BEST PRACTICES IN HEAT PUMP APPLICATION IN NORWAY

USMAN DAR
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- District heating and geothermal in Norway
- Status and challenges
- Best practices – selected examples
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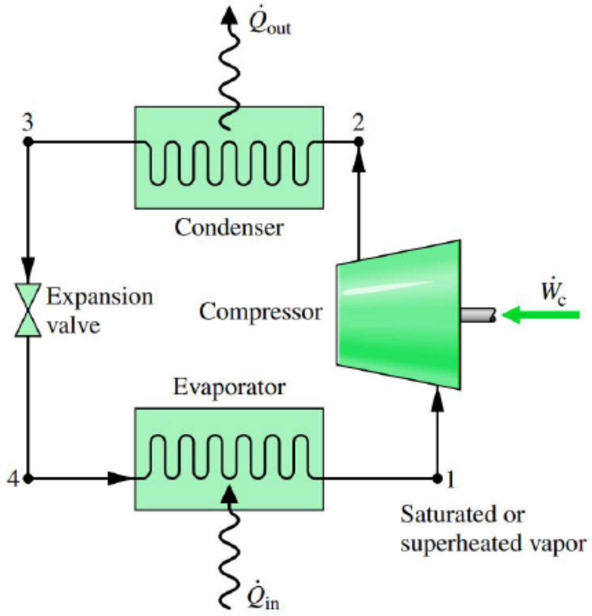
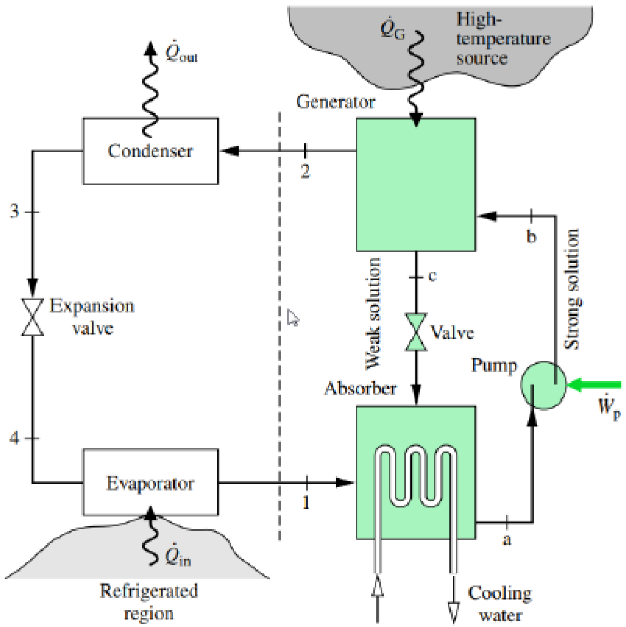
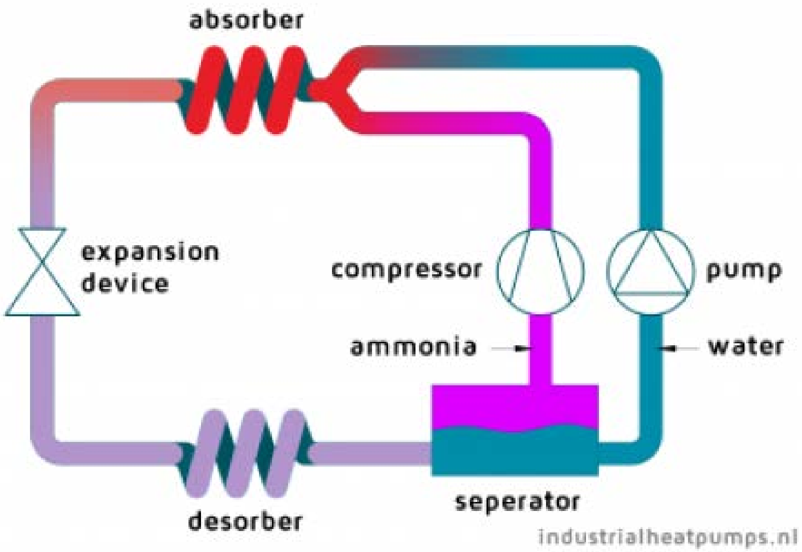
Heat Pump

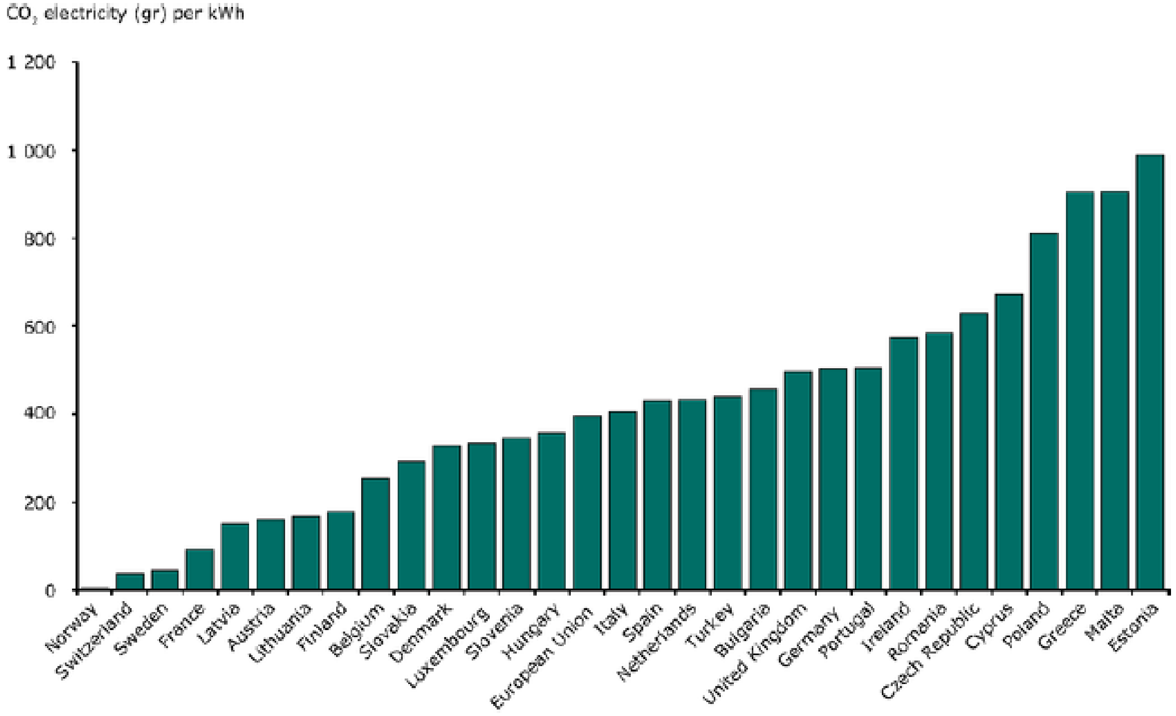
- «a device which enables heat to flow from a colder heat source to warmer heat source»
- Three type of technologies
  - Vapor compressor cycle (VCC) heat pump
  - Vapor absorpsion heat pump
  - Hybrid heat pump (integration of above two)







Choice of heat pump



Natural gas = 277 gr/kWh (EN15306)
Heat with 70% eff = 395 gr/kWh

$$TEWI = \underbrace{(n \times L \times m \times GWP)}_{\text{direct emissions due to leakage}} + \underbrace{(n \times E_{annual} \times EF)}_{\text{Indirect emissions related to electricity generation}} + \underbrace{(L_{demolition} \times m \times GWP)}_{\text{direct emissions at demolition}}$$

Country	kg CO_2/kWh$_{elec}$	TEWI [kg CO_2]	direct emissions due to leakage [%]	indirect emissions [%]	direct emissions at demolition [%]
Norway	0,005	1 839	44,9	32,6	22,5
Sweden	0,04	6 039	13,7	79,5	6,8
Switzerland	0,08	10 839	7,6	88,6	3,8
France	0,09	12 039	6,9	89,7	3,4
Austria	0,22	27 639	3,0	95,5	1,5
Finland	0,24	30 039	2,8	95,9	1,4
Belgium	0,29	36 039	2,3	96,6	1,1
European Average	0,47	57 639	1,4	97,8	0,7
Spain	0,48	58 839	1,4	97,9	0,7
Italy	0,59	72 039	1,1	98,3	0,6
Germany	0,61	74 439	1,1	98,3	0,6
Turkey	0,62	75 639	1,1	98,4	0,5
Netherlands	0,64	78 039	1,1	98,4	0,5
Portugal	0,64	78 039	1,1	98,4	0,5
U.K.	0,64	78 039	1,1	98,4	0,5
Ireland	0,7	85 239	1,0	98,5	0,5
Denmark	0,84	102 039	0,8	98,8	0,4
Greece	0,98	118 839	0,7	99,0	0,3
Luxenbourg	1,08	130 839	0,6	99,1	0,3

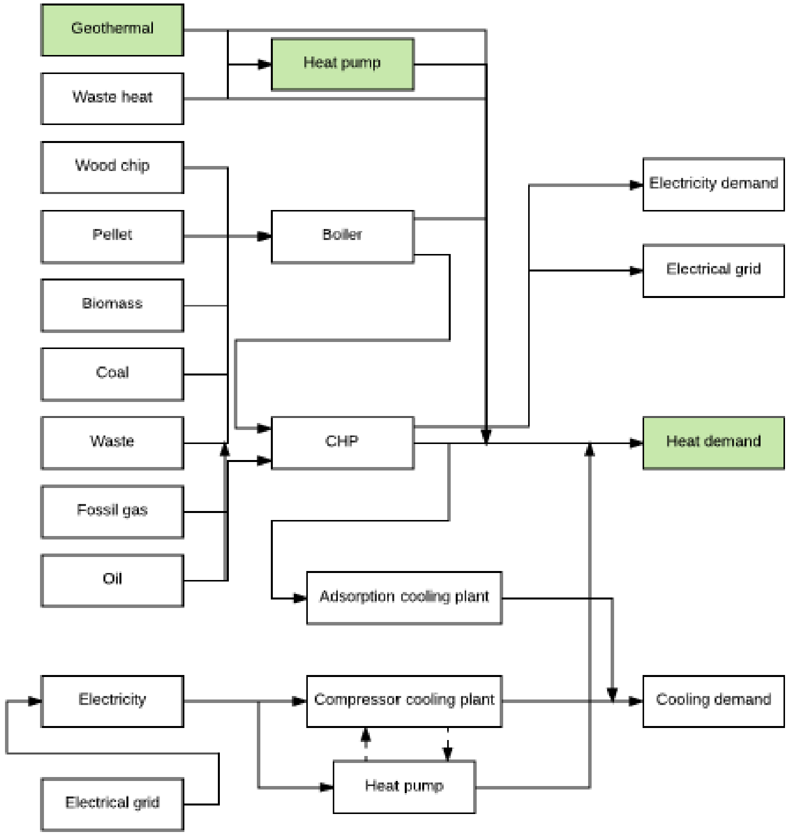
Data for an example. For further info, se report on « Heat pumps technology and environmental impact»

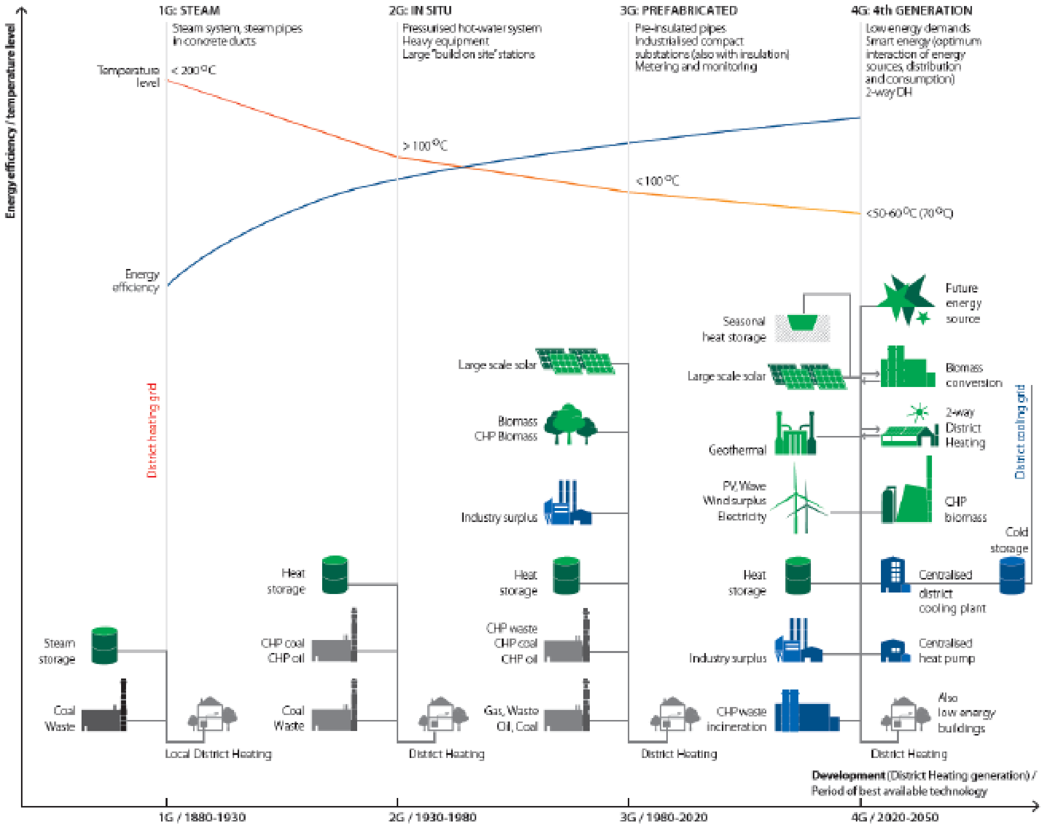
Heat sources

Heat source	Tempatures ved DOT	Temp.variation over heating season
Seawater	3-8˚C	4-5˚C
Ground water	4-8˚C	Little
Fresh water	0-4˚C	5-10˚C
Ground heat	0˚C	Little
Outdoor air	-50 til -10˚C	20-50˚C
Exhaust ventilation air	15-25˚C	Little
Waste water	5-10˚C	4-8˚C
Waste heat industry	>10˚C	Little

Availability and cost are often decisive factors in choice of the heat source

District heating





Status in Norway

- About 1600 km district heating and 75 km district cooling network as per 2013.

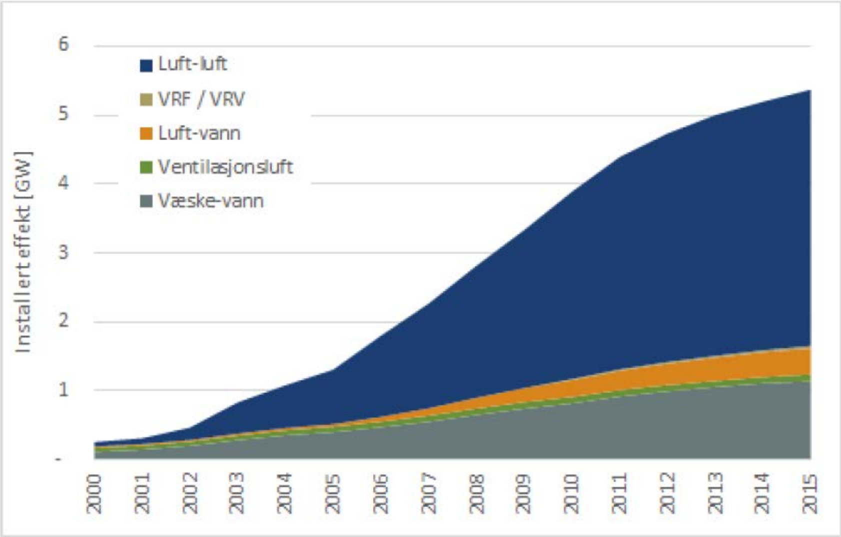
- Most of district heating uses heat from burning of waste
- And use of biomass burning (wood chip)
- and heat pump at small scale (neighbourhood scale application)

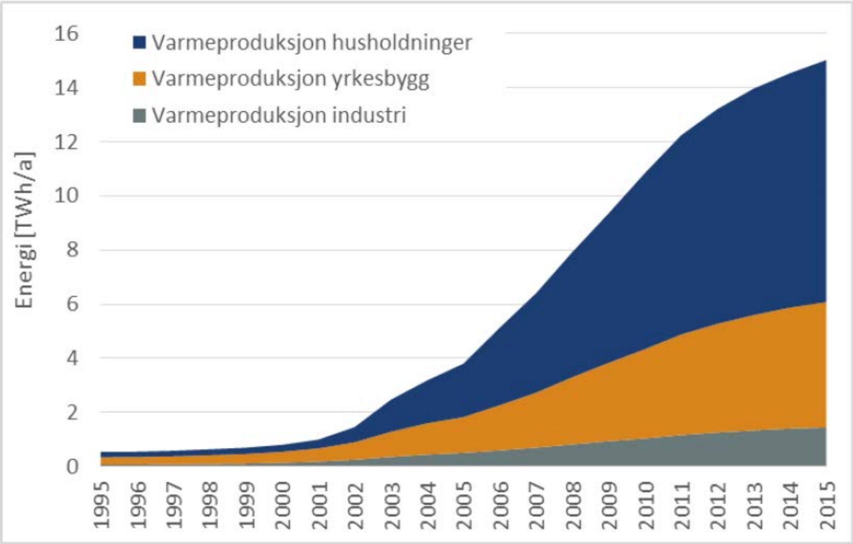
- But we also have world largest high temperature heat pump (14,3 MW) in Drammen DHN

- Every building is obliged to connect to district heating but not obliged to use it.
- In practice, district heating is priced 5 -10 øre/kWh less than electricity price
- Economical to use heat pump !
- Therefore, district heating is often seen as competitor for heat pump at level of individual buildings

- Application of heat pump at small scale

Small scale heat pumps in Norway





(total hydro capacity in norway is 31 GW)

Source: NOVAP/NVE

Heat pump and geothermal energy in Norway

- Application of geothermal heat pump mostly in connection with non-residential buildings
- Shallow geothermal lies at temperatures around 3 – 8°C
- Most of non-residential buildings need both heating and cooling
- Economical to use heat pump that runs all year to deliver both heating and cooling !

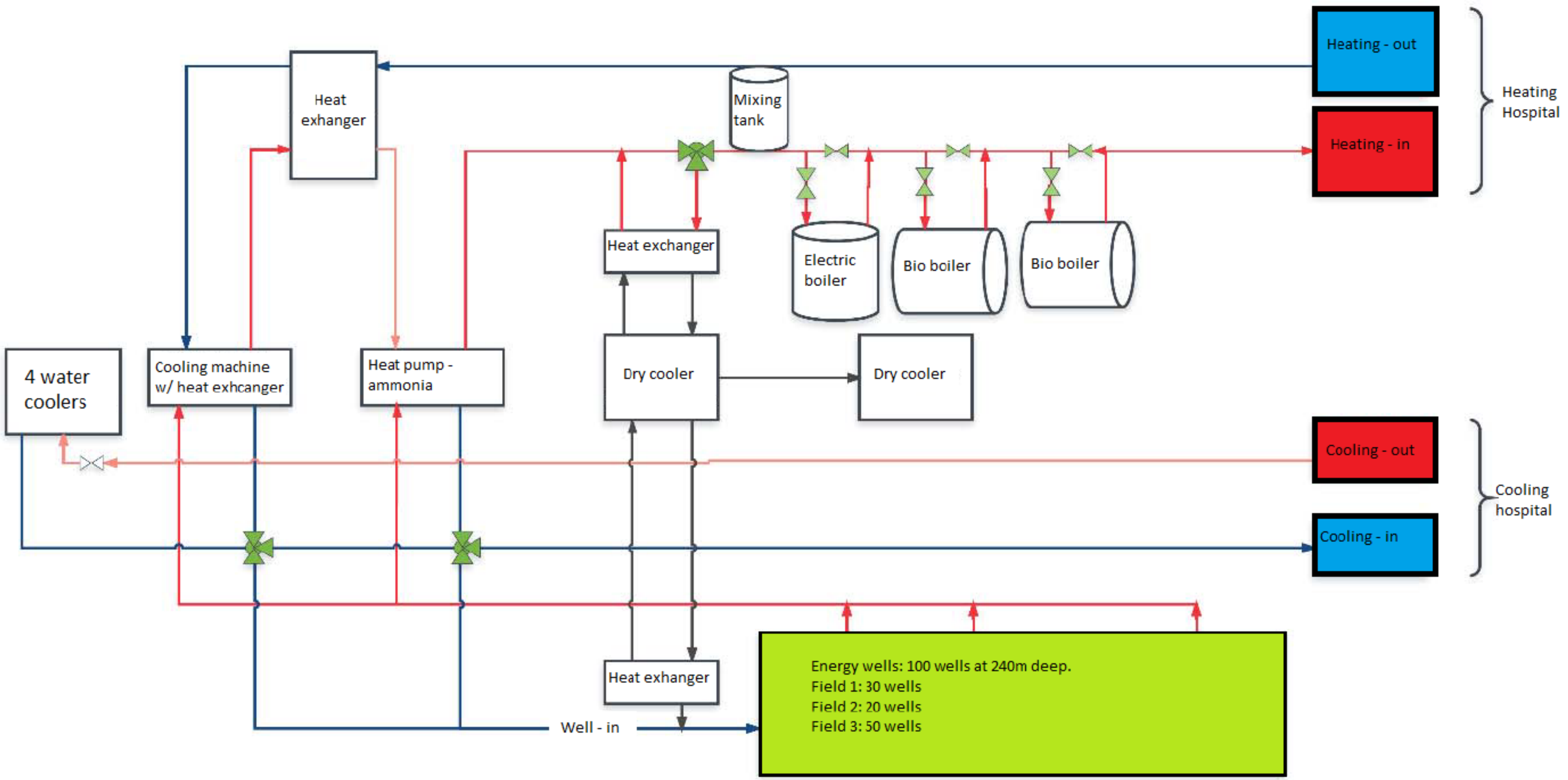
- Several desentralized heating and cooling plants from 100s KW to a couple of MW scale

Best practices: Kalnes heating and cooling plant (1)

- Østfold hospital – 85 000 m² heated area
- 8 GWh heating needs , 4,5 MW design heat load
- 4,5 GWh cooling needs,

Unit	Heating capacity max/min (kW)	Cooling capacity (kW)	Max el use (kW)	Working medium
Heat pump 1	1249/125*	844	405	R717
Cooling machine 2	1030/258	973	390	R134a
Electric boiler	3000/100	-	3000	-
Cooling machine x4	-	1052	340	R134a
Oil boiler x2	3000/300	-	-	-
Condenser x2	-	1017**	12	-

Best practices: Kalnes heating and cooling plant (2)



Best practices: Kalnes heating and cooling plant (3)

Parameters	Value	Unit	Comment
Thermal conductivity	3.38	W/m*K (k)	(Futurum Energi AS 2011)
Number of shallow geothermal boreholes	100		
Depth of well	240	m	
Avg. temp. in boreholes	8	^0C	(Futurum Energi AS 2011)
Max. temp. in boreholes	25	^0C	
Area geothermal park	4200	m^2	7 m between boreholes
Volume geothermal park	1050000	m^3	
Volumetric heat capacity granite	666	Wh/ m^3*K	

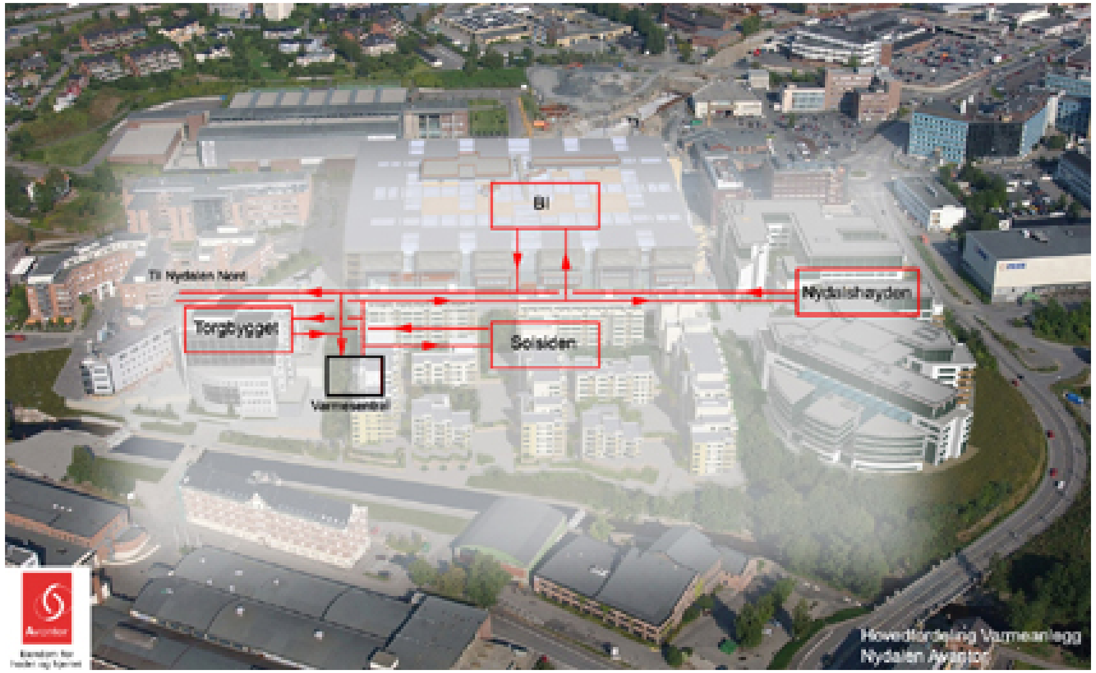
Best practices: Nydale heating and cooling plant (1)

- District heating network using heat pump
- Plant with heat pump delivery both heating and cooling
- 170 000 m² heated area
- 135 000 m² area for cooling

(Radisson SAS Hotell, University campus, Housing and commercial buildings)

- Older heat pump using R134a
- Newer heat pump with NH3
- Made fasing out av fossil oil-based boilers possible

- Governmental support was an important trigger
- Consideration of F-gas regulation and increasing operational cost for CFC



Best practices: Nydale heating and cooling plant (2)

- Design heating load = 6 MW
- Design cooling load = 9,5 MW
- Peak load using el and oil boiler.

Geothermal as energy source

- Vertical 180 boreholes
- Each 200 m deep with 7 m spacing
- U-pipe with PEM (dia 40 mm)

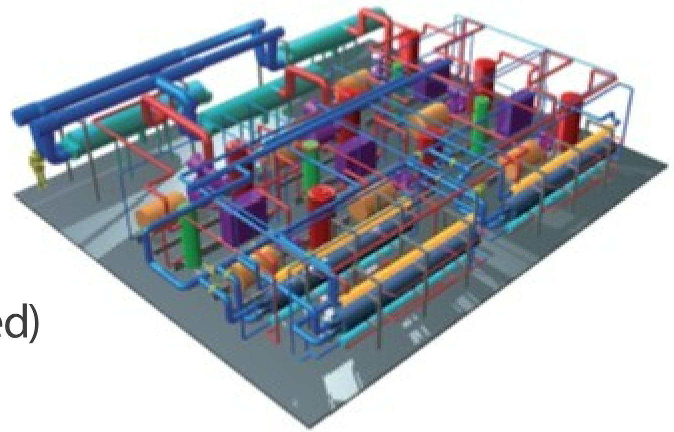
- Heat pump is planned to cover 80% of heating needs
- Fricooling from borehole with use of heat pump to cover peak cooling loads

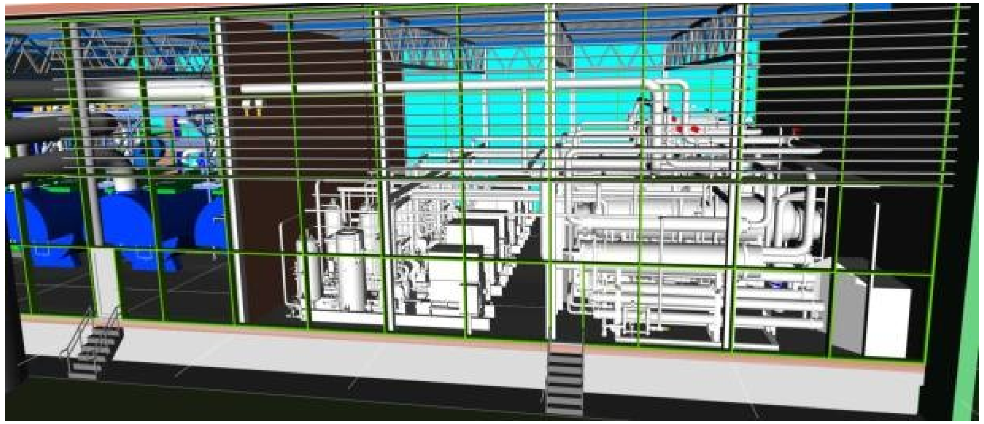
Best practices: Drammen district heating (1)

- NH3 Heat pump 14,3 MW
- Backup load (peak)   30 MW

- Seawater as heat source (8°C)
- DHN supply temperature (outdoor temp. compensated)
  – 120°C winter
  – 75°C summer
  – Heat demand during summer 2 MW
  – Return temperature at 60-65°C

- Peak load boiler operating at constant flow with mixing valve

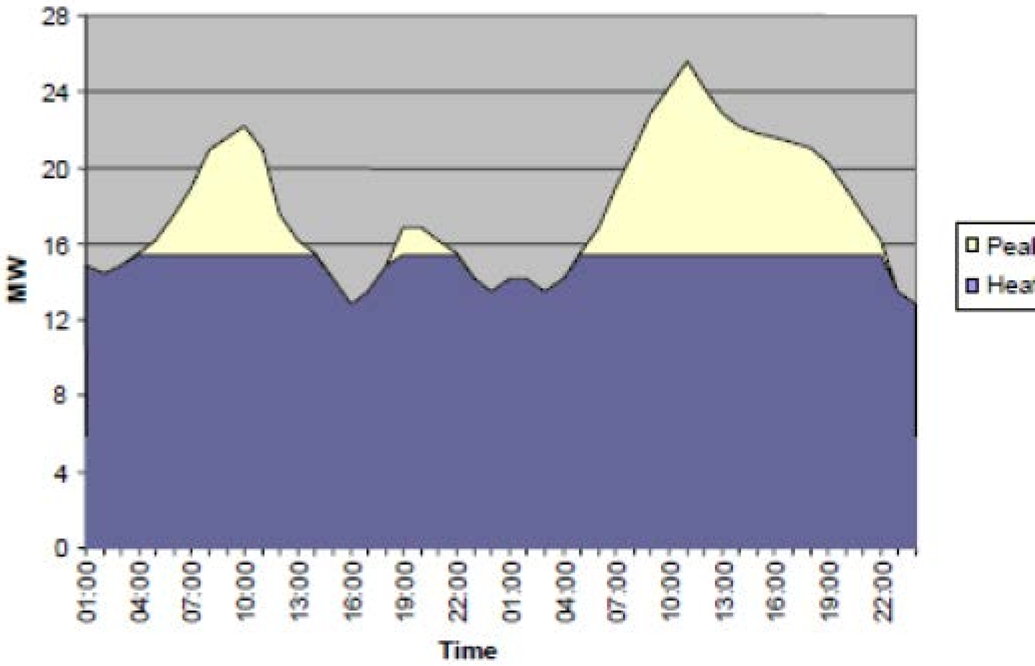




Best practices: Drammen district heating (2)

- Heat pump using single screw compressor
- Upgrading of heat from 8°C to 90°C using two stages
- Capacity regulation down to 10%
- COP > 3 with 90°C supply temperature

- Emerson Vilter mono screw compressor
  – Can deliver 75 barg delivery pressure
  – Condensor pressure 50 bar gives
    89 °C condensation temperature
- Screw compressor are capacity regulated using
  slide controll
- System designed for optimal operation for capacity regulation
  and pressure ratios



Hydrib heat pump

- Commissioned in 2016
- Frevar bio gas production, Norway (waste water and sludge treatment)
- Source temperature 20/14°C
- User 75/95°C
- 800 kW
- COP heating = 2,4 [-]

Recommendation

- Laws and regulations
  - Forbidden to use fossil energy
  - Minimum building efficiency regulation
  - Must have energy flexible heating system
  - Must be renewable
  - Obliged to connect of DHN if present
- Economical incentives
  - Financial incentives production
  - Programs for shifting to low temperature heating in buildings
  - Programs for new technologies
- Wholistic planning
  - Look at both heating and cooling needs
  - New areas with potential of low temperature DHN
  - Base load and peak load planning
  - Use of heat storage and new customers
  - Choice of heat pump, compressor and refrigerants

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