SUSTAINABLE PLACES 2022
Sep. 6 - Sep. 9, 2022 | Nice, France

OST
Ostschweizer Fachhochschule

TRI-HP PROJECT

Trigeneration systems based on heat pumps with natural refrigerants and multiple renewable sources

Dr. Daniel Carbonell

SPF Institute for Solar Technology
Eastern Switzerland University of Applied Sciences (OST)

SPF INSTITUT FÜR SOLARTECHNIK

TRI-generation systems

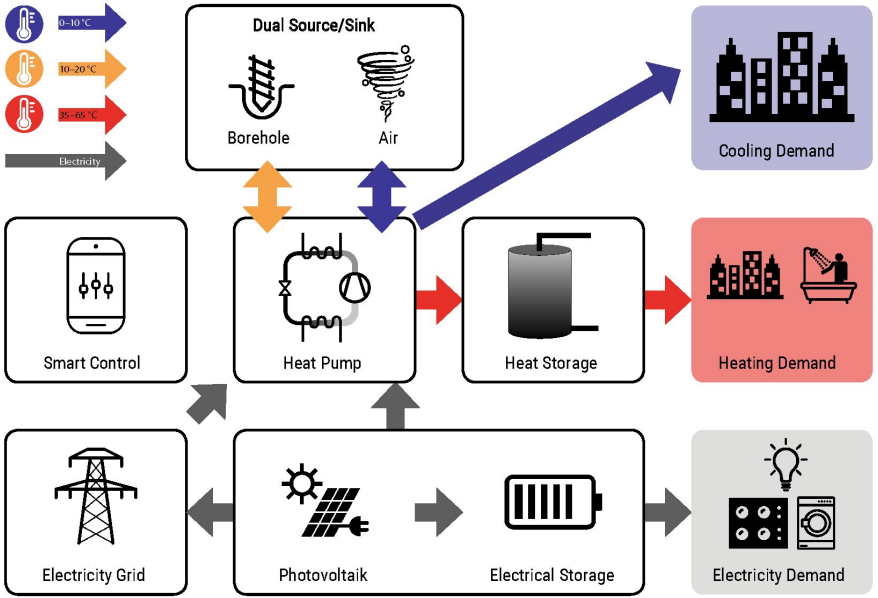
- Based on electrically driven **natural refrigerant heat pumps (HPs)** coupled with PV to provide **heating**, **cooling** and **electricity** to multi-family residential **buildings**

- Targets:
  - **80 % renewable on-site share** with net-zero energy concept (20 % exchanged with the grid)
  - **Cost reduction by 10 – 15 %** compared to current HP technologies with same energetic efficiency
  - **75 % GHG emissions reductions** respect to gas boiler and air chillers with grid purchased electricity.

www.tri-hp.eu

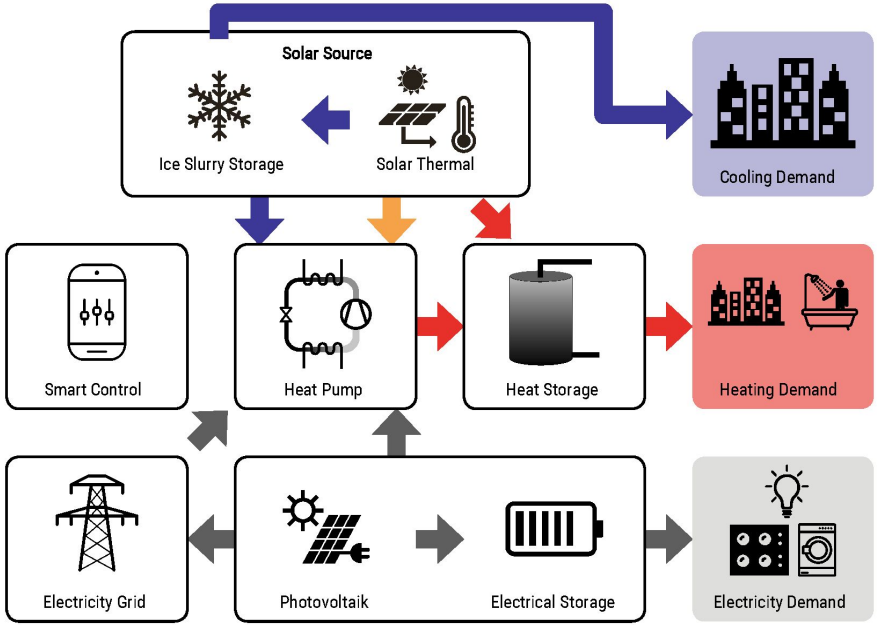
Dual source/sink system

- Source: ground and air
- Heating and cooling with reversible

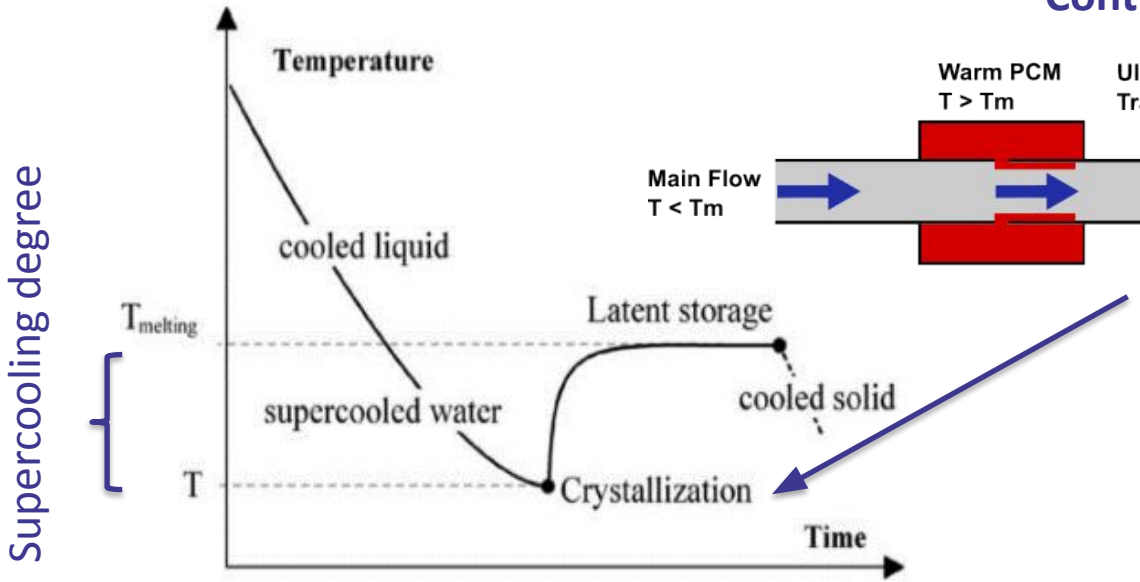


Solar-ice slurry system

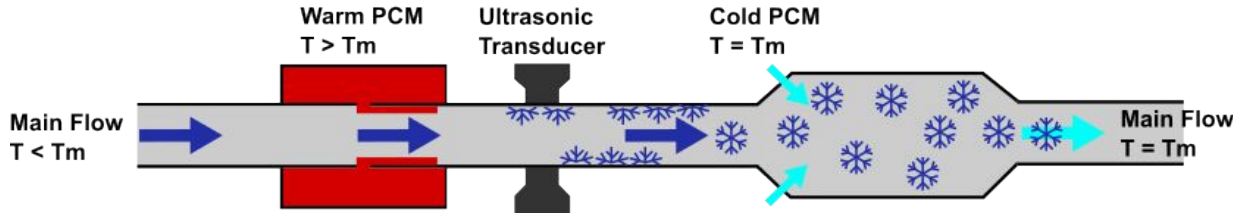
- Source: solar with ice slurry as intermediate storage medium
- Heating with cooling as add-on feature



SUPERCOOLING ICE SLURRY WITH CONTROLLED NUCLEATION

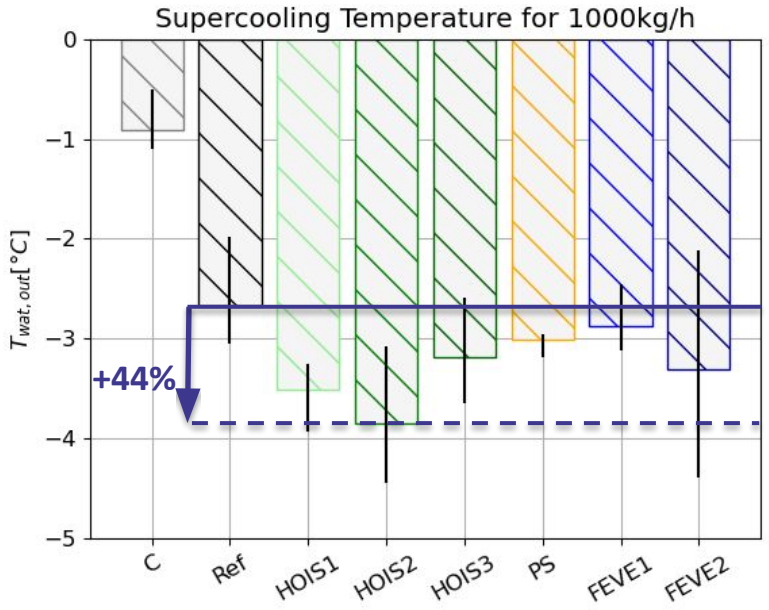


Controlled nucleation via crystallizer



Results – Performance of icephobic surfaces

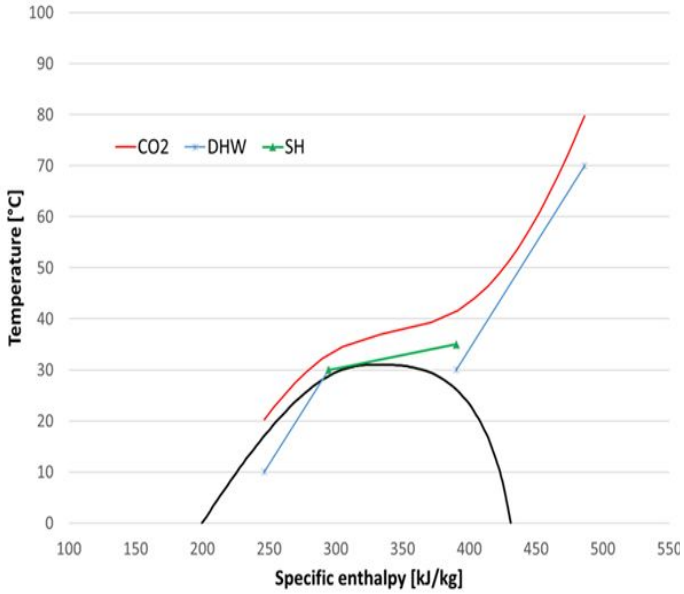
Supercooling Degree

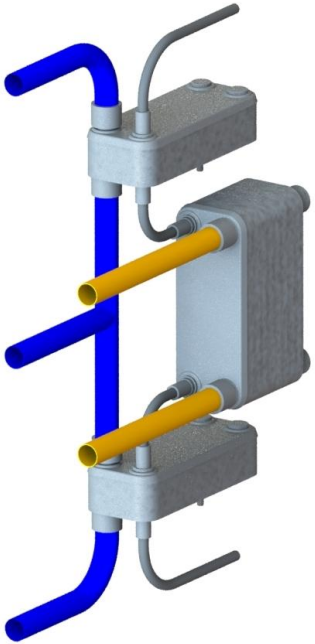


- **Up to 44 % improvement of icephobic coatings respect to untreated heat exchanger**
- Heat exchangers were operated at half of its nominal mass flow rate due to laboratory set-up cooling limitations
  - supercooling is reduced when using nominal mass flow rates.
- **Results published** in “Development of supercoolers for ice slurry generators using icephobic coatings”
  - https://doi.org/10.1016/j.ijrefrig.2022.07.011

Hybrid Organic-Inorganic Silane sol-gel (HOIS), PolySiloxane (PS), FluoroEthylene Vinyl Ether (FEVE)

Relevant results : HX innovation - Tri-partite gas cooler





- Approximation of water temperatures to the temperature profile of CO_2
- Very high thermal output
- Exclusively use of plate copper-brazed heat exchangers
- extremely compactly
- Simultaneous heating of heating and domestic hot water

Results published: “Heat transfer and pressure drop of supercritical CO2 in brazed plate heat exchangers of the tri-partite gas cooler” **https://doi.org/10.1016/j.ijheatmasstransfer.2021.121641**

Relevant results: Natural refrigerant heat pump - CO2

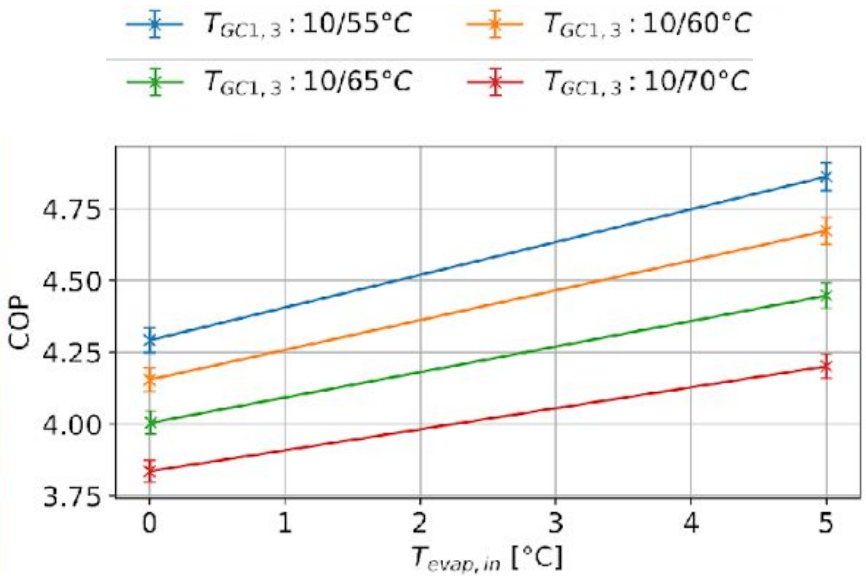
- Refrigerant R-744 (CO2)
- Power controlled, flooded evaporation, ejector tech
- Tri-partite gas cooler for simultaneous DHW and SH
- Supercooler as evaporator

Application:

- Residential buildings with high DHW share
  - for mild/cold climates
- Solar - Ice slurry system
- Some free cooling is available

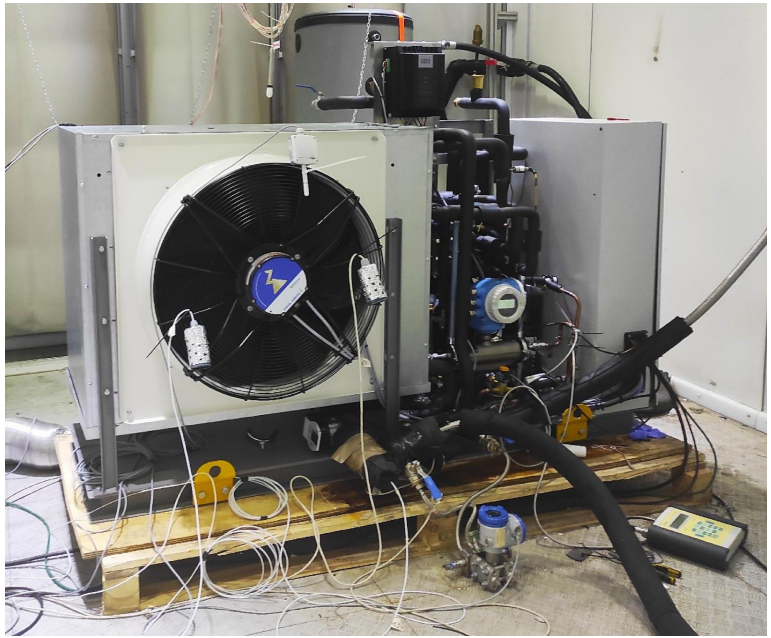
Relevant results: Natural refrigerant heat pump - CO2

- Example of parallel mode : DHW and SH (30/35 °C)
- Power controlled, flooded evaporation, ejector tech



- Results at Tevap,in 0 °C supercooled water by 2 K with COP= 4 at 65 °C for DHW and 35 °C SH
- A propane slurry heat pump was also tested sucessfully
- **Results published for propane slurry heat pump**: *"Residential heat pump for indoor installation operating with R-290 and ice-slurry heat-source"* **http://dx.doi.org/10.18462/iir.gl2022.0039**

Relevant results: Natural refrigerant heat pump - dual source/sink



- Refrigerant R-290 (Propane)
- Power controlled, reversible
- **Innovative dual source/sink heat exchanger**
  - Use of brine and air
- High efficiency in heating and cooling mode

Application:

- Residential buildings with heating and cooling needs
- For mild/warm climates

- **Results published**: *"Dual source heat exchangers as evaporator/condenser in a R90 heat pump: Design and experimental validation"*, http://dx.doi.org/10.18462/iir.gl2022.0011

" Design and experimental validation of a R290 dual-source heat pump", http://dx.doi.org/10.18462/iir.gl2022.0168

Advanced Energy Management System (AEMS)

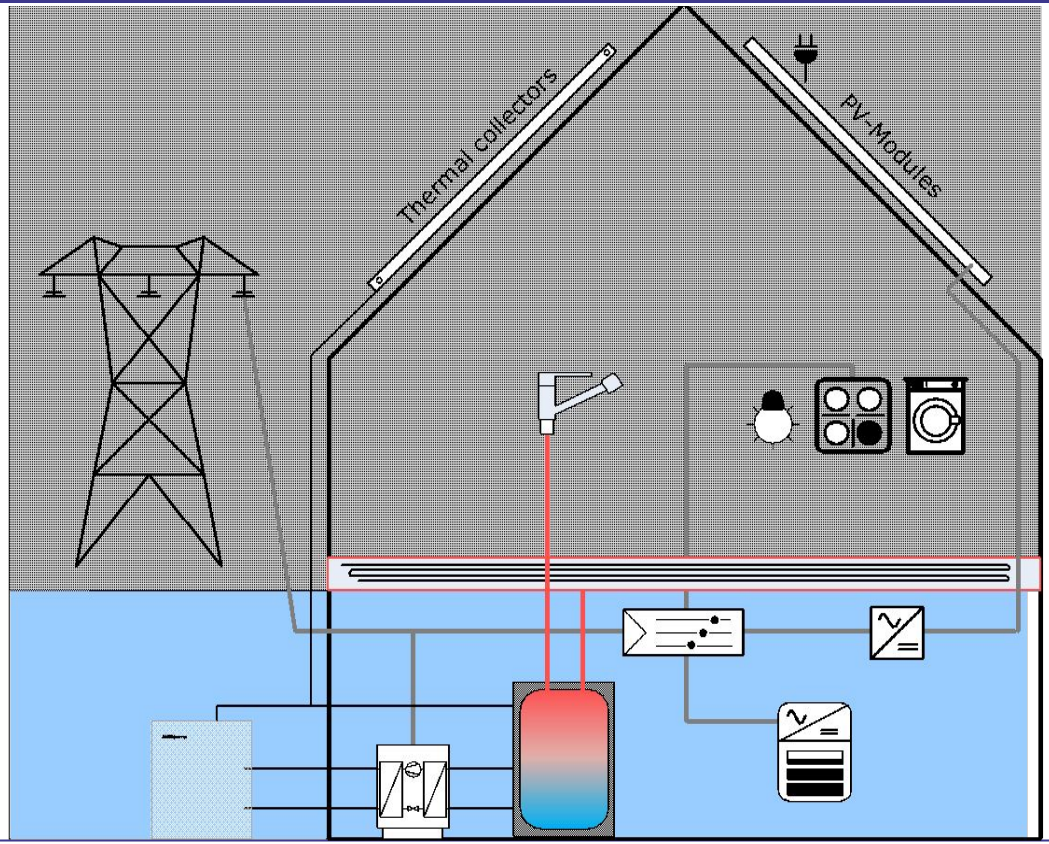
- Development of an optimal energy management algorithm to minimize the energy cost by up to 15 % and increase the share of renewables up to 80%
- Validation and assessment of the potential benefits of the AEMS by means of simulation and experiments covering different scenarios and conditions.
- The AEMS algorithm relies on models of the heat pumps and HVAC systems to determine their optimal operation over a 24 hours horizon in the future, using weather and occupancy forecasts for this purpose
- **Results published:**

"*Co-simulation studies of optimal control for natural refrigerant heat pumps*",
https://doi.org/10.34641/clima.2022.432

"A review of the fault behaviour of heat pumps and measurements, detection and diagnosis methods including virtual sensors",
https://doi.org/10.1016/j.jobe.2021.102254

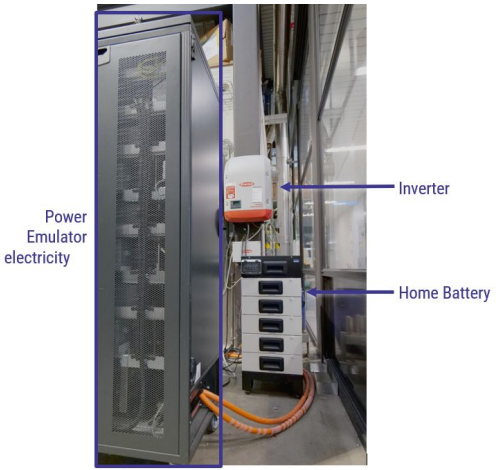
Hardware in the loop dynamic system test

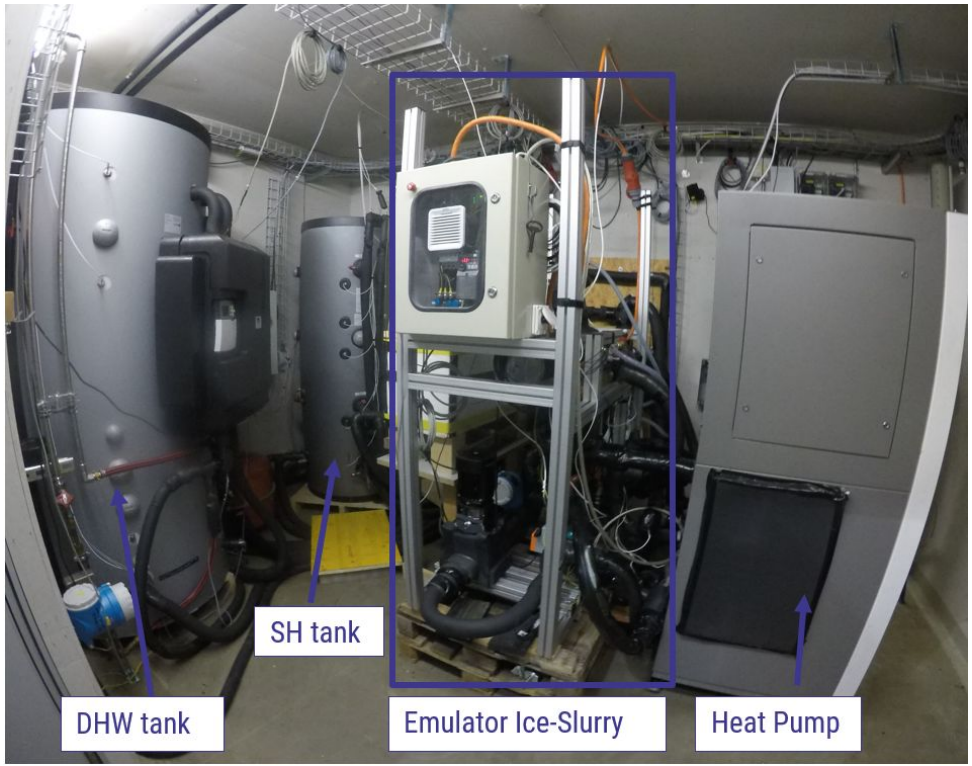
- Concise Cycle test of 6 days representing all year
- Brings the TRL to 5
- Grey part is simulated/emulated
  - Demands, weather, solar thermal and PV
- Blue part is installed in the lab and tested as a whole
- **Results published**: "Concise cycle test methods to evaluate heating/cooling systems with multiple renewable sources", https://doi.org/10.34641/clima.2022.390



Current test on the hardware in the loop dynamic system test

- **System includes**: battery, DHW and SH storages, CO2 heat pump, hydraulics, autonomous control
- **Emulation** of ice slurry tank, PV, solar thermal, DHE and SH demands





Technology Acceptance

- Understanding and improving stakeholder's acceptance
- Analyse and identify the interest and needs of key stakeholders
- Methods
  - Qualitative **interviews** with stakeholders (DE, CH, ES, NO)
  - Regional **stakeholders workshops** (**DE**, CH, ES, NO)

© SPF

- **Published Results** : "*Enhancing stakeholders' acceptance of trigeneration heating and cooling systems: Recommendations from the TRI-HP stakeholder process*" **https:// doi:10.5281/zenodo.5500482.** "*Social acceptance of innovative renewable heating and cooling systems: Barriers, hindrances, drivers and incentives*"**, https://doi.org/10.5281/zenodo.5500469**

Contact:

Dani.Carbonell@ost.ch

www.tri-hp.eu

https://zenodo.org/communities/tri-hp/

TRI-HP PROJECT | Trigeneration systems based on heat pumps with natural refrigerants and multiple renewable sources