat quantity (High)</th>
<th>Unit</th>
<th>India</th>
<th>Reference: Japan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas</td>
<td>MJ/m³</td>
<td></td>
<td>38.66</td>
<td>45</td>
</tr>
<tr>
<td>Electricity</td>
<td>kWh/m³</td>
<td></td>
<td>10.74</td>
<td>12.50</td>
</tr>
<tr>
<td>CO₂ emissions factor</td>
<td>kg/m³</td>
<td></td>
<td>2.1443</td>
<td>2.29</td>
</tr>
<tr>
<td>Power generation efficiency (net system energy demand)</td>
<td>%</td>
<td></td>
<td>22.4</td>
<td>36.9</td>
</tr>
<tr>
<td>CO₂ emissions factor</td>
<td>kg/kWh</td>
<td></td>
<td>0.89</td>
<td>0.550</td>
</tr>
</tbody>
</table>

**CO₂ emissions**: 56% of electric air-conditioner (4.2/7.5)

**Primary energy consumption**: 53% of electric air-conditioner (21/40)
10. Effects of Adopting GHP (2)  Company B

- Calculation conditions

<table>
<thead>
<tr>
<th></th>
<th>Unit</th>
<th>India</th>
<th>Reference: Japan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Power generation efficiency (%)</td>
<td>%</td>
<td>22.4</td>
<td>36.9</td>
</tr>
<tr>
<td>CO2 emissions factor kg/kWh</td>
<td>0.89</td>
<td>0.550</td>
<td></td>
</tr>
</tbody>
</table>

- CO2 emissions: 55% of electric air-conditioner (8.0/14.5)

- Primary energy consumption: 53% of electric air-conditioner (40/76)
11. Comparison of Operating Costs

Gas unit price: Increased by about 1.5 times in last 2 years \(\Rightarrow\) Increased operating costs
\(\Rightarrow\) Improvement of rate of utilization of gas energy is indispensable

**Diagram:**
- Blue line: Same operating costs
  - Costs as of Nov 2011 at demonstration test site
  - October 2013 charges
- Orange line: 20% reduction compared to electric air-conditioner
  - Apr 2013 charges
  - Dec 2013 charges

**Legend:**
- Gas charges (Rs/m³)
- Electricity charges (Rs/kWh)
12. Expansion to India Market in the Future

Improvement of rate of utilization of gas energy:
Application of “cooling/heating+hot water supply (using engine waste heat)” system

- Max. output of warm water: 30 kW
- Warm water temperature: Below 70°C

Based on the usage amount (March to December 2013) by purpose of natural gas at demonstration test site (casting plant), hot-water supply demands are considered adequate.
13. Calculation of Effects of GHP with Hot-Water Supply Function
<Calculation conditions>

- **Used warm water heat quantity**: 15% of gas input energy
- **Boiler efficiency**: 80%  
  (Higher heating value standard)
Thank you for your kind attention.

We would like to express our heartfelt gratitude to all involved in promoting this project for their guidance, support, and cooperation.