IEA Heat Pump Annex 43:

*Fuel driven sorption heat pumps*

*For residential and small scale commercial heating applications*

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Dr Ivan Malenković, Fraunhofer ISE

IEA National Teams Meeting for the UK Heat Pump Industry, BEIS, 20th September 2016
Contents:

• Background to Annex 43 - Fuel (Gas) Driven Sorption Heat Pumps

• State of the art and new developments
Reasons for gas driven heat pumps

• Buildings with radiators which might need higher temperatures
• Replacement of existing boilers, minimal change of existing system
• Gas will be around for a long time!
• Gas will be around for a long time!

Source: McKinsey, BDH
Reasons for gas driven heat pumps

• Buildings with radiators which might need higher temperatures
• Replacement of existing boilers, minimal change of existing system
• Gas will be around for a long time!
• Grid balancing – inability of electricity grid to cope with an all-electric future
The limitations of the energy infrastructure

2010 UK heat & electricity hourly demand variability

Design point for heat delivery system

Peak electricity demand will exceed electrical grid capacity in future

Design point for electricity delivery system

Source: Energy Technologies Institute, 2012
Hence Annex 43:

**Scope**
- Fuel driven sorption heat pumps for residential and light commercial
- Focus on heating mode, reversible allowed

**Goals**
- Identification of market opportunities and barriers
- Identification of the potential applications and importance in future energy systems
- Identification of market supporting measures
- Easy and sustainable market entrance and development
Annex 43: Structure

Task A: Generic systems and system classification
   Leader: ISE

Task B: Technology transfer
   Leader: Uni Warwick

Task C: Field test and performance evaluation
   Leader: Politecnico di Milano

Task D: Market potential study and technology roadmap
   Leader: CNR-ITAE

Task E: Policy measures and recommendations, information
   Leader: ISE
Work structure

A: Generic systems and system classification (ISE)

- WP1: Collection of technology and market relevant data
  - Reports complete for:
    - Austria
    - Germany
    - Italy
    - France
    - UK
    - USA

Available soon!
Work structure

B: Technology transfer (Warwick)

WP 1: link research and industry (workshops) (Warwick)

- Under WP1, EHPA and Annex 43 organised a gas fired heat pump workshop for industry at the EHPA Heat Pump Summit in Nuremberg 2015
- ‘Sorption Friends‘ meeting Sicily, October 2015
- IEA Heat Pump Conference, Rotterdam, 2017
Work structure

C: Field test and performance evaluation (Polimi)

- WP 1: Standardized Monitoring & Measurement Procedure
- WP 2: Test procedures on system level
- WP 3: Laboratory Tests
  (Warwick/Kiwa, reported 2014)
D: Market potential study

- Simulation study from Polimi evaluates different technologies in different climate zones, different building types and building standards
- Combine with market data and actual building stock for technology roadmap
D: Market potential study - Simulation model:

- Selection of ‘market ready’ RE technologies for heating
  - Condensing boiler (tank for DHW)
  - GAHP Air/Water (monovalent and bivalent)
  - EHP Air/Water (monovalent and bivalent)

- Selection of target building and climate
  - 150 m²
  - 2 building standards (renovated, incl. emission system underfloor heating / low temperature radiators)
  - 3 main locations (different climatic zones in Europe)
    - Athens
    - Strasburg
    - Helnsiki
  - more locations can be added later, although ...

2 (buildings) x 3 (locations) x 5 (plants) = 30 sims.

2 (buildings) x 3 (locations) x 9* (plants) = 54 sims.

* Including solar, w/s GAHP and EHP, hybrid
D: Market potential

## Model capabilities

<table>
<thead>
<tr>
<th></th>
<th>GAHP</th>
<th>EHP</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Full load</strong></td>
<td>GUE, AEF (experimental)</td>
<td>COP (manufacturer’s data)</td>
</tr>
<tr>
<td><strong>performances</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Partial load</strong></td>
<td>PL correction factor (experimental)</td>
<td>Cycle losses model (see Afi, Type 201)</td>
</tr>
<tr>
<td><strong>Defrosting</strong></td>
<td>already accounted for in GUE measurement (EN12309-6)</td>
<td>COP correction (see Afi, Type 201)</td>
</tr>
<tr>
<td><strong>System control</strong></td>
<td>Bivalent mode Set point T</td>
<td>Bivalent mode Set point T</td>
</tr>
</tbody>
</table>
D: Market potential study and technology roadmap (CNR-ITAE)

**Additional work for UK climate, housing and infrastructure:**

- Semi-detached 48 m² (x2)
- Detached 74 m² (x2)
- Terraced 45 m² (x2)

Data for average types from Cambridge Housing Model

<table>
<thead>
<tr>
<th>Simulation Building</th>
<th>Plant</th>
<th>Plant Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Detached</td>
<td>CB</td>
<td>Size 1: 18 kW</td>
</tr>
<tr>
<td>2</td>
<td>GHP</td>
<td>Size 2: 9 kW</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>GHP+CB</td>
<td>Size 3: &lt;9 kW</td>
</tr>
<tr>
<td>5</td>
<td>EHP</td>
<td></td>
</tr>
<tr>
<td>Semi Detached</td>
<td>CB</td>
<td>Size 1: 18 kW</td>
</tr>
<tr>
<td>6</td>
<td>GHP</td>
<td>Size 2: 9 kW</td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>GHP+CB</td>
<td>Size 3: &lt;9 kW</td>
</tr>
<tr>
<td>9</td>
<td>EHP</td>
<td></td>
</tr>
<tr>
<td>Terraced</td>
<td>CB</td>
<td>Size 1: 18 kW</td>
</tr>
<tr>
<td>11</td>
<td>GHP</td>
<td>Size 2: 9 kW</td>
</tr>
<tr>
<td>12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>GHP+CB</td>
<td>Size 3: &lt;9 kW</td>
</tr>
<tr>
<td>14</td>
<td>EHP</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Contents:

• Background to Annex 43 - Fuel (Gas) Driven Sorption Heat Pumps

• State of the art and new developments
Heat pumps - technologies

- Electrically driven, mechanical vapour-compression heat pumps
- Fuel driven heat pumps
  - Gas engine heat pumps (mechanical)
  - Thermally driven heat pumps
- Absorption heat pumps
- Adsorption heat pumps
- Others!
Technologies:

- Engines
- Sorption
  - Absorption
  - Adsorption
Absorption
Adsorption

Performance similar in principle
Refrigerants similar:
• Water
• Ammonia
• Alcohols
Existing products:

**Vaillant**

**Technical data of zeoTHERM VAS 106/4**
- Rated heat output range Heating 1,5-10 kW
- Rated heat output range d.h.w. 4,2-12,5 kW
- Adjustable flow temperature 20-75 °C
- Recommended max. flow temperature HC < 40 °C
- El. power consumption max. 100 W
- Appliance width 772 mm
- Appliance height incl. flue outlet 1.700 mm
- Appliance depth 718 mm
- Transport weight (without casing) 160 kg
- Operating weight 175 kg
- Integrated controller zeolite module > no moving parts / no maintenance
Existing products:

**Vaillant system:**
- Water refrigerant, zeolite adsorbent
- Heat pump, solar collector, water storage tank
- Only intended for use with underfloor heating systems with Maximum output temperature of 40°C
- Claimed reduction of annual energy use of 18% compared with a condensing boiler.
- Initial system sale price was around €16,000.
- On market for four years
Existing products:

**Viessmann Gas-Fired Zeolite Compact Heating Appliance**

Features at a glance

- **Hybrid Heating Appliance:**
  - Heating Power Modulation: 1.6 to 10 kW (1 to 7)
  - Booster capacity for DHW: 15 kW

- **SGUE Heating (VDI 4650-2):** 135 % (Hi 35/28 °C)
  
  SGUE Heating (VDI 4650-2): 125 % (Hi 55/45 °C)

- Ambient Heat Source: 2013 GHS
  
  From 2014 also Solar

- Working pair completely environment friendly

- Installation, maintenance and service analog to condensing boiler compact units

- **Gas-Fired Adsorption Heat Pump in the dimensions of Viessmann compact heating appliances**

- Dimensions: BxHxT: 600x595x1875 mm

- Weight: <170 kg (separable in two parts)

Launched 2014
Existing products:

**Robur**

- Ammonia water absorption
- Air, water and ground source options
- DHW at 65°C (gross COP 1.24)
- 38 kW to radiators (supply temperature 50°C) COP of 1.52 (gross), 1.38 (net).
- Saving of about 40% in gas consumption compared to a condensing boiler.
- Single module 854(w) x 1256(d) x 1281(h).
- 18kW unit, is under development.
- The product is ‘badged’ by BDR Thermea
- 40kW unit is c. £12,000.
Existing products:

‘Half sized’ Robur (17kW)
- Developed under Heat4U EU project
- 5 field tested
- Similar performance to large machine
- Now available on the market in Italy
- Manufacture in Germany 2016
- Cost??

[Image of Robur (17kW) heat pump]

Modulation at higher part load
- Start-up peaks for heating and DHW
- Steady-state performance at part load
- Heating supply temperature ~55°C

Cyclic behavior at lower part load
- Similar start-up peaks
- Supply temperature ~38°C
- Performance indicator $\text{GUE}_{\text{NCV}}$ similar to modulation operation

Heat Flow Rate - 14/02/14 (BritishGas)

Heat Flow Rate - 14/04/22 (BritishGas)

Temperatures - 14/02/14 (BritishGas)

Temperatures - 14/04/22 (BritishGas)
Near market products:
Bosch Thermotechnology

- System:
  - Gas driven absorption heat pump (NH\textsubscript{3}/H\textsubscript{2}O)
  - Max. 18 kW heat output
  - Solution recirculation in GEN and ABS
  - Solution cooled DEP
  - Second feed (rich solution) for REC

- Measurements:
  - COP=1.3 - 1.9 depending on operating conditions
  - Knowledge of HEX behavior
  - Input for modelling

- Modelling:
  - Good agreement between measured and predicted COP (error ≤ 5 % in most cases)
Near market products:

**Bosch Thermotechnology**

- **Buderus**
  Logatherm GWPS192-18 i

- **Junkers**
  Supraeco 9000i G

- Planned market introduction: 2016
- Heat source: geothermal/air
- Max. flow temperature: 70 °C
- Heat output (B0/W65): 18 kW
- Modulation range: 1:4
- Max. annual efficiency: 170%
- Heating system: mono-/bivalent

Source: Bosch Thermotechnology GmbH
Bosch 18 kW Gas Driven Heat Pump
Performance Data and System Information

Project Targets:
- Constant high efficiencies up to 180%
- Heat output 18 kW with any source temperature
- Indoor installation
- No additional installation requirements compared to conventional appliances
- Simple hydraulic integration
- Domestic hot water generation with temperatures up to 60 °C
- Solution for brine/water and air/water
- Efficient renewable heating solution for existing buildings
Target Markets:

- Existing one / two family houses
- Mono- and bivalent systems
- Minimum design load: 12 kW
- Heating systems: floor or radiators
- Design Temperatures up to 70° C
• Can be placed anywhere in the building without additional requirements. Type C flue gas connection which allows venting in the event of failure.
• The unit itself is defined as the 'installation room'. If you are below 2.5kg, can install anywhere. Above 10kg need sensors.
• Ammonia charge is 4kg.
<table>
<thead>
<tr>
<th>Specification</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. Flow Temperature</td>
<td>°C</td>
<td>70°C</td>
</tr>
<tr>
<td>Integrated CH circuit</td>
<td></td>
<td>Yes (1 x unmixed)</td>
</tr>
<tr>
<td>Renewable share</td>
<td>kW</td>
<td>up to 8</td>
</tr>
<tr>
<td>Heat Output</td>
<td>kW</td>
<td>18</td>
</tr>
<tr>
<td>Efficiency</td>
<td>%</td>
<td>up to 180</td>
</tr>
<tr>
<td>ErP Rating</td>
<td></td>
<td>A++</td>
</tr>
<tr>
<td>Jahresheizzahl VDI4650-2</td>
<td></td>
<td>&gt; 1.5 at HT application</td>
</tr>
<tr>
<td>Modulation</td>
<td></td>
<td>1:4</td>
</tr>
<tr>
<td>Supply Voltage</td>
<td>V</td>
<td>230</td>
</tr>
<tr>
<td>Height (indoor unit)</td>
<td>mm</td>
<td>1600</td>
</tr>
<tr>
<td>Width (indoor unit)</td>
<td>mm</td>
<td>600</td>
</tr>
<tr>
<td>Depth (indoor unit)</td>
<td>mm</td>
<td>950</td>
</tr>
</tbody>
</table>
WSW192I-18 / WLW192I-18A:

- Compact indoor unit suitable for different sources air / brine / ...
- Outdoor unit with fan and heat exchanger
- Link between in- and outdoor by brine connection
Near market products:
Stiebel Eltron are developing a zeolite – water machine with help from Sortech and similar principal to Vaillant and Viessmann products

System design
- Gas burner with heat pump unit
- Solar hot water tank
- Heat pump unit with fiber heat

Unlikely to undergo further development
Near market products:

Viessmann Gas-Fired Absorption Heat Pump
Features at a glance

- Wall mounted hybrid appliance:
  Gas-fired absorption heat pump and a condensing boiler
- Seasonal heating GUE > 1.4 (55/45 °C)
- Seasonal heating GUE > 1.3 (65/50 °C)
- High modulation range (1.6 to 14 kW)
- Dimensions: BxHxT: 600x595x900 mm
- Weight: <90 kg
- Low noise
- Installation & Maintenance comparable to condensing boilers
Near market (?) products:

Projects in USA:

ThermoLift Inc – Vuilleumier Cycle
• Funded by DOE, etc
  Data from 2015 Building Technologies Office Peer Review,

ORNL – Absorption and Adsorption for water heating
• DOE laboratory
  Slides from US Activities in Sorption Heat Pumps, Ed Vineyard, Kyle Gluesenkamp
  4th Expert Meeting, Vienna, June 9 2015,
The Natural Gas Heat Pump and Air Conditioner

Heat from Burner (15 kW)

Combined Heat Delivered (25 kW)

FREE Heat from Ambient (10 kW)

2015 Building Technologies Office Peer Review

ThermoLift, Inc.
Paul Schwartz, CEO
pschwartz@tm-lift.com
DE-FOA-0000823
Thermally Driven Cycles (Vuilleumier & Stirling)

- Mechanical Compressor
- Thermal Compressor
- Stirling Process
- Vuilleumier Process
ThermoLift first developed a benchtop proof-of-concept for the novel independent mechatronic design. A complete heat pump prototype was designed, simulated, and built by late 2014.

ThermoLift began testing and generated numerous iterations and simulations to develop improved components.
Comparison to State-of-the-Art

![Graph showing efficiency (COP) vs. outside temperature (°F) for different systems: ThermoLift Next Generation, Demonstrator, Simulation, DOE Target Heat Pump, Leading Gas-fired Heat Pump, Electric Heat Pump, Condensing Boiler.](image-url)
Manufacturing Failure ➔ Timeline Setback

Damage following de-compression

Un-zipped cold regenerator

Complete braze failure
Projects in USA:

ThermoLift Inc – Vuilleumier Cycle
  • Funded by DOE, etc
  Data from 2015 Building Technologies Office Peer Review,

ORNL – Absorption and Adsorption for water heating
  • DOE laboratory
  Slides from US Activities in Sorption Heat Pumps, Ed Vineyard, Kyle Gluesenkamp
  4th Expert Meeting, Vienna, June 9 2015,
Gas Sorption Systems Under Development

• Water heating
  – Commercial NH$_3$/H$_2$O (A.O. Smith/ORNL/SMTI)
  – Residential NH$_3$/H$_2$O (SMTI)
  – Residential H$_2$O/IL, membrane-based (GE/ORNL/UF)
  – Residential NH$_3$/carbon (ORNL)

• Space heating
  – Residential NH$_3$/H$_2$O (SMTI)
The Payback Period Challenge in the US (water heating)

- National average retail energy prices:
  - Electricity ~0.10 $US/kWh
  - Natural gas ~14 $US/MMBtu (0.53 $/m³, 0.05 $/kWh\text{thermal})
- Average new residential storage water heater

9,000,000 units shipped/year, most at minimum efficiency level.

| Electric HPWH | 2.35 | $1,050 | $530 | 3.8 year |

Target is 3 year pb with excess capital cost of $300 over non-condensing gas.

Data source: US Department of Energy Technical Support Documentation, 2009
Stone Mountain Technologies, Inc.

SMTI: “Thermal compressors for sustainable heating”

Development Status:

- **Residential Water Heater** –
  - 6 Field Test Units Installed

- **80,000 Btu/hr GAHP** –
  - Three Alpha Prototypes Under Test

- **140,000 Btu/hr GAHP** –
  - Under Development
# SMTI Residential HPWH

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average cycle COP</td>
<td>1.6</td>
</tr>
<tr>
<td>EF</td>
<td>1.3</td>
</tr>
<tr>
<td>First Hour Rating</td>
<td>60 – 80 gallons</td>
</tr>
<tr>
<td>Heating output</td>
<td>~10 kBtu/hr (~3 kW)</td>
</tr>
<tr>
<td>Emissions</td>
<td>10 ng NOₓ/J (projected based on GTI laboratory testing)</td>
</tr>
<tr>
<td>Installation</td>
<td>Indoors or semi-conditioned (garage)</td>
</tr>
<tr>
<td>Venting</td>
<td>½” – 1” PVC</td>
</tr>
<tr>
<td>Gas piping</td>
<td>½”</td>
</tr>
<tr>
<td>Estimated consumer cost</td>
<td>&lt;$1,800</td>
</tr>
<tr>
<td>Ammonia charge</td>
<td>&lt;25% allowed by ASHRAE Standard 15</td>
</tr>
</tbody>
</table>
Residential Space Heating

Heating COP rated at
ambient - 47°F (8.3°C)
hydronic - 100/120°F (37.8/48.9°C):

- COP\(_{\text{cycle}}\) = 1.65
- COP\(_{\text{gas}}\) = 1.45 (including combustion losses)
- COP\(_{\text{hp}}\) = 1.40 (including parasitic)

- 140 kBtu/hr (40 kW)
- Gas-Fired, Air to Water Heat Pump
- Condensing
- 4:1 Modulation
- SCAQMD NOx Compliant
- Outdoor Installation
- GWP = 0
- 550 Watts at 100% fire

Forced air configuration
Near market (?) projects:

boostHEAT (France)

“As compared to the latest generation of condensation boilers, the consumption should be reduced by 45 to 60% in low temperature mode (35°C) and by 25 to 40% in medium and high temperature mode (55 to 65°C)”

Thermally driven compressor using CO$_2$ refrigerant.
Will probably need three stages of compression.
The thermal compressor activates a “standard” thermodynamic cycle (condensation, expansion and evaporation) through an external unit that extracts renewable energy from the air outside.
**Heat Pump Boiler for the home**

- Fuelled by natural gas and renewable energy
- Providing heating and domestic hot water

- All from one unit – a Combination Boiler

<table>
<thead>
<tr>
<th>Seasonal Efficiency for Heating and Hot Water Production (GUE - EN 12309)</th>
<th>Electric Heat Pump Equivalent COP</th>
</tr>
</thead>
<tbody>
<tr>
<td>200% 35°C Low Temperature Heating</td>
<td>5.00</td>
</tr>
<tr>
<td>188% 45°C Medium Temperature Heating</td>
<td>4.70</td>
</tr>
<tr>
<td>175% 55°C High Temperature Heating</td>
<td>4.37</td>
</tr>
<tr>
<td>165% 65°C Very High Temperature Heating</td>
<td>4.12</td>
</tr>
</tbody>
</table>
188% SGUE for 45°C Medium Temp. Heating + Hot Water Production

Gas Utilization Efficiency (GUE)

Heat Pump
Heat Pump + Integrated Boost Burner

Outdoor Air Temperature (°C)

EN 12309 (-10° C/45° C)
Expected values based on lab tests and modelling
<table>
<thead>
<tr>
<th></th>
<th>Thermal Compression Air-Water CO₂ Heat Pump</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Heat Pump Capacity</strong></td>
<td>4 kW at -10 °C Outdoor Air Temp.</td>
</tr>
<tr>
<td></td>
<td>4 - 13 kW at 7 °C</td>
</tr>
<tr>
<td></td>
<td>4 - 18 kW at 15 °C</td>
</tr>
<tr>
<td><strong>Capacity Modulation</strong></td>
<td>20% - 100%</td>
</tr>
<tr>
<td><strong>Integrated Boost Burner</strong></td>
<td>4 - 20 kW</td>
</tr>
<tr>
<td><strong>Capacity Modulation</strong></td>
<td>Integrated boost burner to provide</td>
</tr>
<tr>
<td></td>
<td>additional capacity if needed</td>
</tr>
<tr>
<td><strong>Domestic Hot Water</strong></td>
<td>50 - 60+ °C</td>
</tr>
<tr>
<td><strong>Supply Temperature</strong></td>
<td>Internal 75 - 85 °C hot water storage</td>
</tr>
<tr>
<td></td>
<td>tank with adjustable mixing valve</td>
</tr>
<tr>
<td><strong>Domestic Hot Water</strong></td>
<td>≥ 18 l/min (EN 13203)</td>
</tr>
<tr>
<td><strong>Specific Flow Rate</strong></td>
<td>“XL” load capacity</td>
</tr>
<tr>
<td><strong>Indoor Unit Dimensions</strong></td>
<td>H 200 cm x W 60 cm x D 80 cm</td>
</tr>
<tr>
<td><strong>Outdoor Unit Dimensions</strong></td>
<td>H 116 cm x W 85 cm x D 50 cm</td>
</tr>
</tbody>
</table>
R&D projects:
Sorption Energy

Where has the rest of the hardware gone?
R&D projects:

Sorption Energy

Fits into standard wall-mounted casing

Box-for-box exchange for old boiler

Key competitive advantage

• other gas-fired heat pumps too large for wall mount

Retrofit market >90% of annual sales
Past shell and tube designs

- Recommended by consultants
- Beware consultants!
- Output power low due to lower than expected heat transfer in shell and tube generators.
Future designs

Radical re-design of sorption generators – Shell and tube to finned tube

Tube: stainless steel
Fins: aluminium
Carbon: monolithic
Future designs

Low OD tube – thick fins

![Graph showing COh (volume) vs. SHP (kW/m3) for different pitches: low, med, and high.](image-url)
System under test at Warwick
R&D projects:

Cooll BV (Netherlands)

Carbon – Ammonia thermal wave adsorption, similar to Sorption Energy. No details available.
Climatewell

Climatewell: Integrating SaltX into OEM products

Spin-outs:
SunCool: Solar thermal collector with inbuilt cooling
HeatBoost: heat pumps for residential space and hot water heating. US field trials 2017 and Europe 2018. Incremental cost aimed at 3-4 times annual savings, which are predicted at €500. (50% reduction)

Climatewell supply material and technical support to OEM/component manufacturer.

In 4th generation demonstrator phase. 1800x600x900mm. Indoor air for DHW, water refrigerant.

For ambient air source, use ammonia refrigerant. 8-20kW, SCOP 130%, dT60-90K. Uses Alfa-Laval fusion bonded plate heat exchangers for the salt.
Summary of heat pump products/developments:

<table>
<thead>
<tr>
<th>NH₃ - H₂O absorption</th>
<th>Silica gel / zeolite - H₂O adsorption</th>
<th>NH₃ – carbon / salts adsorption</th>
<th>Reciprocating machines</th>
</tr>
</thead>
</table>
| • More mature technology  
  • Good COP  
  • Physically large  
  • Toxic refrigerant | • Water ref. does not extract heat below 5°C  
  • Needs gas backup  
  • LT output  
  • Low COP  
  • Large | • Similar to NH₃ - H₂O but slightly lower COP  
  • Potential to be compact and low-cost  
  • Toxic refrigerant | • Potentially good / superior COPs  
  • Complex  
  • Costly? |

| Robur  
  Bosch  
  SMTI | Vaillant  
  Viessmann  
  Sortech | Sorption Energy  
  Cooll  
  Climatewell | ThermoLift boostHEAT |
Thank you for your attention

• Any questions?