How to maximise energy efficiency and cost effectiveness of different type heat pump projects – three case studies

Presenter: Alex Koncar – GreenKon Pty Ltd, Sydney, Australia
E-mail: alexkoncar@greenkon.com.au
06/12/2017
Review of three heat pump projects – opportunities and challenges

• **Ground Sourced Heat Pumps** (vertical ground loops) - Regional Office in Australian Alpine Area, NSW, Australia

• **Air-to-Air Heat Pump** (recycled rejected heat) – Small Heritage Art Gallery, NSW, Australia

• **Water-to-Water Heat Pump** (recycled heat from heated effluent) – sewerage treatment plant at high altitude – An Australian Ski Resort, NSW, Australia
Drivers for improving energy efficiency of HVAC Systems

- Increasingly high energy cost to run HVAC Systems
- Adverse Impact of HVAC Systems on the Environment
- Awareness of limited fossil-fuel based energy resources
Typical applications of Heat Pumps

Space cooling and space heating for smaller facilities, where they do not compete against chillers (residential, commercial, public, hospitality, health, government & industrial buildings).

Domestic Hot Water heating

Water heating (and sometimes cooling) for Aquatic centres

Industrial thermal applications
Example:

Two-level High School Boarding House – four rooms zoned per face and a level of the building - multi head split air cooled reverse cycle AC units - 96 indoor and 25 outdoor AC units

48th International HVAC&R Congress and Exhibition, Belgrade, 6–8 Dec. 2017
Improvement of COP of Heat Pumps & Heat Pump HVAC Systems

Improvement of COP of Heat Pumps
(R&D and manufacturing)

*Air-to-Air HP COP as high as 4.5*

Improvement of COP of Heat Pump HVAC Systems - Control Systems and Engineering
Improvement of COP of Heat Pump HVAC Systems - advance controls (control strategies, control parameters and control limits)

Goals:

Maximised System Energy Efficiency

Minimised operating time

Minimised load

Minimised operational and maintenance costs

Prolonged life of equipment
Improvement of COP of Heat Pumps

Better heat sources and heat sinks than the outside air (water, ground, industrial fluids, etc.)

Recycling of waste heat (DHW or Reheating during controlled dehumidification) or waste cooling

Equipment improvements (indoor and outdoor fans, heat exchangers, efficiency of refrigeration circuits, type and variable speed of compressors, fans, better expansion devices, etc.)
Communication and co-operation are essential!

- Science
- R & D
- Applications
- Consultants
- Implementation
- Trades
Review of three Heat Pump projects – opportunities and challenges

The projects demonstrate:

- Improvement of energy efficiency of an existing Heat Pump HVAC System (not properly designed and commissioned)

- Energy Efficient Design of new Heat Pump HVAC systems (for close control environment – 24/7 regulated temperature and RH)

- Supplementary use of Heat Pump systems for industrial purposes (heating of sewage at high altitude STP)
Review of three Heat Pump projects – Case 1

Regional Visitors Centre – Alpine Area, Australia
One-level building - Offices, Visitors Centre & Cinema

Improvement of an existing Ground Sourced Heat Pump HVAC System
Review of three Heat Pump projects – Case 1

Existing HVAC System consisted of 24 geothermal heat pumps - ground sourced (vertical loops) and basic controls
Review of three Heat Pump projects – Case 1

- Advertised as “State of the art HVAC System”, when it was built

- Our energy audit had identified cost effective energy saving potential of almost 50%, due to excessive use of the heat pumps, in terms of operating hours and load
Review of three Heat Pump projects – Case 1

Opportunities for improvement (Design, Installation, Commissioning):

• Minimisation of excessive infiltration – “O/A louvre” 15-16m2 in the roof plantroom area, which was not needed, as O/A supply was ducted (common O/A duct for all HPs)
Review of three Heat Pump projects – Case 1

Opportunities for improvement (Design, Installation, Commissioning):

• Several non-ducted R/A eggcrate grilles (commissioning issue)
• Openings (fixed louvres) between the roof and space areas (design issue)
Review of three Heat Pump projects – Case 1

Opportunities for improvement (HVAC Controls - Poor control strategies and control parameters):

- Inappropriate cooling, heating and dead space temperature bands,
- O/A not used for conditioning (No Economy Cycle)
- Excessive O/A supply to AC units via a common OAF and ductwork
- Too early/too long Start Up time (No Optimum Start)
- Too much O/A for public areas with variable occupancy (No Demand Ventilation)
- AC units running over weekend during winter time, when the offices were closed
Review of three Heat Pump projects – Case 1

Implemented rectification measures achieved 47% savings – verified by utility bills, included:

• **Envelope performance improvements** - Sealing of “O/A Louvre”, fixed louvre towards internal spaces and ducting of R/A for not properly commissioned AC units

• **Control improvements** - New HVAC Control System – BMS (advanced control strategies, control parameters and control limits)
Review of three Heat Pump projects – Case 2

Small Heritage Art Gallery – NSW, Australia

Improvement of energy efficiency of a new Air-To-Air Heat Pump System, used for Close Control Environment
Review of three Heat Pump projects – Case 2

Design challenges

• Close Control Environment 24/7 (space temperature and relative humidity)
• Limited electricity supply (not sufficient for 60 kW electric re-heaters)
• No gas (remote site in a mountain environment)
• Heritage building – AHU had to be located in the roof void area
• Energy efficiency & arrangement of HVAC controls
• Harsh Climate (cold winters and hot summers)
• Noise of AC outdoor unit (mountain low – noise environment)
• Operations and Maintenance (Remote area)
Review of three Heat Pump projects – Case 2

Design solutions

• *Energy efficient equipment* (Air-to-Air Heat Pump with added third coil to recycle rejected heat, to reheat S/A in DEHUM mode of operations of HVAC System)

• *Energy efficient HVAC Controls – BMS* (optimised space temperature & RH bands, innovative Economy Cycle & Demand Ventilation, variable S/A, cooling mode with minimal dehumidification)

• *6 pole fan motors for outdoor AC unit* (minimised noise)

• *On-site (Roof void) assembling of indoor AC unit* (to avoid damaging the roof with a cranage transport arrangement)
Review of three Heat Pump projects – Case 2
Review of three Heat Pump projects – Case 2

BMS Print Screen – 3 – stage air cooled DX AC Unit
Innovative use of Economy Cycle for pre-cooling, cooling and heating
Review of three Heat Pump projects – Case 2

Benefits of new AC Design

• More energy efficient Heat Pump HVAC System, by 40%, than “as business as usual” design

• Reduced energy consumption, energy cost and carbon footprint

• Eliminated potential use of electric duct heaters

• Eliminated need for electricity upgrade

• Minimised noise

• Avoided cranage and not damaged the roof of the heritage building during implementation (modular installation of the indoor AC unit in the roof void)
Review of three Heat Pump projects – Case 3

Sewerage Treatment Plant – Ski Resort, Australia

**Water-to-Water 140 kW Heat Pump that recycles heat from effluents**

**Challenges**

- **High Altitude (1750m) Sewerage Treatment Plant**
- Sewerage is heated to 14 deg C to enable bacteria to become active
- **21,000 litres LPG tank was used in 7 days during ski season**
- **High Cost of LPG**
- **High cost of over-snow transport**
- **High cost of maintenance of LPG fired hot water heaters**
Review of three Heat Pump projects – Case 3

Solution

• Supplementary 140 kW water-to-water heat pump that uses mainly less expensive Off-Peak (nights and weekend) electricity tariff

• Heat source is an effluent pond with temperature of around 12-13 deg C, even during subzero O/A temperatures (as every three hours new batch of processed heated sewerage is discharged into the effluent pond)
Review of three Heat Pump projects – Case 3

**Specifications:**

<table>
<thead>
<tr>
<th>Water to Water Heat Pump Specifications</th>
<th>HWW150</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ELECTRICAL INPUT</strong></td>
<td></td>
</tr>
<tr>
<td>Voltage/Phase</td>
<td>415 Volts / 3 Phase / 50 Hz</td>
</tr>
<tr>
<td>Maximum Cont. Current (MCC)</td>
<td>80 Amps</td>
</tr>
<tr>
<td>Min. Circuit Size</td>
<td>100Amps</td>
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<tr>
<td>Nominal Heating capacity</td>
<td>140 kW Heating</td>
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<tr>
<td>Power input</td>
<td>35 kW</td>
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<tr>
<td>COP</td>
<td>4</td>
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<tr>
<td>Noise Level</td>
<td>59 dBA @ 3 m</td>
</tr>
</tbody>
</table>

**Technical Data: Compressor**

- Make: Copeland Scroll
- Refrigerant: R407C
- Number Per Unit: 3
- FLA (Full Load Amp): 80 Amps
- Voltage / Phase: 415 Volts / 3 Phase / 50 Hz
Review of three Heat Pump projects – Case 3

Projected benefits (the project is being tendered):

• Reduced projected cost of heating sewage by 62% (including reduced cost of over-snow transport)

• Reduced thermal pollution of a nearby creek, where effluents were discharged, by around 5 deg C

• Reduced maintenance costs and prolonged life of LPG hot water heaters
Review of three Heat Pump projects

CONCLUSION:

• Heat pumps can be successfully applied to diverse range of projects, including HVAC and industrial projects

• High Control expertise and ongoing involvement of energy management consultants, are essential for achieving an optimal energy efficiency
Review of three Heat Pump projects

THANK YOU!

Q & A
Path to achieve minimal operational costs of commercial, predominantly cooling HVAC Systems (several hundred thousand dollars per annum, per commercial facility is typically wasted)

Energy efficiency:
1. **Energy efficient equipment** (properly selected and commissioned)
2. **Energy efficient controls** - control strategies, control parameters, control limits (properly selected and commissioned)
3. **Ongoing fine tuning of energy efficiency and performance of HVAC Systems** (intimate involvement of an energy management consultant, supported by properly trained FMs and HVAC and BMS maintenance contractors) – occasional energy audits “mud the water”

HVAC/BMS maintenance:
1. **Intimate involvement of HVAC Consultant**, specialised in energy efficiency and maintenance
2. **Properly specified and supervised maintenance** (including water efficiency of cooling towers and properly determined Discharge Factor)
3. **Communication and reporting**

SYSTEM ERROR - LACK OF AWARENESS, AND CONSEQUENTLY LACK OF CARE, FOR ENERGY EFFICIENCY AND MAINTENANCE, LEADING TO HIGHER ENERGY AND MAINTENANCE COST AND SHORTER LIFE SPAN OF EXPENSIVE HVAC SYSTEMS

EDUCATE CONSULTANTS WITH THE ABOVE IN MIND, AND STOP “BLANK CHECK MAINTENANCE PRACTICES” !!!