«COOLING TECHNOLOGIES»

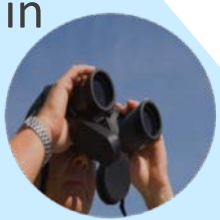
IEA Technology Collaboration Programme on
Heat Pumping Technologies (HPT TCP)

Chair Stephan Renz

A/C TECHNOLOGIES AND MARKETS

In the Past

- Substantial declines in product and lifecycle cooling costs in many A/C markets
- Higher sales volumes
- Higher energy efficiency
- Transition away from ozone-depleting substances (ODS)



Expectations for the future

- Rapid growth of A/C markets in developing nations with hot, humid climates
- Increased frequency of extreme heat waves due to global warming
- Continued efficiency improvements
- Transition to low-Global Warming Potential (GWP) refrigerants
- Advancement of non-vapor-compression A/C technologies
- Cooperation with other TCP's

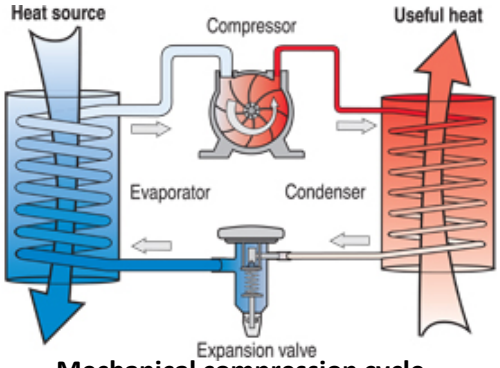
WHAT IS THE HPT TCP?

- A Technology Collaboration Programme (TCP) within **the IEA** since **1978**
- An international framework of **cooperation** and **networking** for different HP actors
- A forum to exchange **knowledge** and **experience**
- A contributor to **technology improvements** by RDD&D projects

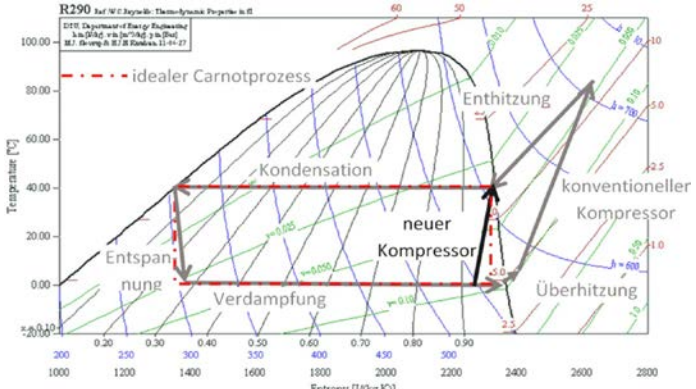
16 Participating Countries

Austria
Belgium
Canada
Denmark
Finland
France
Germany
Italy
Japan
Netherlands
Norway
South Korea
Sweden
Switzerland
United Kingdom
United States

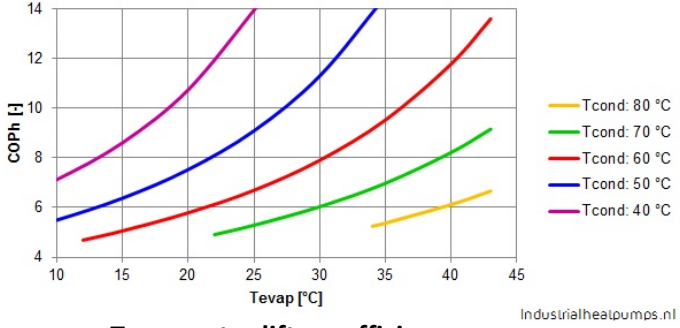
WHAT IS - HEAT PUMPING TECHNOLOGIES



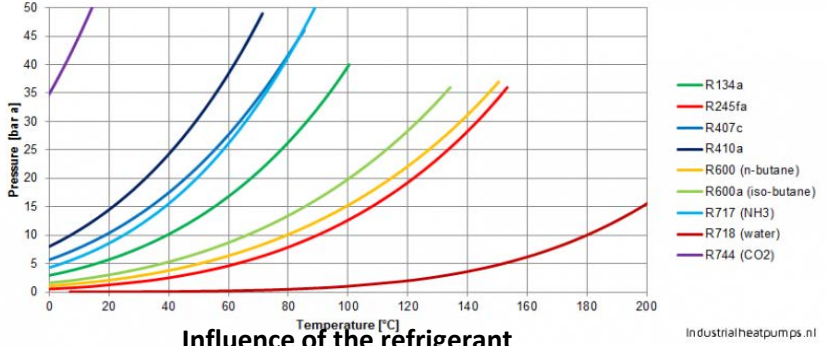
Mechanical compression cycle



Thermodynamic cycle in T-s-Diagramme

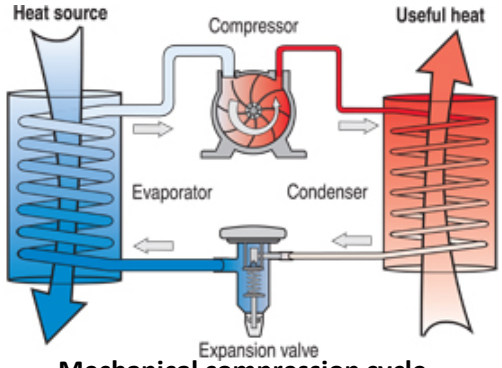


Temperatur lift vs. efficiency



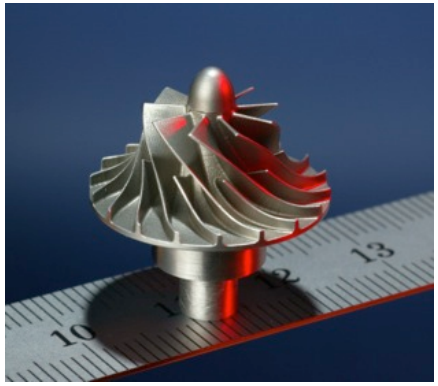
Influence of the refrigerant

WHAT IS - HEAT PUMPING TECHNOLOGIES



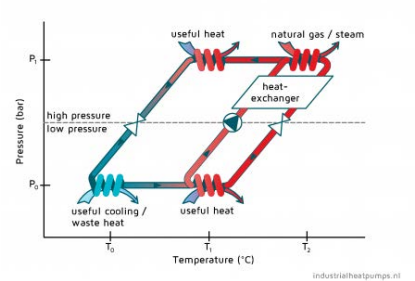
Mechanical compression cycle

Large heat pumps ....

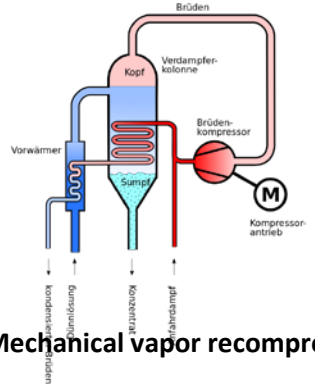


..... smalll heat pumps

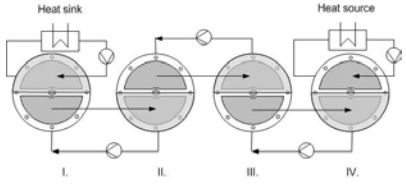
Other heat pump cycles



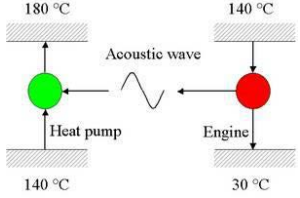
Absorption heat pump



Mechanical vapor recompression

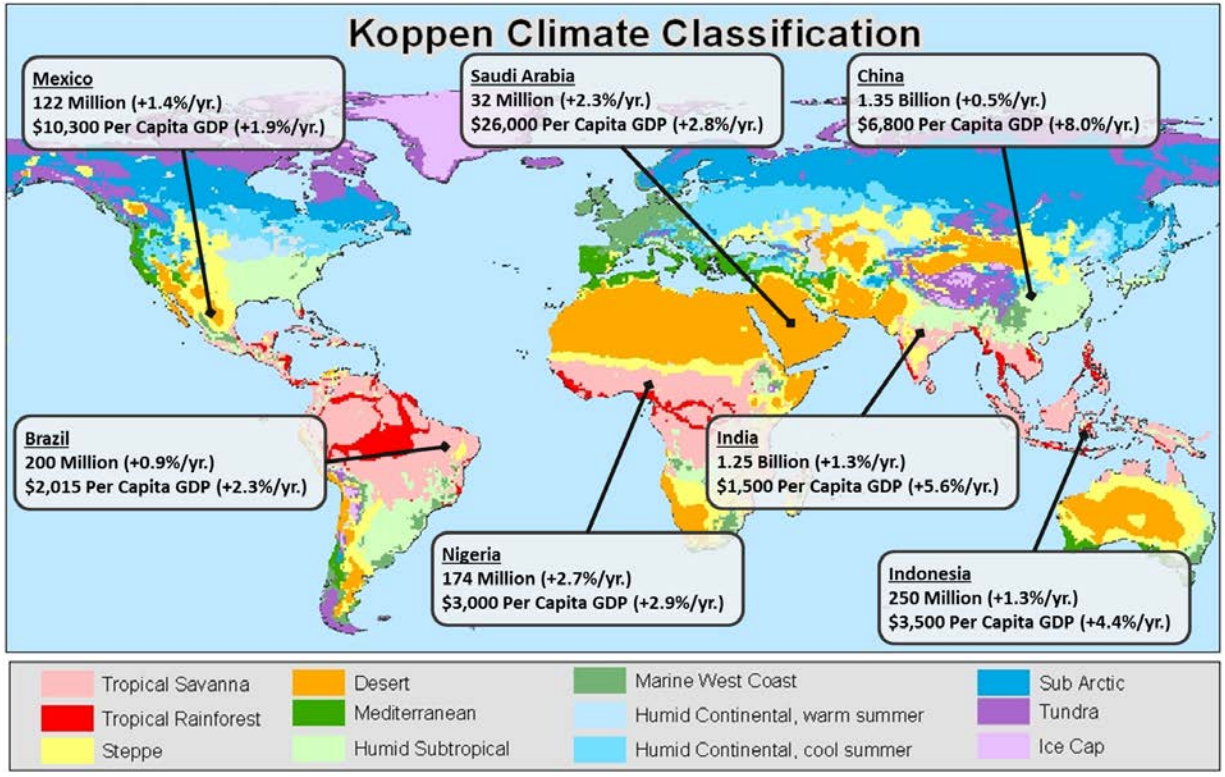


Electro-magnetic heat pump



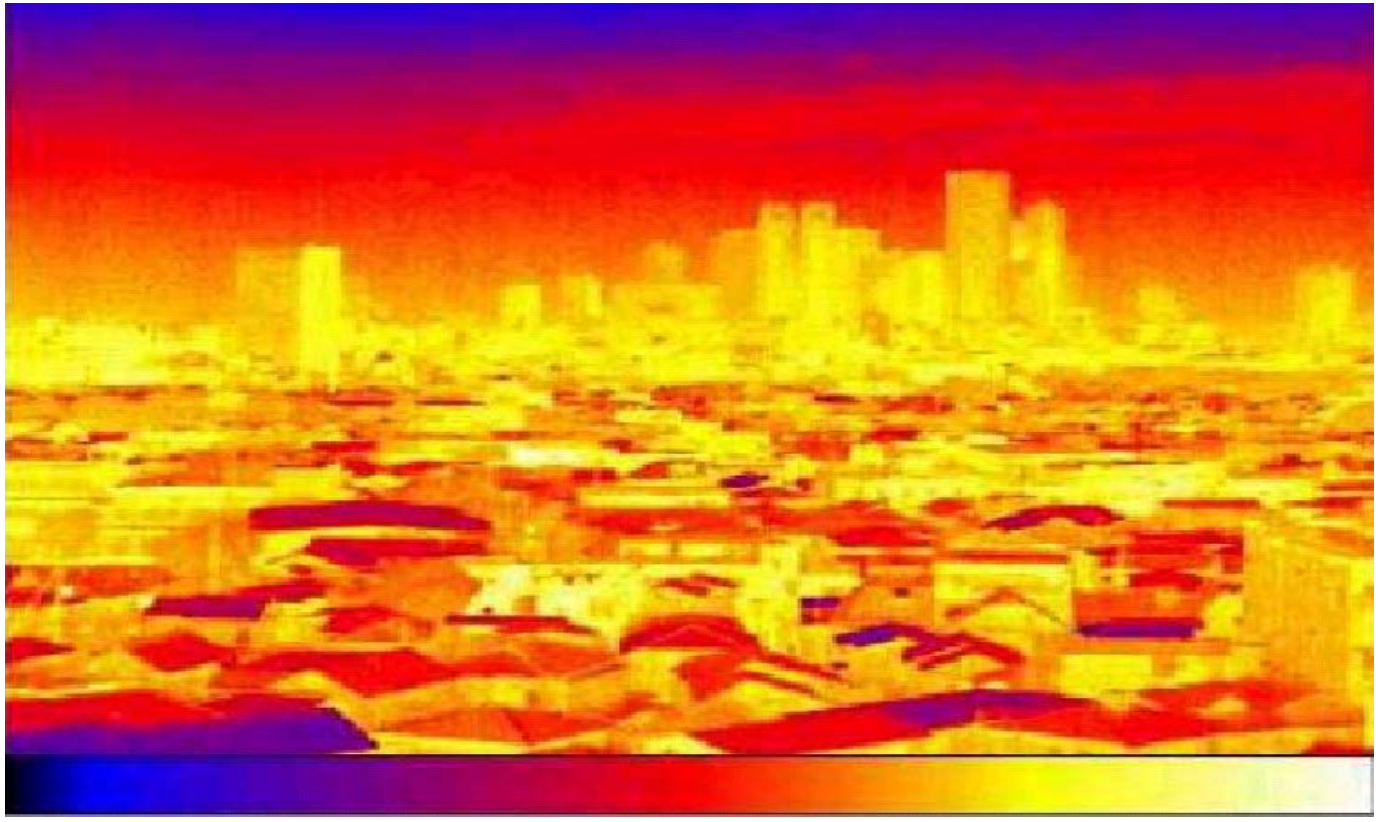
Thermo-acoustic heat pump

DEVELOPMENT OF SPACE COOLING DEMAND (1/3)



Many **countries with strong population** and **GDP growth** are in **hot and humid climates**, further driving increased A/C use.

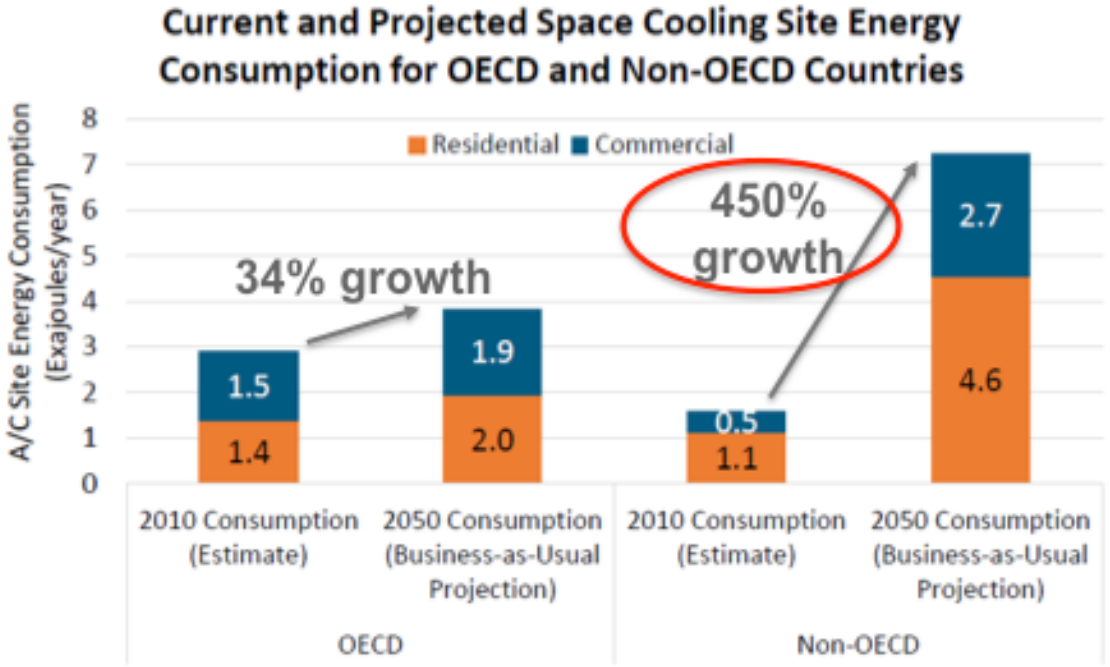
DEVELOPMENT OF SPACE COOLING DEMAND (2/3)



Heat island effect

DEVELOPMENT OF SPACE COOLING DEMAND (3/3)

- Aggressive growth of A/C energy consumption by 2050 will be driven primarily by non-OECD countries.
- Rising standards of living and population growth drives increased A/C adoption.
- Current A/C penetration in developing nations is limited, e.g., 3% in 2010 in India
- **India alone has potential space cooling demand that is 14 times larger than that of the U.S**



CHALLENGES AND OPPORTUNITIES OF COOLING TECH'S

- **Efficiency of the thermo cycle**
- **Dehumidification**
- **Global Warming Potential (GWP) of the refrigerant**
- Energy transfer from the room
- Energy transfer to the environment
- Required temperature lift
- Decentralised or central solution
- Source of electricity (and its GWP)

- Electricity grid (capacity, total energy and peak loads)
- Other energy sources/sinks
- Need & Opportunities of storage system
- Existing building stock or new
- Size of the building
- Purpose of the building
- Standard of building technologies
- "Culture" of thermal comfort

EMERGING R&D SOLUTIONS FOR COOLING TECH'S

- **Advanced Vapor-Compression Systems**
- A/C technologies that significantly lower refrigerant GWP and energy consumption while maintaining cost-competitiveness; for example:
  - Low-GWP refrigerants (e.g., natural refrigerants and synthetic olefins)
  - Climate-specific designs
- **Emerging Non-Vapor-Compression (NVC) Systems**
- A/C technologies that do not rely on refrigerant-based vapor-compression and can provide energy savings (with high-volume cost similar to today's); for example:
  - Solid-state & caloric (thermoelectric, magnetocaloric)
  - Electro-mechanical (evaporative, thermoelastic)
  - Thermally driven (absorption)
- **Integration of A/C and Other Building Systems**
- A/C technologies that share excess heat and other resources with other systems to provide significant savings for the building; for example:
  - Capturing waste energy from A/C **for water heating** and dehumidification

Outcome from Annex 40
Heat Pumps and NZEBs

Temperature and Humidity Individual Controll HVAC System with the New Desiccant Device – DESICA-

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November. 11, 2014
Annex 40 Workshop

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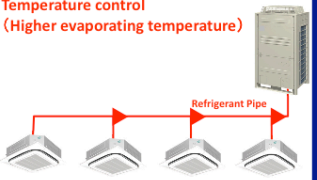
Introduction of the New HVAC System

THIC can achieve higher performance in each of the sensible or latent heat treatment

Temperature control
(Higher evaporating temperature)



Higher sensible heat capacity
Multiple split air-conditioning system
" Variable Refrigerant Flow (VRF) "

+

Humidity control
(Use Humidity sensor)

Highly Effective Compact Desiccant Unit
"Heat Pump Desiccant (HPD)"

- For temperature, performance improvement was easily achieved by raising evaporating temperature.
- For humidity, we focused on desiccant technology to achieve high performance.

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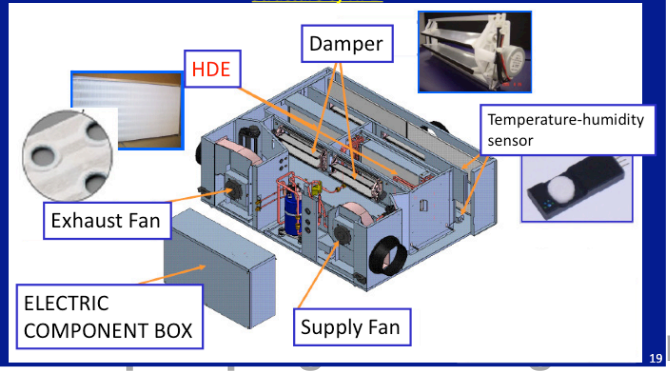
High Performance Heat Pump Desiccant system

The HP desiccant is realized with
2.5 times higher performance and 1/3 of compactness.

Structure of HPD



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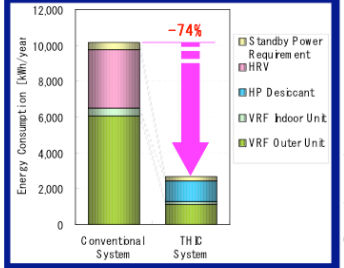
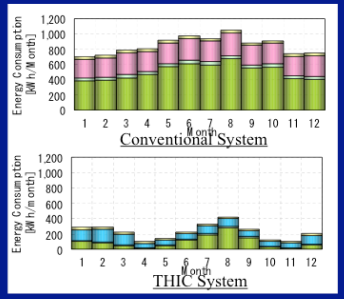
Evaluation of the Whole Year Operation

In case that the THIC system is installed in the high quality buildings, total amount of the energy consumption throuth a year will be reduced by more than 70%.





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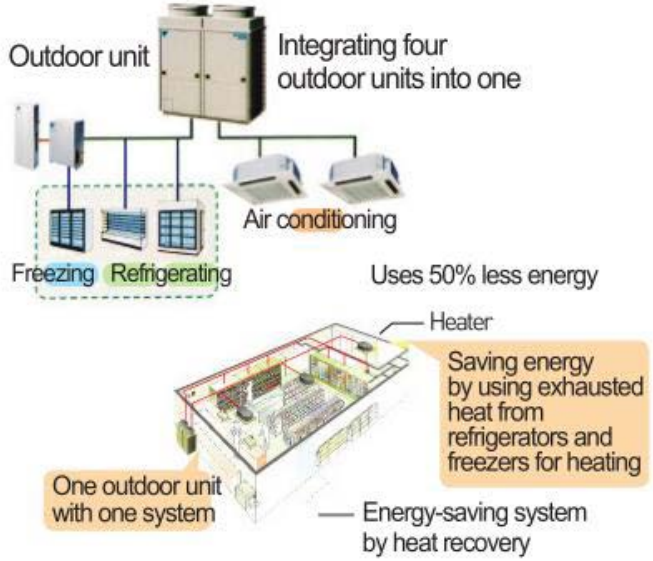
RECENT DEVELOPMENTS IN COOLING TECH'S

- **Membrane air conditioner**
  - Dehumidification by nano-composite membrane instead of cooling
  - Development of membrane heat and mass exchanger
  - Development of prototype air conditioner and feasibility test
  - One of the candidate technologies in DOE report of non-vapor compression HVAC technologies.

- **Integrated system of refrigeration, air conditioning and freezing**
  - Combined with a heat pump system
  - Target for commercial sector like supermarket



DIRECT VS. INDIRECT GHG EMISSIONS IMPACTS

- 2010 global A/C GHG emissions:
  - Direct (HFC, HCFC refrigerant emissions during operation, end-of-life) ➔ 26% or 175 $MMtCO_2$-eq
  - Indirect (CO_2 emissions from electricity generation) ➔ 74% or 516 $MMtCO_2$-eq
- Electricity consumption is the largest driver of global A/C GHG emissions, but simultaneous pursuit of reductions in BOTH direct and indirect emissions is required to achieve international goals.
- Direct emissions in developing countries are typically higher than in developed countries.
  - Few developing countries have in-service recovery or end-of-life recycling regulations
  - Leads to deliberate venting of refrigerants

LOW-GWP PRODUCT AVAILABILITY

Products using low-GWP, 4th generation refrigerants are already available in some applications.

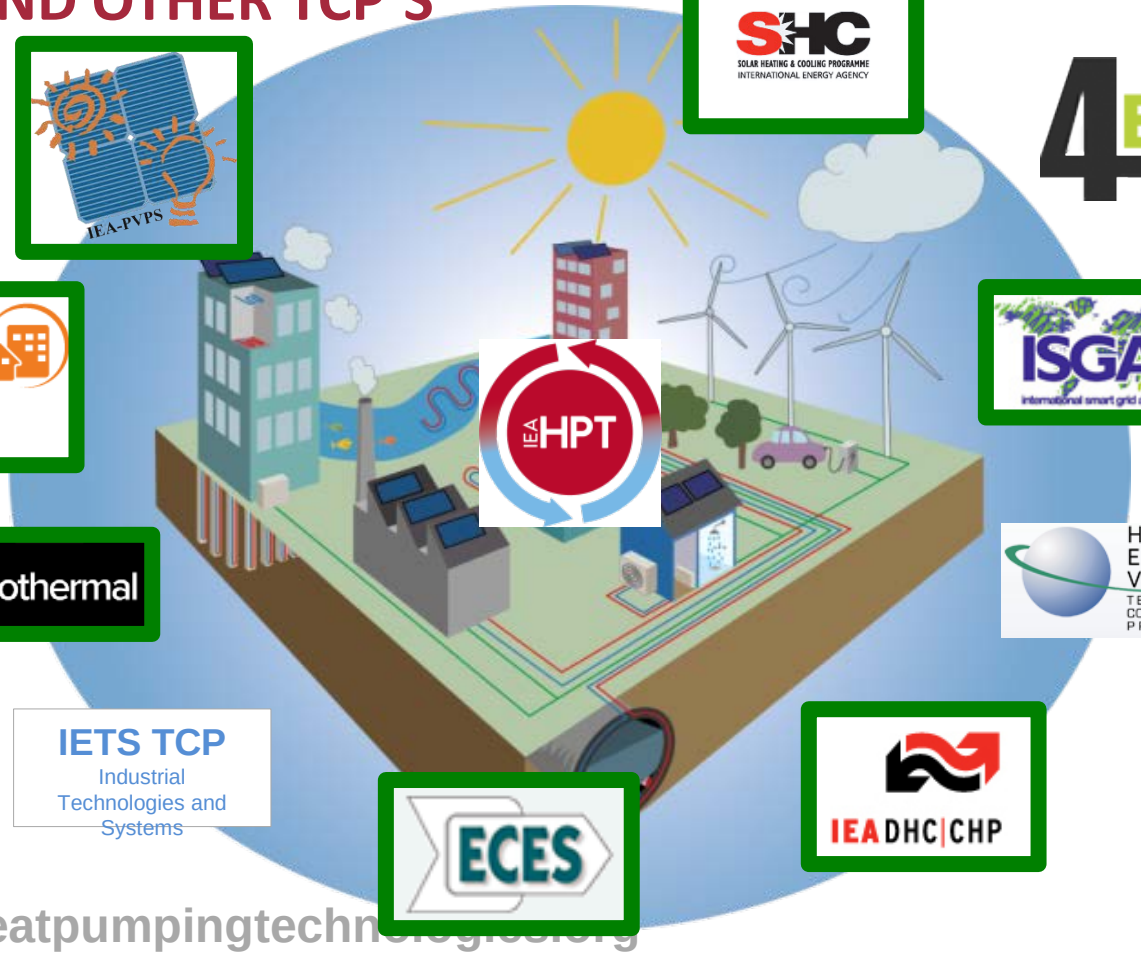
- Offer comparable or improved efficiency relative to today's typical equipment
- Currently available in four key product categories, including ductless split systems, by far the largest market segment globally (>60% of the market)
- Flammability and cost are key limiting factors

	Equipment	Status	Approved for use in U.S.	U.S. SNAP Application Submitted	Example		2012 Global Annual Sales (US$B)
					Best GWP	Detail	
Residential	Room and portable	●	✓	✓	<10	R-290; R -32	$3.4 ★
	Ducted split & single-package	◔		✓	<700	Multiple candidates	$3.3
	Ductless split system	●		✓	<10	R-32; R-290	$48.5 ★
Commercial	Packaged terminal	◔	✓	✓	<700	R-32	$0.2
	Packaged rooftop unit	◔		✓	<700	Multiple candidates	$4.6
	Ductless (VRF/VRV)	◔			<700	R-32	$10.7
	Scroll / recip. chiller	◔		✓	<700	DR-55 (R-452B) ★	$8.3 (all chillers)
	Screw chiller	●	✓	✓	<10	R-513A; R-1234ze(E)	
	Centrifugal chiller	●	✓	✓	<10	R-1233zd(E), R-1234ze(E) ★	

Source for market size: Approximate 2012 global sales data (includes equipment using all refrigerants) from BSRIA; U.S approval status from EPA website

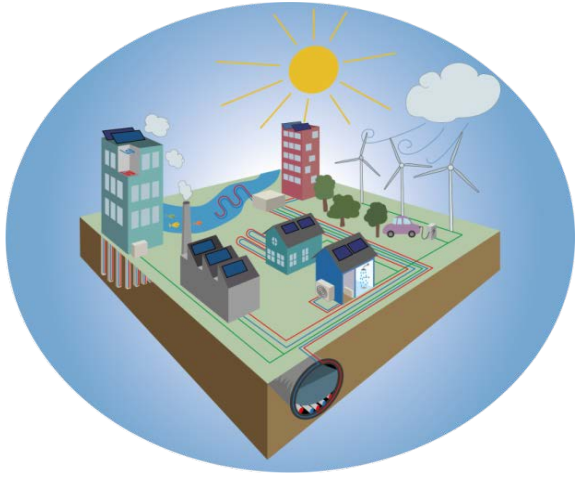
● Commercially available in some global markets; ◔ Product under development; ◔ Tested in Lab

HPT TCP AND OTHER TCP'S



COOLING TECHNOLOGIES FOR THE NEXT DECADE

- **Flexible, sustainable and clean system solutions** (e.g. in urban areas) using combinations of heat pumping technologies with **energy storage**, **smart grid**, **solar** and **wind** energy, **thermal networks**, **energy prosumers**



Thanks for your attention