# WÄRMEPUMPEN
# IN
# ÖSTERREICH, DER EU UND DER IEA

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Graz University of Technology, Austria

# Entwicklungen des industriellen Zeitalters

| | | |
|---|---|---|
| 1765 | James Watt | Dampfmaschine |
| 1814 | Stephenson | Dampfeisenbahn |
| 1816 | Gebrüder Stirling | Heissluftmotor |
| 1824 | Sadi Carnot | Dissertations |
| 1834 | Perkins/Evans | Kompressionskältemaschine |
| 1834 | Michael Faraday | Elektromotor |
| 1839 | William Grove | Brennstoffzelle |
| 1839 | Alexandre Becquerel | Photovoltaic Effect |
| 1842 | Robert Mayer | 1. Hauptsatz der Thermodynamik |
| 1850 | Clausius | 2. Hauptsatz der Thermodynamik |
| 1853 | Ritter von Rittinger | Brüdenverdichtung |
| 1865 | Carré | Absorptionskältemaschine |
| 1865 | Linde | Kältetechnik |
| 1876 | Nikolaus Otto | Ottomotor |
| 1881 | Edison Comp. | Dampfkraftwerk |
| 1883 | C.G. de Laval | Dampfturbine |
| 1885 | Markus/Benz | Kraftfahrzeug |
| 1893 | Rudolfs Diesel | Dieselmotor |
| 1900 | Willies H. Carrier | Gebäudeklimatisierung |
| 1903 | Gebrüder Wright | Flugzeug |
| 1912 | Viktor Kaplan | Kaplanturbine |
| 1930 | Midgely/Henne | (H)CFCs |
| 1937 | Zuse | Computer Z1 |
| 1942 | Enrico Fermi | Kontrollierte Kernspaltung |

# Carnot, Sadi (1796-1832)

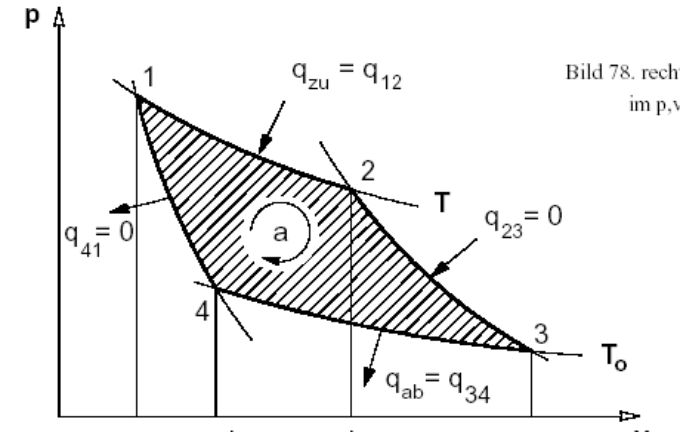



Bild 78. rech
im p,v

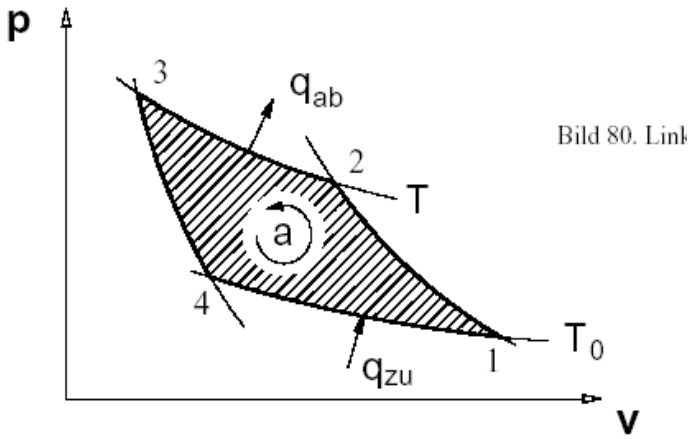
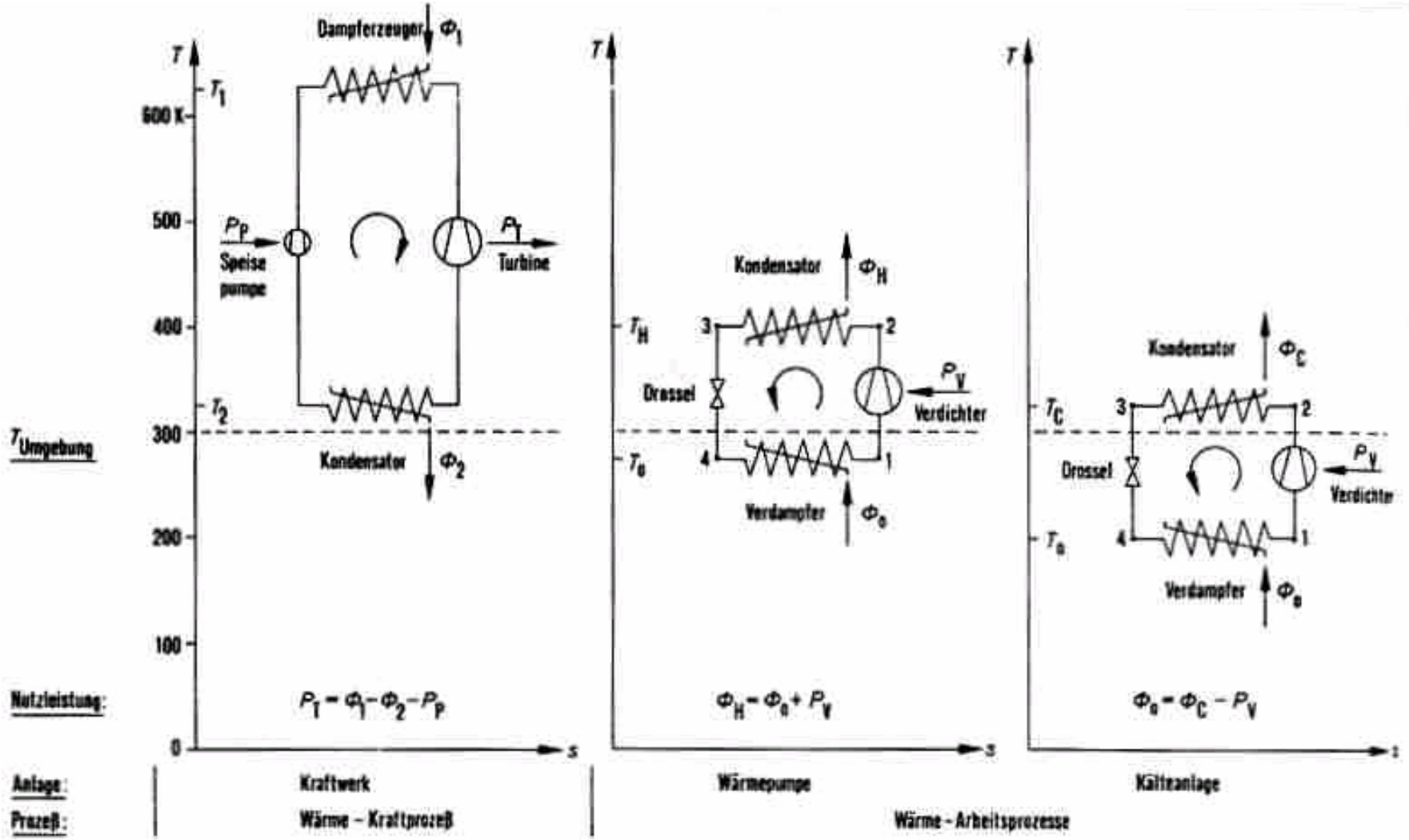
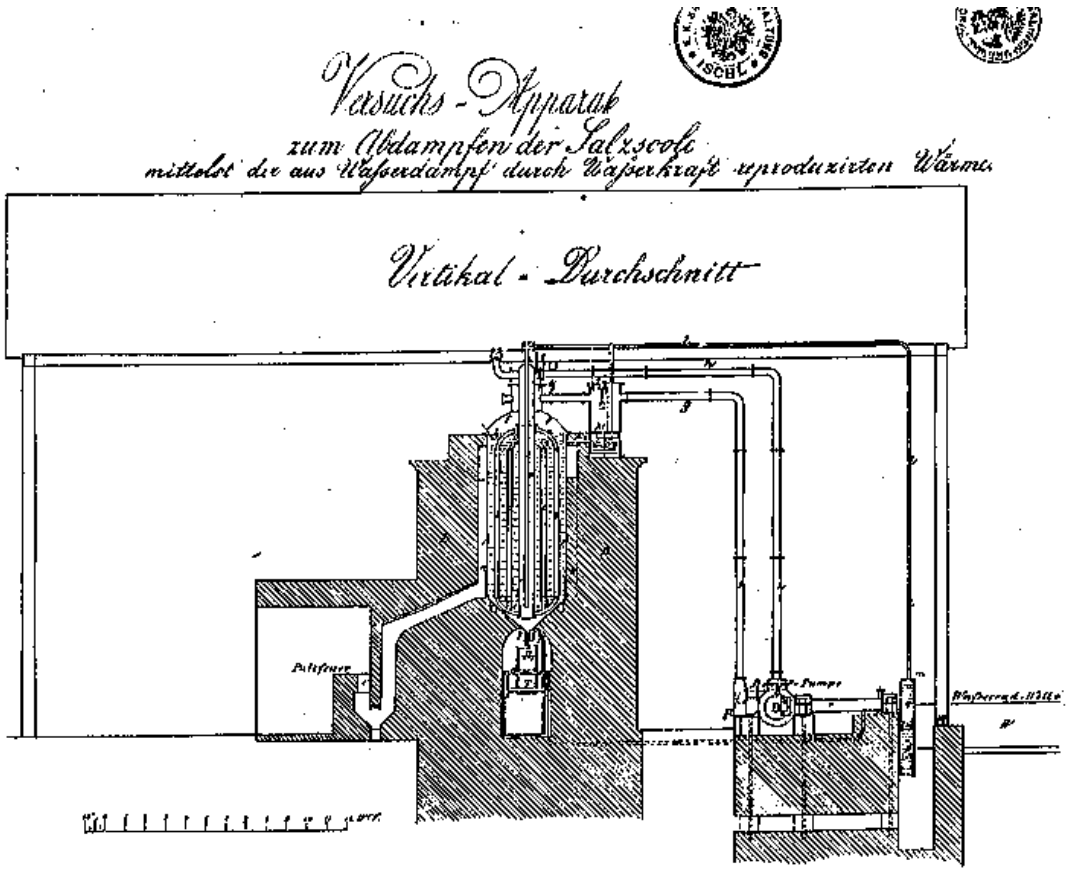
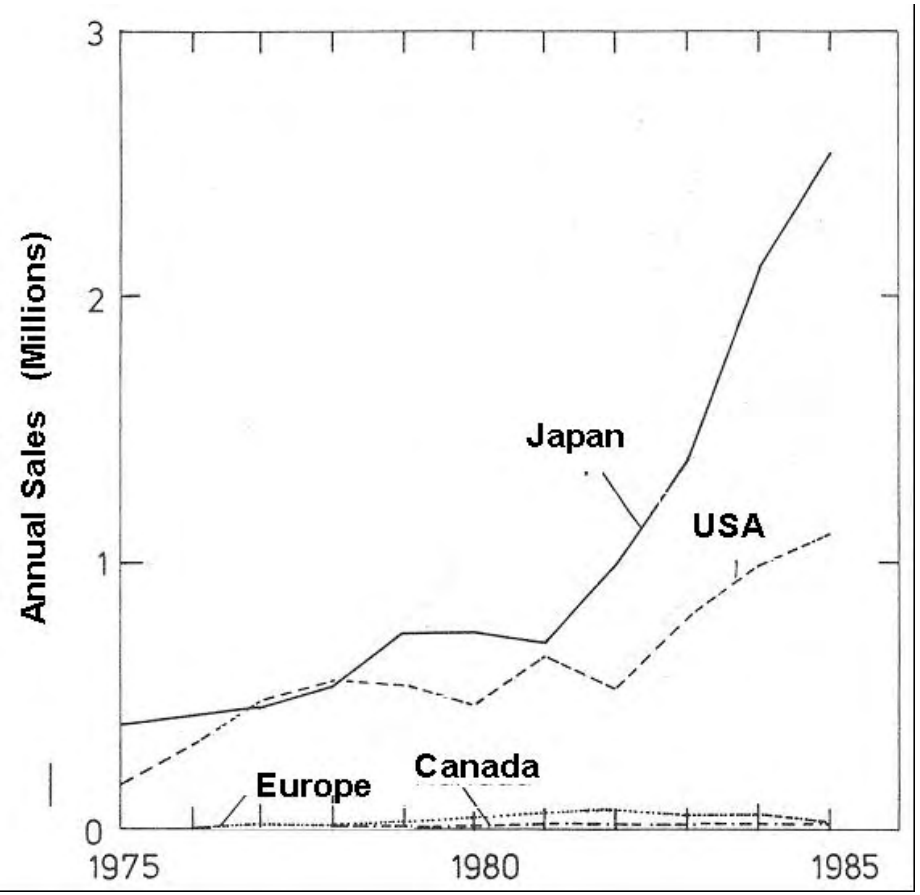


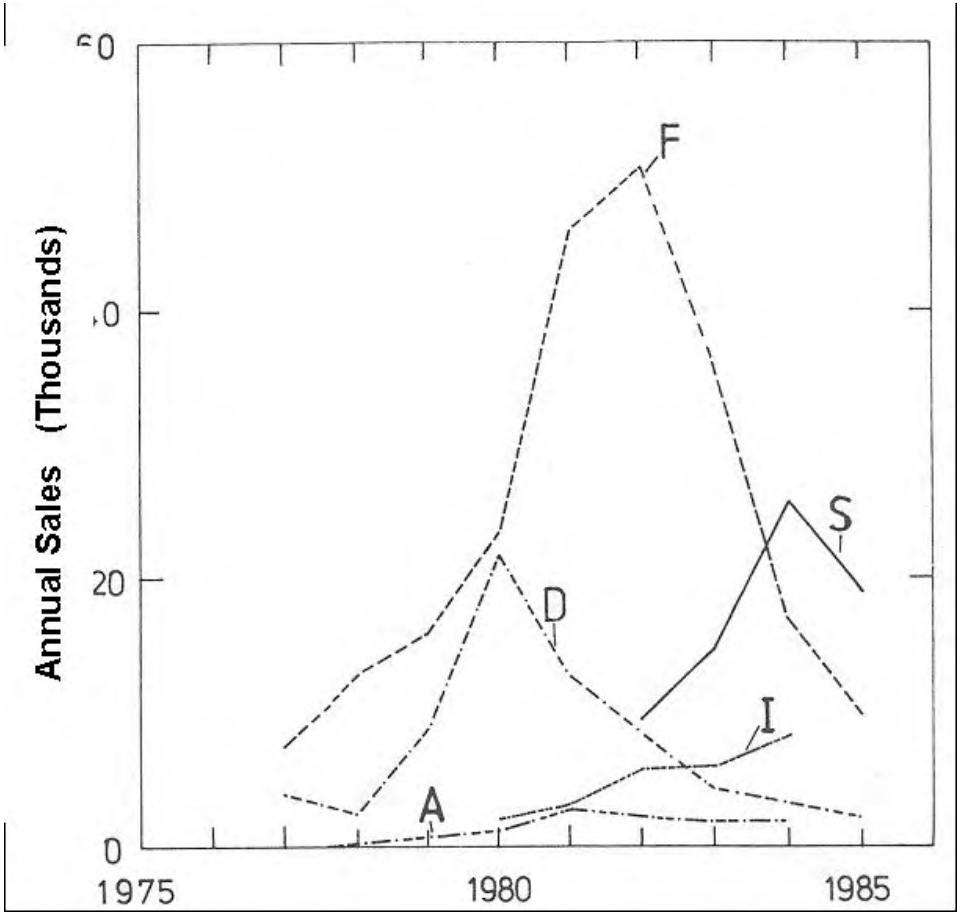

Bild 80. Link

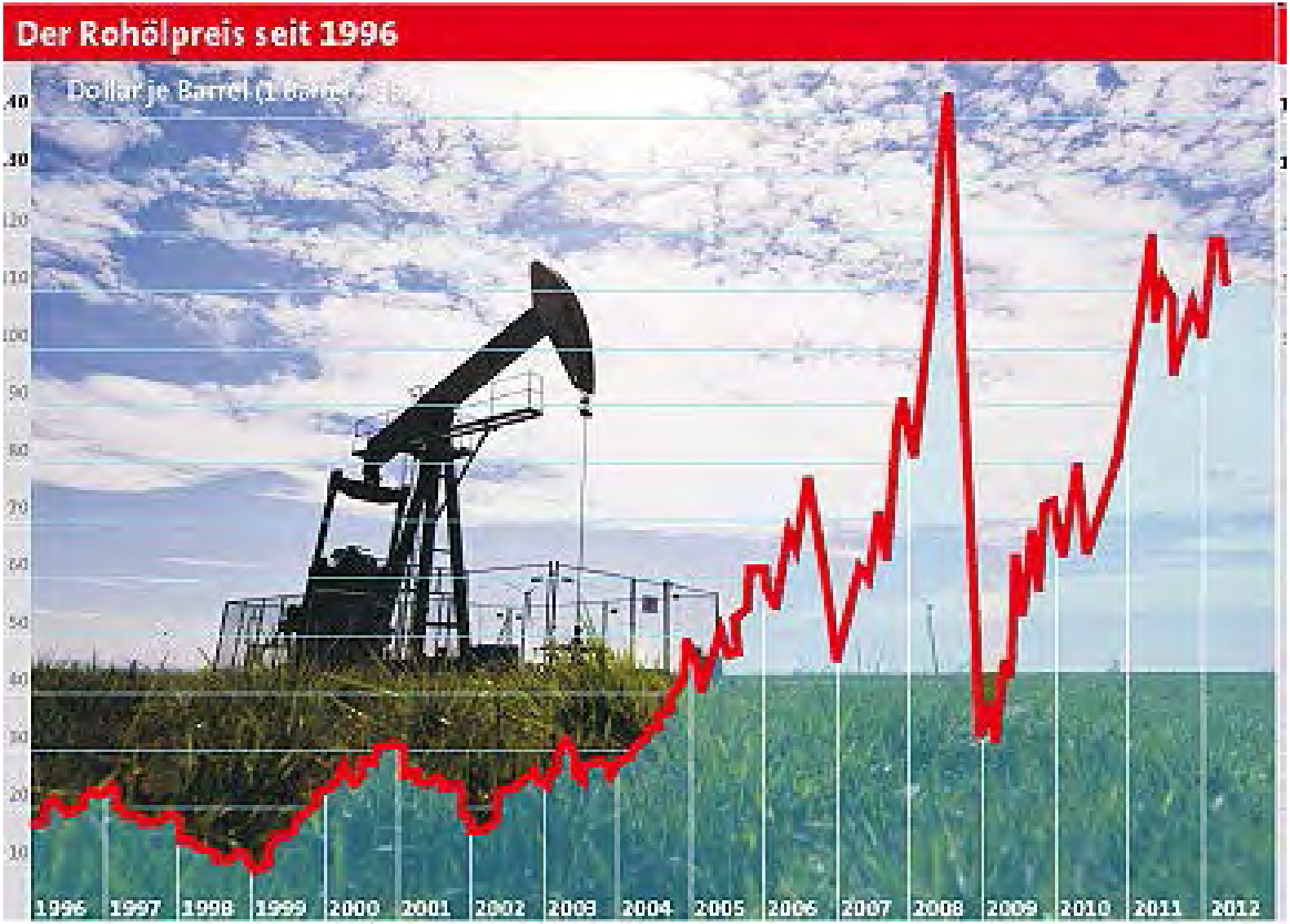

Dampferzeuger
$\Phi_1$
T
$T_1$
600 K
500
400
$T_2$
300
200
100
0
$T_{Umgebung}$
$P_P$
Speise pumpe
$P_T$
Turbine
Kondensator
$\Phi_2$
Nutzleistung:
$P_T = \Phi_1 - \Phi_2 - P_P$
Anlage:
Kraftwerk
Prozeß:
Wärme – Kraftprozeß
Kondensator
$\Phi_H$
$T_H$
3
2
Drossel
$P_V$
Verdichter
$T_0$
4
1
Verdampfer
$\Phi_0$
$\Phi_H = \Phi_0 + P_V$
Wärmepumpe
$T_C$
$\Phi_C$
$\Phi_0 = \Phi_C - P_V$
Kälteanlage
Wärme - Arbeitsprozesse




Peter Ritter von Rittinger 1853


Annual Sales (Millions)
3
2
1
0
1975
1980
1985
Japan
USA
Europe
Canada


Annual Sales (Thousands)
0
20
1975
1980
1985
F
D
S
I
A


Der Rohölpreis seit 1996
Dollar je Barrel (1 Barrel = 159 Liter)
40
30
20
10
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012

# HEAT PUMP PROGRAMME

**Mitte der Siebziger: Erstes First Implementing Agreement (IA) for a Programme of Research and Development on the Application of Heat Pump Systems to Energy Conservation**

**Erastes Projekt: Programme on Heat Pump Systems with Thermal Storage**

**1978: Neues IA for a Programme of Research and Development on Advanced Heat Pump Systems**

**1992: Umbenannt in IA for a Programme of Research, Development, Demonstration and Promotion of Heat Pumping Technologies**

**Jetzt: IEA Heat Pump Programme.**

| | | |
|---|---|---|
| **IEA Heat Pump Center** | **1982** | **FIZ Karlsruhe, Germany** |
| | **1990** | **NOVEM, Netherlands** |
| | **2004** | **SP, Schweden** |

# Current Participating Countries

Austria
Canada
Denmark (2013)
Finland (2009)
France
Germany
Italy (2008)
Japan
Netherlands
Norway
South Korea (2008)
Sweden
Switzerland
The United States
The United Kingdom (2010)

**Executive Committee**

The board of HPP; one vote per member country.
Meets twice a year, mainly in a member country
Combined with a Workshop.

**The Heat Pump Centre**

The central information activity of HPP
Publications (e.g. project reports)
Electronic newsletters (4/year)
Program Support to ExCo, NTs and Project leaders
Generation of new activities
Contact within the IEA with IAs, the Secretariat, BCG, FBF
Contact with EC, UNEP, IIR, EHPA, ASHRAE, ARHI, EPEE

Website: www.heatpumpcentre.org

# The HPP has organised
# 11 International IEA Heat Pump Conferences,

**1984 in Graz, Austria,**
**1987 in Orlando, Florida, USA**
**1990 in Tokyo, Japan,**
**1993 in Maastricht, the Netherlands,**
**1996 in Toronto, Canada**
**1999 in Berlin, Germany;**
**2002 in Peking, China**
**2005 in Las Vegas, USA**
**2008 in Zürich, Schweiz**
**2011 in Tokio, Japan (web-Conference)**
**2014 in Montreal, Canada**

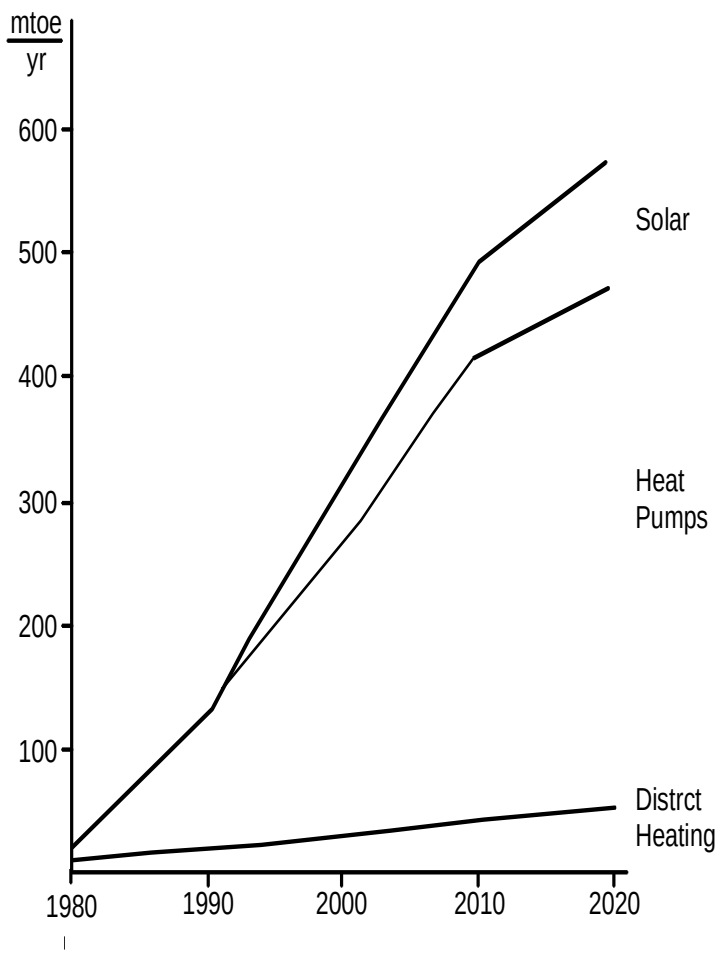
**2017 in Schweden**

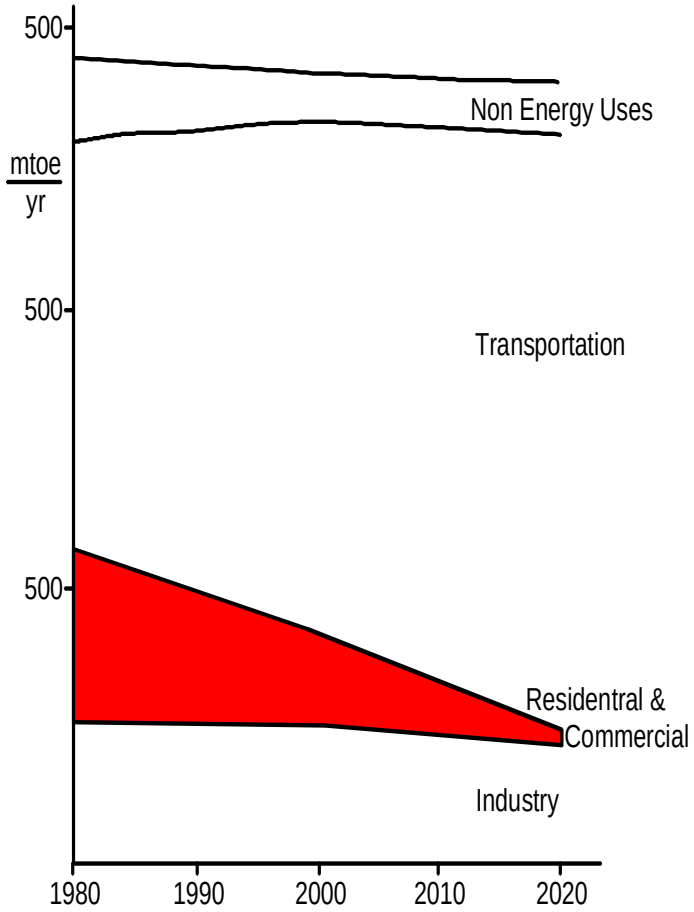
# HPP Annexe (beendet)

Annex 37 Demonstration of field measurements on heat pump systems in buildings - Good examples with modern technology
Annex 35 Application of Industrial Heat Pumps
Annex 34 Thermally Driven Heat Pumps for Heating and Cooling
Annex 33 Compact Heat Exchangers in Heat Pumping Equipment
Annex 32 Economical Heating and Cooling Systems for Low Energy Houses
Annex 31 Advanced Modeling and Tools for Analysis of Energy Use in Supermarkets
Annex 30 Retrofit Heat Pumps for Buildings
Annex 29 Ground-Source Heat Pumps Overcoming Market and Technical Barriers
Annex 28 Test Procedure and Seasonal Performance Calculations for Residential Heat Pumps with Combined Space and Domestic Hot Water Heating
Annex 27 Selected Issues on CO2 as Working Fluid in Compression Systems
Annex 26 Advanced Supermarket Refrigeration/Heat Recovery Systems
Annex 25 Year-Round Residential Space Conditioning Systems using Heat Pumps
Annex 24 Absorption Machines for Heating and Cooling in Future Energy Systems
Annex 23 Heat Pump Systems for Single-Room Applications
Annex 22 Compression Systems with Natural Working Fluids
Annex 21 Global Environmental Benefits of Industrial Heat Pumps
Annex 20 Working Fluid Safety
Annex 19 Cancelled
Annex 18 Thermophysical Properties of Environmentally Acceptable Refrigerants
Annex 17 Experiences with New Refrigerants in Evaporators

# HPP Annexe (beendet)

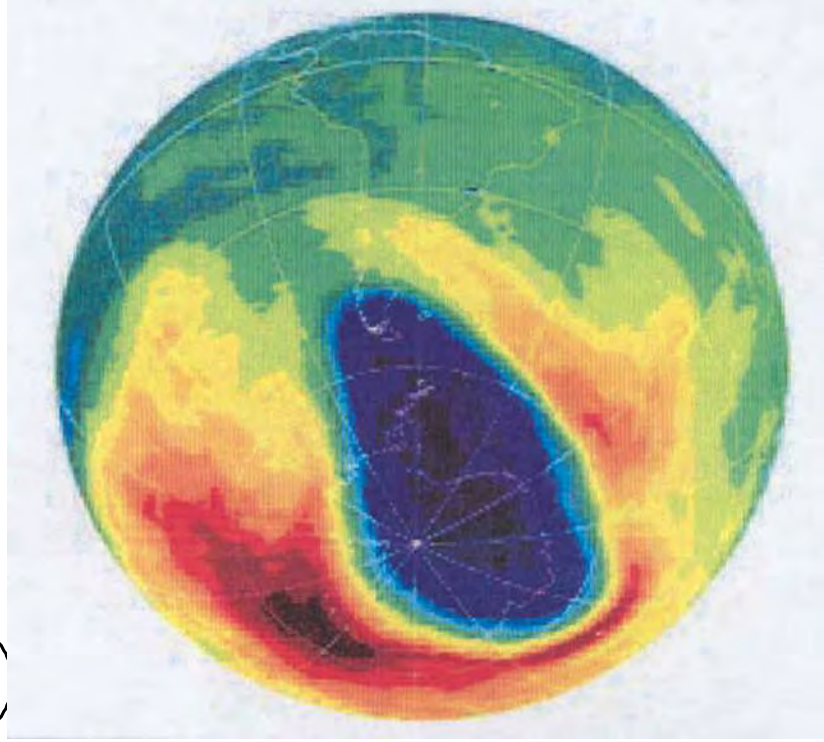
Annex 16 IEA Heat Pump Centre (Novem)
Annex 15 Heat Pump Systems with Direct Expansion Ground Coils
Annex 14 Working Fluids and Transport Phenomena in Advanced Absorption Heat Pumps
Annex 13 State and Transport Properties of High Temperature Working Fluids and Non-Azeotropic Mixtures
Annex 12 Modelling Techniques for Simulation and Design of Compression Heat Pumps
Annex 11 Stirling Engine Technology for Application in Buildings
Annex 10 Technical and Market Analysis of Advanced Heat Pumps
Annex 9 High-Temperature Industrial Heat Pumps
Annex 8 Advanced In-Ground Heat Exchange Technology for Heat Pump Systems
Annex 7 New Development of the Evaporator Part of Heat Pump Systems
Annex 6 Study of Working Fluid Mixtures and High-Temperature Working Fluids for Compressor-Driven Systems
Annex 5 Integration of Large Heat Pumps into District Heating and Large Housing Blocks
Annex 4 IEA Heat Pump Centre (FIZ Karlsruhe)
Annex 3 Heat Pump Systems Applied in Industry
Annex 2 Vertical Earth Heat Pump Systems
Annex 1 Common Study of Advanced Heat Pumps Heat Pump Systems with Thermal Storage

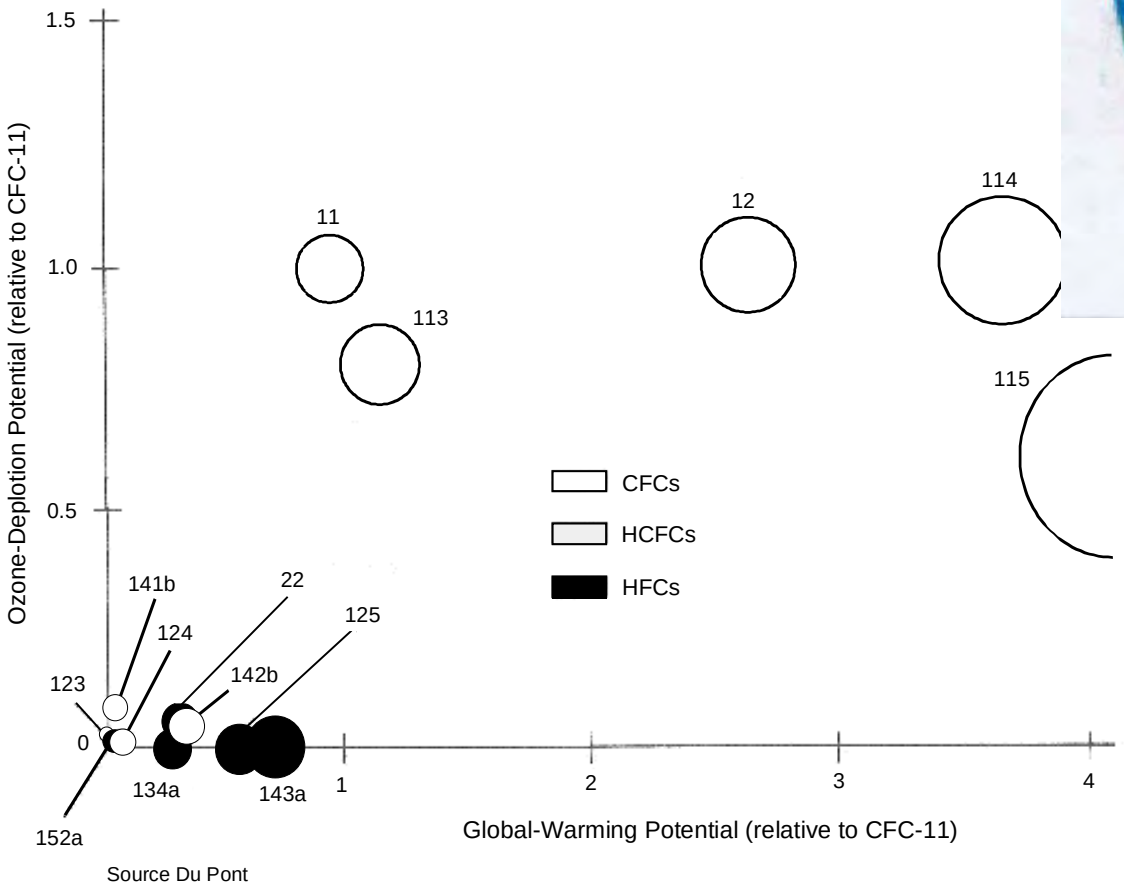


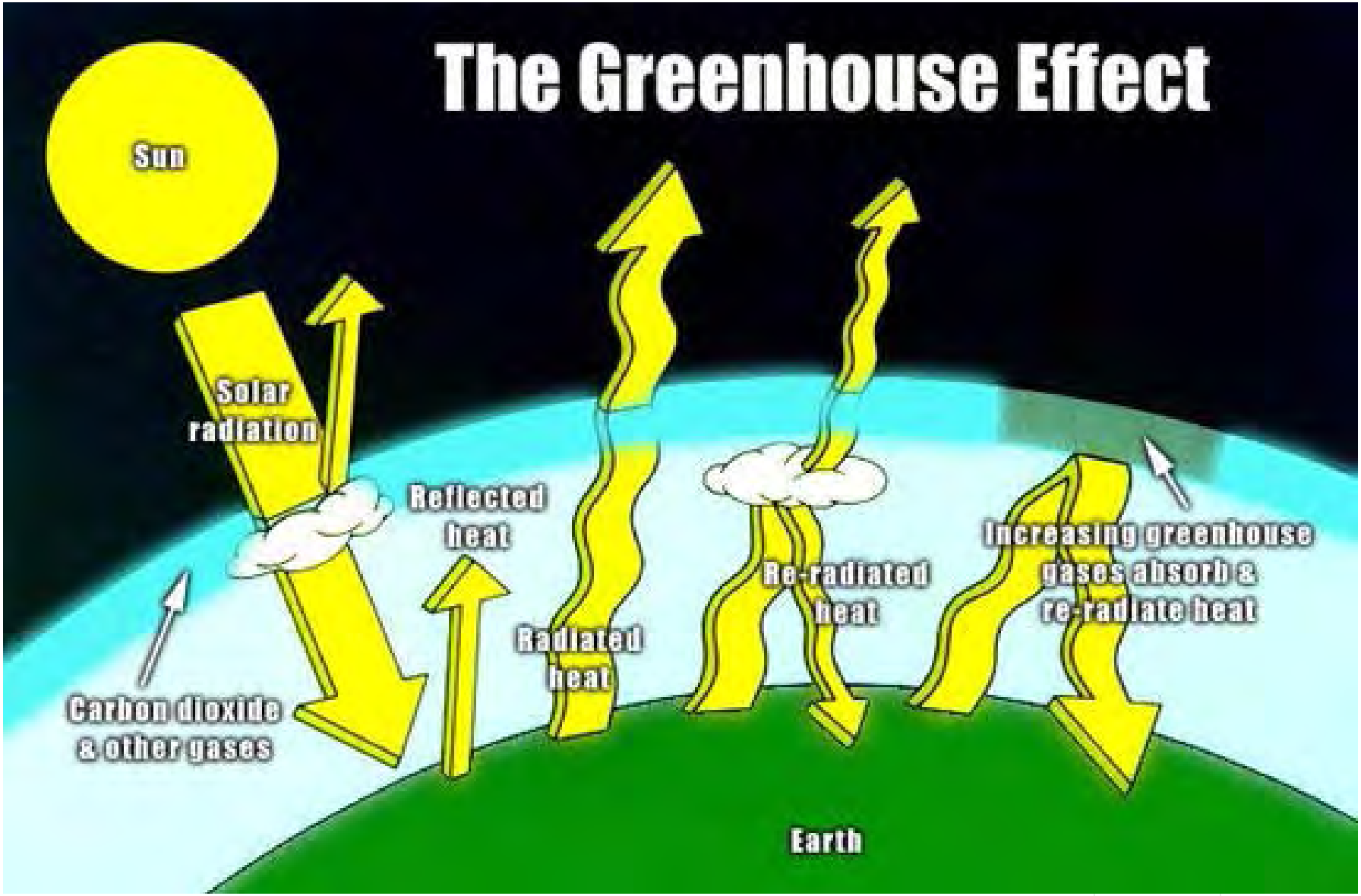

# Strategy Study of the IEA 1980

# Ozone Depletion
# Global Warming






Source Du Pont


The Greenhouse Effect
Sun
Solar radiation
Reflected heat
Radiated heat
Re-radiated heat
Increasing greenhouse gases absorb & re-radiate heat
Carbon dioxide & other gases
Earth

# HPP Annexe mit Beteiligung Österreichs
# ohne Beteiligung Österreichs (laufend)

Annex 44 Performance indicators for energy efficient supermarket buildings

Annex 43 Fuel-driven sorption heat pumps

Annex 42 Heat pumps in smart grids

Annex 41 Cold Climate Heat Pumps (Improving low ambient temperature performance of Air-Source Heat Pumps)

Annex 40 Heat pump concepts for nearly zero energy buildings

Annex 39 A common method for testing and rating of residential HP and AC annual/seasonal performance

Annex 36 Quality installation and maintenance

# HPP Annex Vorschläge

Total refrigerant Management System

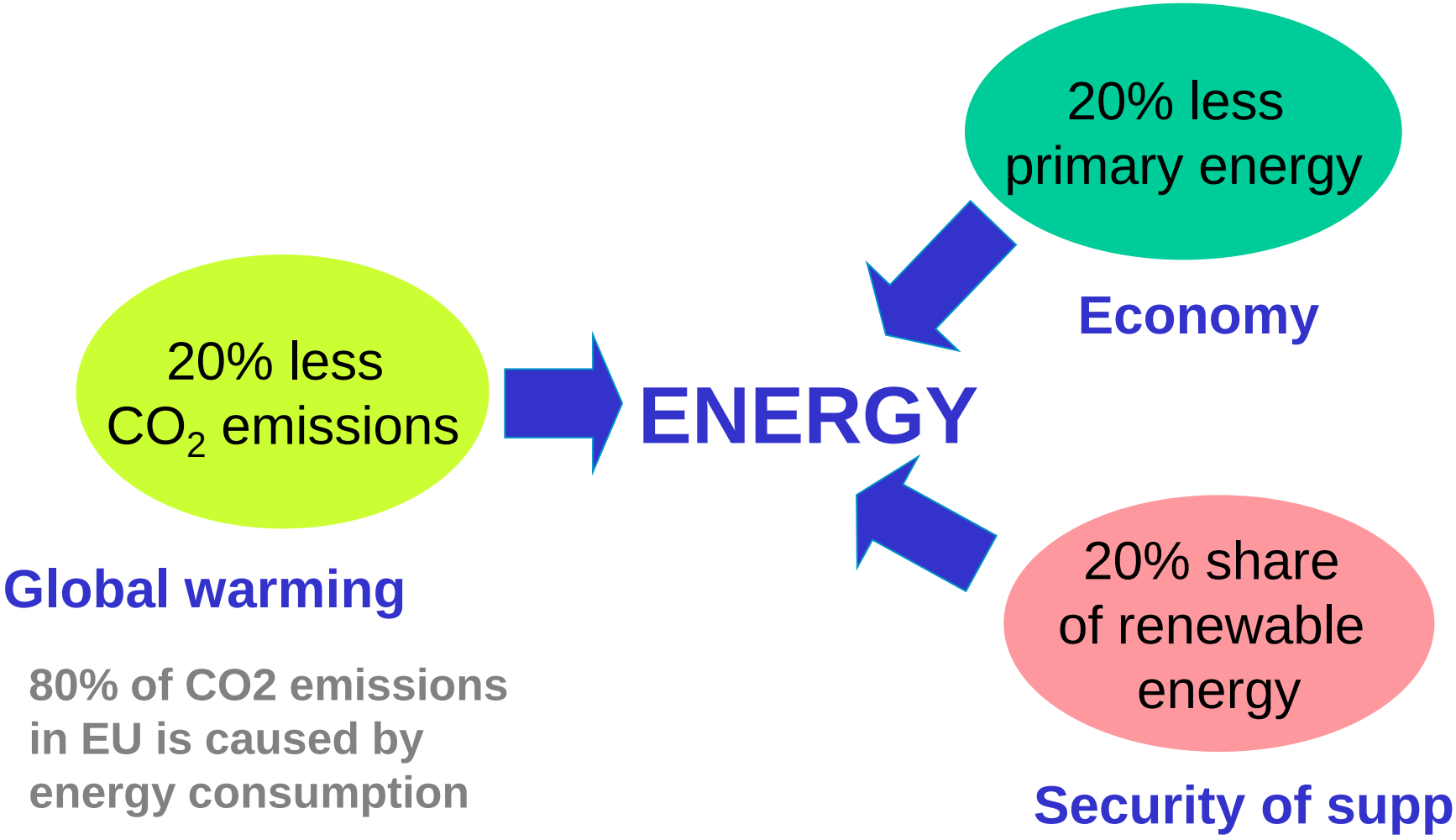
Market implementation of heat pumps

Hybrid heat pumps

Heat pumps in multi-family buildings

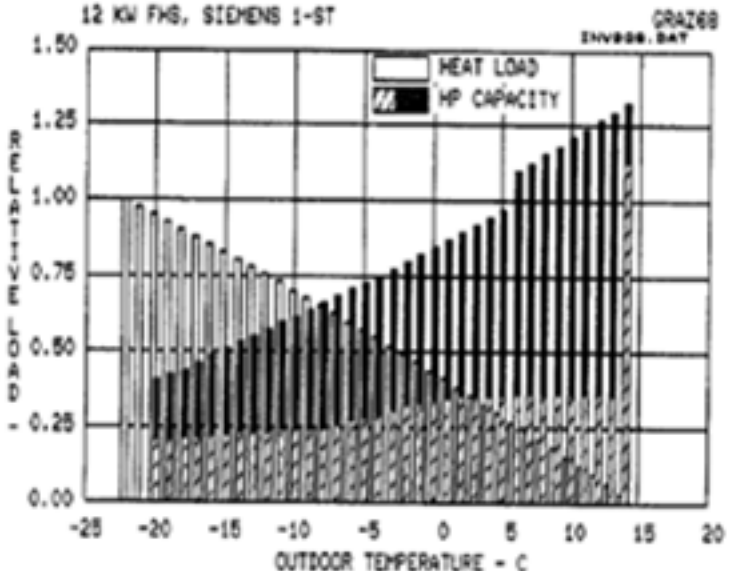
Heat pumps in district heating and cooling systems

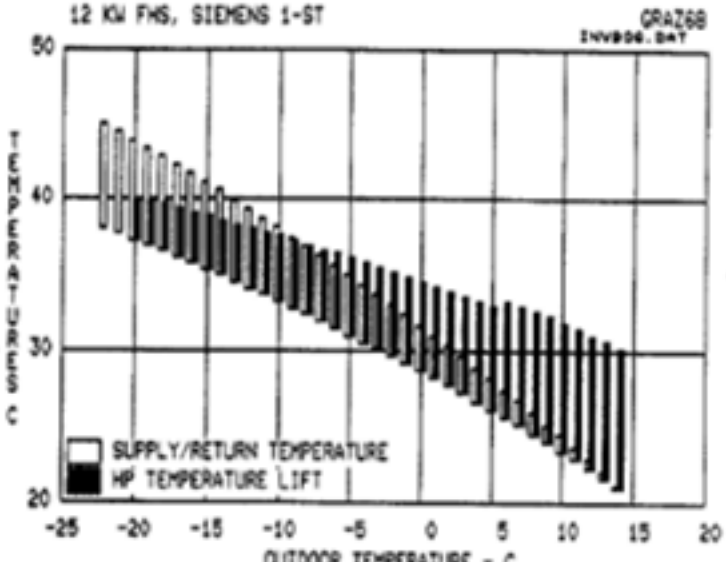
Heat Pump Water Heaters

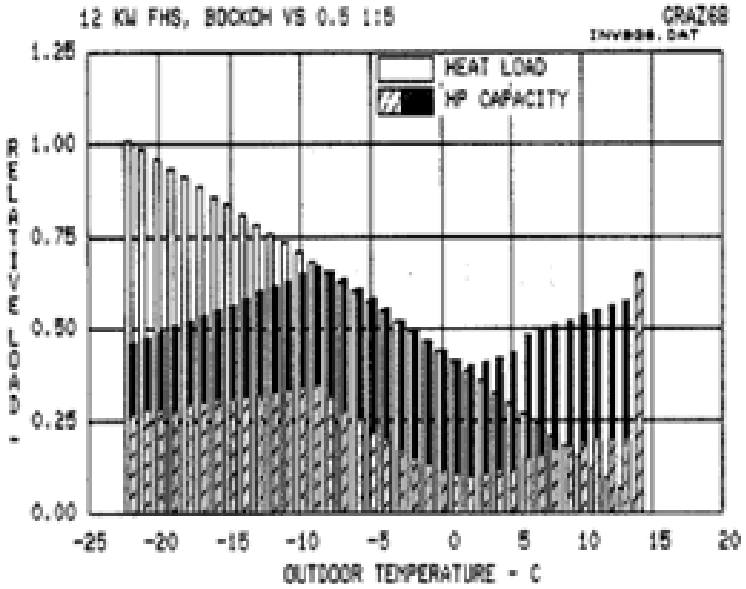


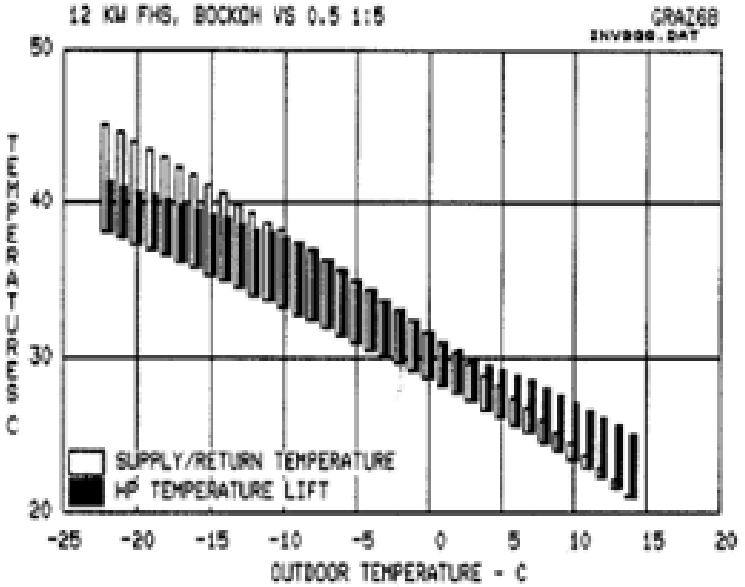

RES-, EPB-, ErP-, Energylabelling- und EE-Directiven
F-Gas Regulation etc.

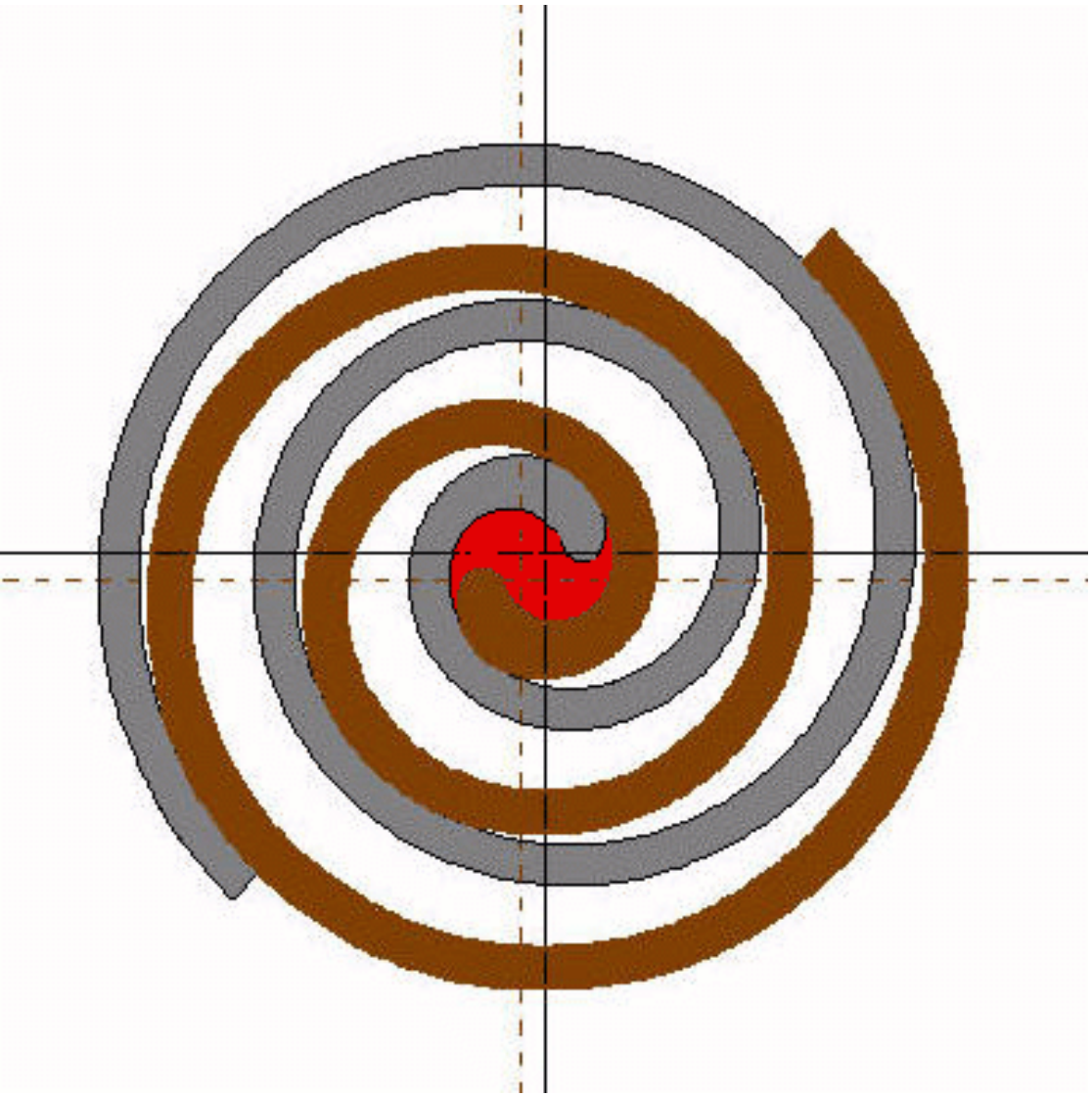

TERRA-C

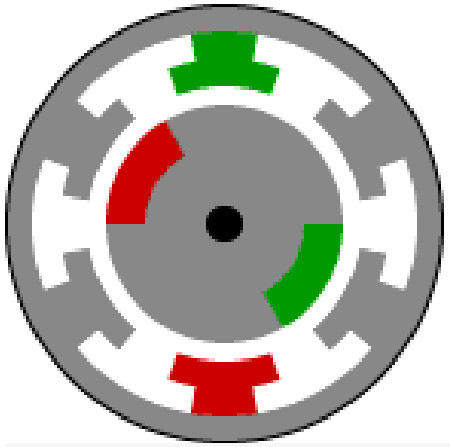

12 KW FHS, SIEMENS 1-ST
GRAZ68
INV868.DAT
HEAT LOAD
HP CAPACITY
RELATIVE LOAD
1.50
1.25
1.00
0.75
0.50
0.25
0.00
-25 -20 -15 -10 -5 0 5 10 15 20
OUTDOOR TEMPERATURE - C

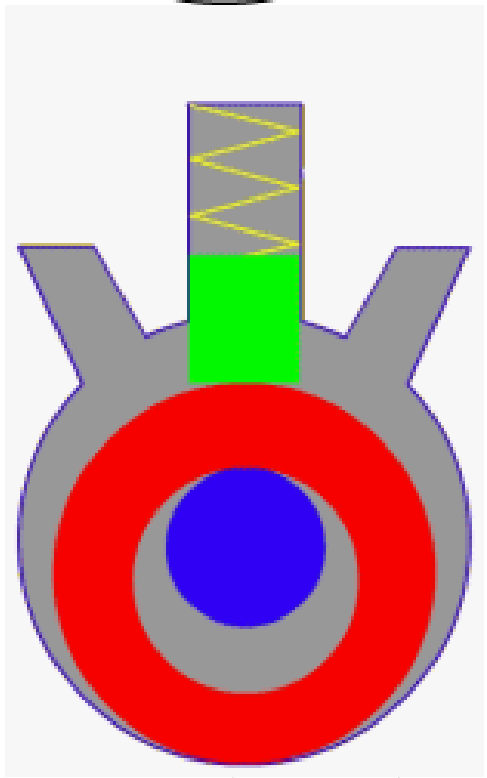

12 KW FHS, SIEMENS 1-ST
GRAZ68
INV868.DAT
TEMPERATURES C
50
40
30
20
SUPPLY/RETURN TEMPERATURE
HP TEMPERATURE LIFT
-25 -20 -15 -10 -5 0 5 10 15 20


12 KW FHS, BOCKOH VS 0.5 1:5
GRAZ68
INV868.DAT
HEAT LOAD
HP CAPACITY
RELATIVE LOAD
1.25
1.00
0.75
0.50
0.25
0.00
-25 -20 -15 -10 -5 0 5 10 15 20
OUTDOOR TEMPERATURE - C

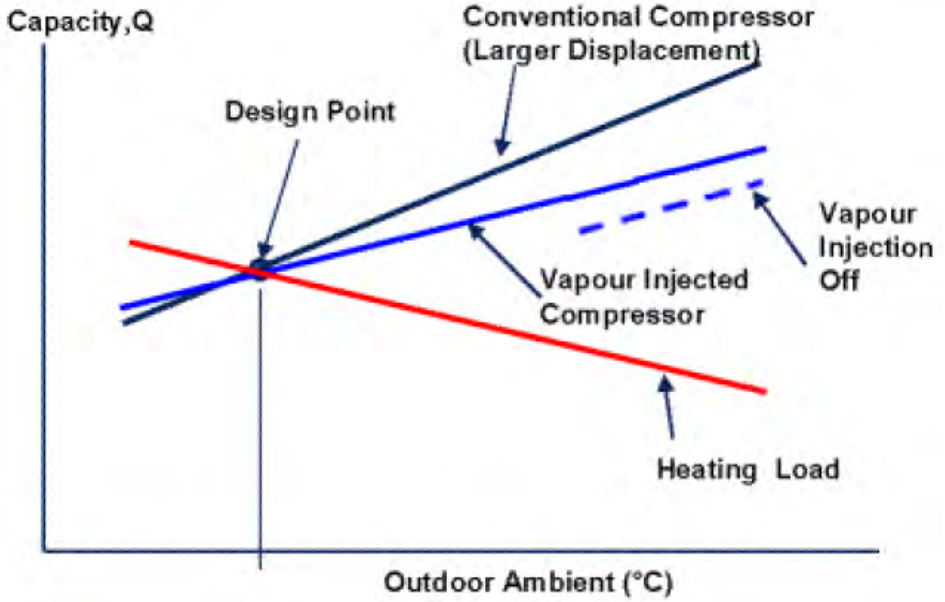

12 KW FHS, BOCKOH VS 0.5 1:5
GRAZ68
INV868.DAT
TEMPERATURES C
50
40
30
20
SUPPLY/RETURN TEMPERATURE
HP TEMPERATURE LIFT
-25 -20 -15 -10 -5 0 5 10 15 20
OUTDOOR TEMPERATURE - C

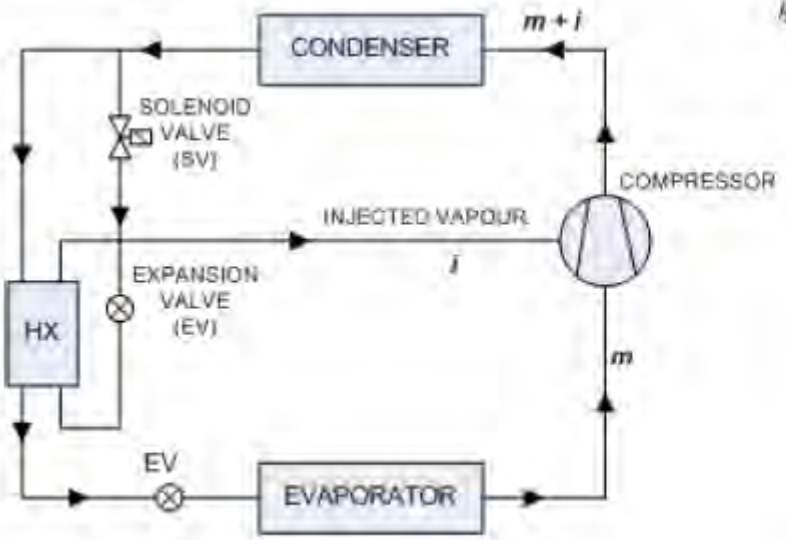


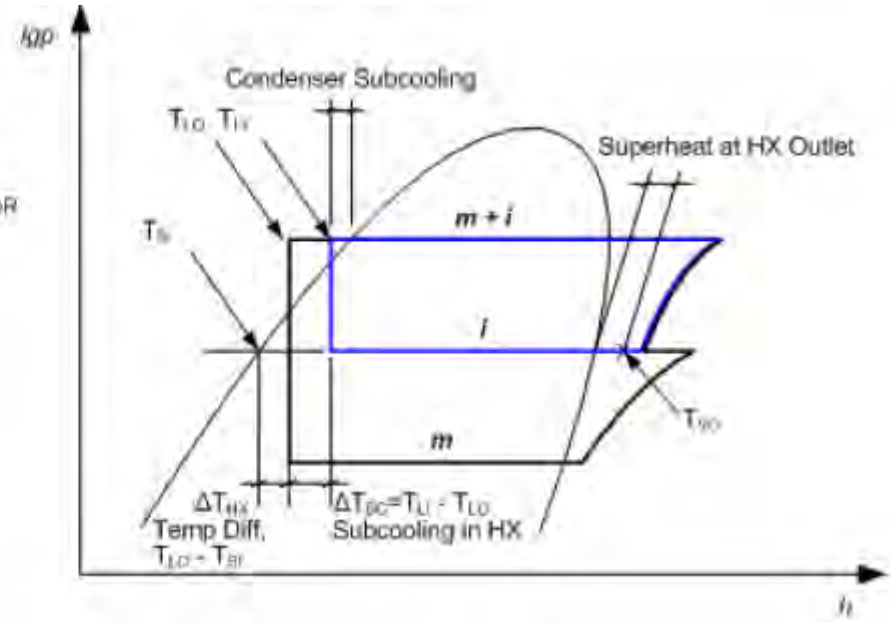


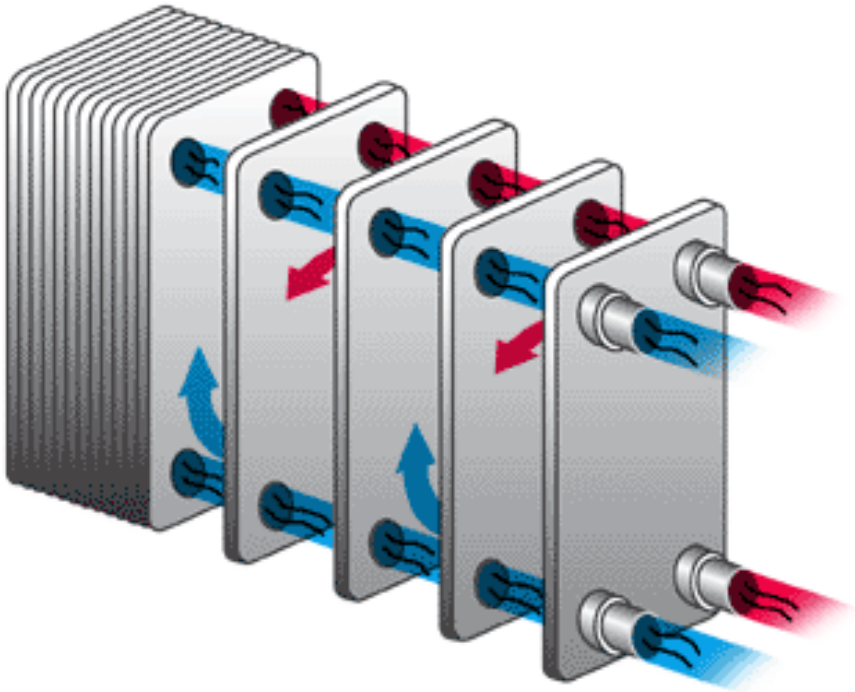


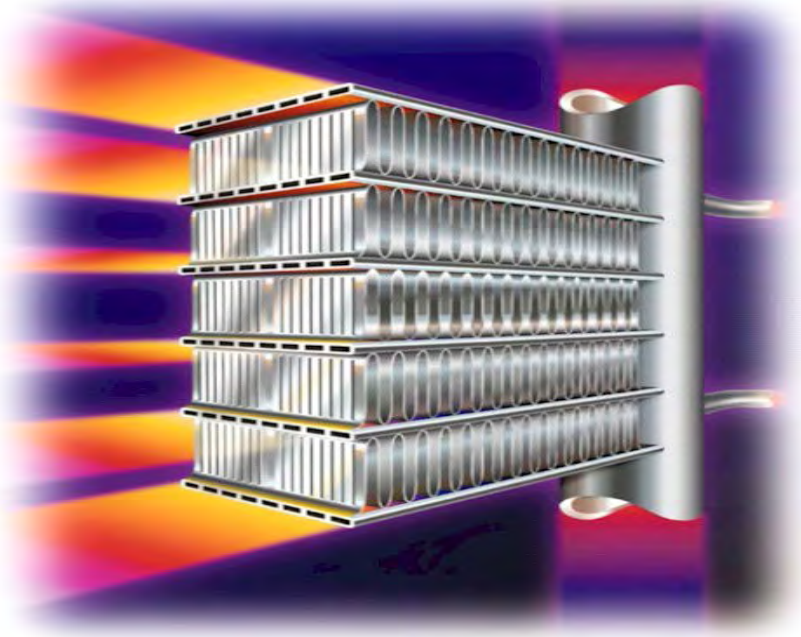
# Economiser Cycle with a Scroll

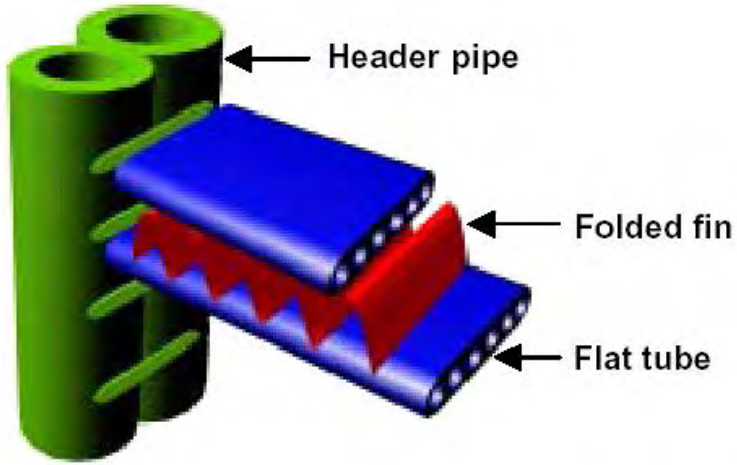


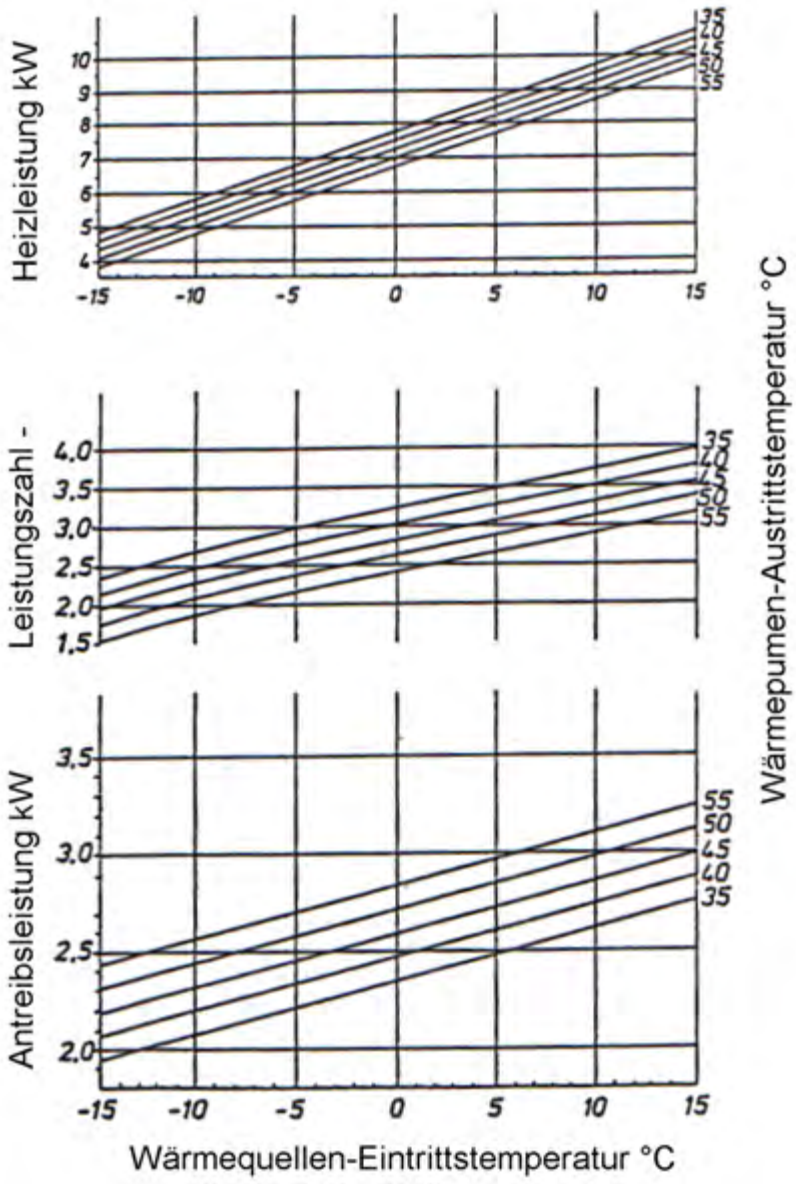



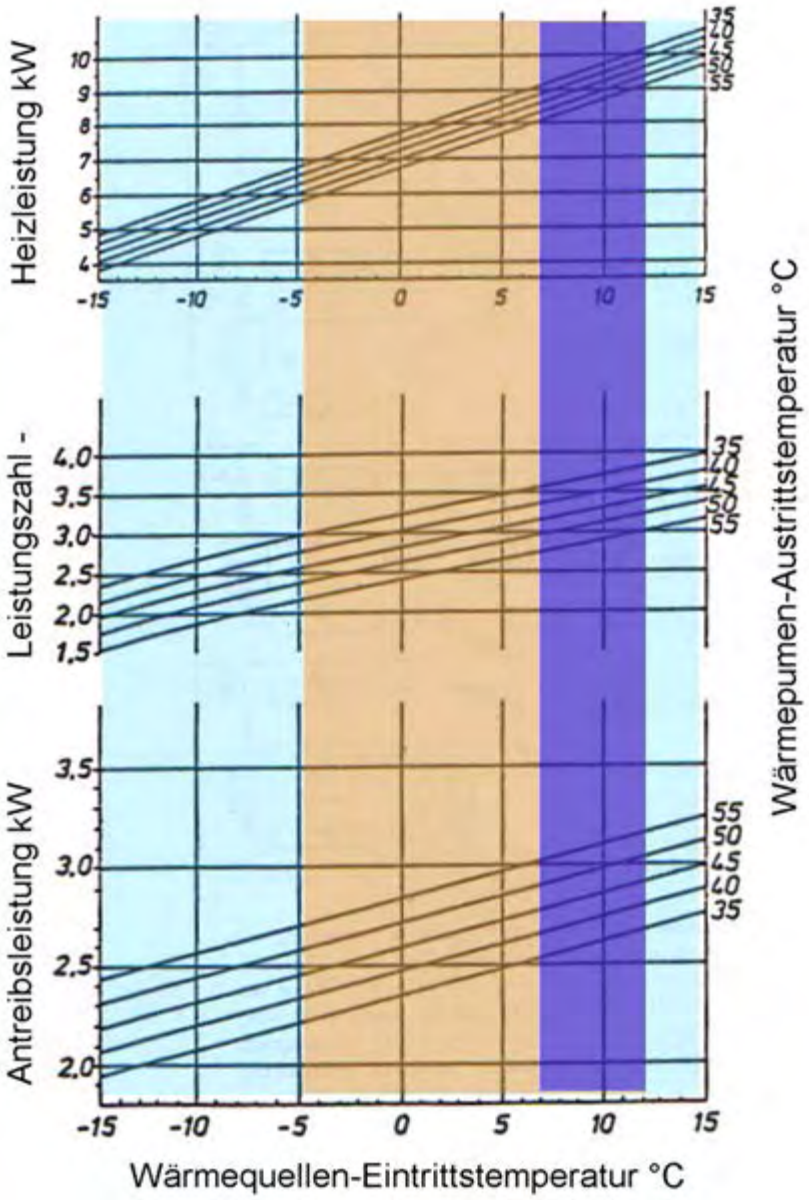



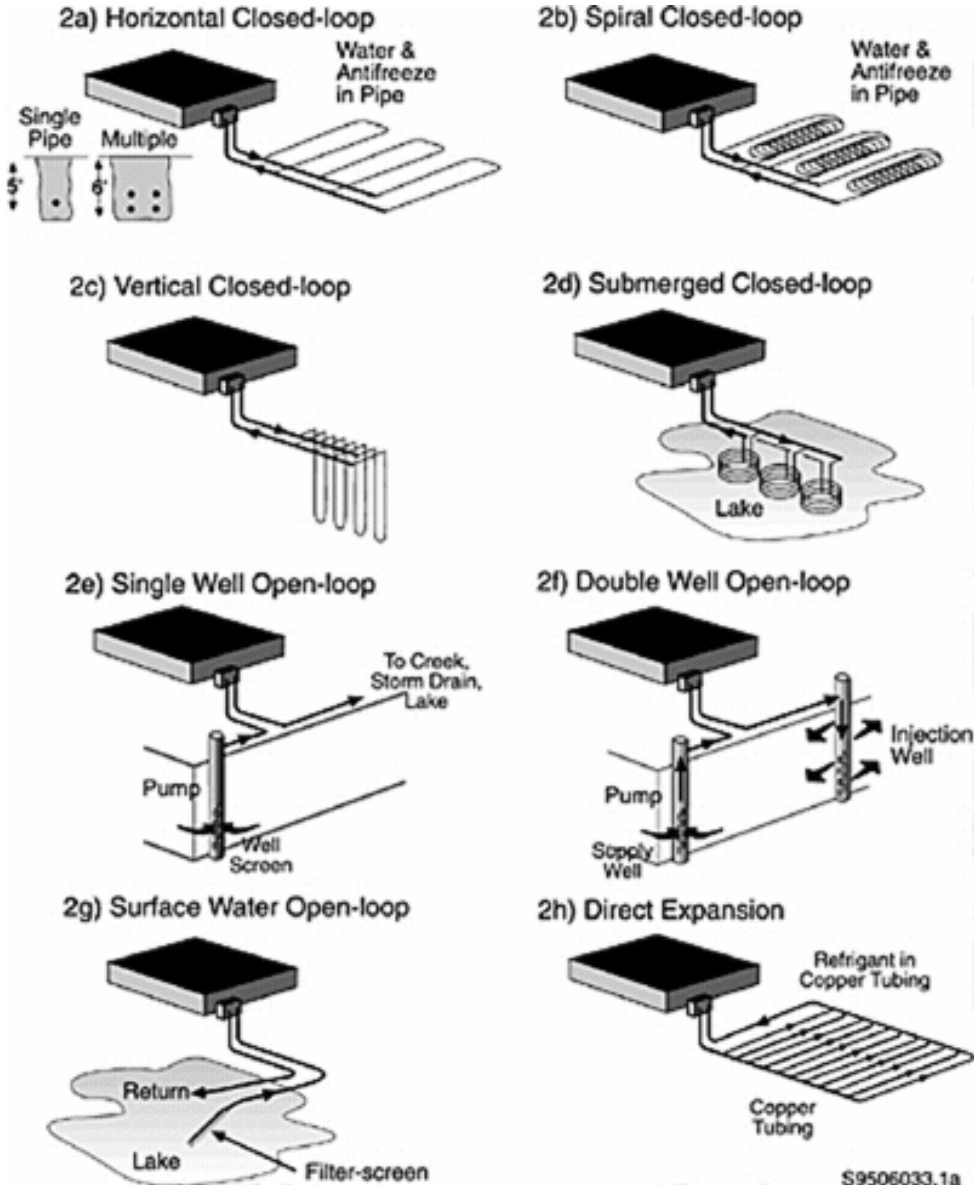


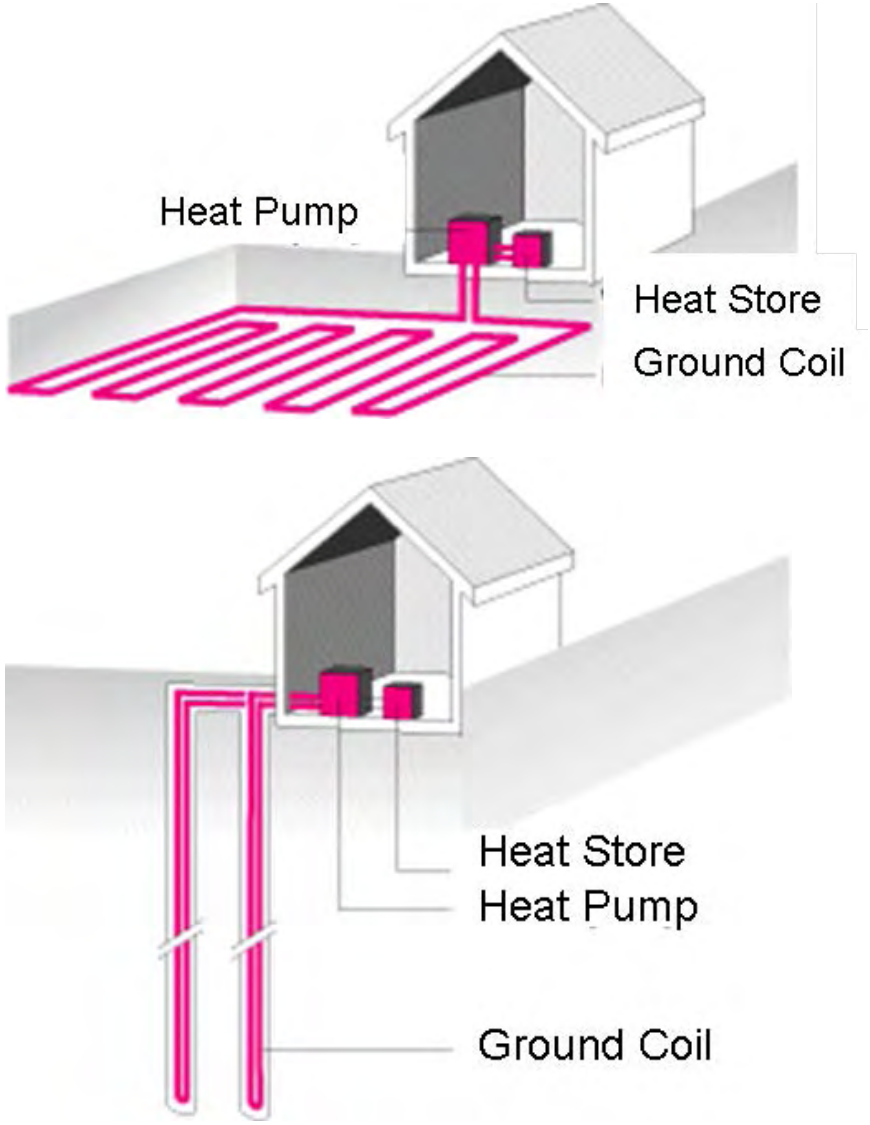



Header pipe
Folded fin
Flat tube

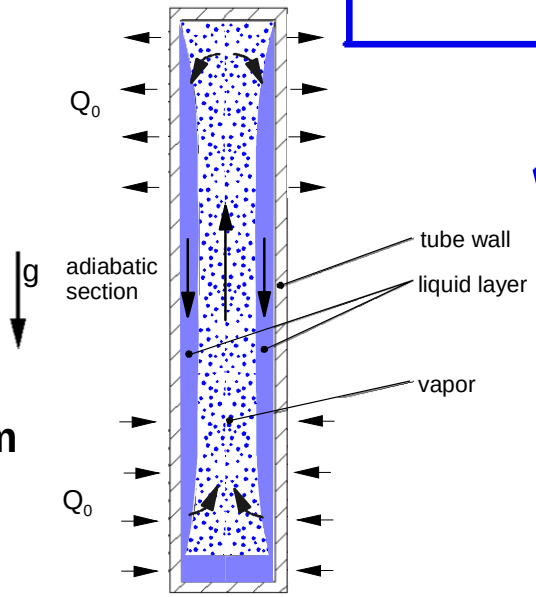

Heizleistung kW
Leistungszahl -
Antreibsleistung kW
Wärmepumen-Austrittstemperatur °C
Wärmequellen-Eintrittstemperatur °C

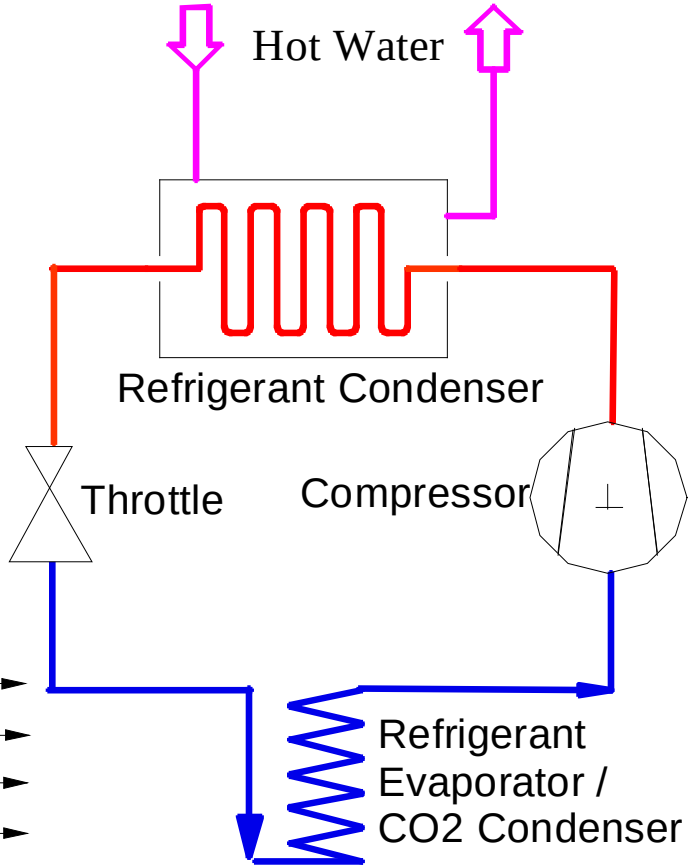

Heizleistung kW
Leistungszahl -
Antreibsleistung kW
Wärmepumen-Austrittstemperatur °C
Wärmequellen-Eintrittstemperatur °C


2a) Horizontal Closed-loop
Water & Antifreeze in Pipe
Single Pipe
Multiple
5'
6'
2b) Spiral Closed-loop
Water & Antifreeze in Pipe
2c) Vertical Closed-loop
2d) Submerged Closed-loop
Lake
2e) Single Well Open-loop
To Creek, Storm Drain, Lake
Pump
Well Screen
2f) Double Well Open-loop
Injection Well
Pump
Supply Well
2g) Surface Water Open-loop
Return
Lake
Filter-screen
2h) Direct Expansion
Refrigant in Copper Tubing
Copper Tubing
S9506033.1a

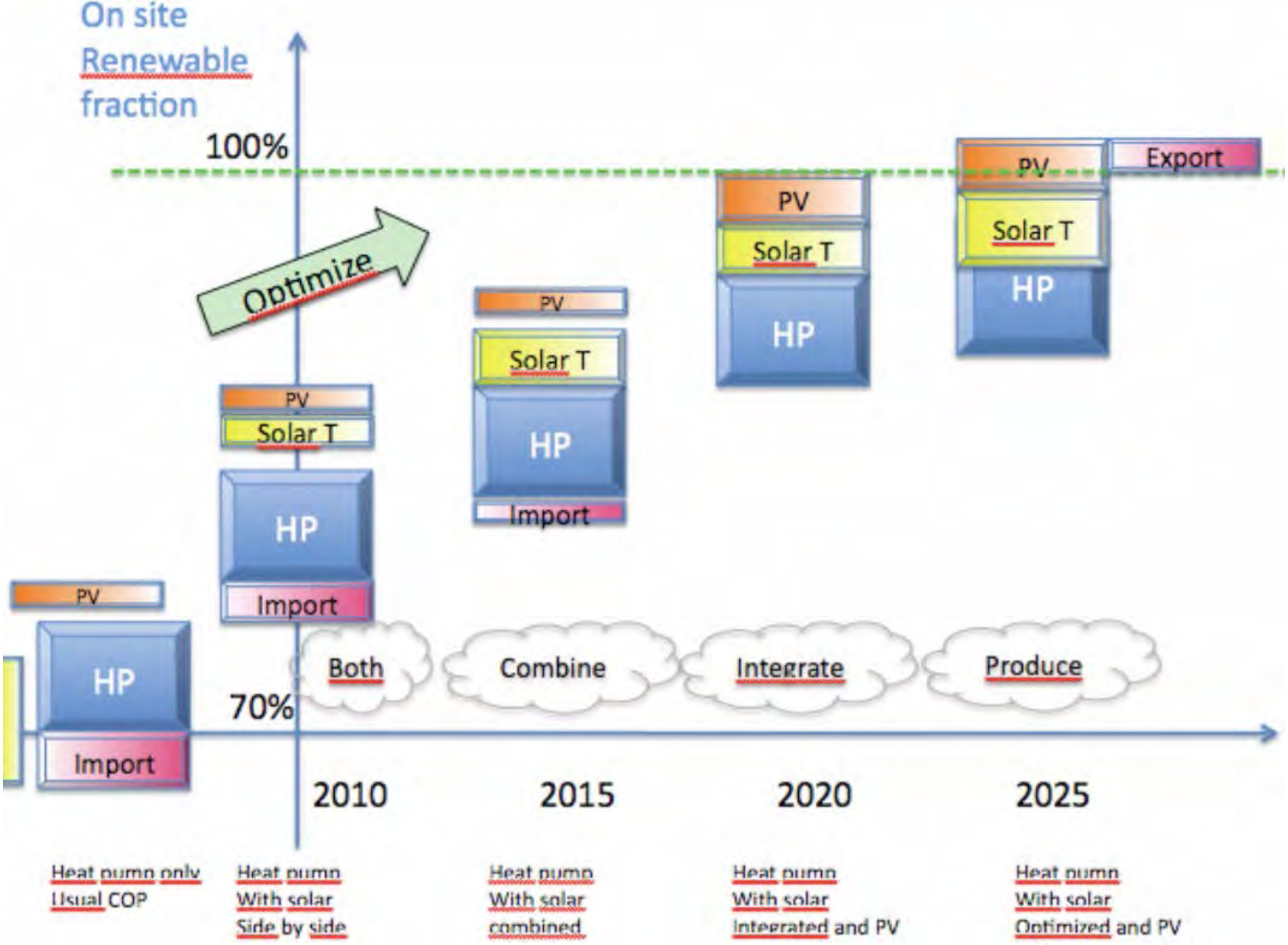

Heat Pump
Heat Store
Ground Coil
Heat Store
Heat Pump
Ground Coil

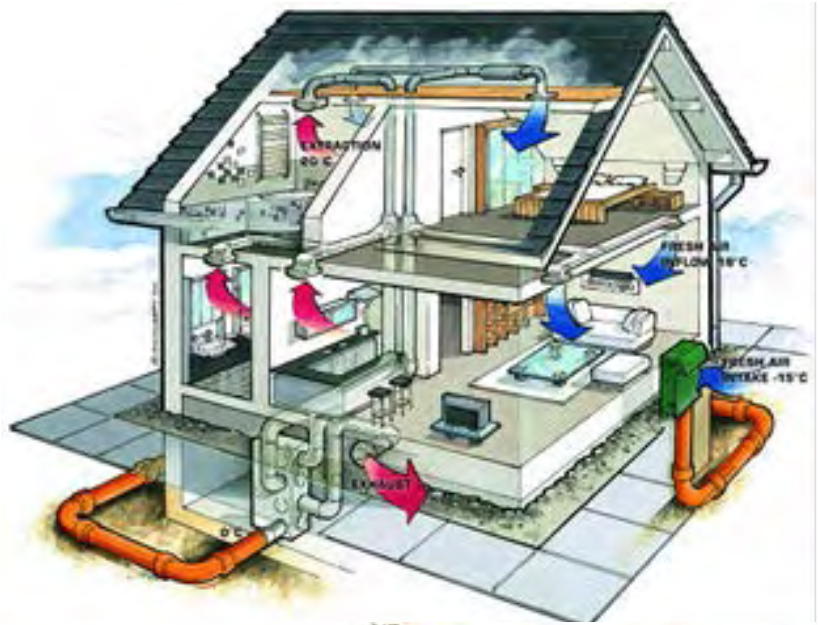
**DX System**

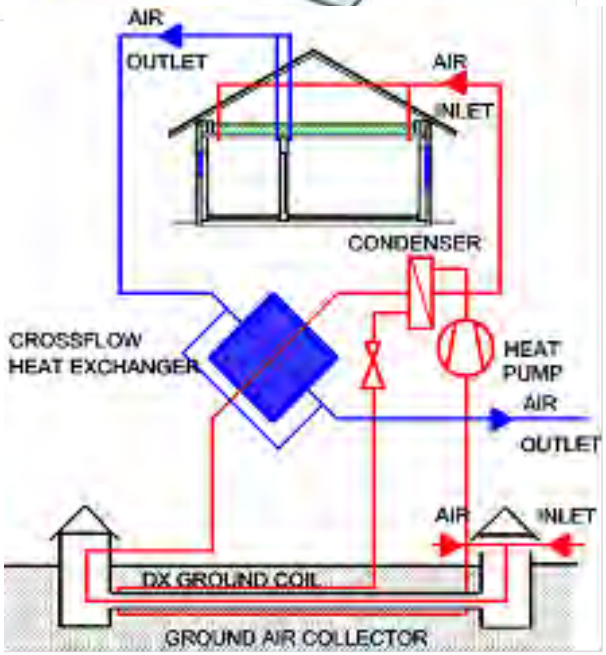


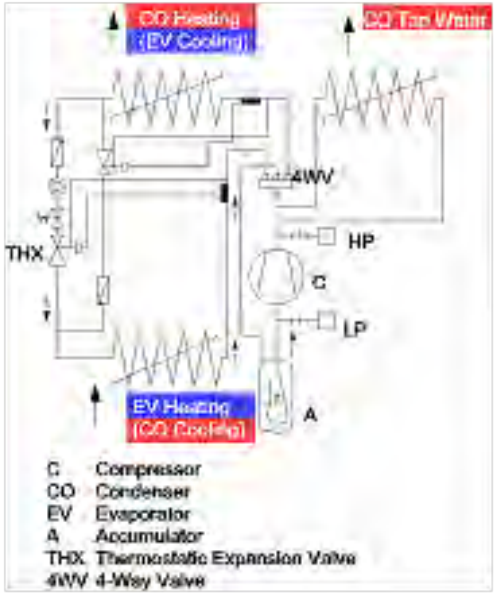



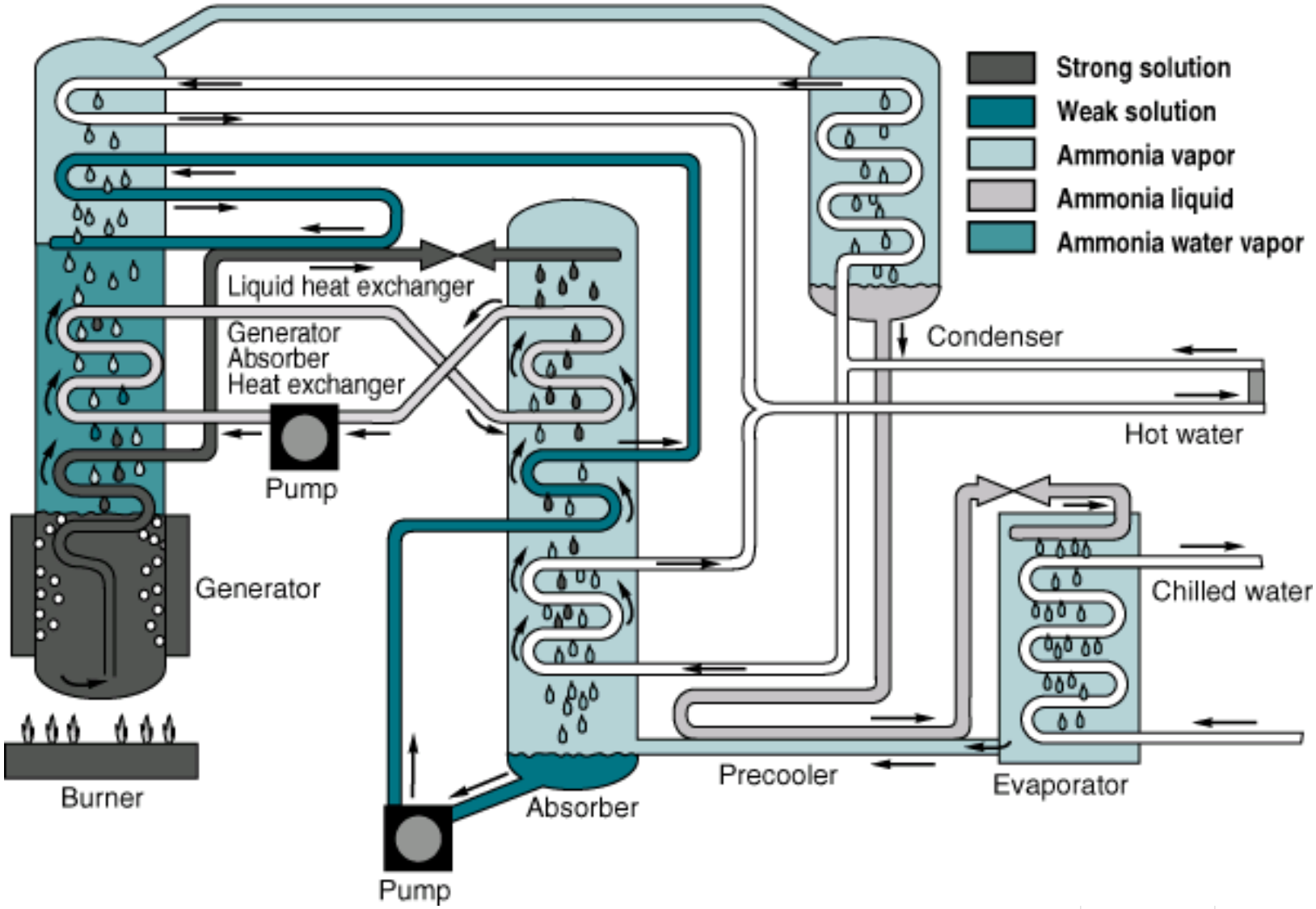

**CO2 Thermosyphon**

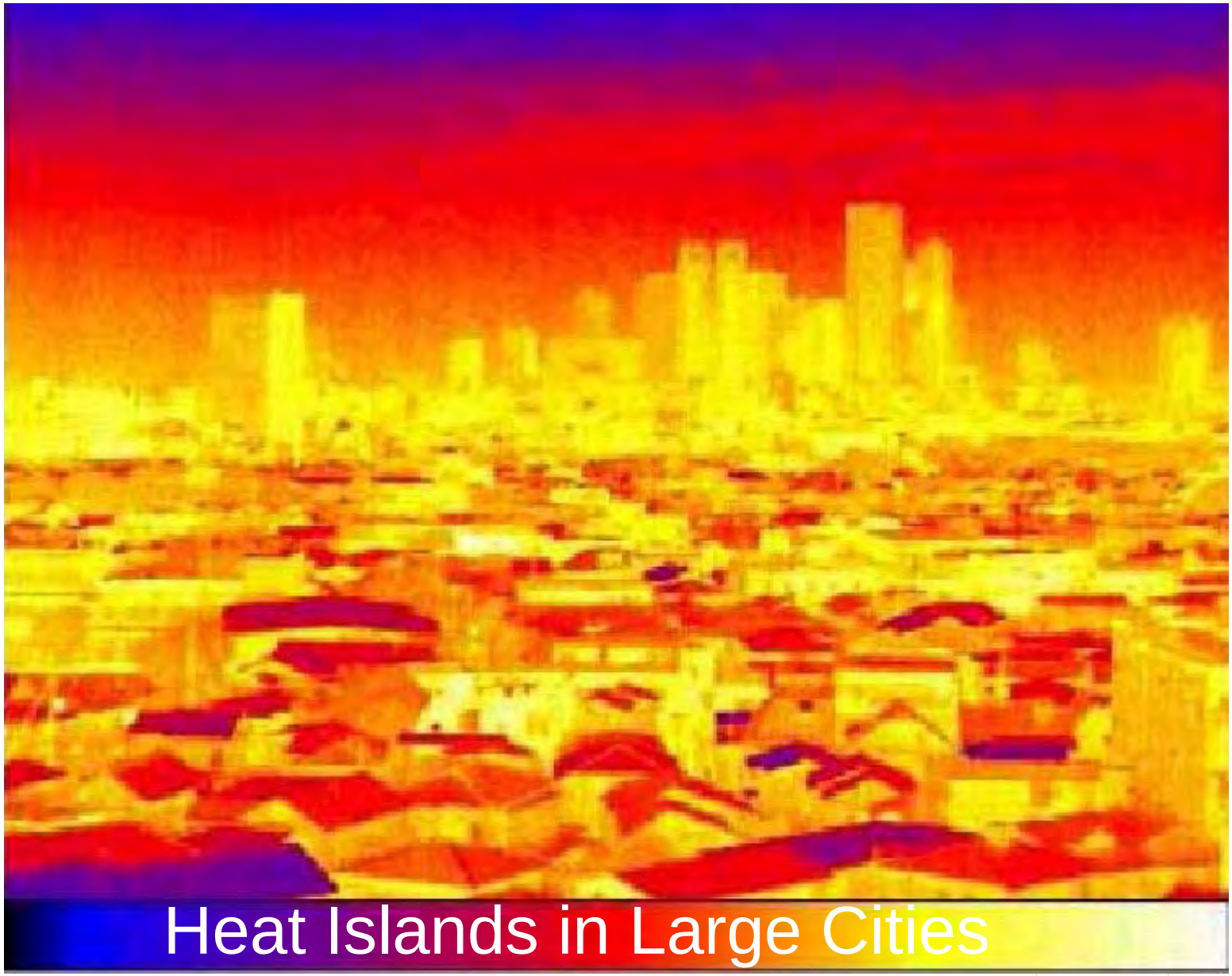

On site
Renewable
fraction
100%
70%
Optimize
PV
Solar T
HP
Import
Export
Both
Combine
Integrate
Produce
2010
2015
2020
2025
Heat pump only
Usual COP
Heat pump
With solar
Side by side
Heat pump
With solar
combined
Heat pump
With solar
Integrated and PV
Heat pump
With solar
Optimized and PV




AIR
OUTLET
AIR
INLET
CONDENSER
CROSSFLOW
HEAT EXCHANGER
HEAT
PUMP
AIR
OUTLET
AIR
INLET
DX GROUND COIL
GROUND AIR COLLECTOR

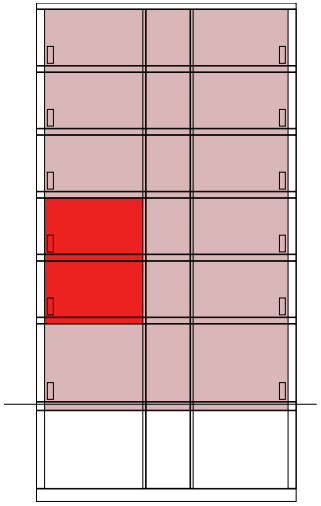

CO Heating
(EV Cooling)
CO Tap Water
4WV
HP
THX
C
LP
A
EV Heating
(CO Cooling)
C Compressor
CO Condenser
EV Evaporator
A Accumulator
THX Thermostatic Expansion Valve
4WV 4-Way Valve

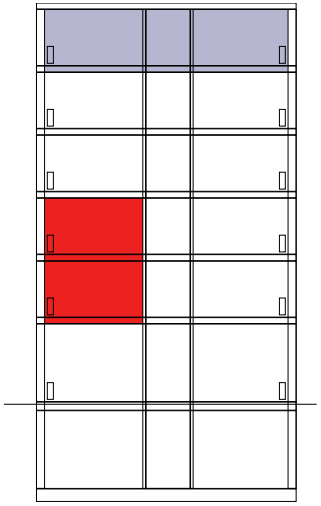

Strong solution
Weak solution
Ammonia vapor
Ammonia liquid
Ammonia water vapor
Liquid heat exchanger
Generator
Absorber
Heat exchanger
Pump
Generator
Burner
Condenser
Hot water
Chilled water
Precooler
Evaporator
Absorber
Pump

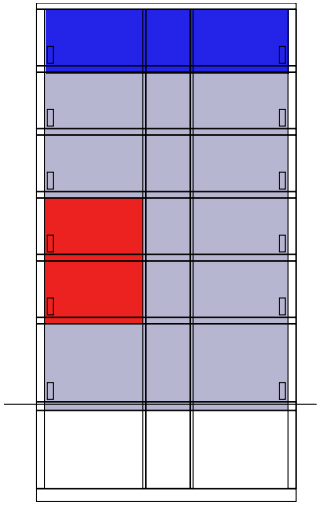


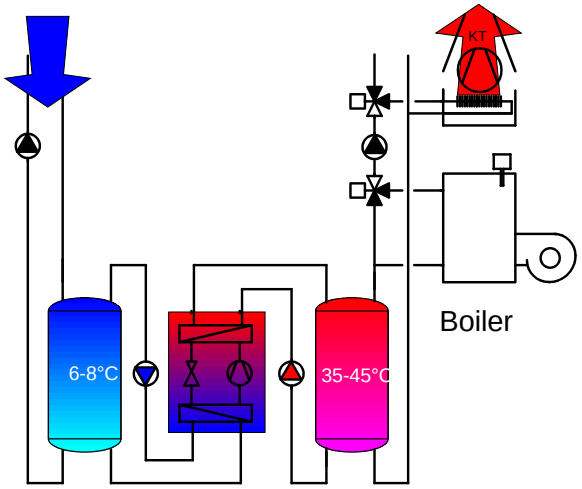
# Heat Islands in Large Cities


BigSkyline.com

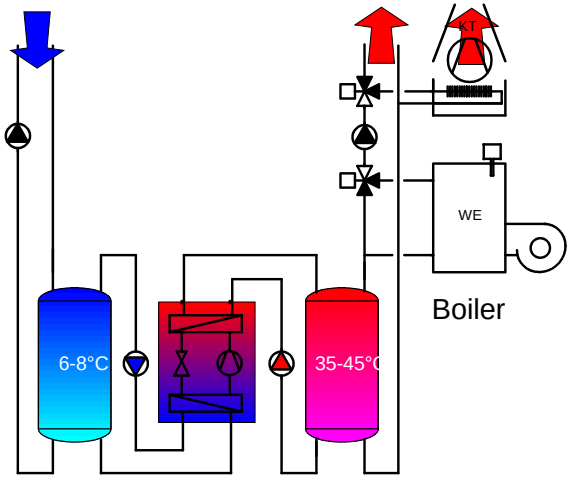




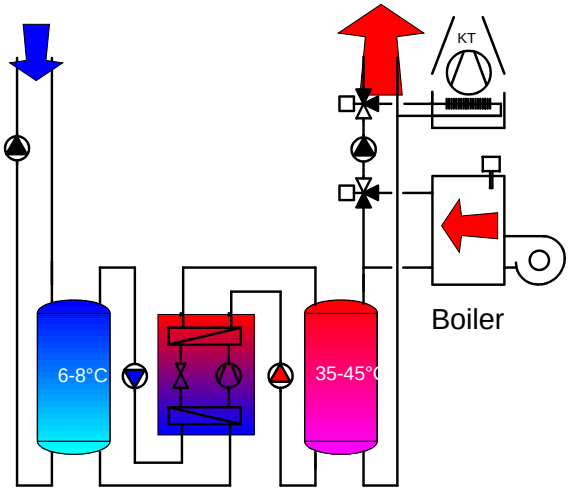




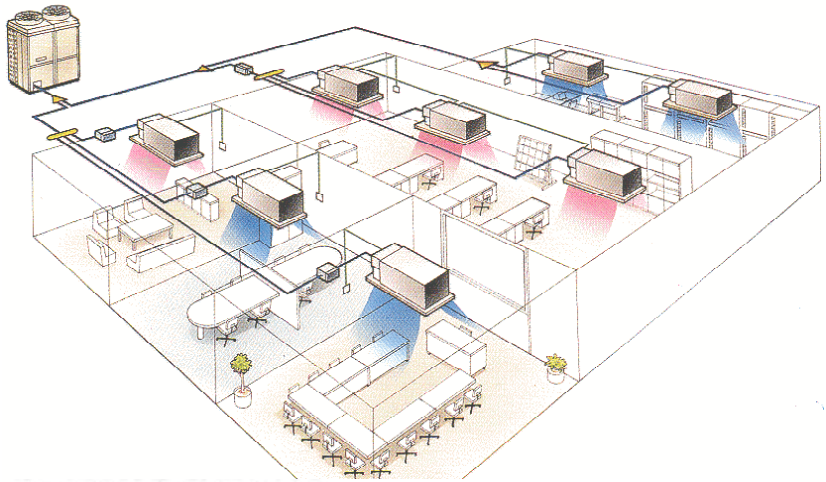

Cooling

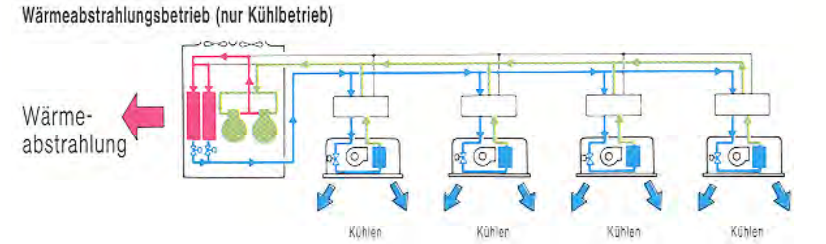


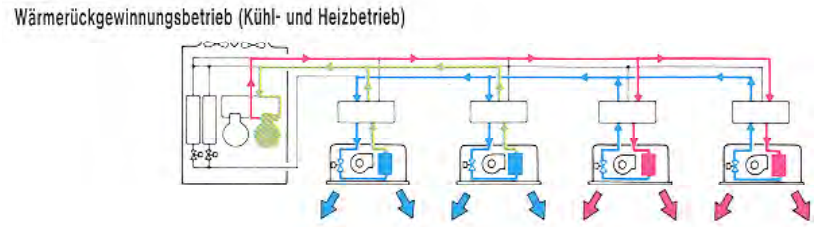

Cooling and Heating

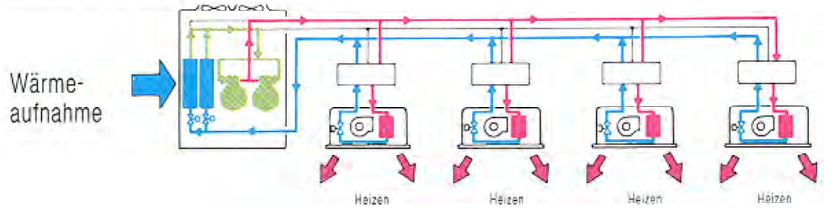



Heating

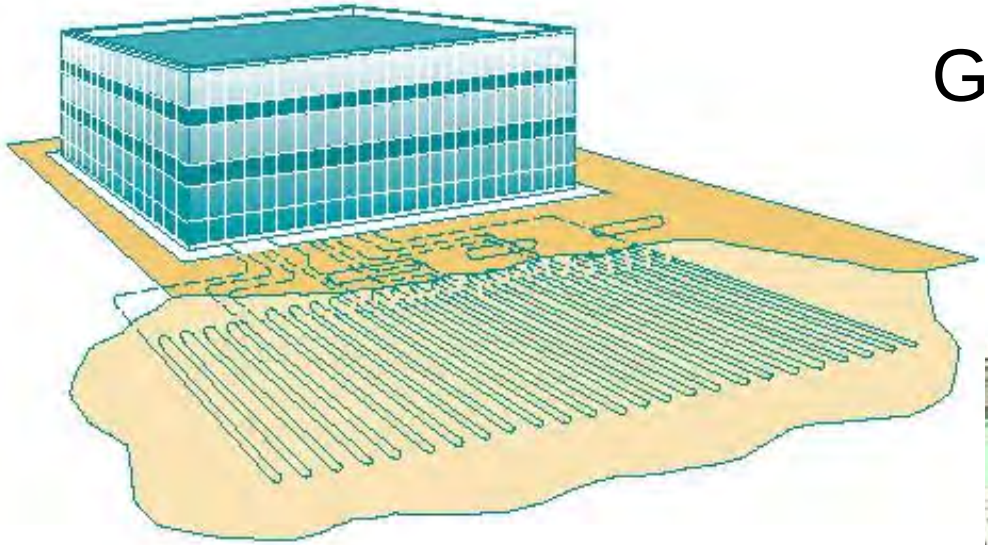


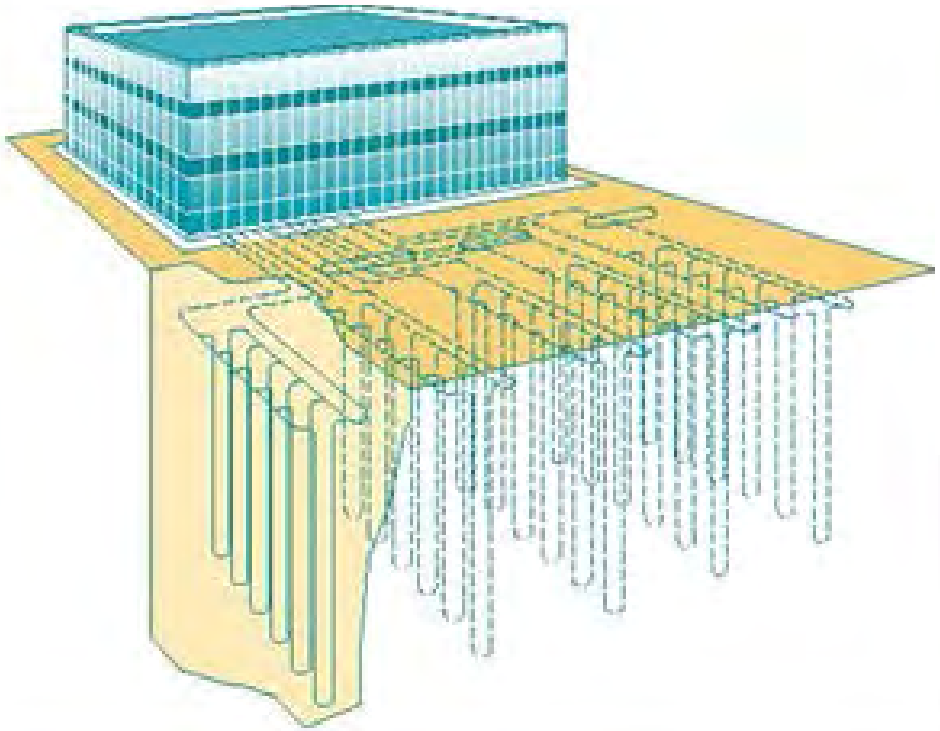

Wärmeabstrahlungsbetrieb (nur Kühlbetrieb)
Wärme-
abstrahlung
Kühlen
Kühlen
Kühlen
Kühlen

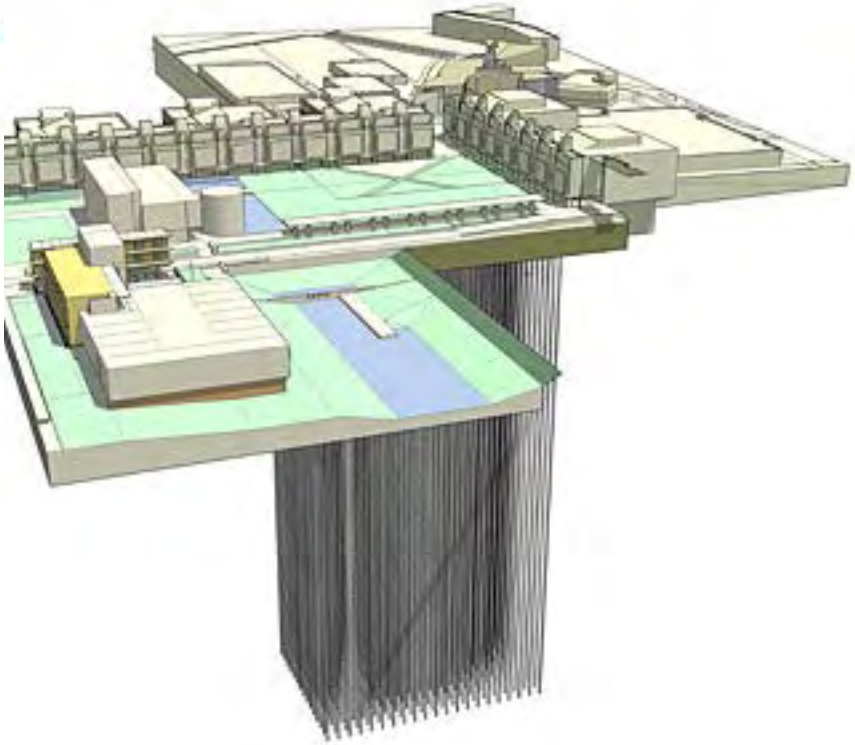

Wärmerückgewinnungsbetrieb (Kühl- und Heizbetrieb)

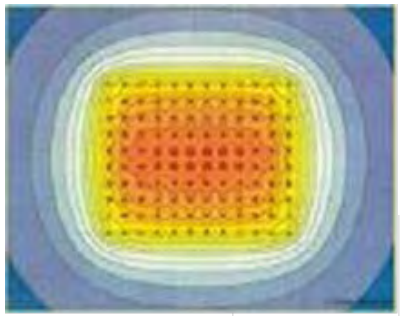

Wärmeaufnahmebetrieb (nur Heizbetrieb)
Wärme-
aufnahme
Heizen
Heizen
Heizen
Heizen

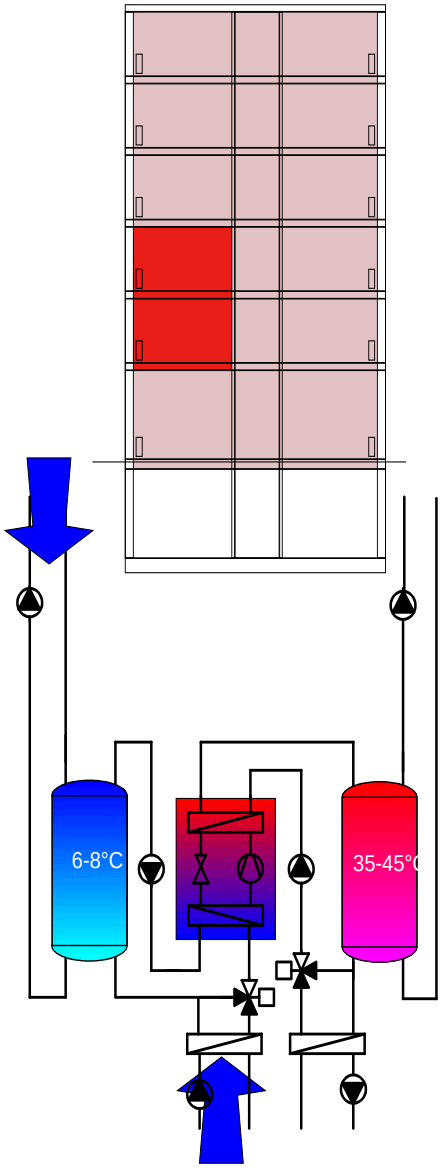
# Ground-Coupled Systems



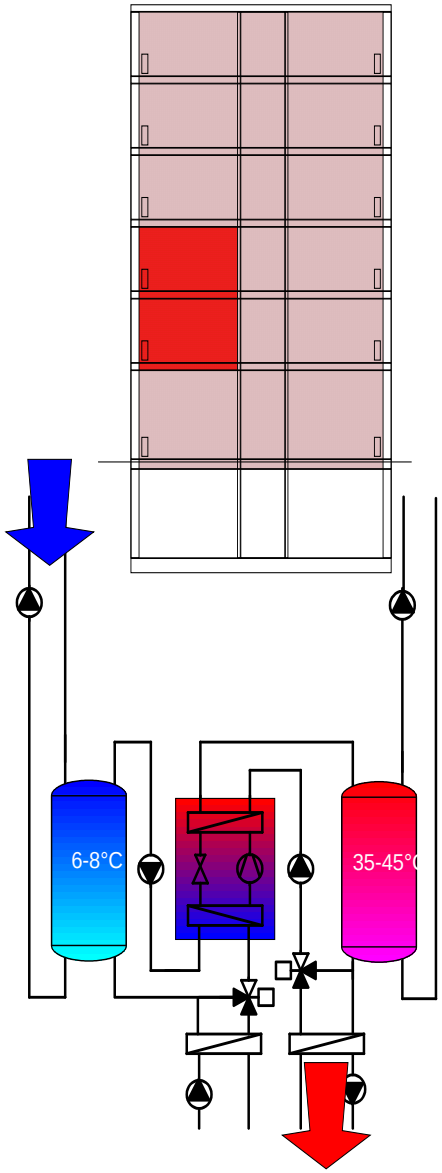




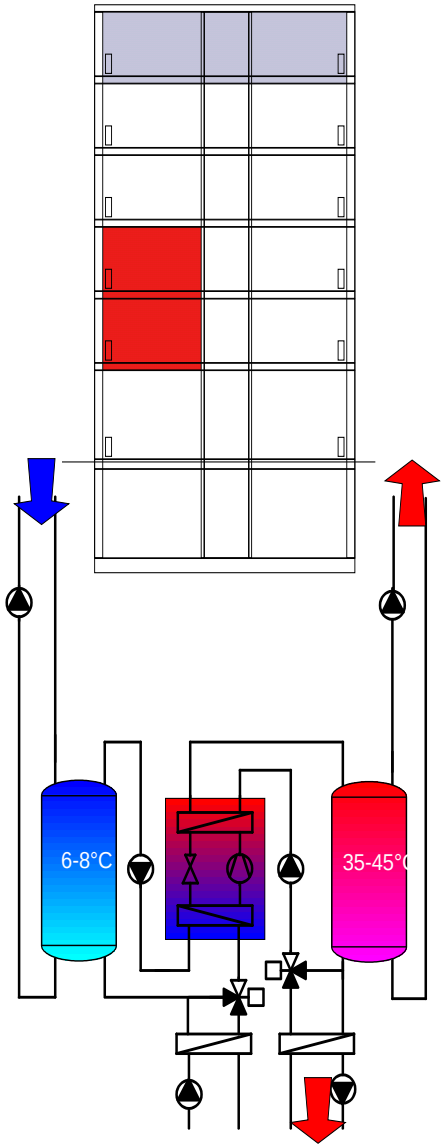




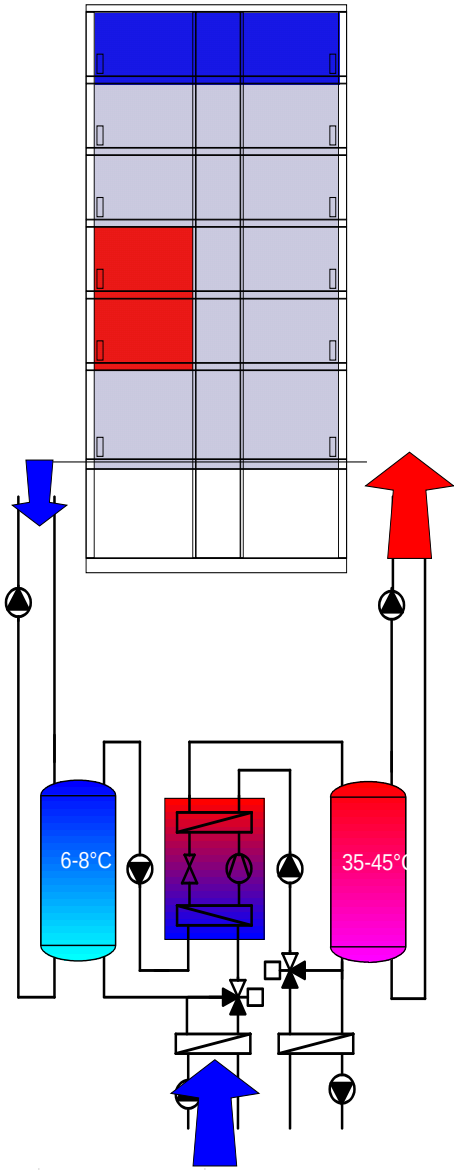

Direct Cooling



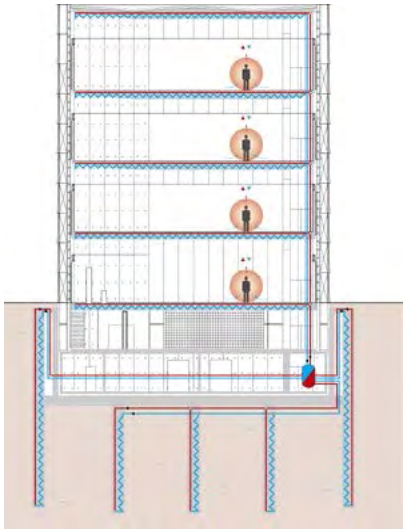

Cooling

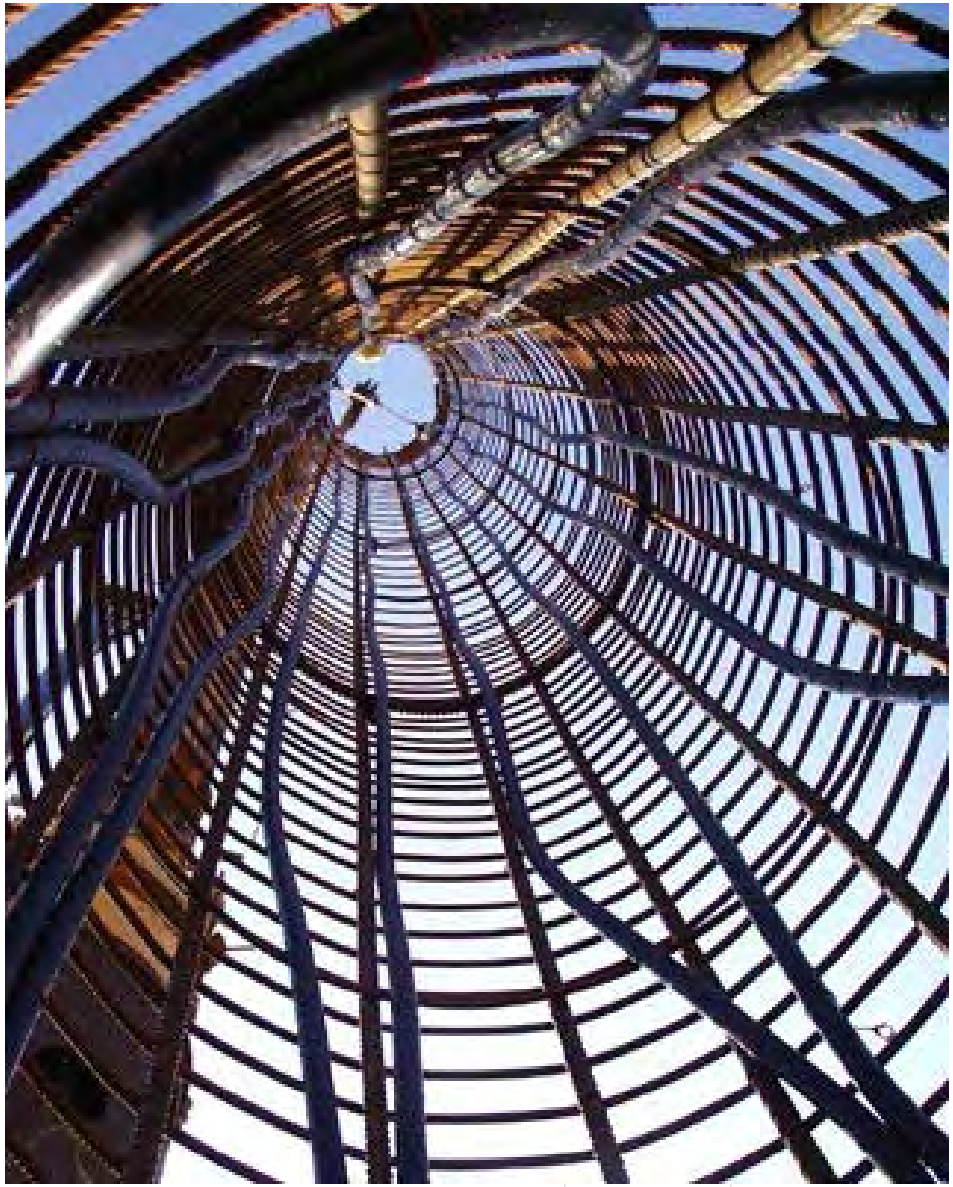



Cooling and Heating




Heating





# Heat Pumping Technologies

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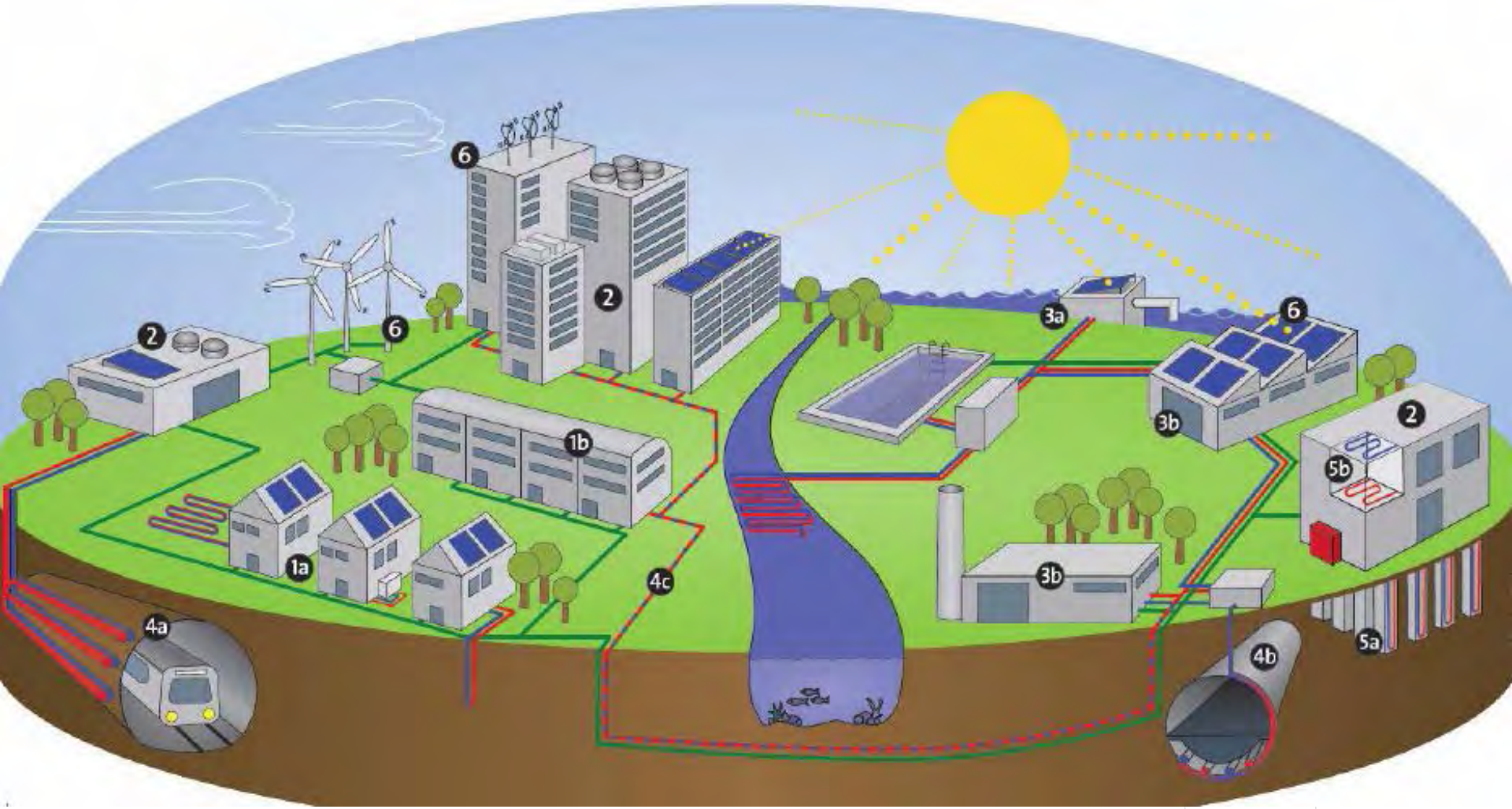
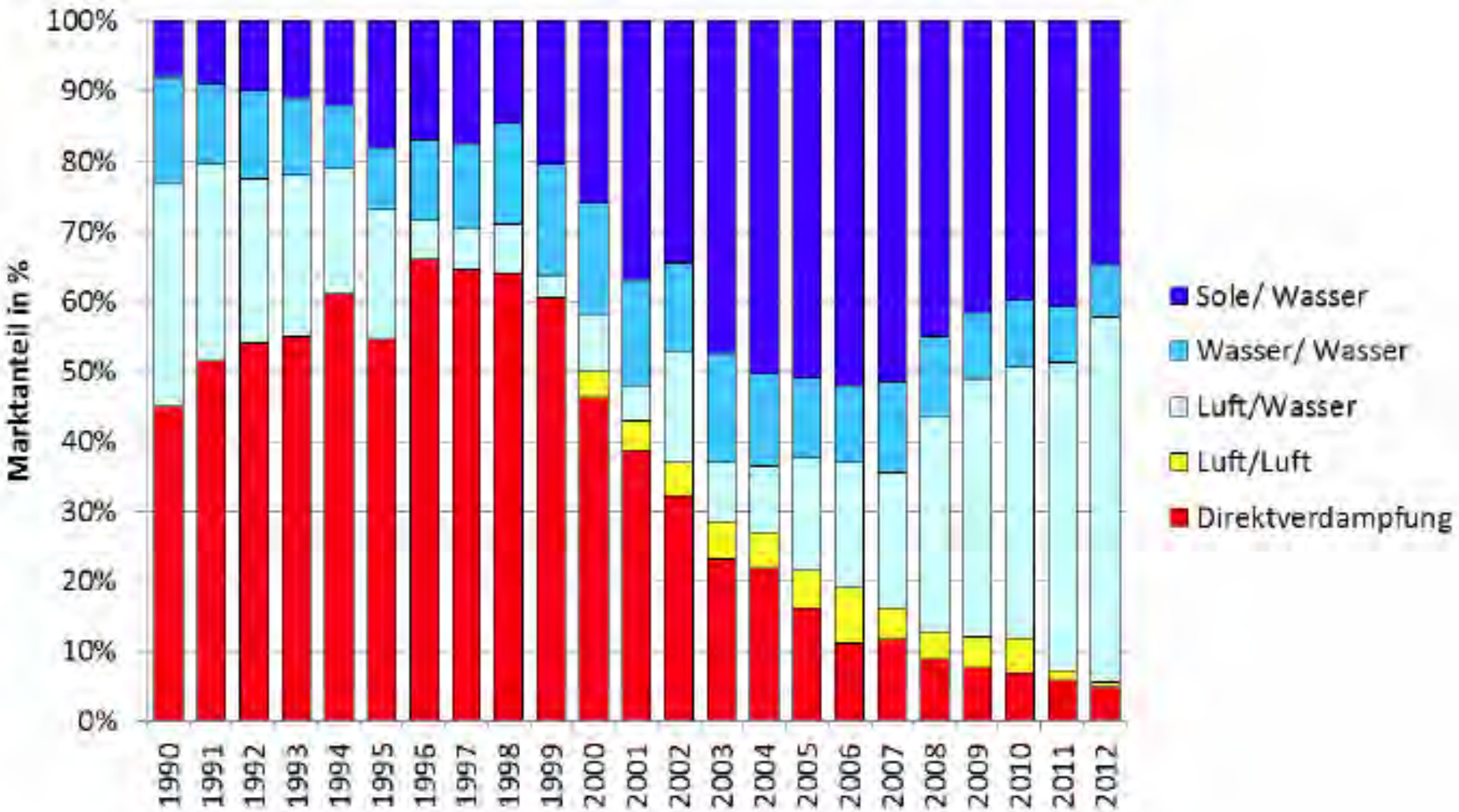
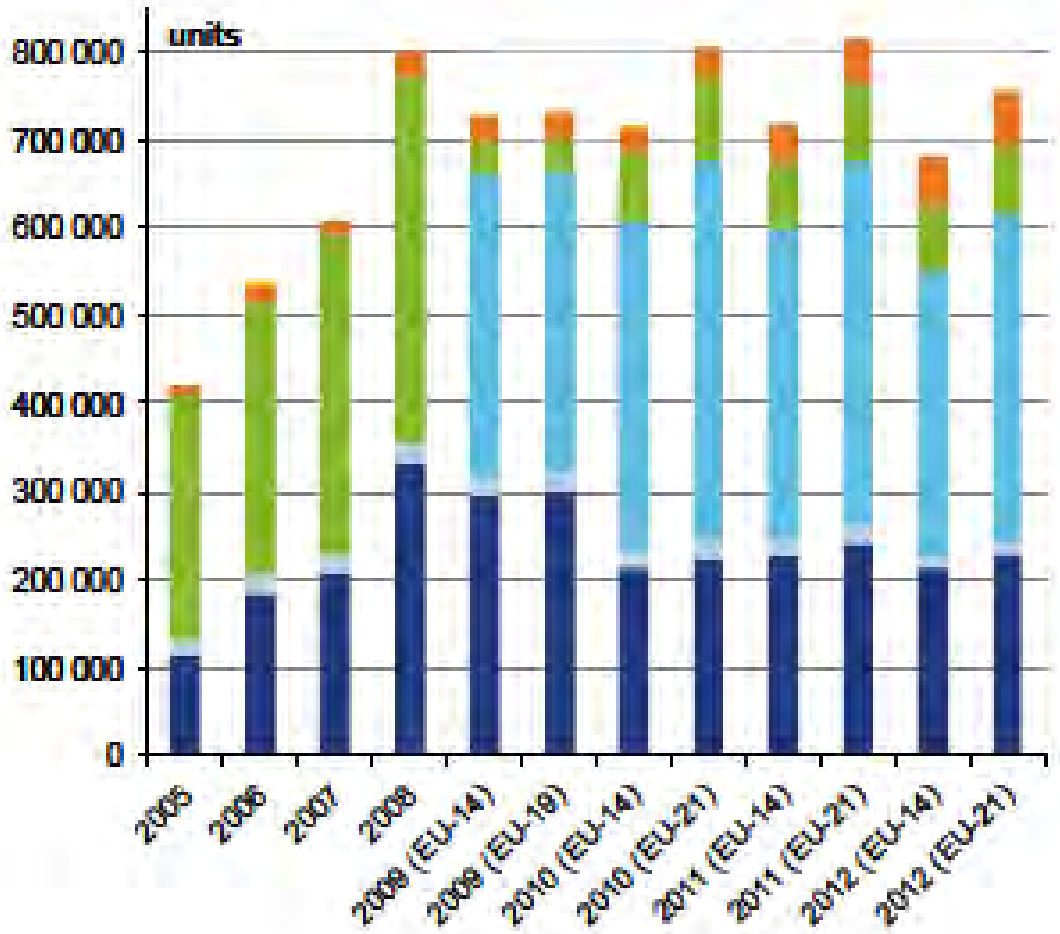



Marktanteil in %
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
Sole/ Wasser
Wasser/ Wasser
Luft/Wasser
Luft/Luft
Direktverdampfung



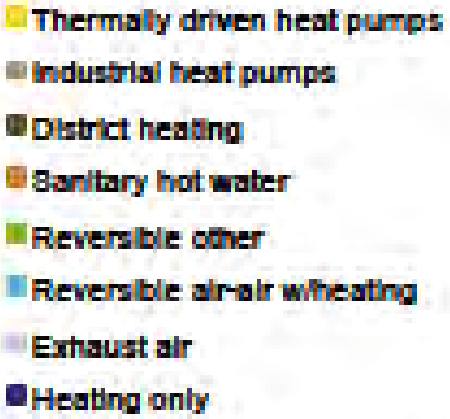




Figure 1-1: Development of heat pump sales in Europe 2005–2012 | by category.

| | sum EU-14 | sum EU-21 | cumulated total |
|---|---|---|---|
| | 419 620 | | |
| | 536 031 | | 955 650 |
| | 606 161 | | 1 561 811 |
| 2008 | 799 902 | | 2 361 713 |
| 2009 | 726 698 | 731 803 | 3 093 516 |
| 2010 | 714 560 | 802 584 | 3 896 100 |
| 2011 | 718 134 | 814 996 | 4 711 096 |
| 2012 | 679 302 | 755 043 | 5 466 139 |

Quelle: EHPA Heat pump statistics 2013

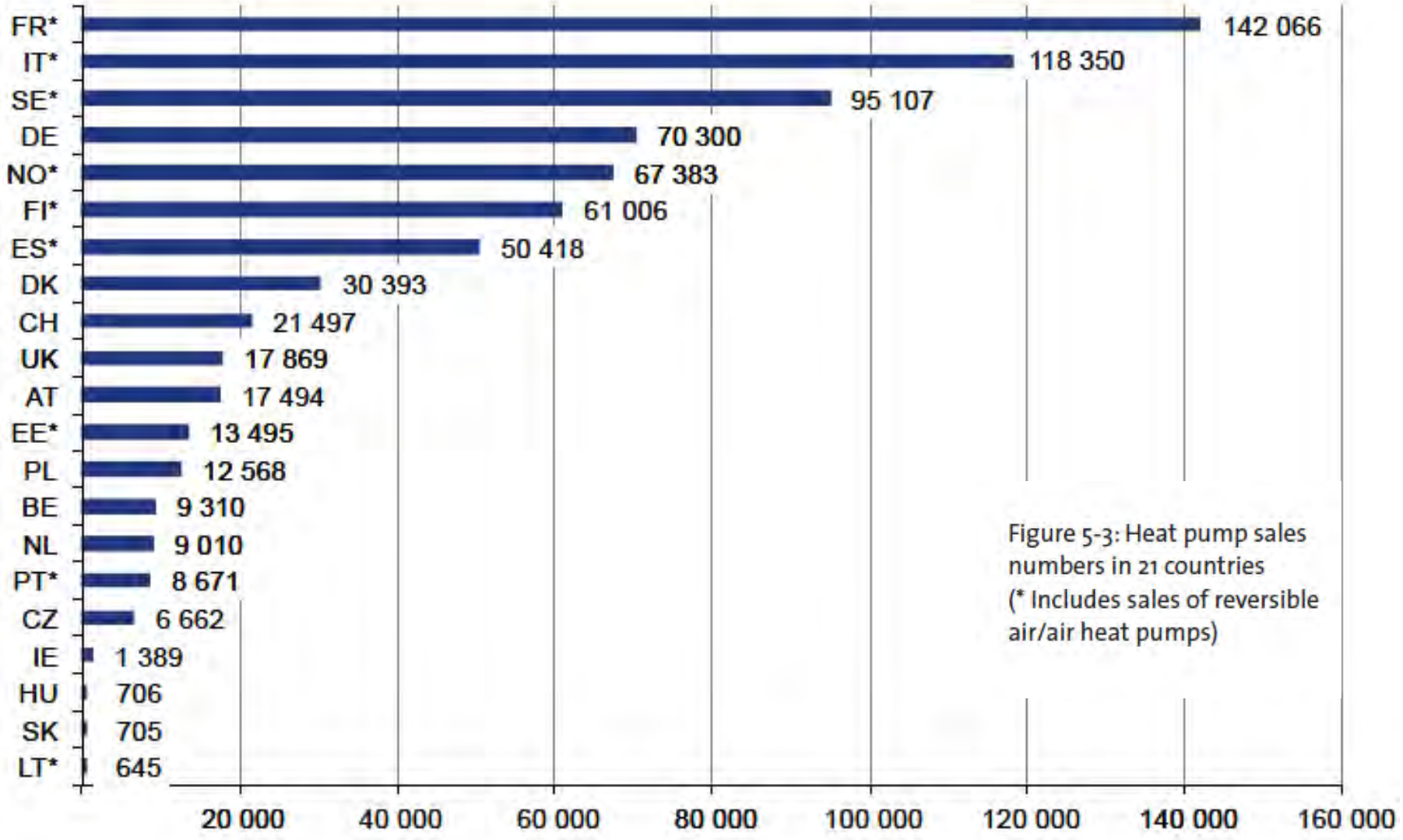


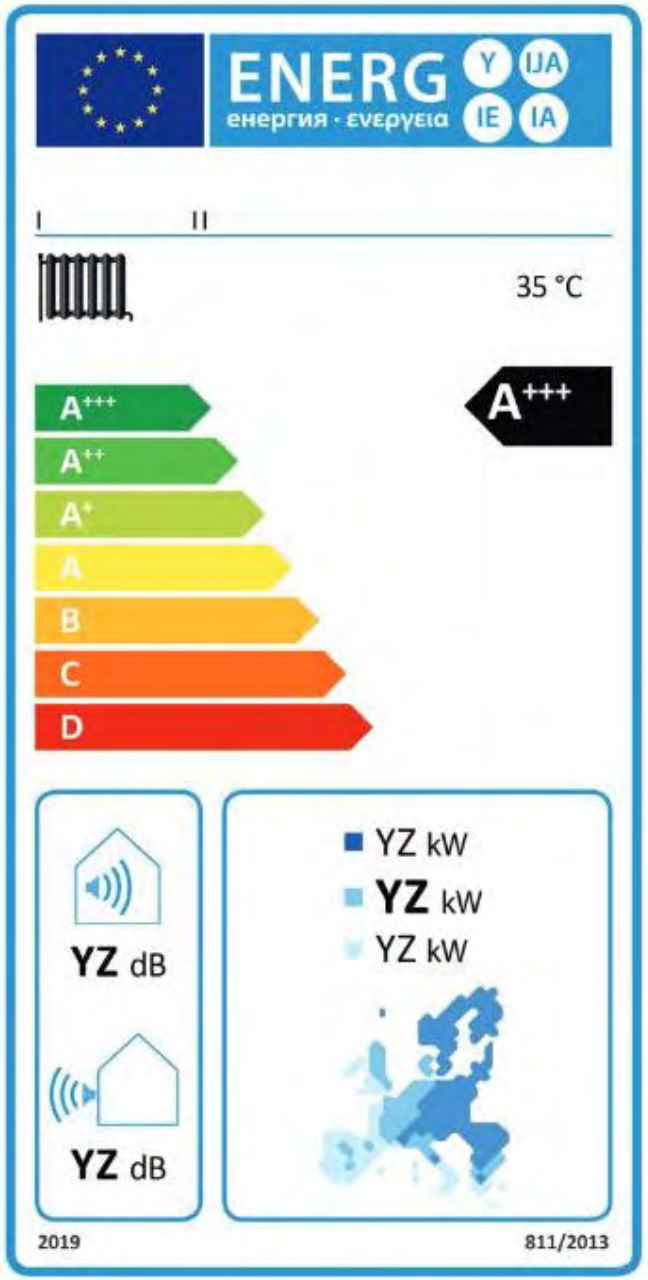

Figure 5-3: Heat pump sales numbers in 21 countries (* Includes sales of reversible air/air heat pumps)

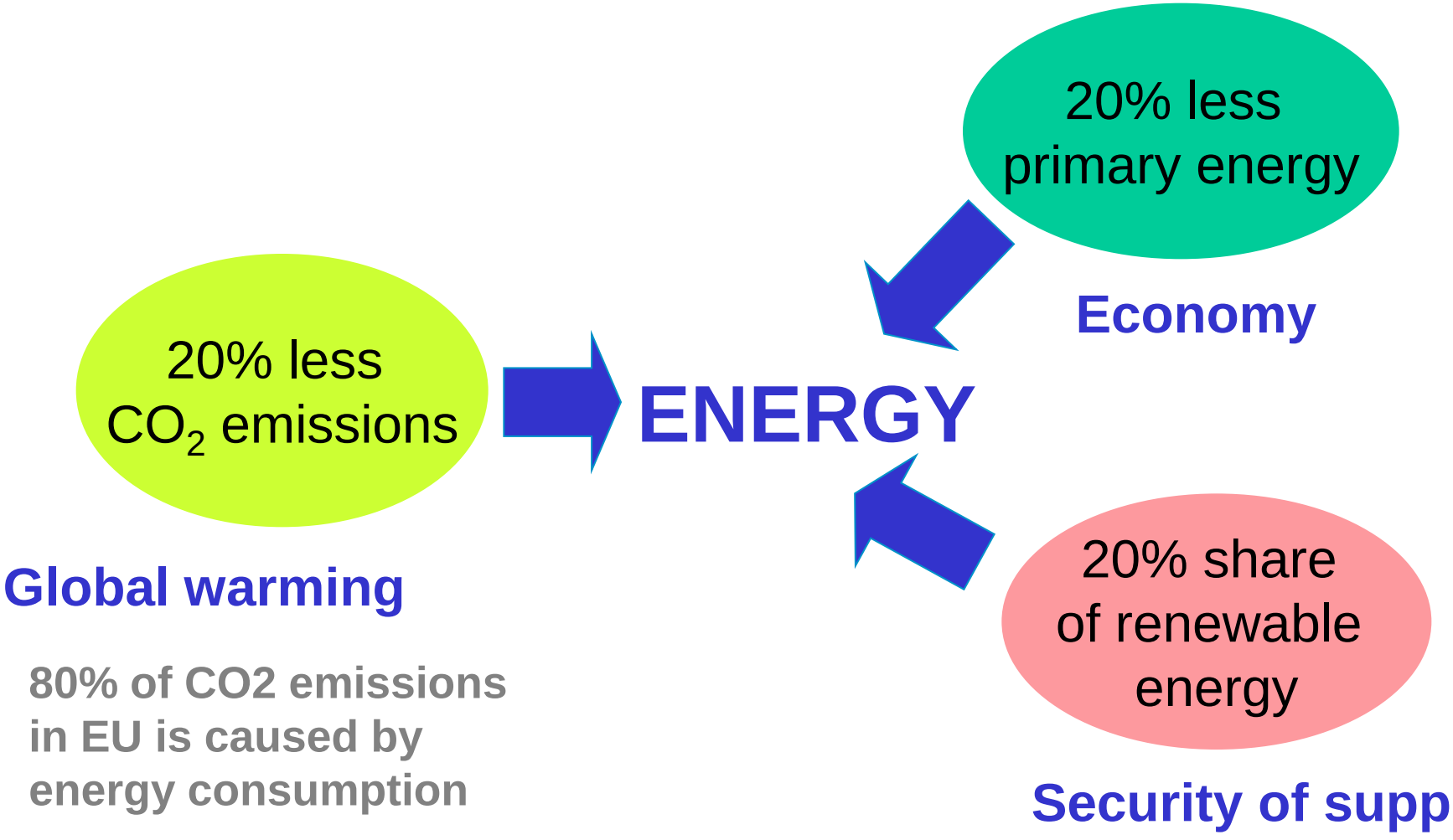
Quelle: EHPA Heat pump statistics 2013

**Heat pumping technology can reduce exposure to supply risk by significantly reducing energy import levels and providing greater fuel flexibility through the use of electricity as a multi-fuel based energy carrier.**

**The wider use of heat pumping technology can significantly reduce carbon dioxide emissions at modest (often zero or negative) cost.**

**Heat pumping technology can reduce the infrastructure costs for energy supply networks.**

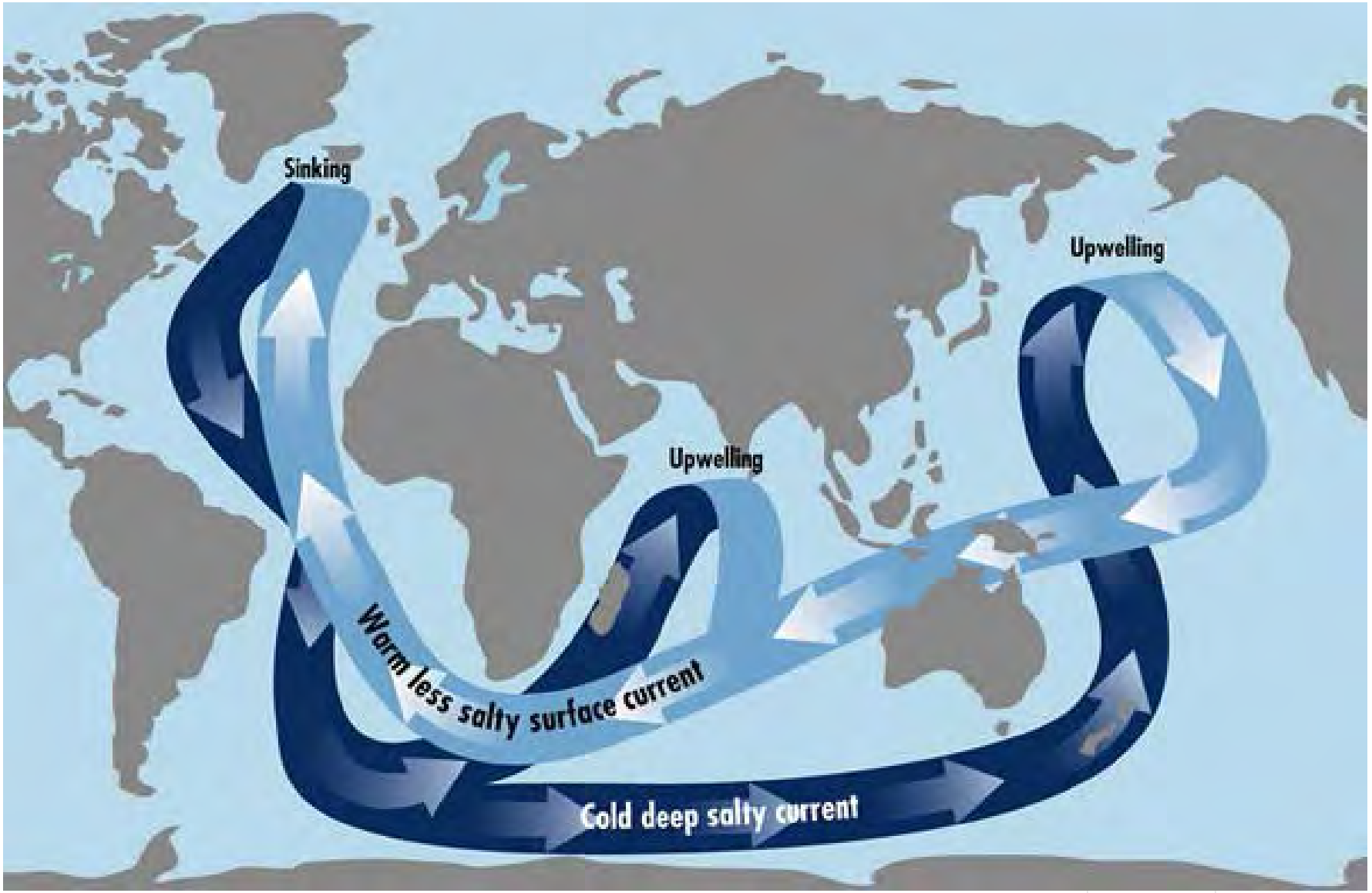





**Less dependence, more efficiency:**

**why heat pumps are key to an Energy Efficient World**

# Die Globale Wärmepumpe




Positive proof of global warming.
18th Century
1900
1950
1970
1980
1990