COMPARATIVE ANALYSIS OF WORLDWIDE HEAT PUMP PROJECTS RELATED TO PROPANE

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Motivation

Next to the successful introduction of HCs in refrigerators it was shown in 2000 to what performance improvements the application of HCs could lead:

- 15.0% for applications of commercial refrigeration,
- 8.8% for air conditioning and
- 9.6% for heat pumps.

Component availability was a long-term issue, but more components are now available (i.e. > 7 Mio. sold R290 compressors in 2020)

Nevertheless, there is a lack of demonstrations applying R290 and other refrigerants in the same or very similar setups (to allow easily understood similarities/differences).

Source: 1, 2
What resources for propane heat pumps are in scope? Only domestic use (AC, HP)

- Projects (as publicly documented)
  - About 80 projects/publications found with focus on reported experimental results related to R290/Propane/Alternative Refrigerants
  - But experimental comparison with other refrigerants are still scarce
  - For a more complete list of found projects related to experimental comparisons, see [link](#). Password: isefhg

- Domestic (and partially commercial) systems (probably not complete)
  - AC: Godrej, Gree, Midea, Haier, Hisense, Changhong, TCL, Aux and Yair
  - HP: Kensa, Nibe, Hautec, Vaillant, AIT/CTA/Novelan, Lexeta, Wolf, Heliotherm, Dimplex, Roth

Source: 3, 4
### BAFA Data

- BAFA is the Federal Office for Economic Affairs and Export Control that coordinates paying out grants for domestic heat pumps for houseowners.
- About 600 air-to-water heat pumps with variable-speed compressors.
  - Version date of the used list: 2019.
- About 20 air-to-water propane heat pumps were found and included.
  - Version date of all included propane heat pumps: 2021.
- COP median values for A-7/W35 and A2/W35 better but worse for A7/W35.

#### ALL INVERTER-CONTROLLED ATW HPs

<table>
<thead>
<tr>
<th></th>
<th>A-7/W35</th>
<th>A2/W35</th>
<th>A7/W35</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min</td>
<td>2,1</td>
<td>2,9</td>
<td>3,4</td>
</tr>
<tr>
<td>Median</td>
<td>2,7</td>
<td>3,5</td>
<td>4,8</td>
</tr>
<tr>
<td>Max</td>
<td>4,2</td>
<td>4,3</td>
<td>5,9</td>
</tr>
</tbody>
</table>

#### PROPANE

<table>
<thead>
<tr>
<th></th>
<th>A-7/W35</th>
<th>A2/W35</th>
<th>A7/W35</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min</td>
<td>2,4</td>
<td>3,0</td>
<td>3,6</td>
</tr>
<tr>
<td>Median</td>
<td>2,8</td>
<td>3,8</td>
<td>4,3</td>
</tr>
<tr>
<td>Max</td>
<td>3,2</td>
<td>4,7</td>
<td>5,7</td>
</tr>
</tbody>
</table>

Source: 5
Selected activities
Low-GWP AREP II (US DOE Program)

- Test of mini-split units at high ambient conditions

<table>
<thead>
<tr>
<th>Test condition</th>
<th>Outdoor Dry-bulb temperature</th>
<th>Dry-bulb temperature</th>
<th>Wet-bulb temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>AHRI B</td>
<td>27.8 (82)</td>
<td>26.7 (80.0)</td>
<td>19.4 (67)</td>
</tr>
<tr>
<td>AHRI A</td>
<td>35.0 (95)</td>
<td>26.7 (80.0)</td>
<td>19.4 (67)</td>
</tr>
<tr>
<td>T3*</td>
<td>46 (114.8)</td>
<td>26.7 (80.0)</td>
<td>19 (66.2)</td>
</tr>
<tr>
<td>T3</td>
<td>46 (114.8)</td>
<td>29 (84.2)</td>
<td>19 (66.2)</td>
</tr>
<tr>
<td>Hot</td>
<td>52 (125.6)</td>
<td>29 (84.2)</td>
<td>19 (66.2)</td>
</tr>
<tr>
<td>Extreme</td>
<td>55 (131)</td>
<td>29 (84.2)</td>
<td>19 (66.2)</td>
</tr>
</tbody>
</table>

- COP 7-11% better compared to R22 as baseline refrigerant
- But drop of about 5-10% in cooling capacity

Source: 6
Selected activities

Antunes et al.

- Test of small commercial refrigeration system
- $T_{\text{cond}}$ about 40°C
- COP 8-11% better than R22 baseline system and 2-4% better than R32
- Compressor frequency controlled to match same refrigerating capacity

Source: 7
Selected activities
Schnabel et al. (LC150 project)

- Ongoing research for the transition of heat pumps from (only) outdoor towards indoor systems by refrigerant charge reduction
- Project with eight European heat pump manufacturers

<table>
<thead>
<tr>
<th></th>
<th>@B0/W35/F60Hz/SH10</th>
<th>Dimension</th>
<th>V 1.0</th>
<th>V 2.5</th>
<th>V 2.6</th>
<th>V 3.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compressor</td>
<td>Scroll Manufacturer 1</td>
<td></td>
<td>Rotary v1 Manufacturer 2</td>
<td>Rotary v1 Manufacturer 2</td>
<td>Rotary v1 Manufacturer 2</td>
<td></td>
</tr>
<tr>
<td>Condenser</td>
<td>Long Asymmetric</td>
<td></td>
<td>Long Asymmetric</td>
<td>Short Asymmetric</td>
<td>Short Asymmetric</td>
<td></td>
</tr>
<tr>
<td>Evaporator</td>
<td>Long Asymmetric</td>
<td></td>
<td>Long Asymmetric</td>
<td>Long Symmetric</td>
<td>Long Symmetric</td>
<td></td>
</tr>
<tr>
<td>Heating cap.</td>
<td>[kW]</td>
<td>4,4</td>
<td>4,75</td>
<td>4,8</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>COP</td>
<td>[-]</td>
<td>3,6</td>
<td>3,75</td>
<td>3,85</td>
<td>4,1</td>
<td></td>
</tr>
<tr>
<td>Charge</td>
<td>[g]</td>
<td>190</td>
<td>220</td>
<td>200</td>
<td>290</td>
<td></td>
</tr>
<tr>
<td>Heating cap./ charge</td>
<td>[g/kW]</td>
<td>43,18</td>
<td>46,32</td>
<td>41,67</td>
<td>58</td>
<td></td>
</tr>
</tbody>
</table>

Steering Committee, definition of requirements, receipt of results and access to IPs

Source: 8
Conclusions

- Propane as a refrigerant gets increased intention and can fulfill forecasted efficiencies
- To have control on the safety issues related to propane charge reduction methods are applied as a general design measure for all components
- Indoor applications could become more realistic based on the work from

Outlook on LC150 project

- More than 80 systems will be tested based on newly available components
- Recent results will be published regularly during the Annex 54
Resources

1. Colbourne and Suen, Assessment of Performance of Hydrocarbon Refrigerants, IIR Gustav Lorenzen Conference, 2000, Purdue, USA

2. See at chinaiol.com: http://www.chinaiol.com/News/Content/202103/72_27510.html

3. UFOPLAN Report „Wärmepumpen mit natürlichen Kältemitteln“ (in German but executive summary in English) (FKZ 3709413192) (Link)

4. Z. Yi, Overview of commercialized R290 technology, UNEP Asia-Pacific Regional Workshop on Environmentally Friendly Refrigerants in Room Air Conditioners, 2016, Shenzhen, China (Link to the workshop invitation, www.unep.fr seems to be down at 26th April 2021)

5. BAFA, German Federal Office for Economic Affairs and Export Control is coordinating grants for heat pumps and provides an (almost) exhaustive list on available heat pumps on the German market (Link)

6. O. Abdelaziz, S. Shrestha, Soft-Optimized System Test of Alternative Lower GWP Refrigerants in 1.5-ton Mini-Split Air Conditioning Units, AHRI Low-GWP AREP TEST REPORT #62, ORNL (Link)

7. Antunes et al., Experimental evaluation of refrigerants R290, R32 and R410a in a refrigeration system originally designed for R22, HEFAT 2014, 10th International Conference on Heat Transfer, Fluid Mechanics and Thermodynamics, Orlando, Florida, USA

8. Schnabel et al., LC150 - Development of a refrigerant-reduced heat pump module with propane (in German), ongoing project of the German Federal Ministry of Economic Affairs and Energy, project number 03EN4001A (Link)
Thank you for your attention!

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Off the records – Presentation of activities next meetings

(Completion/fulfillment of announced activities of all meetings since 2019.)

- First mentioned at 2\textsuperscript{nd} meeting: Test and comparison of a R32 split AC system after “soft optimization” changes with R290 (ongoing until 06/2021)
  - no comparison with R410A or other A2L refrigerants as announced
  - only tested at different HAT conditions in AC and not HP mode

- First mentioned at 2\textsuperscript{nd} / 3\textsuperscript{rd} meeting: Outflow CFD study of a R290 compact unit with 10 different use cases as part of risk assessment support (8 cases finished, ongoing until 05/2021)
  - 25/50/75/100\% LFL cloud data freely available for interested parties

- First mentioned at 3\textsuperscript{rd} meeting: Attempt to objectively review LCCP parameters
  - Degradation of modern synthetic refrigerants (finished)
  - Outlook of decarbonization potential for Germany in 2030 and 2040 by applying R290 heat pumps (finished)

- Future announcement: update on LC150 project

- First mentioned at 2\textsuperscript{nd} meeting: Modification of the heat pump with respect to refrigerant charge reduction down to 500 g (cancelled)
Off the records – annual report contributions

- Integration of ongoing activities about low-GWP refrigerant applications
  - In 2020
    - RWTH Aachen, TU Braunschweig, TU Dresden, Fraunhofer ISE
  - 2021/2022
    - same group of institutions
    - try to get feedback from more/other German stakeholders (University of Duisburg/Essen, ILK Dresden, TU Berlin, ZAE Bayern, etc.)