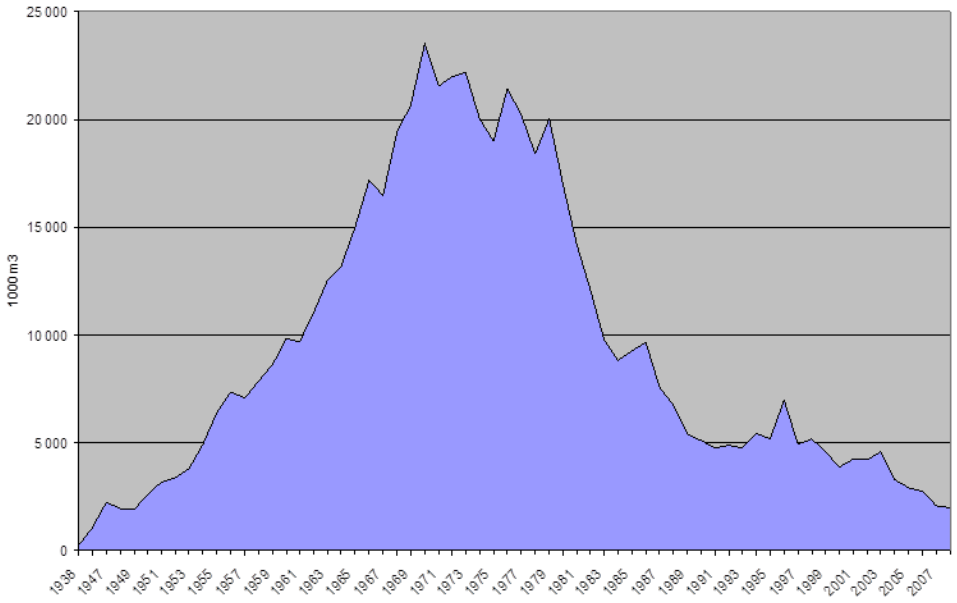
SWEDEN -
Benefits and Energy Efficiency of Central Systems - District Cooling



Inter-regional Thematic and Network Meetings for National Ozone Officers – Europe and Central Asia

Global Initiatives, Challenges, and Energy Efficiency Opportunities in the Refrigeration, Air Conditioning and Heat Pump Sectors

15-19 January, Paris

Husamuddin Ahmadzai, Tekn. dr.
CEng, C(E), FIMMM, FAusIMM

Content

- Strategies and Legislation ODS-HFC-EE
- District Cooling EE - Emissions
- Swedish Best Practice, Examples
- Conclusions

SWEDEN - EU strategies that enhance Energy Efficiency and Reduce Emissions

- EU's objective of cutting its overall greenhouse gas emissions by 80% of 1990 levels by 2050.
- Globally – Montreal Protocol – UNFCCC Paris Agreement
- EU has adopted three ODS-F gas related legislations:
  - EU Ozone Depleting Substances Regulation No 1005/2009;
  - the Mobile Air Condition Directive on air conditioning systems used in small motor vehicles; Directive 2006/40/EC
  - the 'F-gas Regulation' which covers all other key applications using F-gases, Regulation No 517/214

SWEDEN - EU strategies that enhance Energy Efficiency and Reduce Emissions

- Heating and cooling consume half of the EU's energy and much of it is wasted (EC Strategy on Heating and Cooling, 16.2.2016)
- EU has 4 key directives addressing Energy Efficiency (EE)
  - EU Directive 2012/27/EU of 25 October 2012 on Energy Efficiency: Definitions, Scope, Targets, Use, Supply, Transmission; Heating, Cooling
  - EU Directive 2009/125/EC of 21 October 2009 setting the framework for setting eco-design requirement for energy related products: Integrates environmental aspects into design of energy products placed on the market; life-cycle; re-use; harmonised standards; assistance to SME

SWEDEN - EU strategies that enhance Energy Efficiency and Reduce Emissions

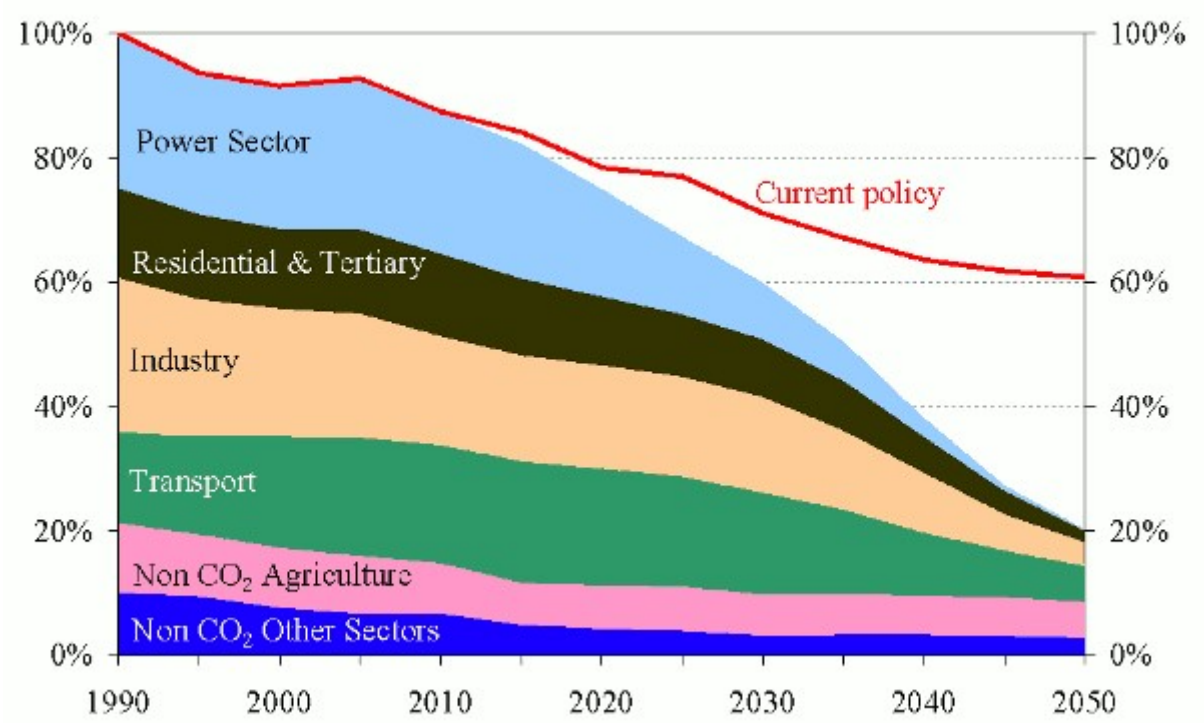
- EU Directive 2010/31/EU of 19 May 2010 on the Energy Performance of Buildings; Inter alia: methodology for calculation of performance of buildings (existing, new, major renovation); nearly zero energy buildings; systems requirements – heating, air-conditioning, ventilation, hot water systems; certification, incentives, market barriers; inspection, independent control, use of indicator kWh/m2-y reflecting national/regional/local conditions;
- EU Directive 2010/75/EU of 24 November 2010 on industrial emissions (integrated pollution prevention and control). Information exchange via Best Available Techniques (BAT) reference documents (BREF)- industrial sector specific. Energy efficiency is a criteria. BREF on Energy Efficiency (BREF 2009); economics and cross media BREF (2006). Horisontal issues.

SWEDEN - EU strategies that enhance Energy Efficiency and Reduce Emissions

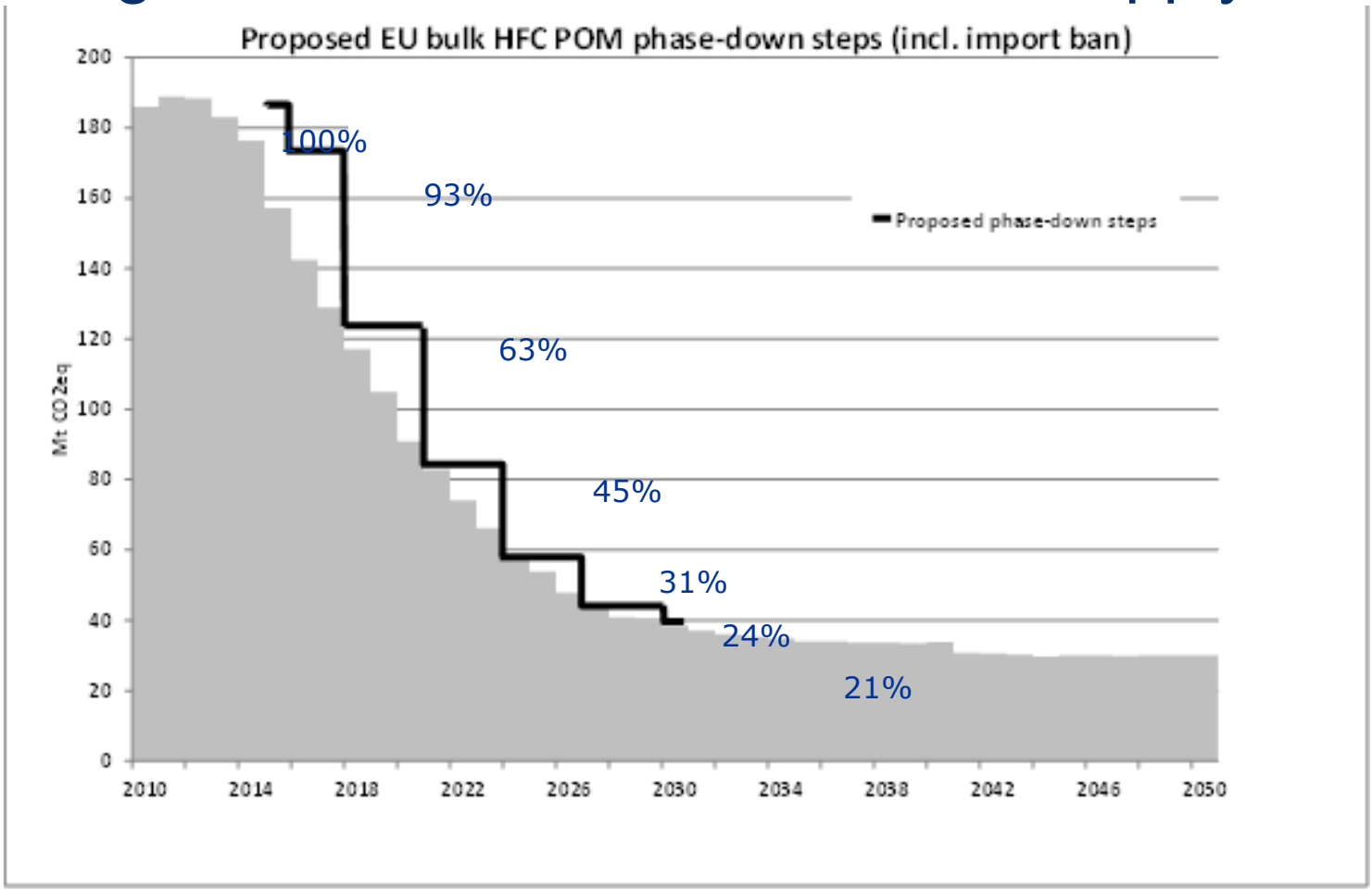
- Regulation (Montreal, UNFCC; EU Regulation)
- Technology and practice and cost effectiveness
  - Servicing, prevent leakage & emissions
  - Alternatives that are EE & avoid the use of F-gases
  - Standards, Design, Certification
    - Building Research Establishment Environmental Assessment Method (BREEAM); BREEAM-SE; EU reg.
    - Leadership in Energy and Environmental Design (LEED) (http://www.usgbc.org/leed) 4 ratings: Certified, Ag, Au, Pt; ASHRAE 90.1 - > 4 stories high bldgs.
- Tax, tariff pricing and incentives
- Business Models, public-private enterprise, municipalities and district communes

EU - SE strategies that enhance Energy Efficiency and Reduce Emissions

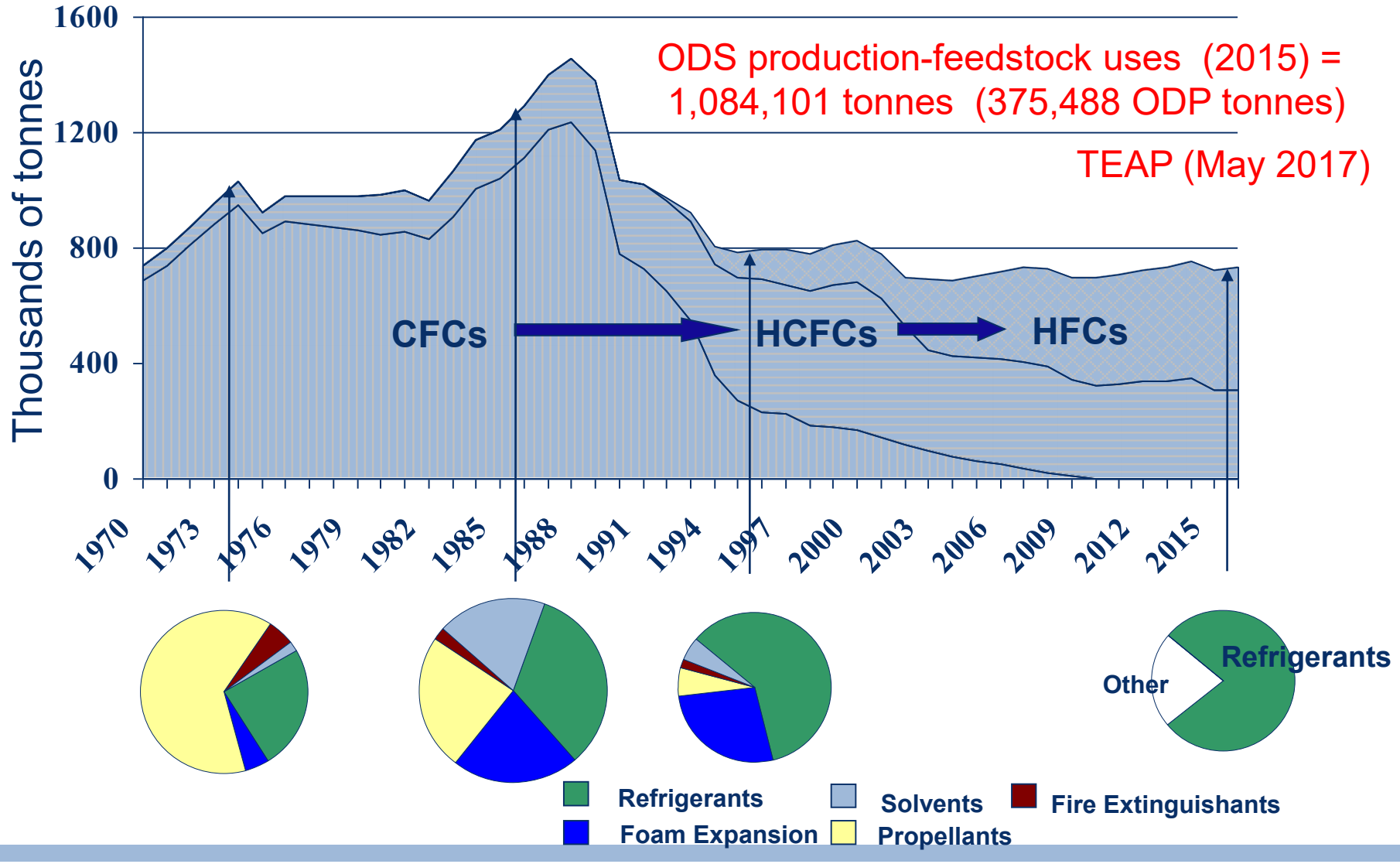
EU's objective of cutting its overall greenhouse gas emissions by 80% of 1990 levels by 2050.



EU Legislation: Phase-down of HFC supply



An Industry in Transition



Estimated RACHP Equipment Systems operating Worldwide (TEAP 2017)

Application	Sector	Equipment	Number of units in operation
Refrigeration and food	Domestic refrigeration	Refrigerators and freezers	1.5 billion
	Commercial refrigeration	Commercial refrigeration equipment (including condensing units, stand alone equipment and centralized systems)	90 million
	Refrigerated transport	Refrigerated vehicles (vans, trucks, semi-trailers or trailers)	4 million
		Refrigerated containers ("reefers")	1.2 million
Air Conditioning	Air conditioners	Air-cooled systems	600 million
		Water chillers	2.8 million
	Mobile air conditioning systems	Air conditioned vehicles (passenger cars, commercial vehicles and buses)	700 million
Heat pumps		Heat pumps (residential, commercial and industrial equipment, including reversible air-to-air air conditioners)	160 million

Refrigeration, air-conditioning and heat-pump sector (RACHP) – 3.1 billion

80% of the impact from RACHP is associated with generation of electricity

Current best eqpt. operates @ 50-60 % of theoretical max. EE Coming decades – Innovation 70-80% of TEE

Leak Rates per Sector (ExCom document 72/42)

ANNEX

Leak rates per subsector :

On average between 22 to 44% /annum (EXCOM document 72/42)

Subsector	Estimated annual emission rates in HPMPs		
	Average (%)	Lowest value (%)	Highest value (%)
Residential air-conditioning	29	4	79
Commercial air-conditioning	40	3	70
Industrial air-conditioning	40	8	54
Transport	23	8	40
Chillers	22	14	30
Commercial refrigeration	38	2	82
Industrial refrigeration	44	7	100

Source: A sample of 38 approved HPMPs in which this data is available. The data corresponds to estimations made by each country and the methods may differ between countries.

District Energy Systems – District Cooling – Heating: Improved Energy Efficiency, Less Emissions

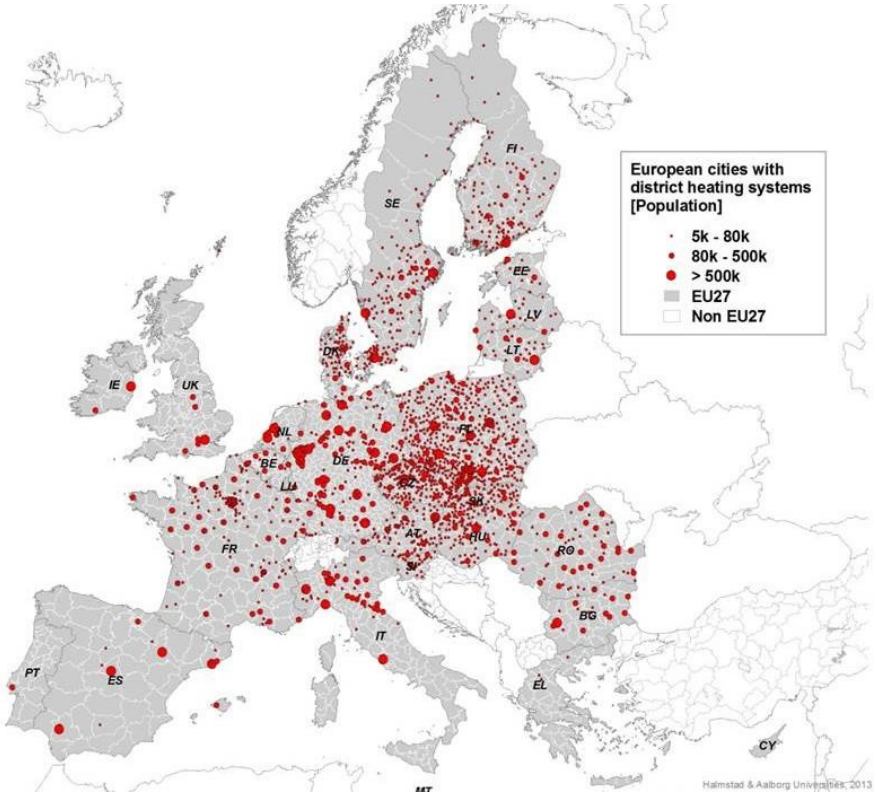
Parameter	District Cooling	Alternative
Cooling Energy Demand, MWh/y	110 000	110 000
Cooling Energy Demand, MW	13	13
Electricity Demand, MWh/y	6 340	33 330
Electricity Demand, MW	1	4
Emissions, CO2, tonnes/y	3 918	20 598
Refrigerant, HFC, kg/y	17 160	33 000
Leakage, %	< 1	ca 8

Source: Capital Cooling, 2013

District Heating in the EU

- ***62 million EU citizens served***
- ***Share of citizens served by DH:~13%***
- ***Sales totalling ~1,500 PJ or 420 TWh*** *(enough to heat New York for 50 years)*
- ***Total trench length of DH pipeline system over 140,000 km***

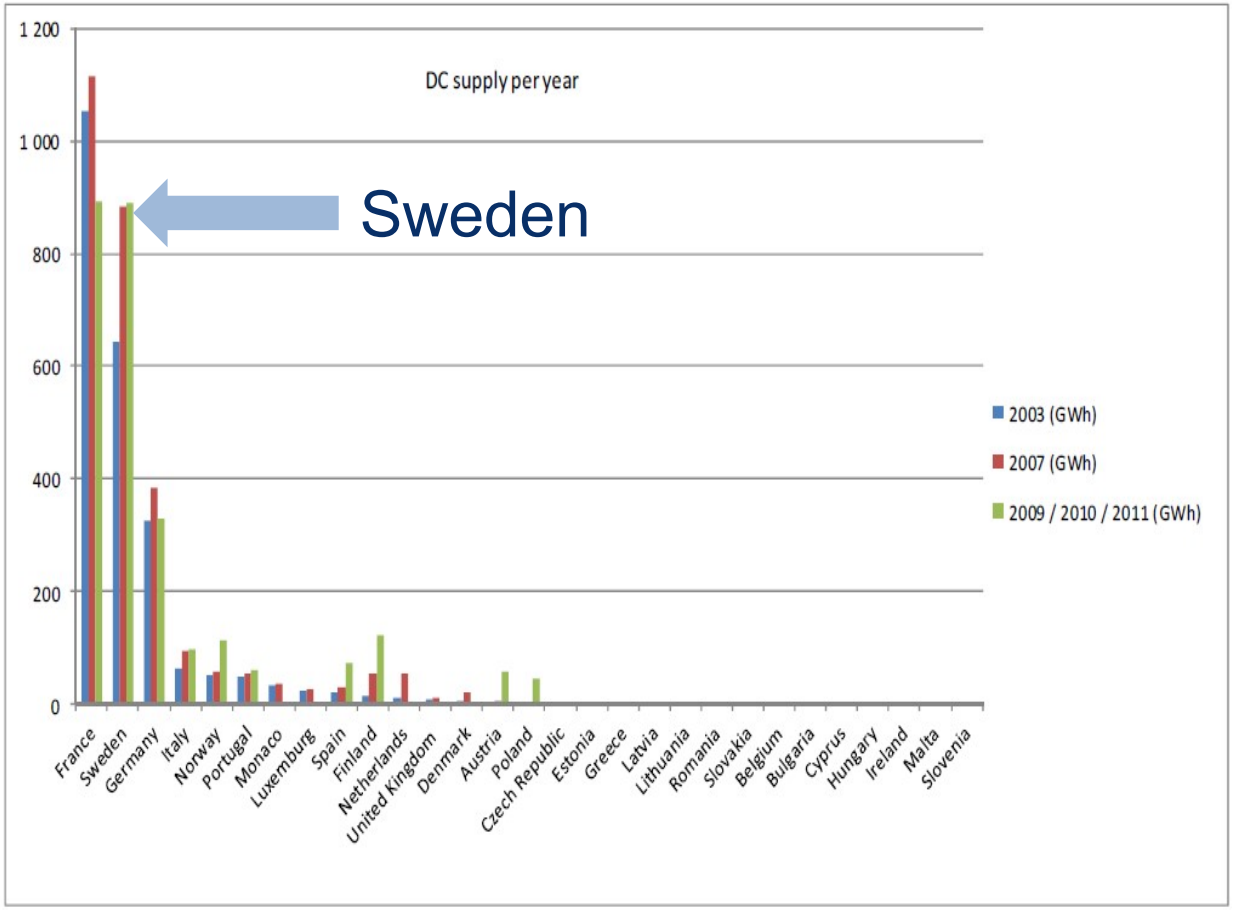
  (= 7 Great Walls of China; = 3.5 times around the globe)
- ***DH installed capacity ~250 GWth***



… And over 5000 District Heating Systems already exist in the EU

Source: Euroheat & Power (DHC Country by Country survey 2013)

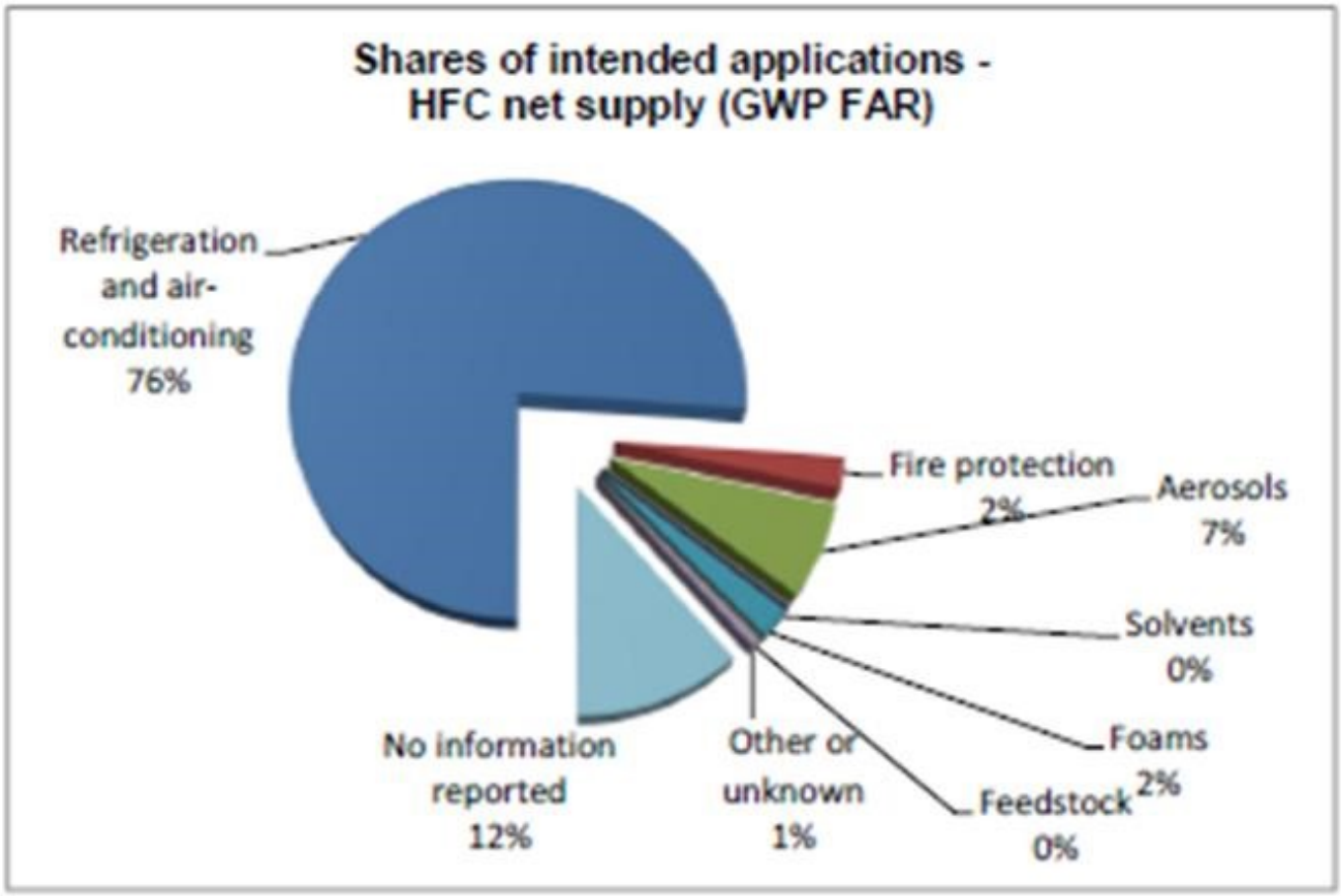
District Cooling in EU



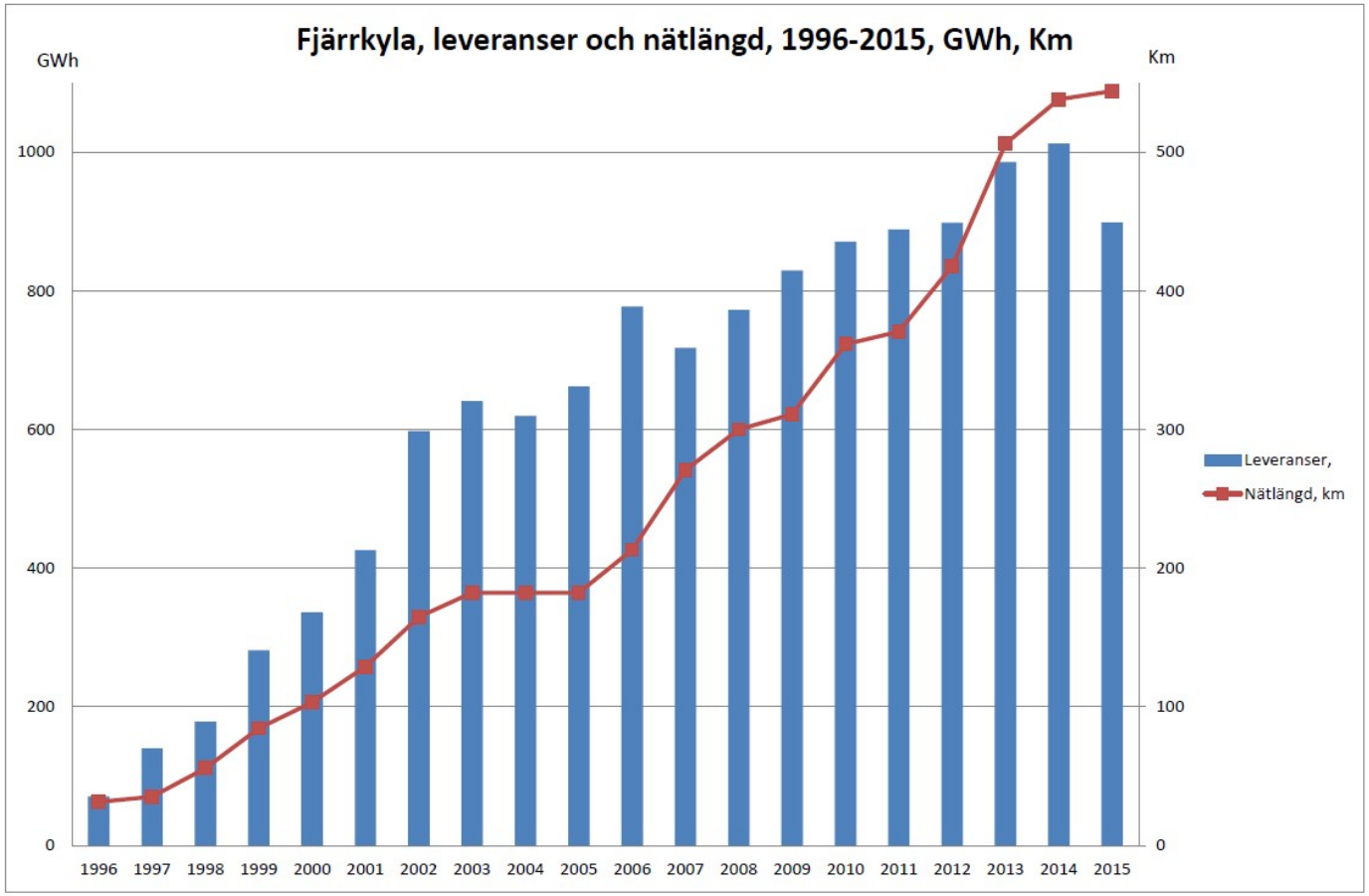
- Today 3TWh DC in EU
- Approximately 1-2% market share for DC in the EU
- Market Share in Sweden >25% (1TWh)

Source: Euroheat & Power

Segment EU – HFC Use RAC 76%

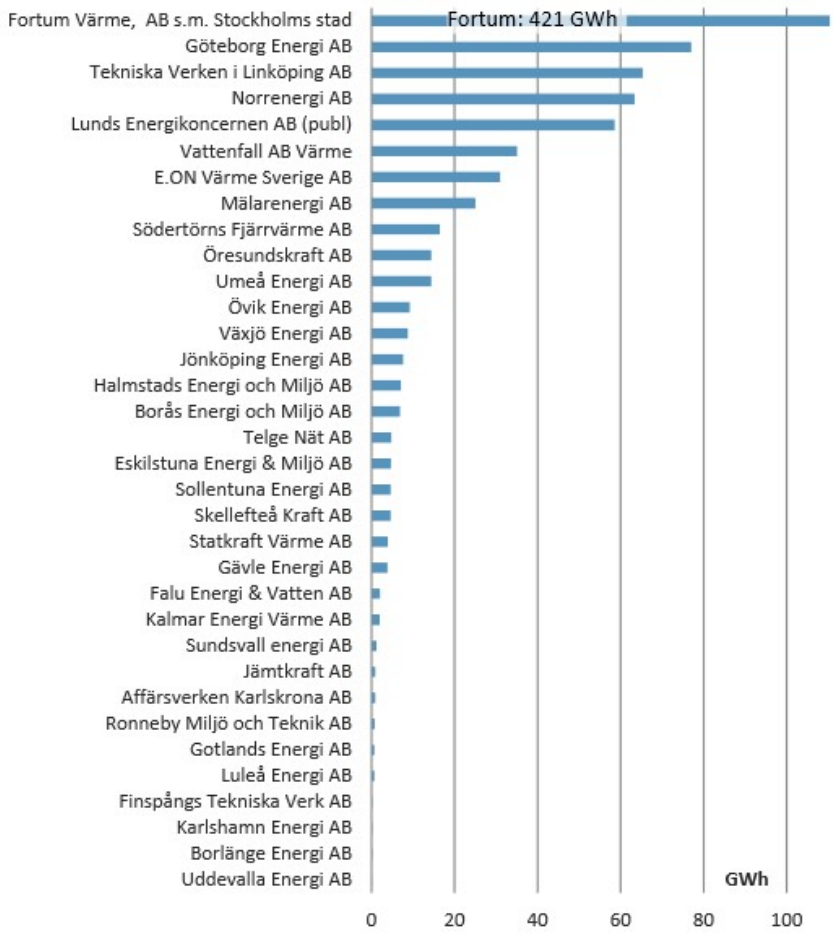


Sweden – DC Delivery/network

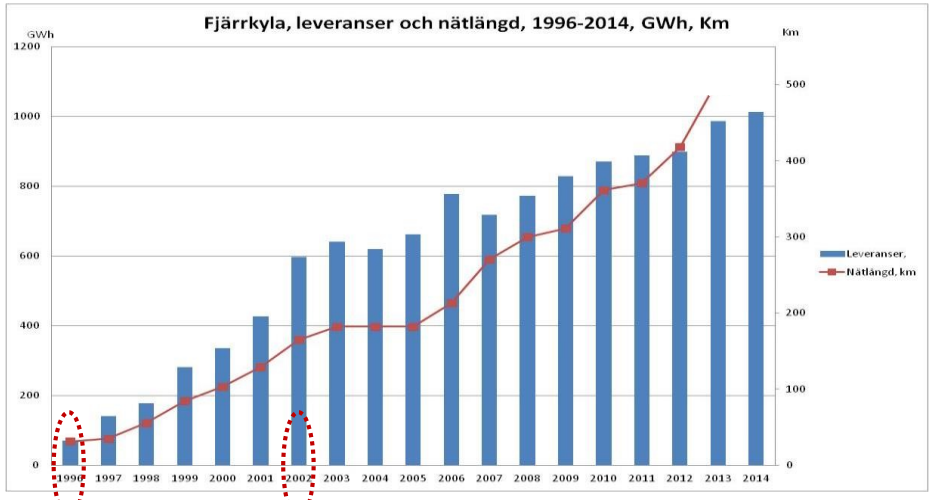


1000 GWh
550 km

District Cooling in Sweden



- First DC 1992
- Triggered by Sweden early phase out of CFC&HCFC (1996&2002)
- 34 Swedish locations
- >500km DC pipes
- >1.000GWh
- Today >25% market share

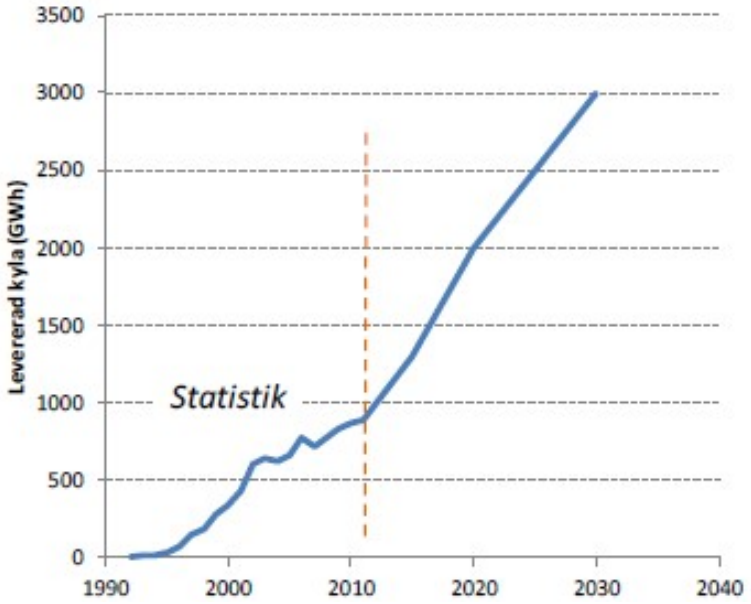


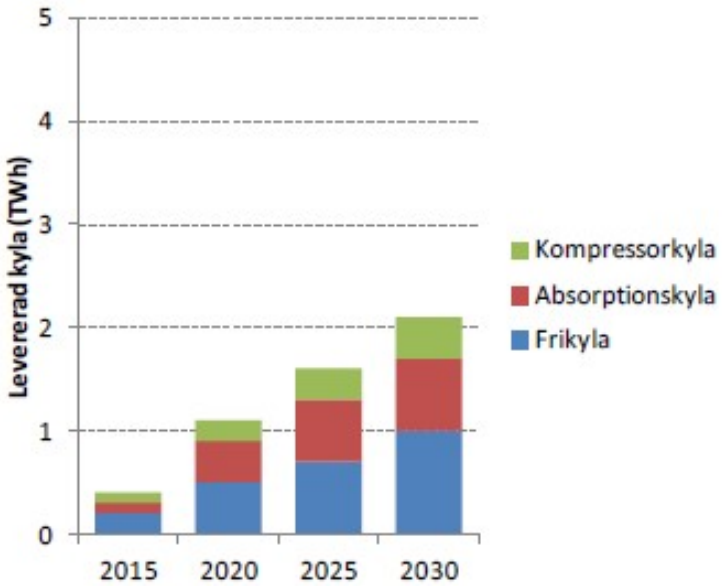
R 12 R 22

Source: Swedenergy

Sweden DC Forecast

European demand (2018): 660 TWhc

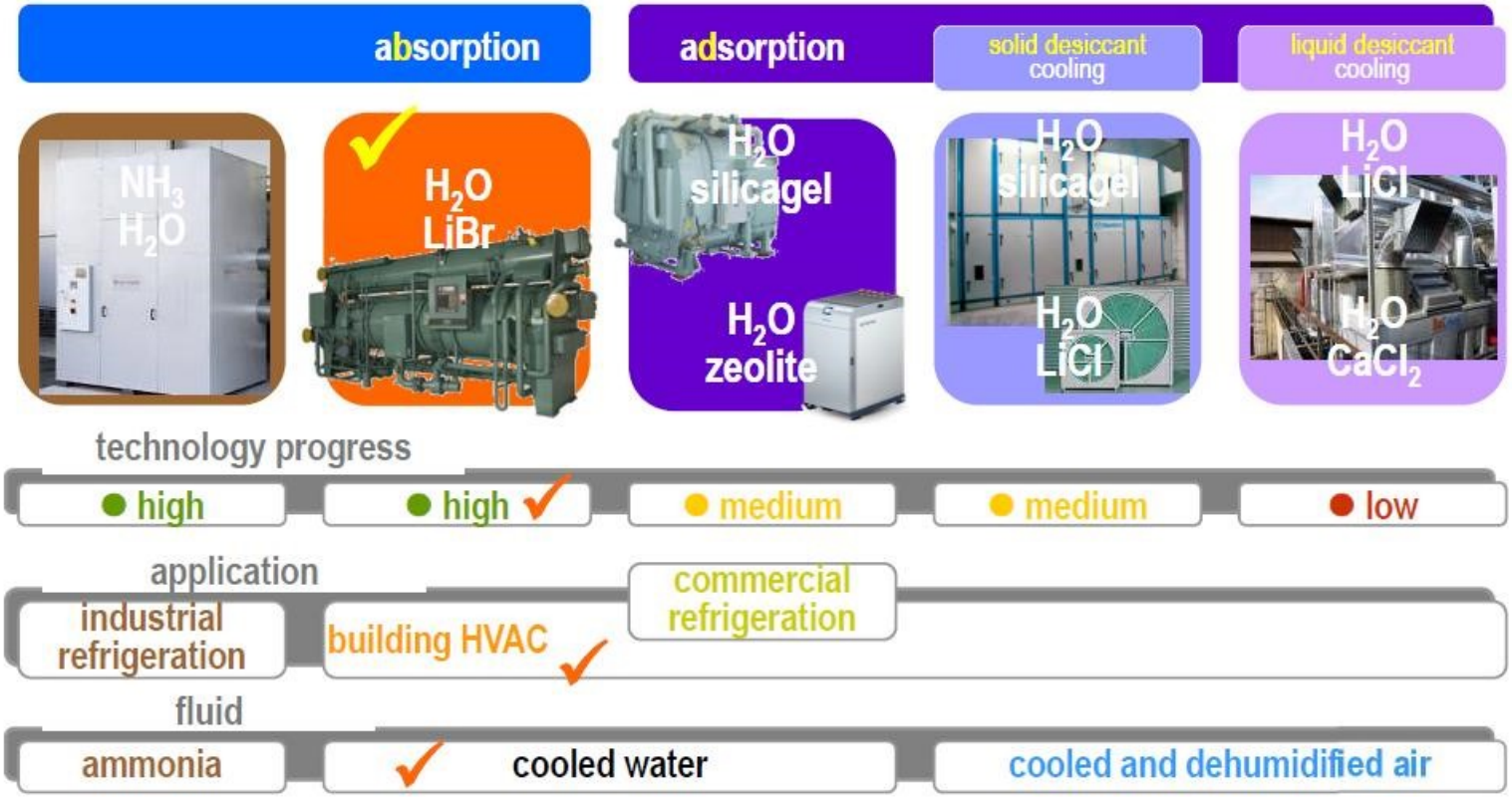




Estimated development of DC up to 2030 TOTAL in DC SUPPLIED (left Fig.) and INCREASE of DC w.r.t. 2010 baseline and technology choice (Fig to the right).

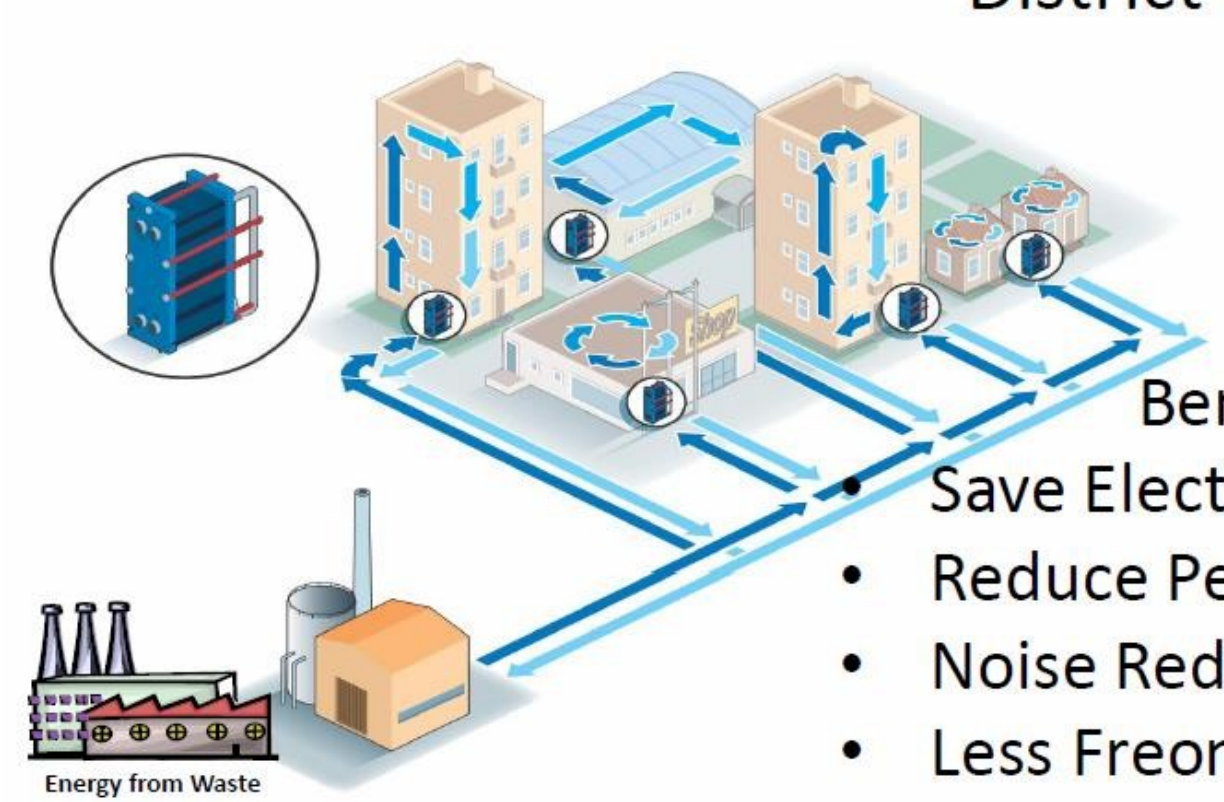
Ref: H. Sköldberg et al 2013

Not in Kind Tech. Options – District Cooling



Waste to Energy ”Waste-to-Cooling”

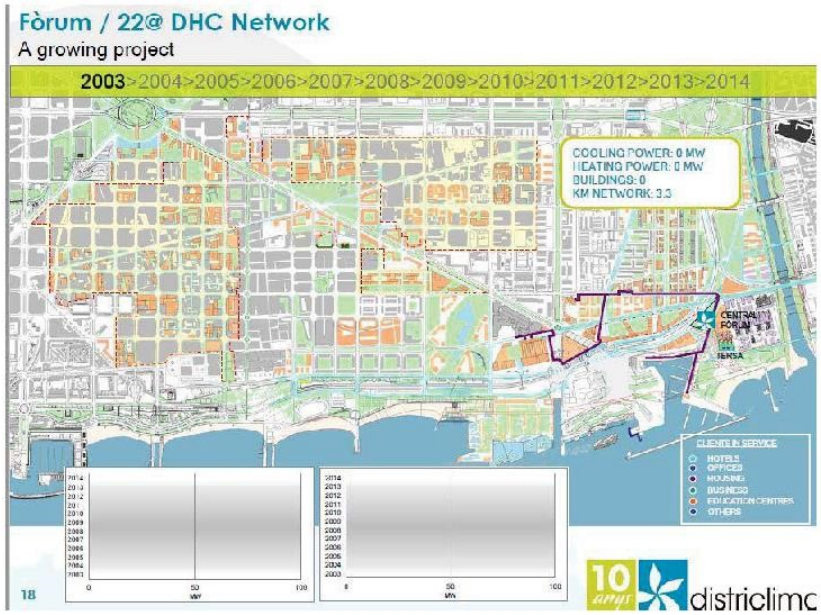
District Cooling



Benefits

- Save Electricity
- Reduce Peak Demand
- Noise Reduction
- Less Freon emissions

Start and Connect - Barcelona

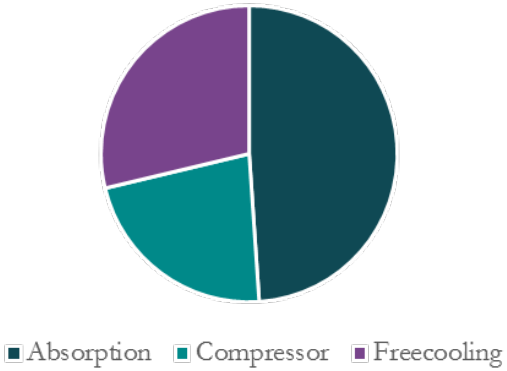


S. Ugona (2016)

Sweden Best Practice– Linköping

Linköping

Production



General Information

- Linköping is city in Sweden with 150.000 inhabitants.
- The first cooling delivery was made in 1997 in collaboration between the Tekniska Verken (the city energy utility) and Linköping University and triggered by the Swedish early phase out of R12&R22 (CFC&HCFC) and to make use of the summertime surplus heat
- In 2016 the network provided cooling solutions to 140 customers with a total demand of 55 MW (16.000 RT) with an output of total 100 GWh/year.
- Total investment is about 30 M€

Key Figures

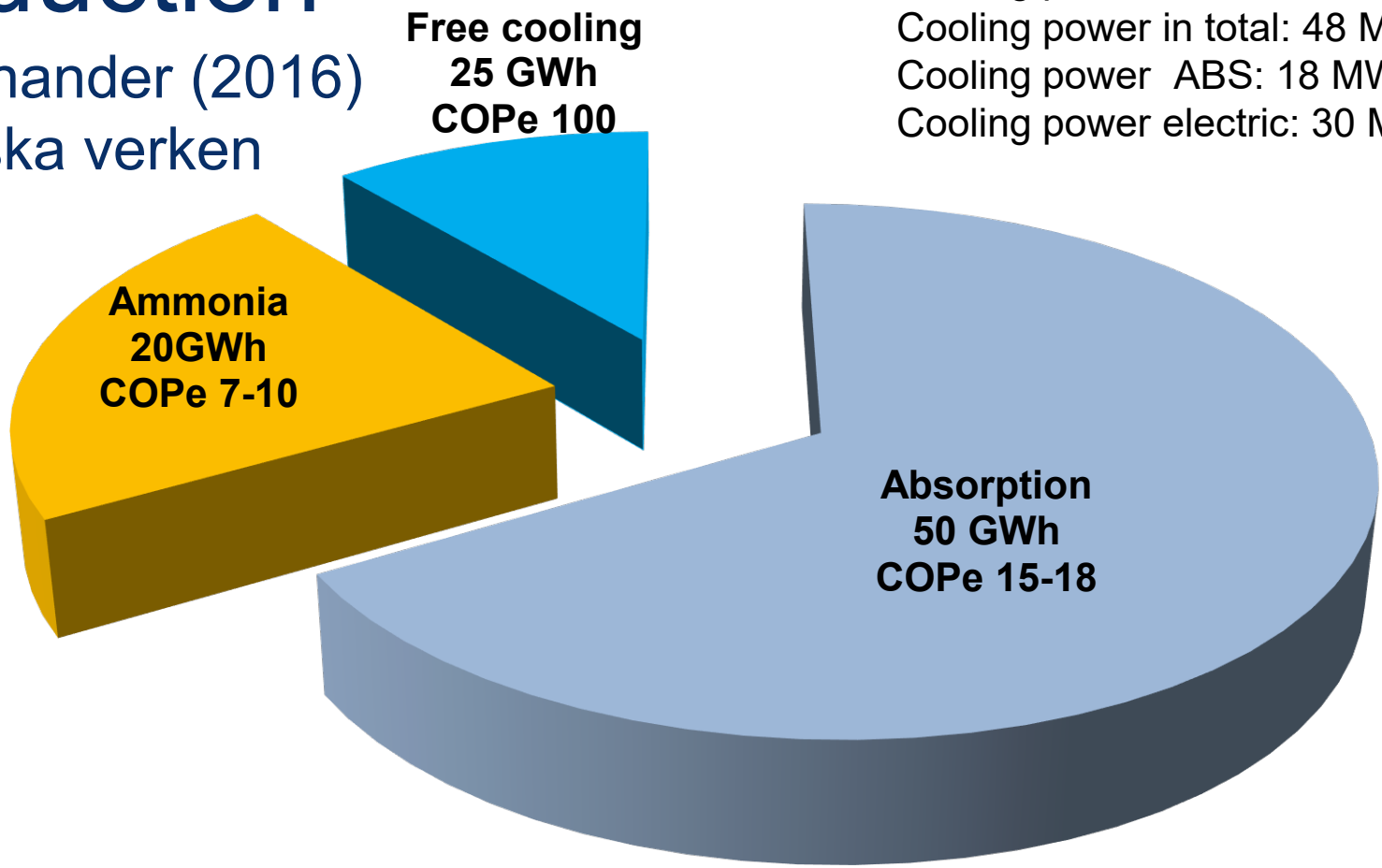
1. HFC phase down: 100%
2. Energy Efficiency: SSEER* = 10,7

*SSEER: Seasonal System Energy Efficiency Ratio

Production

J. Fornander (2016)
Tekniska verken

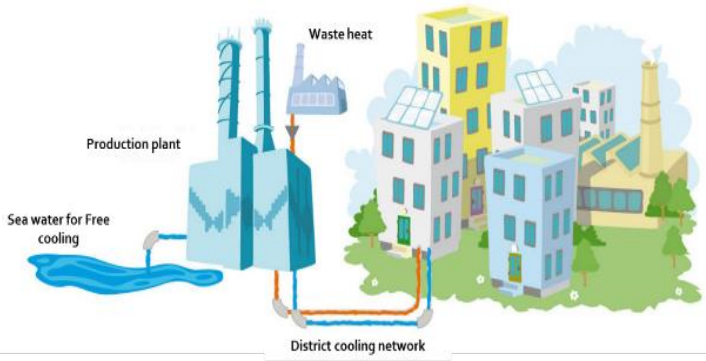
Cooling production: 95 GWh
Cooling power in total: 48 MW
Cooling power ABS: 18 MW
Cooling power electric: 30 MW

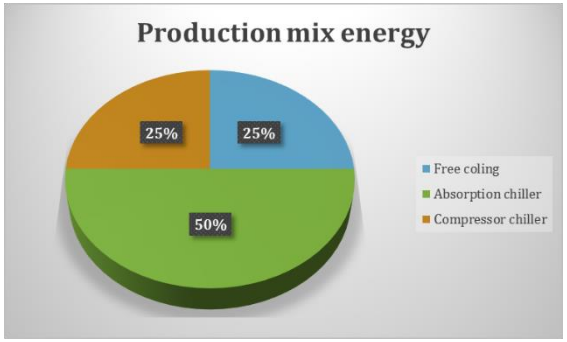


COPe= Coefficient of Performance, electricity to cooling

Sweden Best Practice– Göteborg

Gothenburg





General Information

- Gothenburg is city in Sweden with 570.000 inhabitants.
- The first decentralized cooling delivery was made in mid 90th triggered by the Swedish early phase out of CFC&HCFC and in 2007 these systems where integrated by a large-scale network in the entire centre of Gothenburg to improve efficiency and to be able to serve more customers
- In 2016 the network provided cooling solutions to 57 customers and 147 buildings with a total demand of 88 MW (25.000 RT) with an output of total 90 GWh/year.
- Total investment is about 80 M€

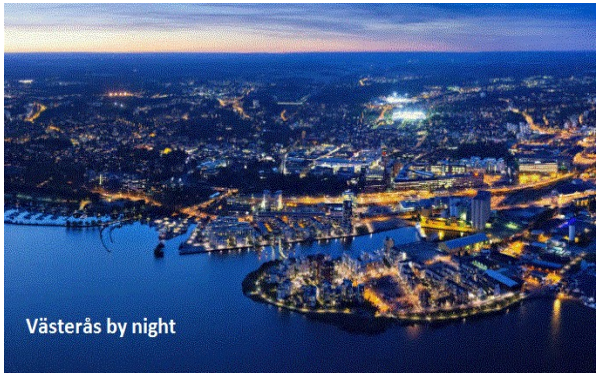
Key Figures

1. HFC phase down: >75%
2. Energy Efficiency: SSEER* = 9

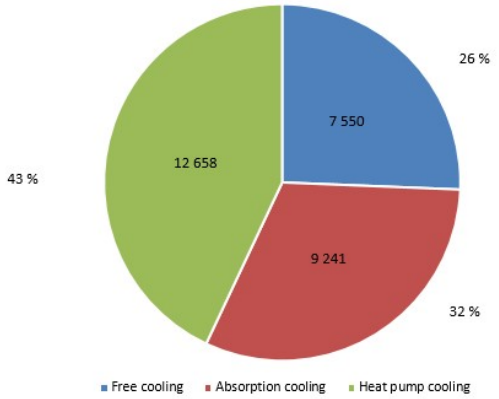
*SSEER: Seasonal System Energy Efficiency Ratio

Sweden Best Practice– Västerås

Västerås



District cooling - Production mix MWh and %, 2013-2016



General Information

- Västerås is city in Sweden with 147.000 inhabitants.
- The first cooling delivery was made in 1992 and was initiated to take advantage of the cold waste water that is a byproduct of producing district heating from treated sewage and also triggered by the Swedish early phase out of CFC&HCFC and adding absorption chillers in 2002 to make use of the summertime surplus heat
- In 2016 the network provided cooling solutions to 72 customers with a total demand of 20 MW (6.000 RT) with an output of total 28 GWh/year.

Key Figures

1. HFC phase down: >70%
2. Energy Efficiency: SSEER* = 6,5

*SSEER: Seasonal System Energy Efficiency Ratio

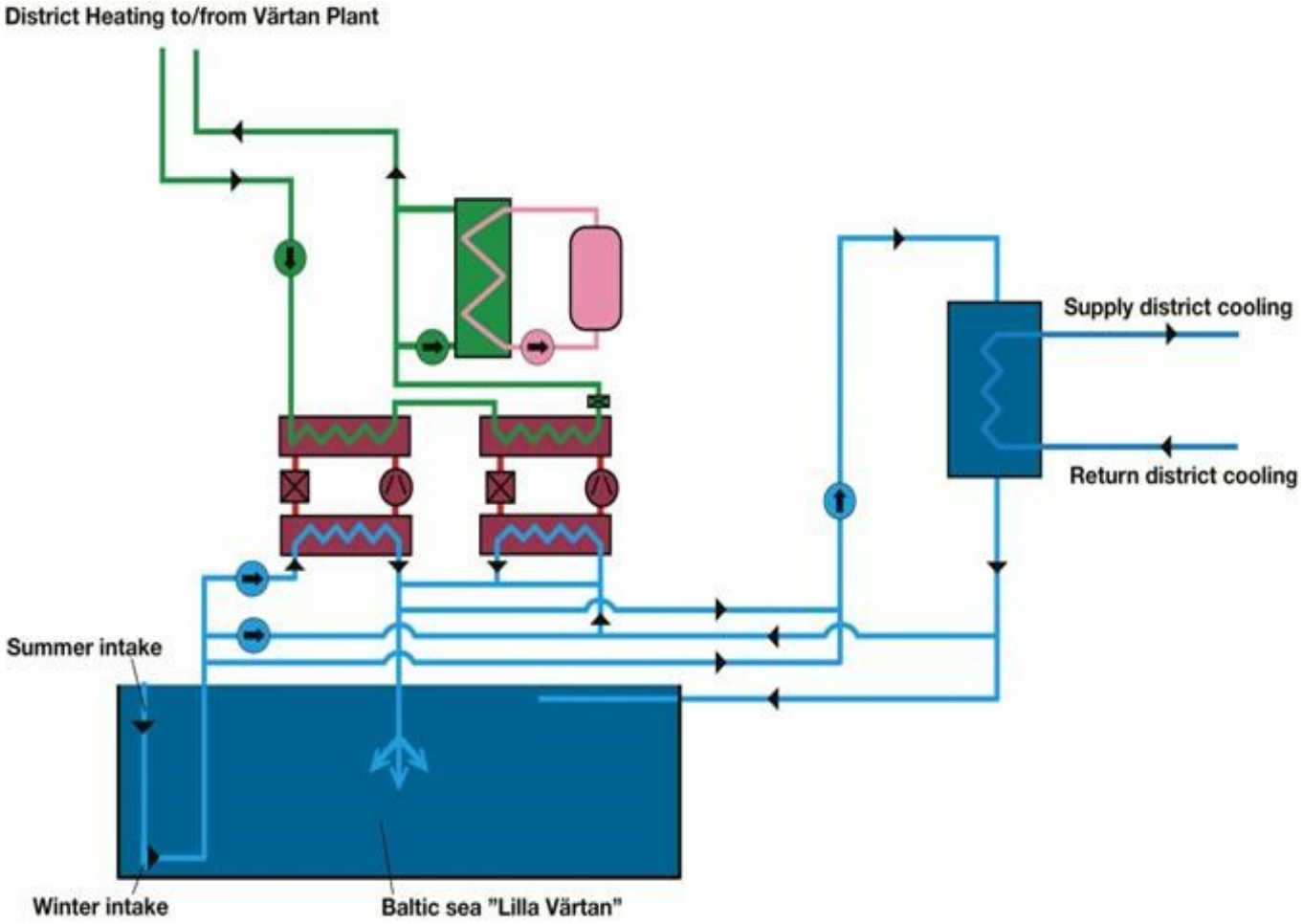
Energy Efficiency Multiples for District Cooling/SWAC systems

34 Swedish locations

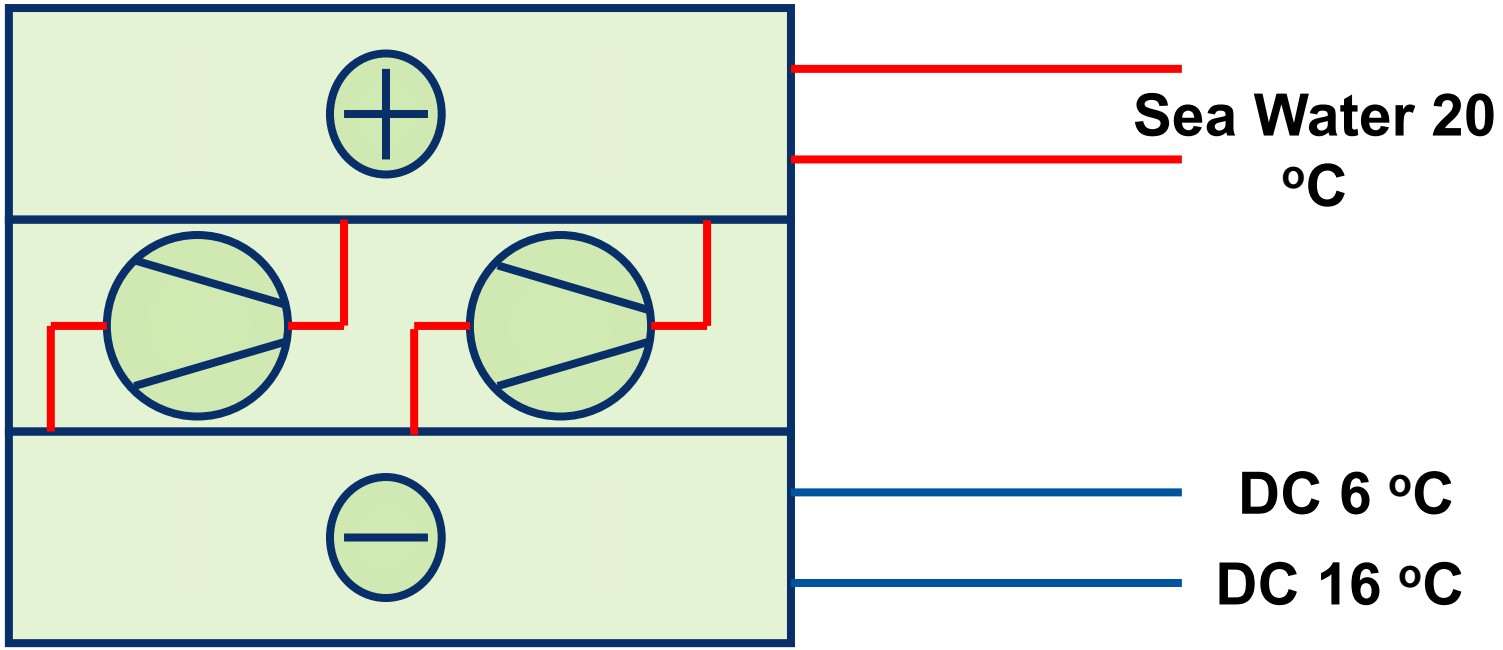
Project	Energy Efficiency multiple	Type
Reference	1	Conventional Chillers and Split systems
Lusail, Qatar	2	Centralised chillers
Västerås	3-4	MIX: heatpump cooling/absorption/lake free cooling
Gothenburg	4-5	MIX: chillers/absorption/sea water free cooling
Linköping	5-6	MIX: NH3 chillers/absorption/river free cooling
Stockholm, Sweden	5-6	MIX: heatpump cooling/sea water free cooling
	7-10	
Maldives	>10	SWAC (deep sea water cooling)

Source: Devcco 2017

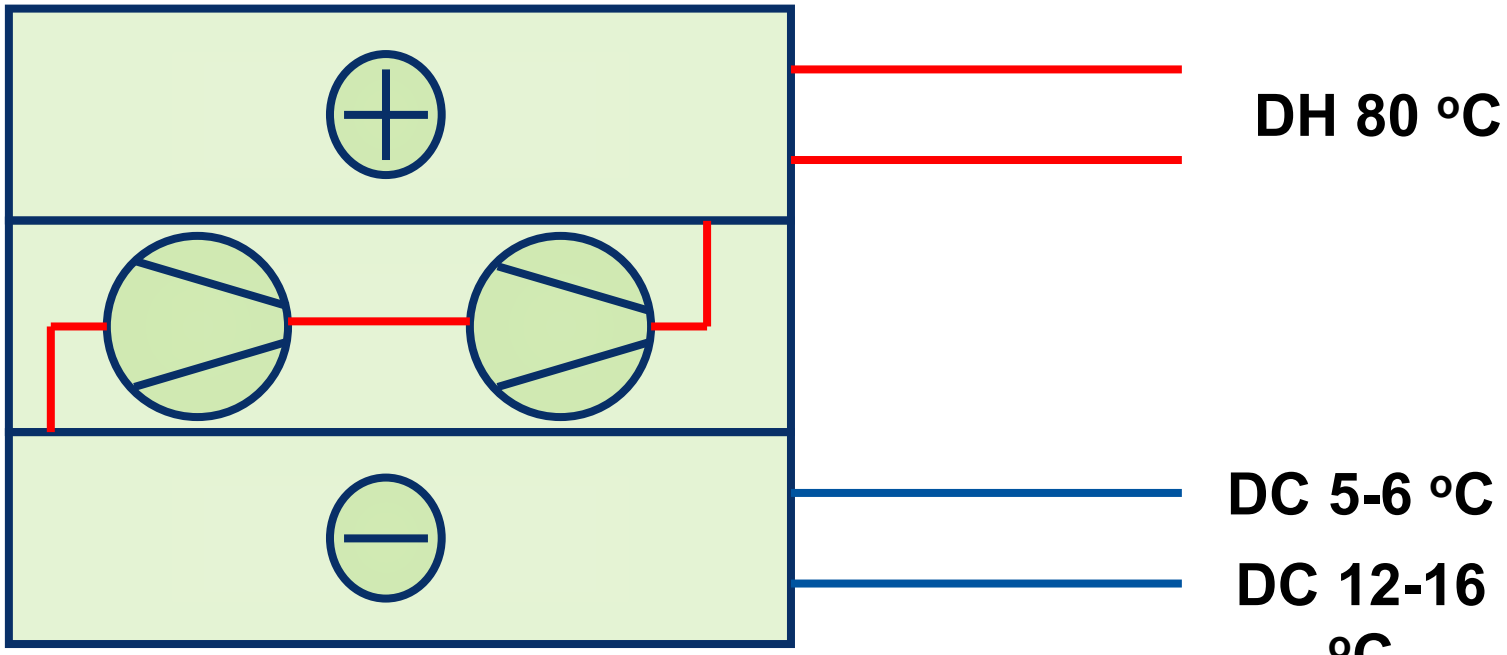
Technology - combined DH and DC production (Stockholm)



“Nimrod” Combined Heat pump and Chiller (C. Boberg, 2016)



“Nimrod” Combined Heat-pump and Chiller (C. Boberg, 2016)



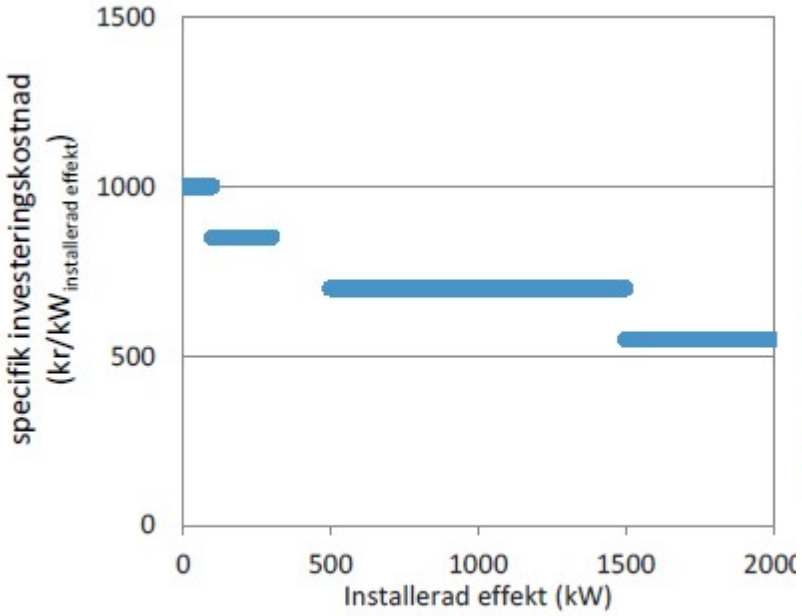
Sweden: Stockholm Heat Pumps – District Cooling Focus (Fortum, 2016)

- Fortum has 6 bigger heat pump plants in Stockholm, most of them are designed to produce heat and cooling simultaneously.

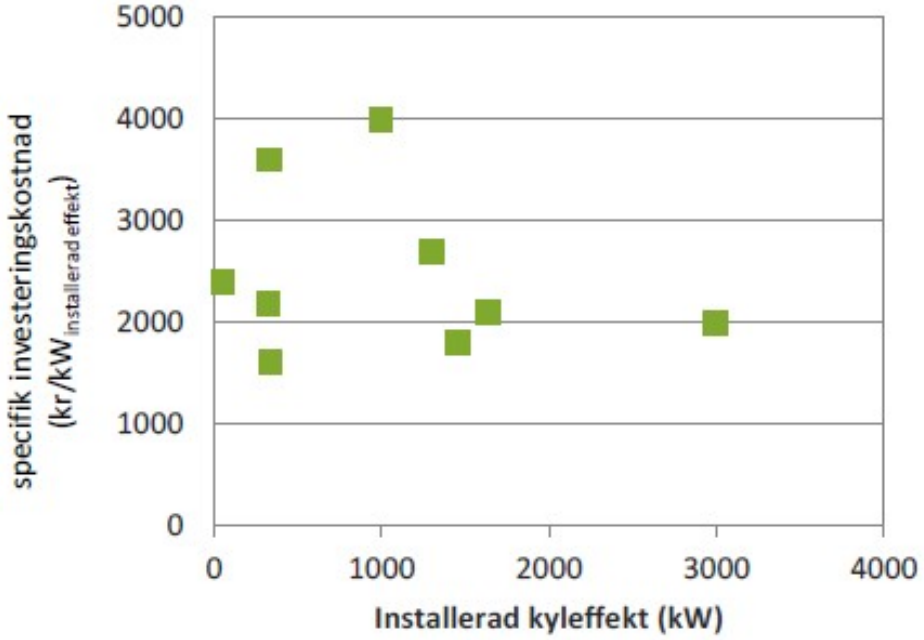
	Heating	Cooling
– Ropsten1 & 2	150 MW	0 MW
– Ropsten 3	100 MW	92 MW
– Nimrod	36 MW	40 MW
– Hammarby	230 MW	40 MW
– Kista/Akalla	25 MW	40 MW
– Vilunda	44 MW	10 MW

Sweden – Some Costs for small systems (Swedish Energy Market Inspectorate, 2013)

Specific investment costs, DC central, Designed for Primary and return temperature of 6 °C and 16 °C and 8 and 18 °C respectively in the Secondary loop.

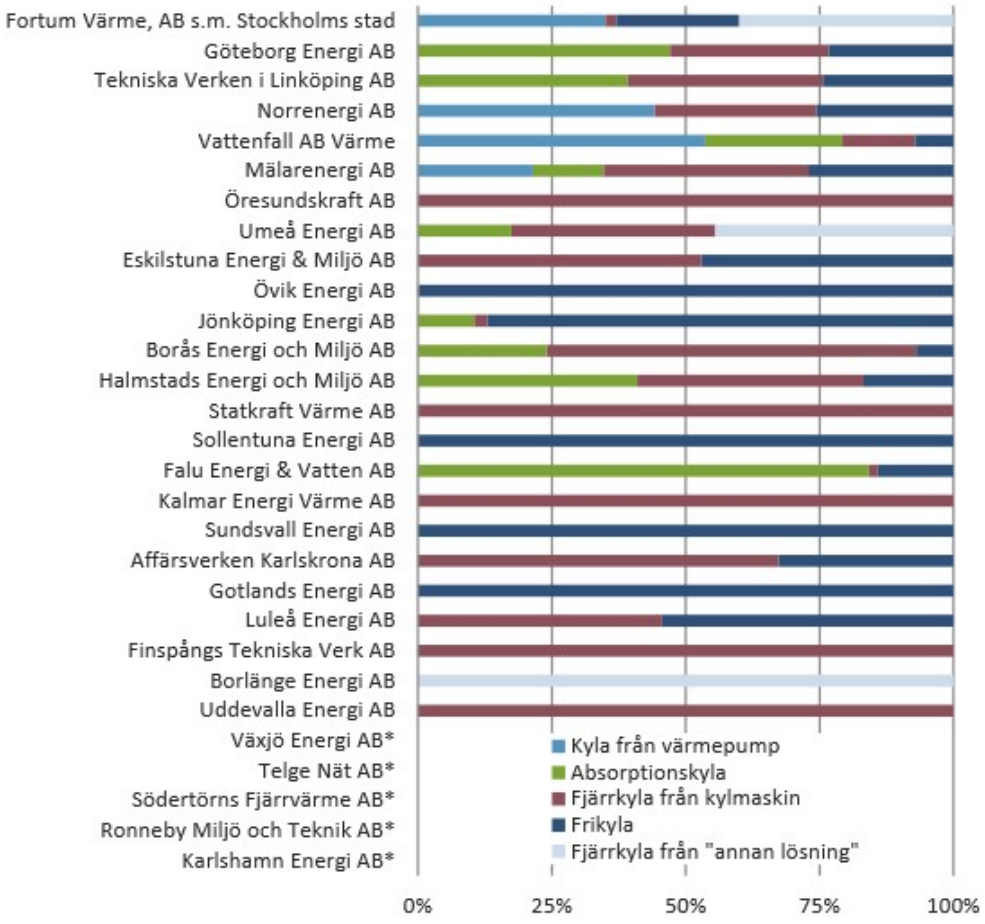


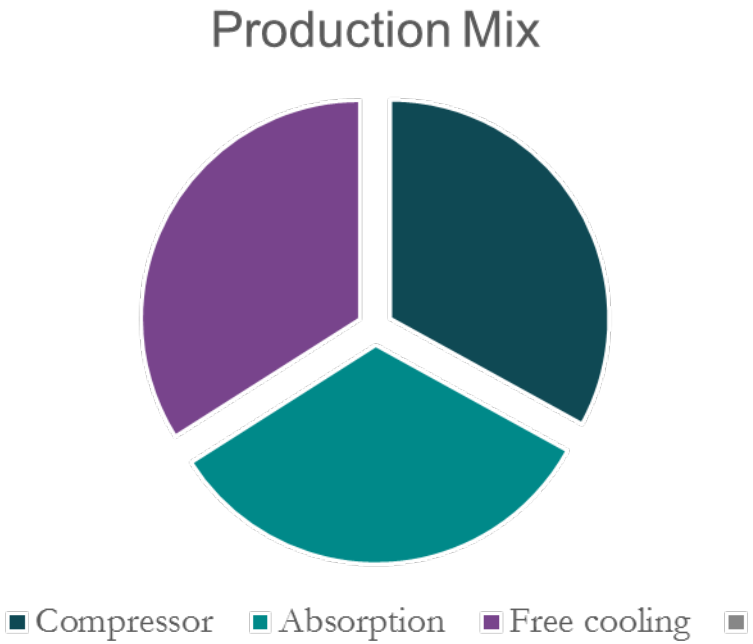
Specific investment costs for compressor based Stand Alone Systems (1-5 MW)



Källa: Profu 2013

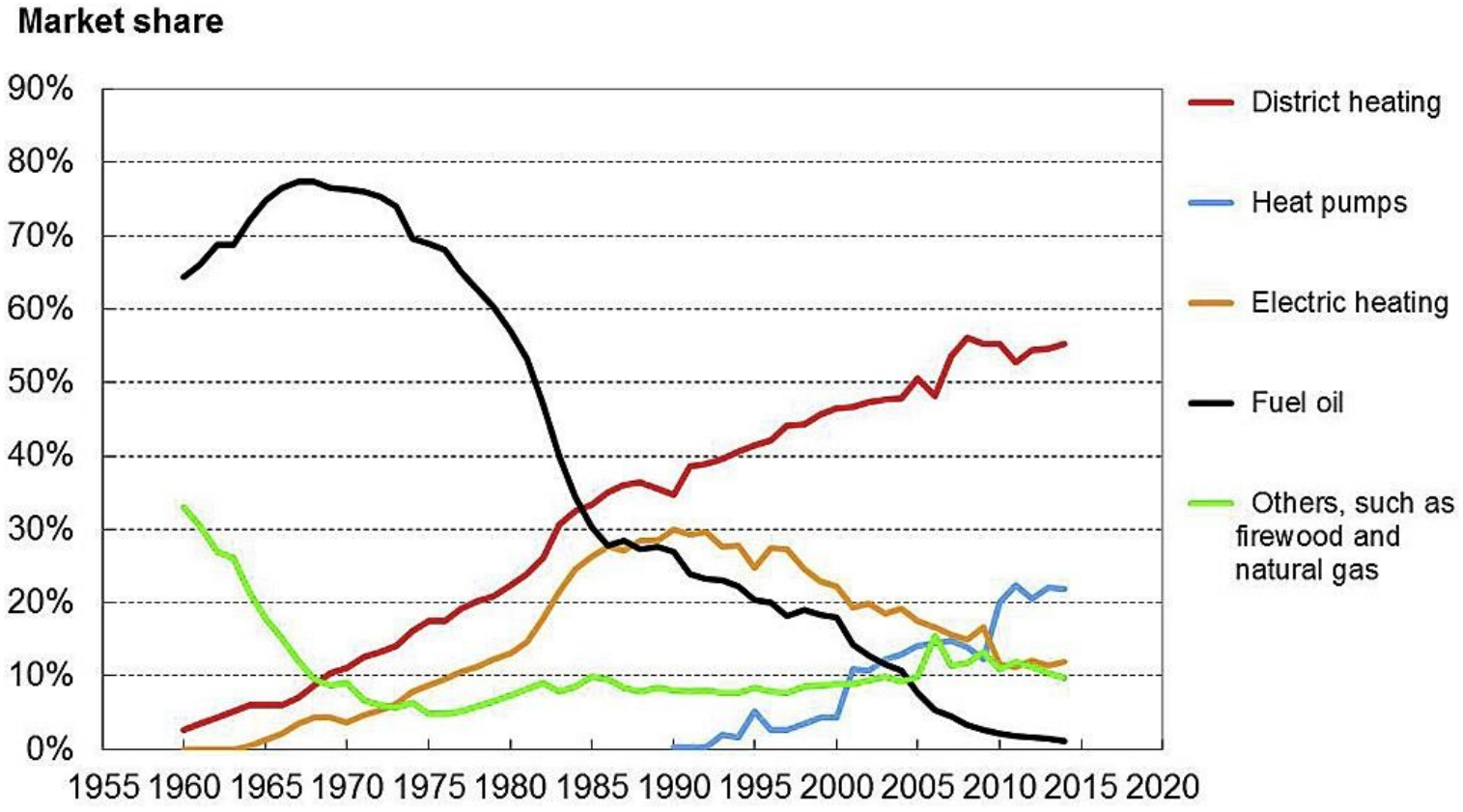
DC in Sweden





Source: Swedenergy

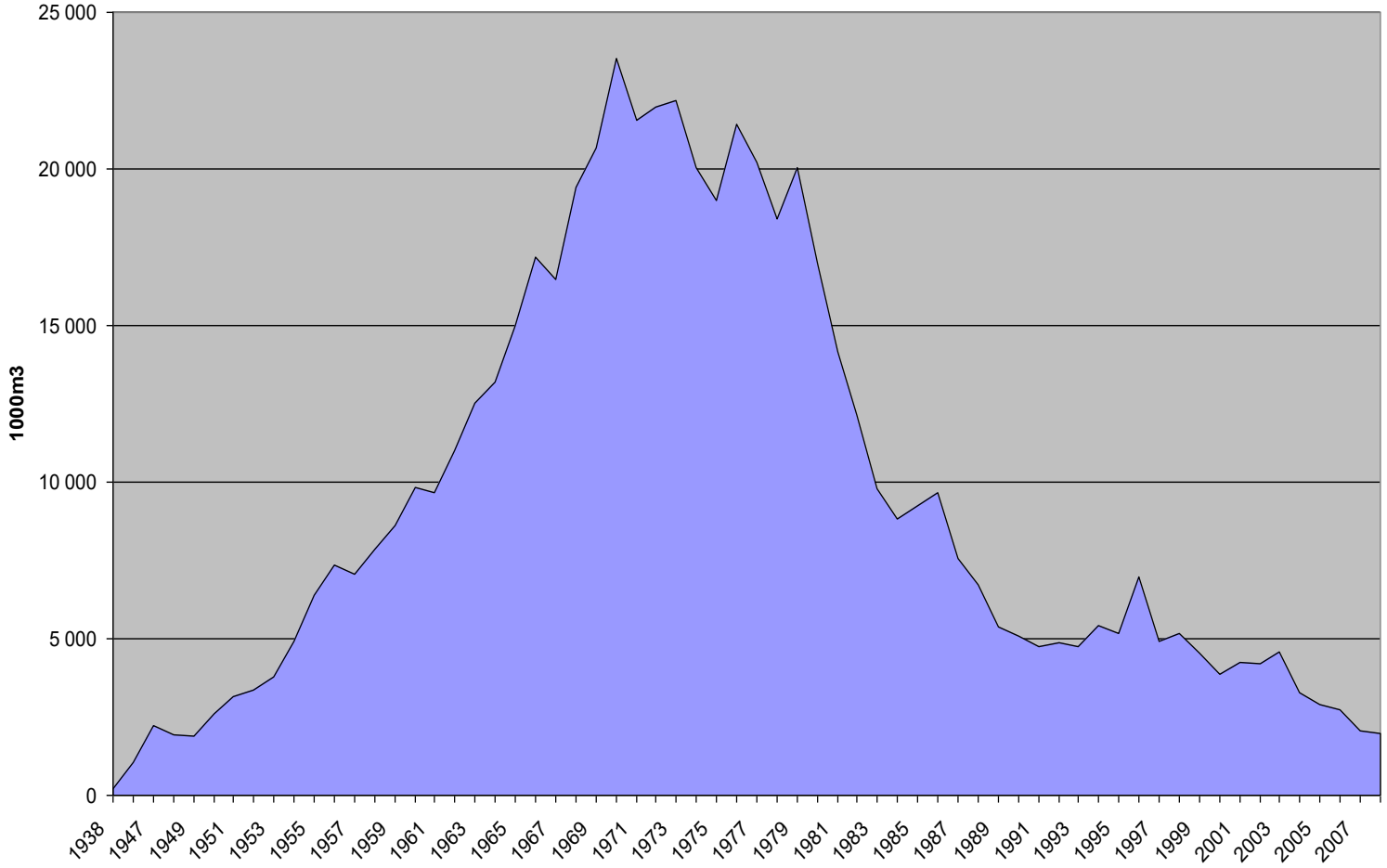
Sweden-Market Share Heating



Market shares for heat supply to residential and service sector buildings in Sweden between 1960 and 2014 with respect to heat delivered from various heat sources.

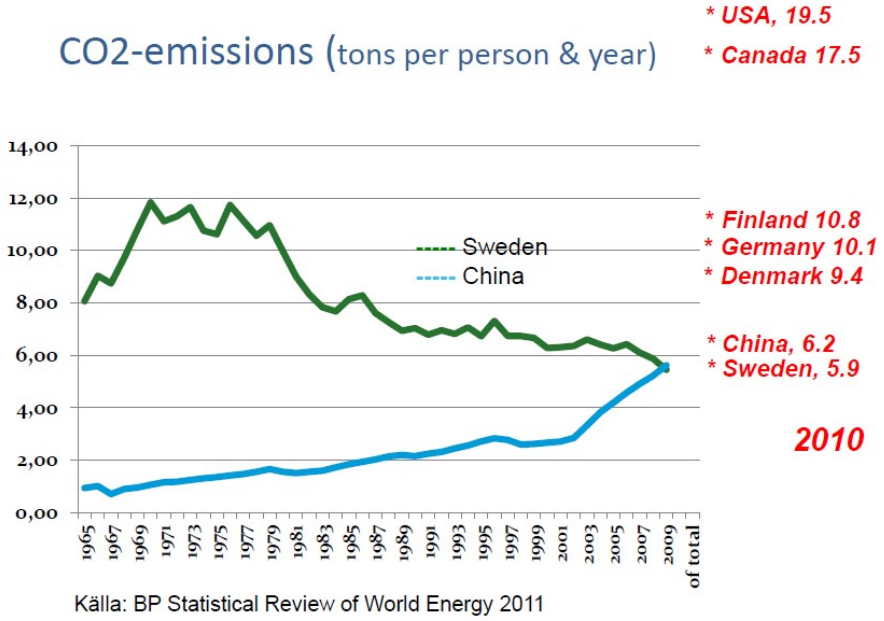
Source: Sven Werner 2017

SWEDEN: Reduction of the use of oil for heating purposes. 1938-2009 (Ref. Öfverholm, Energimyndigheten)



SWEDEN: Decoupling of GHG and GDP growth

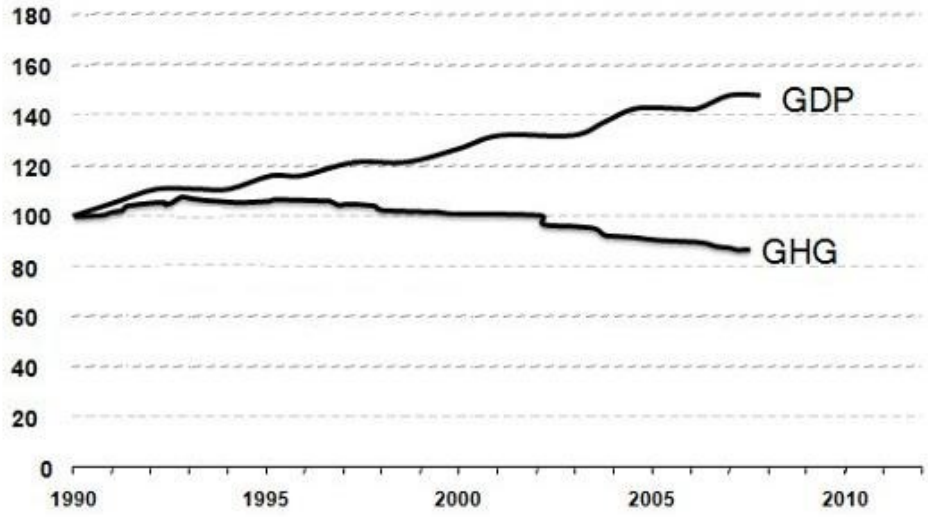
+ 50 GDP
- 20 GHG



Källa: BP Statistical Review of World Energy 2011

** USA, 19.5*
** Canada 17.5*
** Finland 10.8*
** Germany 10.1*
** Denmark 9.4*
** China, 6.2*
** Sweden, 5.9*

2010



Jaccard-Simon Fraser University

CONCLUSION: District Energy Systems Trends

- Goal 50% DH market share and 25% DC market share;
- Fast Development in the Nordic countries, DC can reach the Swedish market share of >25% within the next 5-10 years;
- Security of Supply - Less EU dependency of imported fuel;
- Governmental push for District Energy in the UK, French utility companies expanding in Europe and elsewhere;
- Absorption cooling in Swedish DC systems;
- Swedish DH suppliers in Sweden reaching beyond their physical grids - offering geo-energy and/or energy services (Eon & Vattenfall);

District Energy System – MP ozone-climate

- Kigali Amendment – Binding phase-down of HFC production and consumption by 85 percent by 2045 – 2050 globally;
- Reduction by 74-84 Gt CO2-e by 2050 a global temperature increase by up to 0.5 grad C by 2100;
- Energy efficiency (EE) gains in the context of the ODS-HFC measures under the MP has a potential to save 487-1137 GW. Equivalent to emissions of 80-100 Gt CO2-e . Thereby provide an additional opportunity to avoid a temperature increase by up to [0.5 degrees C];
- +0.5 + 0.5 ? ≤ 1◦C;

CONCLUSION: Pathways ozone - climate

- Efforts to achieve another up to 0.5 ºC through Energy Efficiency (EE) – however, requires a major cooperation effort between existing processes;
- EU's target to reduce CO2 emissions by 80 percent by 2050
- Main Existing legislation at hand:
  - ODS-F gases Regulations 1005/2009; 517/214; Directive 2006/40
  - Legislation w.r.t EE, Directive 2012/27/EU on Energy Efficiency
  - Directive 2009/125/EC on Eco-design;
  - Directive 2010/31/EU on Energy Performance of Buildings;
  - the EU's Industrial Emission Directive 2010/75/EU regarding best available technology and practice (BAT-BEP) etc. (Production; Waste to Energy));
- Model Design, financing, investment, implementation, regulation of a cost effective goods-services procurement;
- Leverage certification, pioneering BREEAM, and LEED, local certification.