Swedish experiences with heat pumps in district heating systems

Background

Extent and history

Type of heat pumps

Heat sources

Phase out of CFC/HCFC

How to reduce leakage

Experiences of availability, M&O, performance

Life span expectancy

Economy

Discussion & questions

A sort personal presentation

- Some 35 years in energy sector
- Heat pump experience since 1982
- Nowadays mostly district cooling
- Started in a public utility – now a consultant at ÅF

Reasons for the heat pumps in DH

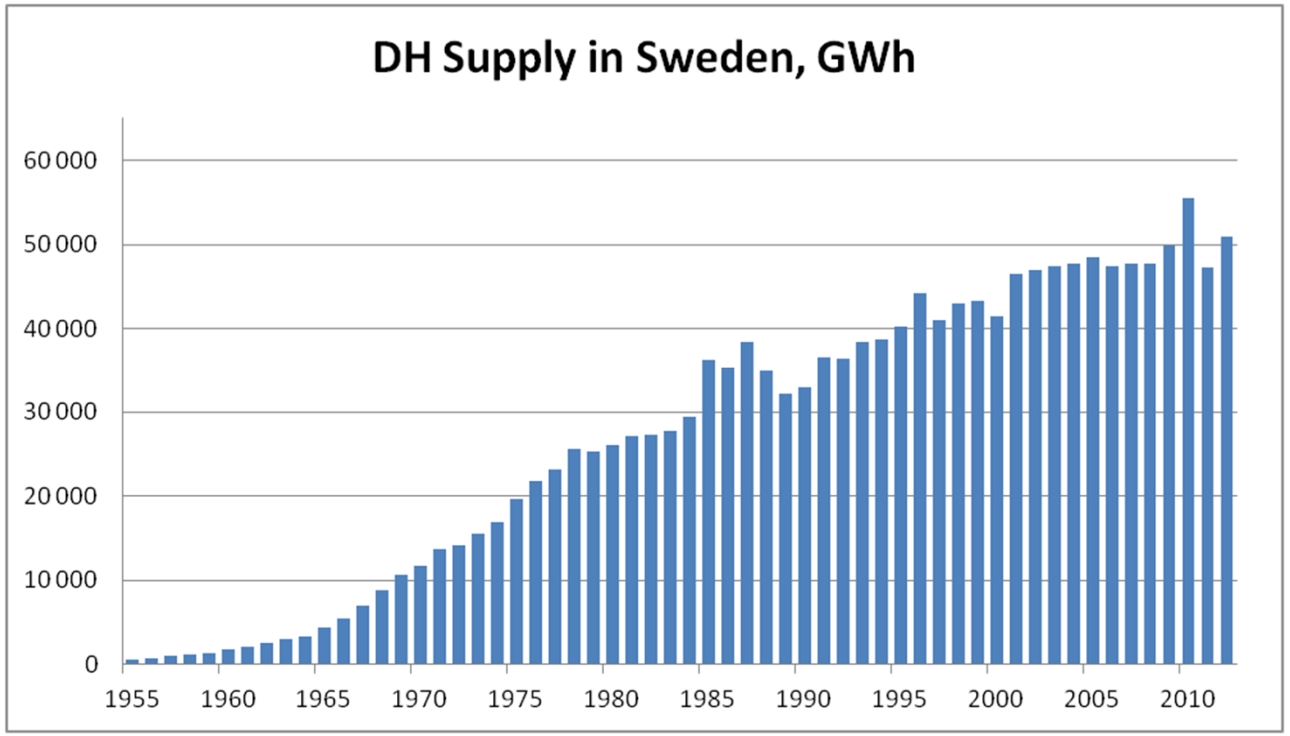
- A high dependance on oil in the 70s, 80s
- Low electricity prices (hydro, nuclear, reduced power exchange with non-Nordic countries)
- To improve local environment
- The technology became more commercial
- Access to heat sources and power grid
- (the “freon”-problem was not fully known)

Physical preconditions for HPs in DH nets

- “Short” distance between heat source and DH net
- A well known heat source
- Access to power grid, quite close
- Access to heating plants for final temperature and back-up
- Reasonably low DH temperatures

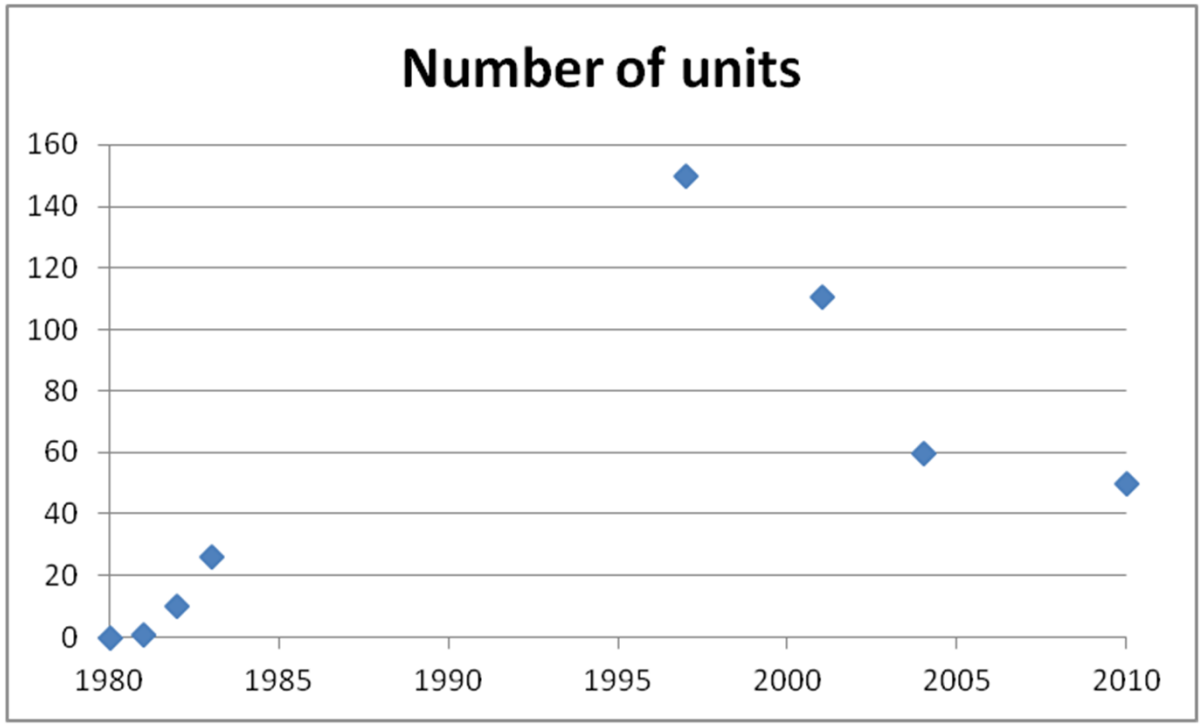
Textbox for image text, naming sources etc.

DH expansion in Sweden

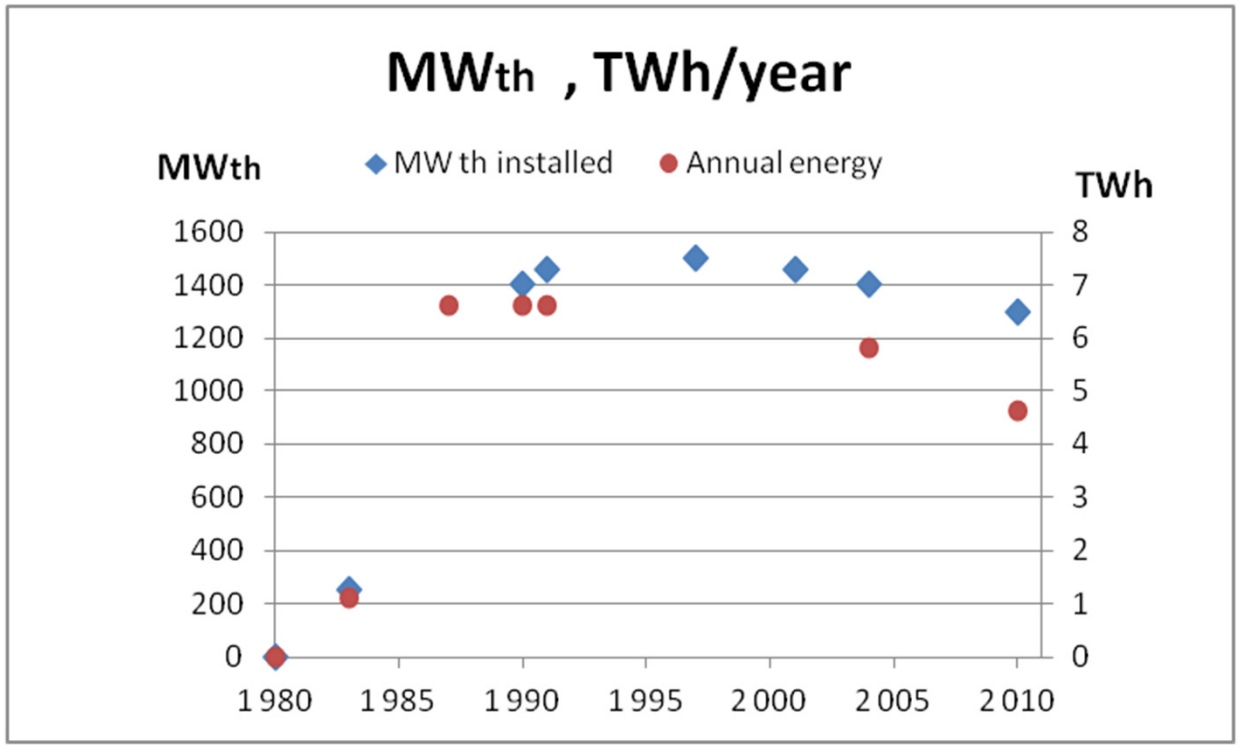


source: Svensk Fjärrvärme

Heat pumps in operation for DH



Heat pump statistics



Type of heat pumps

Piston compressors ; 0.1—2 MWth (multiple compressors)

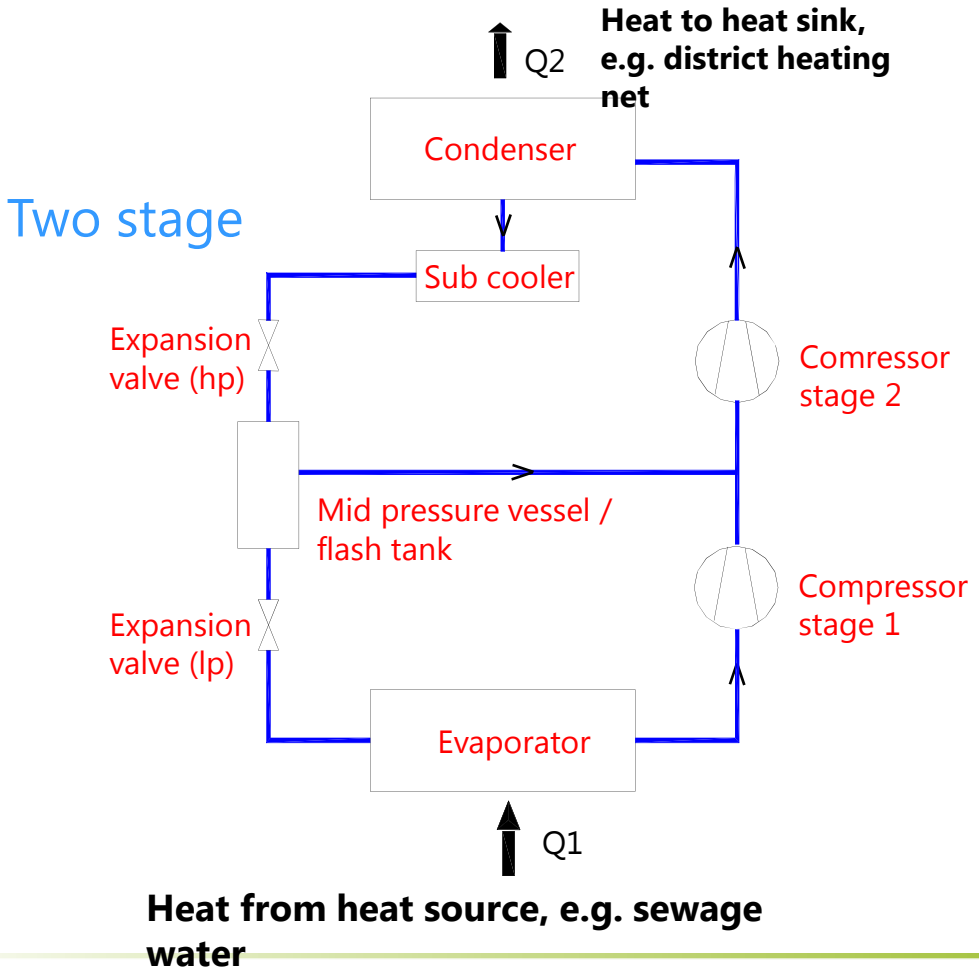
Screw compressors; 0.5 – 3 MWth

Turbo compressors; 2- 45 MWth (mostly two stages)

Turbo HP are clearly dominating, almost totally today

None of those use natural refrigerants, all use electric motors, constant speed

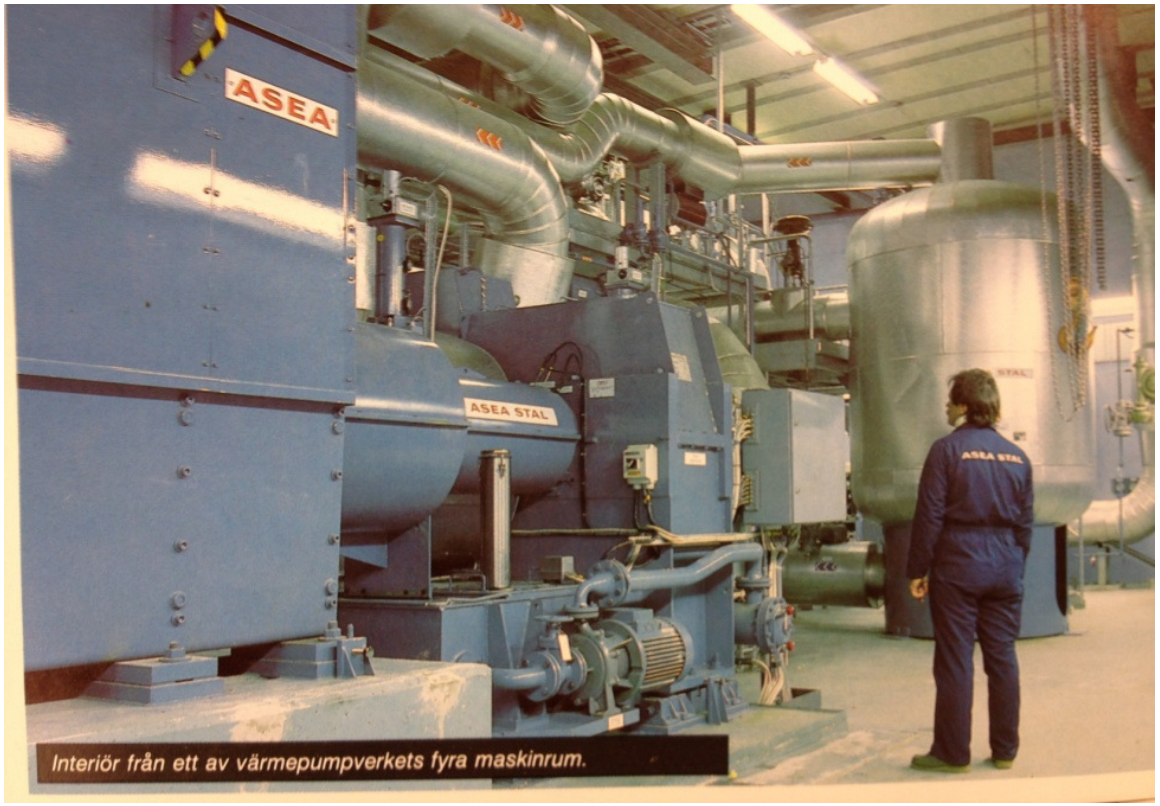
Typical turbo heat pump



Example turbo heat pump (1)

Friotherm, 30 MW , Ropsten HP Plant

Example turbo heat pump (2)



Asea Stal (now Siemens), 25 MW , Hammarby HP Plant

Heat sources

(listed approx. in abundance)

- Treated sewage water
- Sea / brackish water (with open type evaporator)
- Waste heat from industrial process
- District cooling
- Lakes (with open type evaporator)
- Flue gas condensation
- Ground water
- Geothermal

Phase out of CFC / HCFC

Legal restrictions in Sweden concerning existing heat pump

- Ban on filling of CFC in 1998
- Ban on use of CFC in 2000
- Ban on filling of HCFC in 2002
- Ban on use of HCFC in 2015

- Note: most heat pumps used CFC12

Textbox for image text, naming sources etc.

Phase out of CFC / HCFC

Test of refrigerant, extent of use

- CFC 12 and CFC500 were replaced by HFC, all turbo to HFC 134a
- First test on large turbo compressor in 1991
- Status in 1997:

	Number	Refr. tons
R 12	47	186
R 22	21	328
R 134a	76	573
R 500	3	52
Absorption	4	0
Total	151	1139

Phase out of CFC / HCFC

Status today

- All CFC is replaced
- Some large HP with R22 will be converted before 2015
- Some plants have been shut down

- Some problems with moisture and choice of oil, but in total conversions has functioned as planned.
- Up to 25% reduction in capacity when R22 is replaced with HFC134a !

Reducing leakage of refrigerant

The major problem / challenge

Multi stage turbo compressors have a large refrigerant filling , approx.

1 ton / MWth

Annual leakage was originally high, 5 % and higher..

Much work was to be done to reduce leakage:

- More welded systems
- Continuous monitoring leakage to air and water
- Better shaft sealing
- Education, policy
- Today leakage is probably 1-2 % as average
- Advice for new machines: consider refrigerants as hazardous!
- Details in report 609 from Värmeforsk, 1997 (in Swedish)

Experiences from operation

Availibility, break-downs

- In general high availability (97-98%), but some break-downs have caused long standstill;

i. Much problem with shaft sealing (leakage !) and high temperature O-rings

ii. Corrosion on water-side in heat exchangers

iii. Vibration

iv. Impeller crash

v. etc

- Advice: large revisions at least every 3 years, skilled personnel

Textbox for image text, naming sources etc.

Experiences from operation

Capacity, COP

- As a rule contracted performance have been met

  Advice: measure on refrigerant side + electric power

- COP has been 3-3.5 , up to 4 (exkl. pumps)
- Carnot factor approx. 0.6 (up to 0.65)

Experiences from operation

Maintenance

- Advice: large revisions at least every 3 years

(1,5 – 2 MSEK for a 25 MW heat pump)

- Total cost is hard to get but “best guess” is 20-30 SEK/MWh
- Annual analysis of oil and refrigerant !

Operation

- Operators in a central control room is ok, but not far away.
- Daily rounds for inspections
- Continuous operation is preferred. Do not start more often than once a day.

Life expectancy

Turbo heat pumps are normally designed for 20-25 years.

But can by replacing parts be prolonged to much more.

Critical objects:

- Compressor motor
- Heat exchanger tubes
- Gear, coupling
- Monitoring system /computer
- Guide vanes, impellers

- Every start-up shortens life-span !

What about economy?

It has not been followed up for the DH society

- It has been a success in general. HPs were planned to pay-off in short time (3-5 years) and has been in operation for 25 years..., however with lower income each year.
- Investment today is approx. 3500-4000 SEK / kWth for the heat pump itself, total project cost is much higher.
- Without fossil fuel taxes it would have been another picture

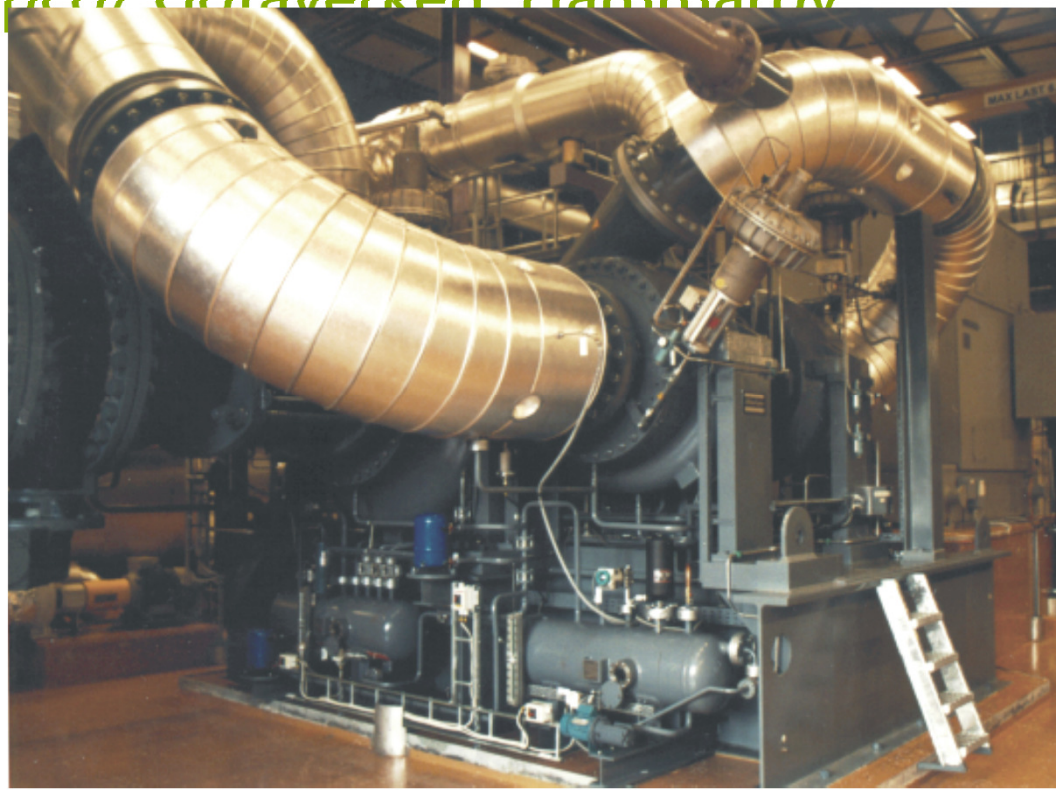
Heat pumps –larger with time

Loudden 1982, 2*2,5MW

Ropsten 3 , 1986-87, 4*25MW

45MW 3-stage HP

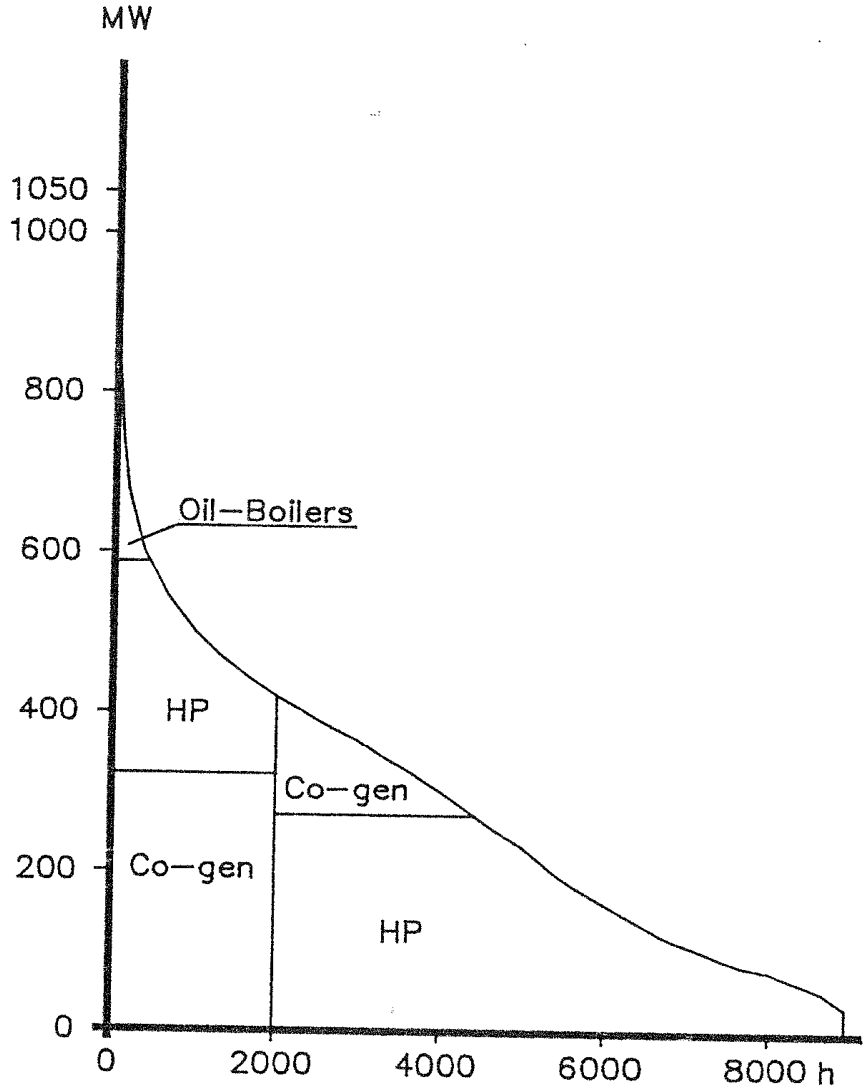
Atlas Copco/ Götaverken, Hammarby



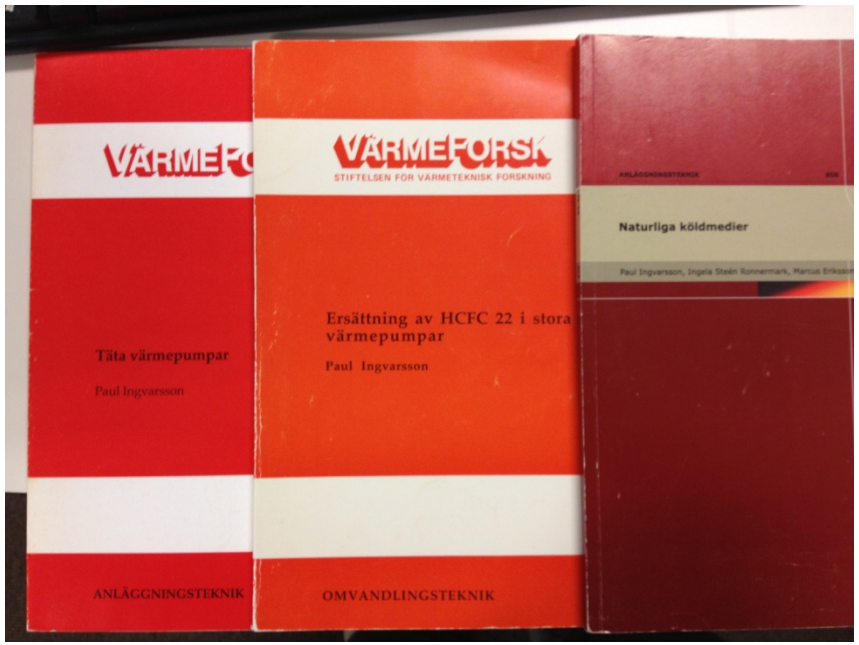
Local environmental change
Emissions in Stockholm, 1980s

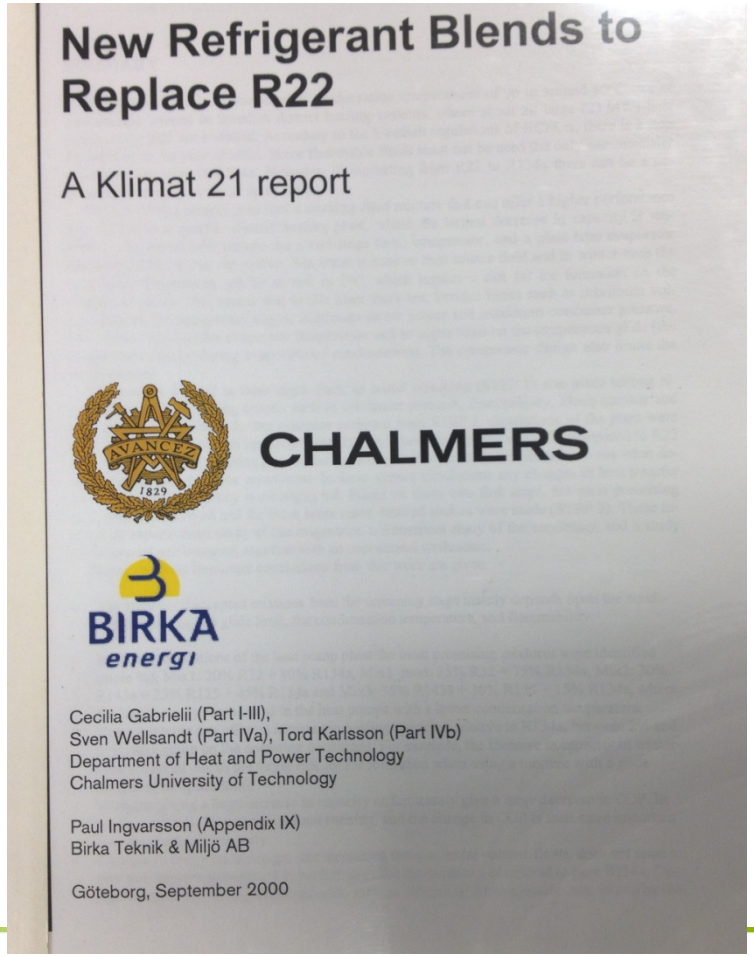
	1980	1989
Sulphur, tons	2670	400
NO_x, tons	1820	230
Particulates, tons	100	10

During this period, the district heating load has increased somewhat. However, part of the reduction in emission is due to the reduction in the electrical energy generated.


MW
1050
1000
800
600
400
200
0
Oil—Boilers
HP
Co—gen
Co—gen
HP
0
2000
4000
6000
8000 h

Some public reports





Contact information

- **Paul Ingvarsson**
  ÅF division Industry
  Besöksadress: Frösundaleden 2A | Postadress: 169 99 Stockholm
  Direkt: +46 (0)10 505 14 76 | Mobil: + 46 (0)70 683 07 51 | Fax 010-505 00 10
- e-post: paul.ingvarsson@afconsult.com http://www.afconsult.com