SMART INTEGRATION OF DISTRICT HEATING AND COOLING

GREATER COPENHAGEN TAARNBY MULTI UTILITY

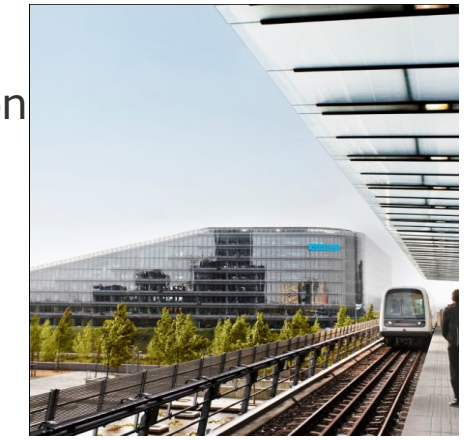
Stateofgreen, June 24 2021

Anders Dyrelund

RAMBØLL Bright ideas. Sustainable change.

PRESENTATION AND BACK GROUND

- Ramboll
  - Independent Multidisciplinary Consulting Eng. Comp. Owned by the Ramboll Foundation
  - 16.000 Employees 300 offices in 35 countries, mainly Northern Europe and US
  - New office in Japan
  - World leading within several energy services, e.g. off shore wind and DH&C
- Anders Dyrelund
  - Civ.Eng. in buildings, Graduate diploma in Economics
  - 1975-81 Ramboll (BHR)
  - 1981-86 Danish Energy Authority
  - 1986- Ramboll
  - 1980 The First Heat Plan in Denmark for Aarhus, PM
  - 1981- Copenhagen Regional DH, task manager/consultant
  - 1990- Consultancy services to more than 20 countries



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DEVELOPMENT FROM 2013 TO 2021

A solid majority of the Parliament agreed June 2020:

- Still objective to become independent of fossil fuels or CO_2 neutral in 2050
- Off shore wind shall be the dominating natural renewable energy source
- Heating and electricity shall meet the objective already in 2030
- The challenge is not to establish the wind farms, but to utilize the fluctuating renewable energy source in a smart cost effective way
- **Therefore larger market share of DH&C**
- Shift from gas boilers to DH or individual heat pumps has startet, taking into account cost-effectiv eness and environmental
- Ramboll from 10,000 to 16,000 employees

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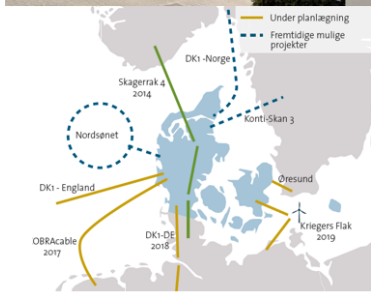
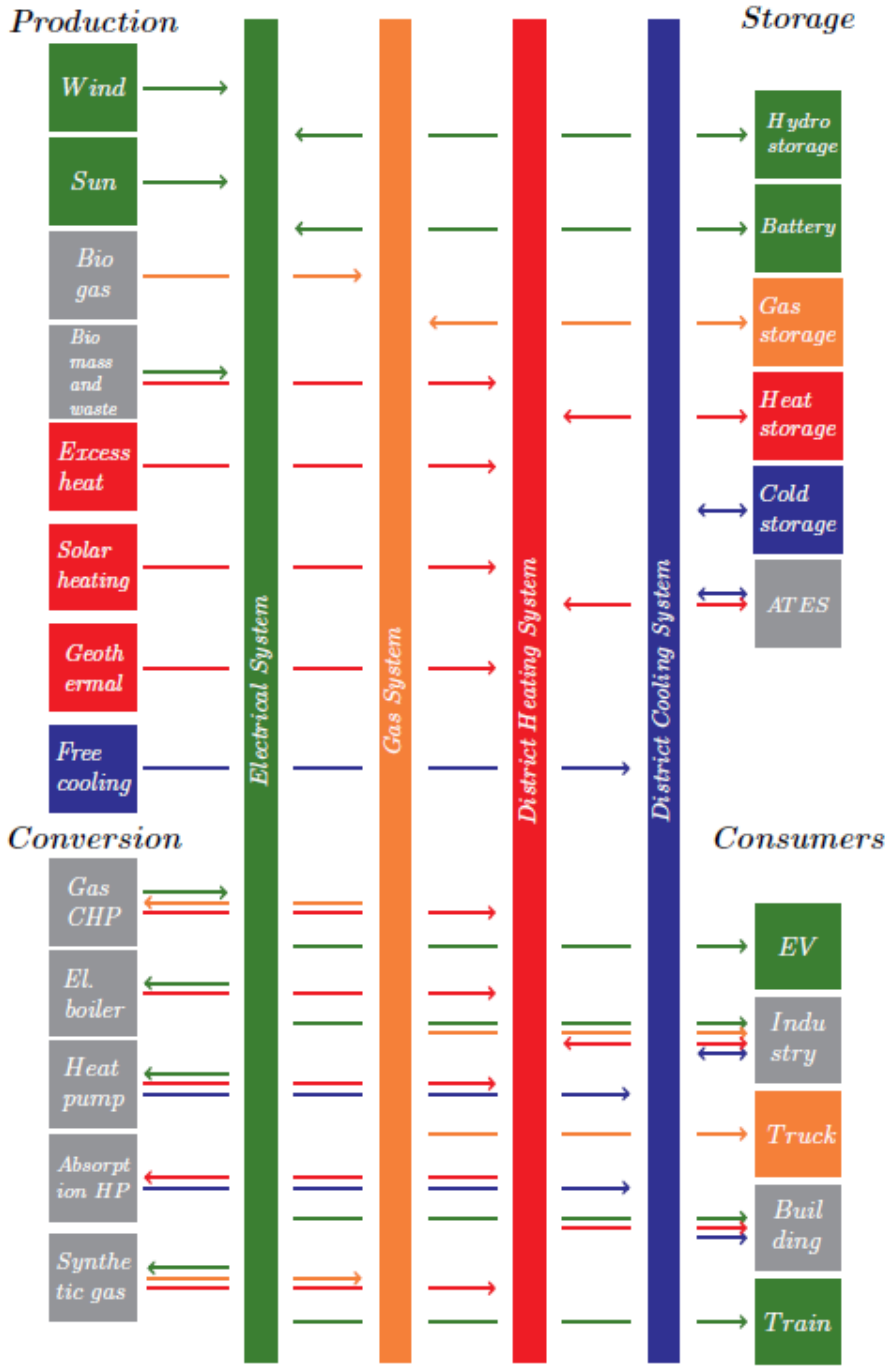
Energy infrastructure in Denmark
Technical DH&C development 2010-

- District cooling in city centers
- Lower temperatures in consumers installations paves the way for more low-temperature DH
- Large heat pumps and electric boilers to use surplus wind
- Large efficient heat pumps to upgrade low quality heat
- Larger storages to use available heat
- More shift from gas to DH
- More integrated markets

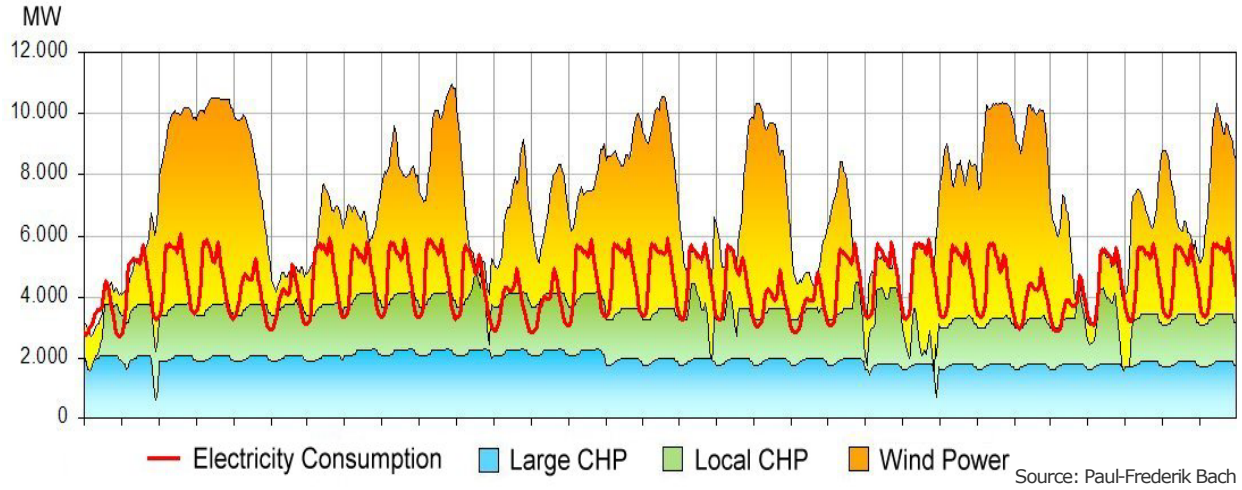


THE SMART ENERGY SYSTEM COST-EFFECTIVE, RESILIENT AND LOW CARBON

- National power grid
- National natural gas grid
  - Gas storage, CHP, Biogas, P2Gas
- City-wide district heating grid
  - Storage for CHP and RES
- City district cooling grid
  - Storage and optimal cooling
- Buildings and other end-users
  - Low-temperature heating
  - High-temperature cooling



THERMAL VIRTUAL ELECTRICITY STORAGE (LIKE A BATTERY) REDUCE CURTAILMENT OF WIND AND BALANCE THE SYSTEM



Source: Paul-Frederik Bach

- Baseline
  - Small heat pumps without storage or gas boiler back-up
  - Can-not adjust consumption to the fluctuations of the wind
- The virtual electricity storage:
  - DH hot water and DC cold water
  - Hot and cold water storage tanks and pits
  - Large heat pumps, to be interrupted at any time as long as needed
  - Electric boilers at low electricity price + up/down-regulation
  - Gas fuelled CHP plants, only at high electricity price + up-regulation
  - Gas (biogas) boilers back-up

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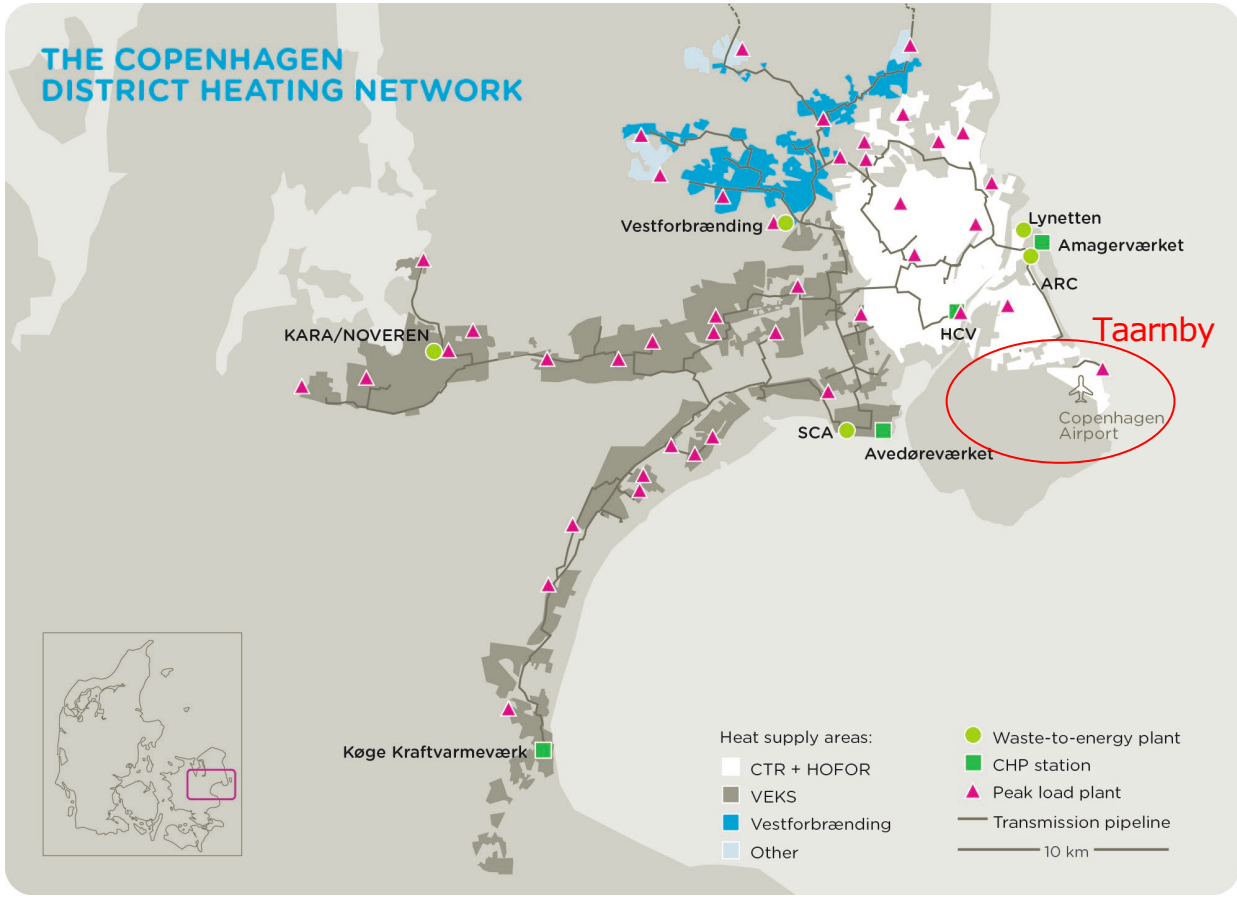
GREATER COPENHAGEN DISTRICT HEATING SYSTEM

- Smart city land mark
- 70 million m2 - 1 mill. residents
- 12,000 GWh heat production
- 20 municipalities (Copenhagen 50%)
- 3 heat transmission companies
- Optimal market share of DH vs. gas
- 99 % connection to the DH grid
- 3 biomass CHP plants (65%)
- 3 waste to energy plants (30%)
- Heat pumps, Peak boilers.. (5%)
- 3 x 24,000 m3 heat storage tanks
- **8 District cooling** systems in operation, more in the pipe lin



See also case 1 out of 8 in this publication from EU:
https://publications.jrc.ec.europa.eu/repository/handle/JRC104437

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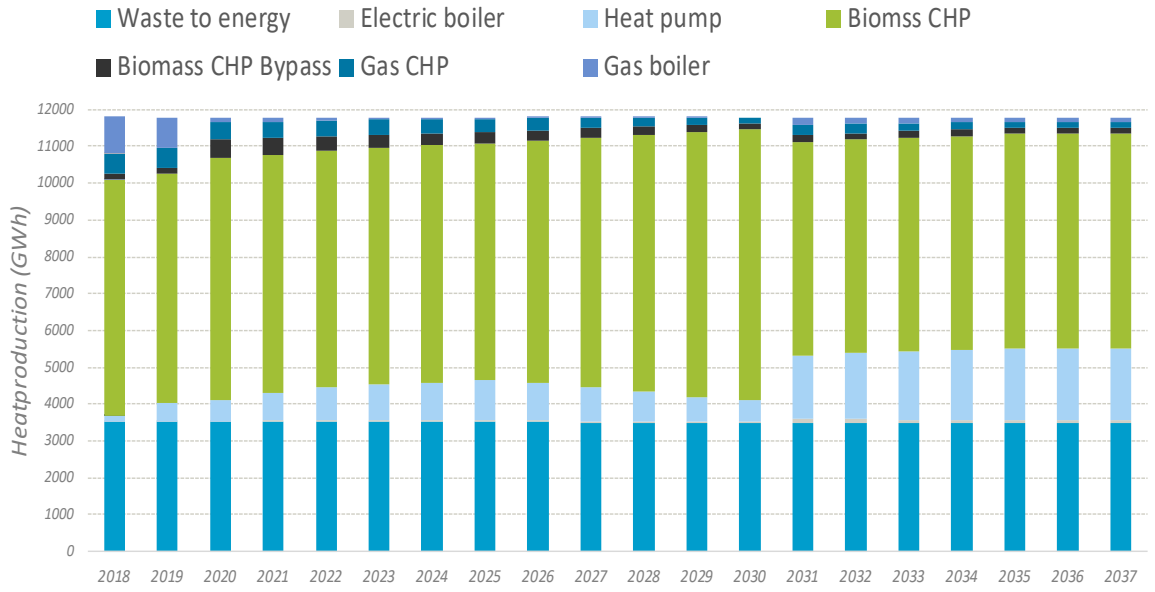
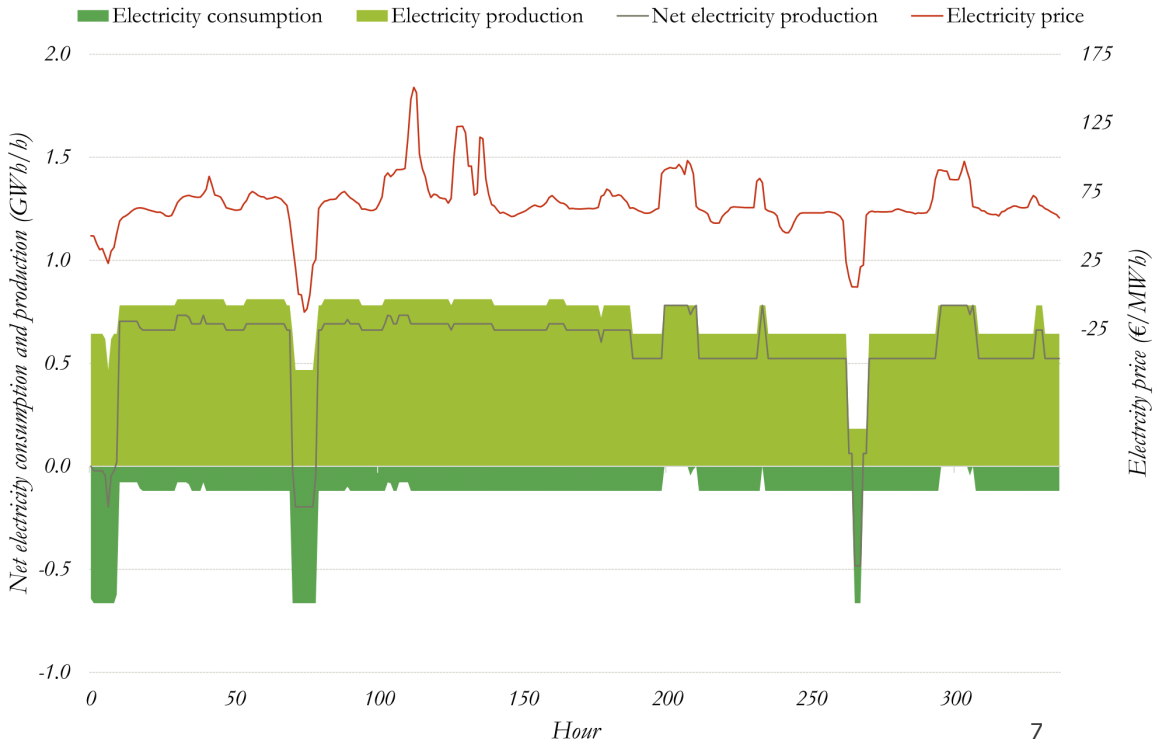
A TRANSITION FROM COAL-GAS-BIOMASS CHP TO A MIX OF BIOMASS CHP, HEAT PUMPS FOR DH&C AND ELECTRIC BOILERS

- Waste for energy is fully used
- CHP by-pass steam turbines + electric boilers
- Large heat pumps mainly for combined DH&C
- Large heat storages tanks and pits
- Large chilled water storage tanks

Transition towards 2030 - Huge demand response on electricity prices

Smart integration of electricity from fluctuating wind and solar PV





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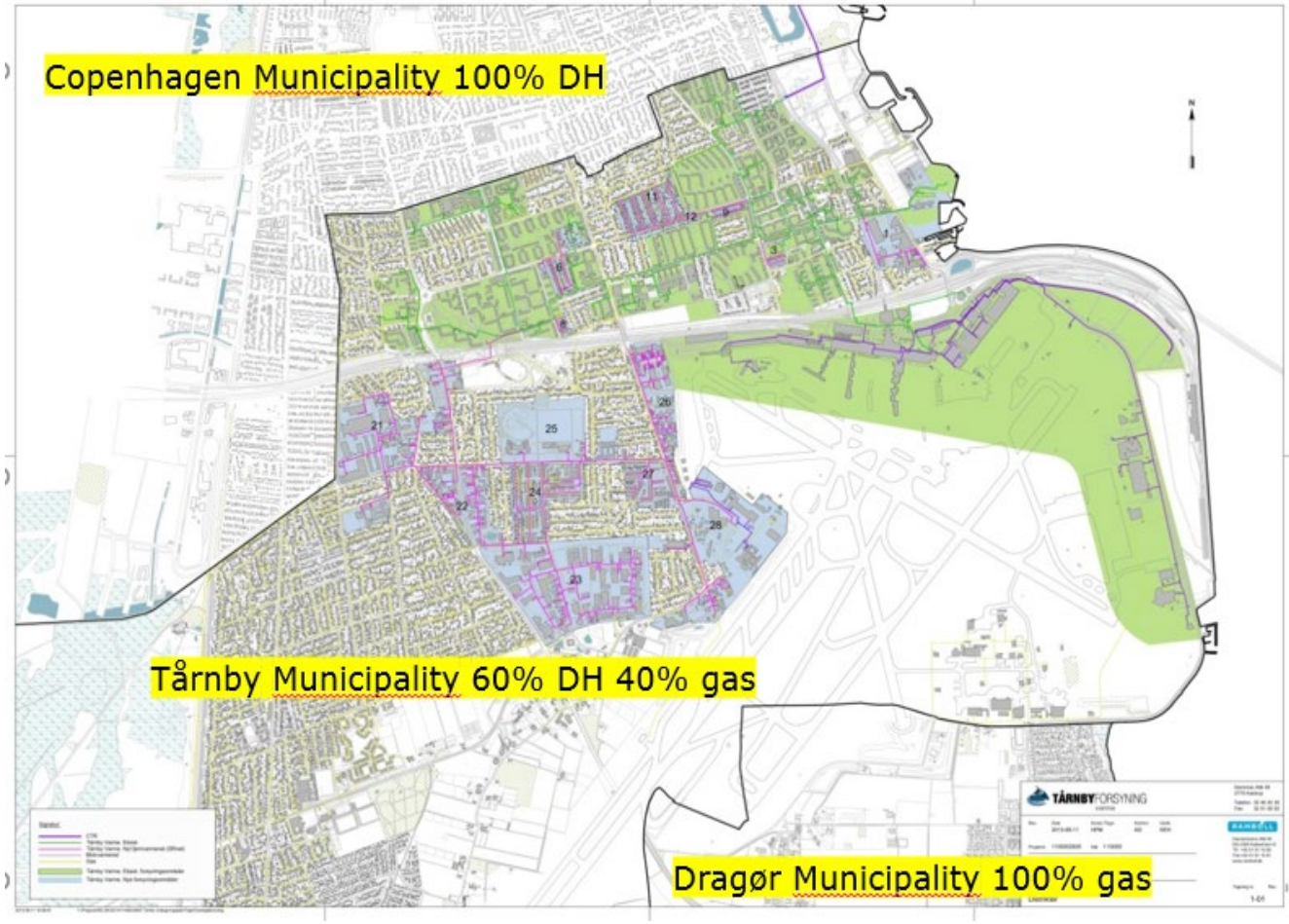
DISTRICT HEATING IN TAARNBY IS A PART (2 %) OF THE GREATER COPENHAGEN SYSTEM

- 1980
  - 100% oil boilers in Taarnby
- 1985 optimal zoning of new DH and gas grid
  - 60% to hot water DH, large buildings (green)
  - 40% to gas, single family houses (no color)
- 2018
  - First DC system combined with DH
  - Integration of DH with airport campus grid
- 2020-2030
  - Second stage of the DC project
  - More DH to replace gas boilers (blue)
- 2030-2035
  - Remaining buildings to DH and heat pumps



KEY FIGURES OF THE DH SYSTEM FOR INTEGRATING DC

DH demand 170 GWh (growing)

Heat losses in network 6%

60 MW Maximal capacity demand

7 MW minimum capacity summer

60 MW Heat from the transmission system

60 MW back-up boiler at the airport

6,5 MW_{heat} HP extracting heat from cooling, wastewater and ground water

Summer: ground source cooling base load, HP is peak, all buildings can be supplied from HP, at 70 dgr.C

Winter: HP base load, temperature to most consumers is boosted by transmission system

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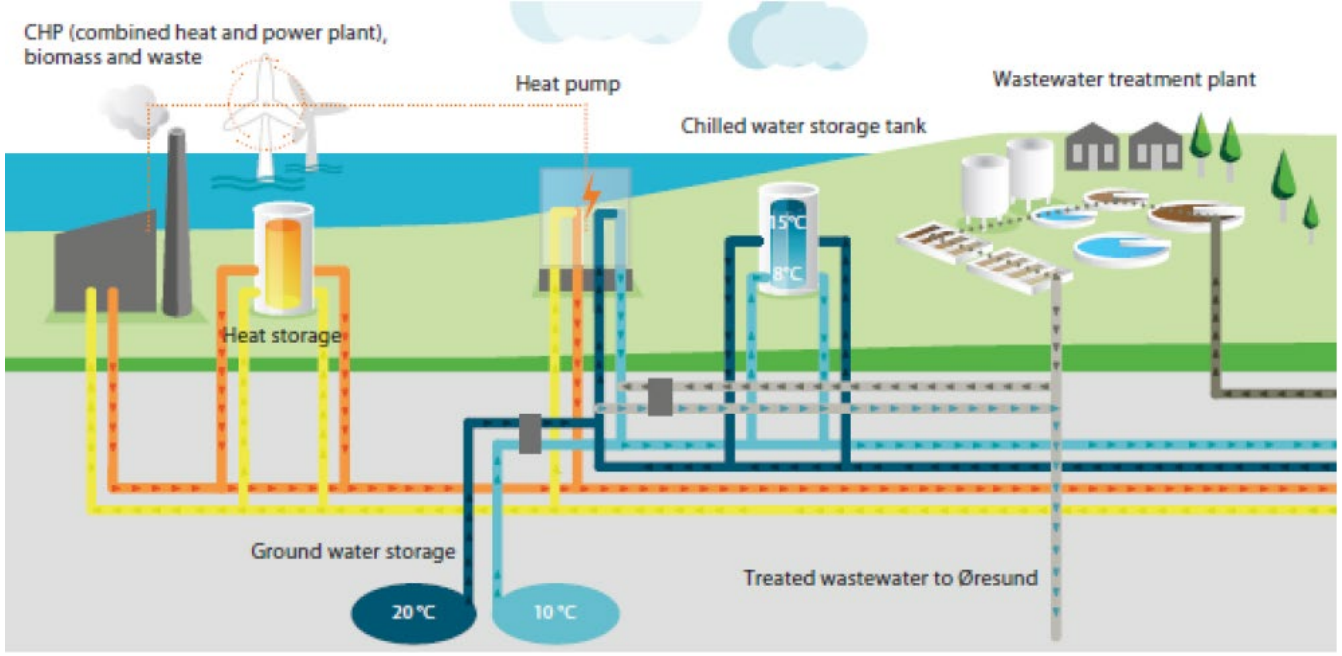
SMART SECTOR INTEGRATION

- Air from waste water cleaned, which paved the way for a new city district
- New metro station paved the way for Kastrup Business District, all buildings have need active cooling in Danish climate
- Plant is located at the wastewater treatment plant as space is expensive
- 5 circulating integrating water loops:
  - from tank to DC grid
  - from heat pump to cold storage tank
  - from heat pump to DH grid
  - from heat pump to treated wastewater
  - from heat pump to ground water



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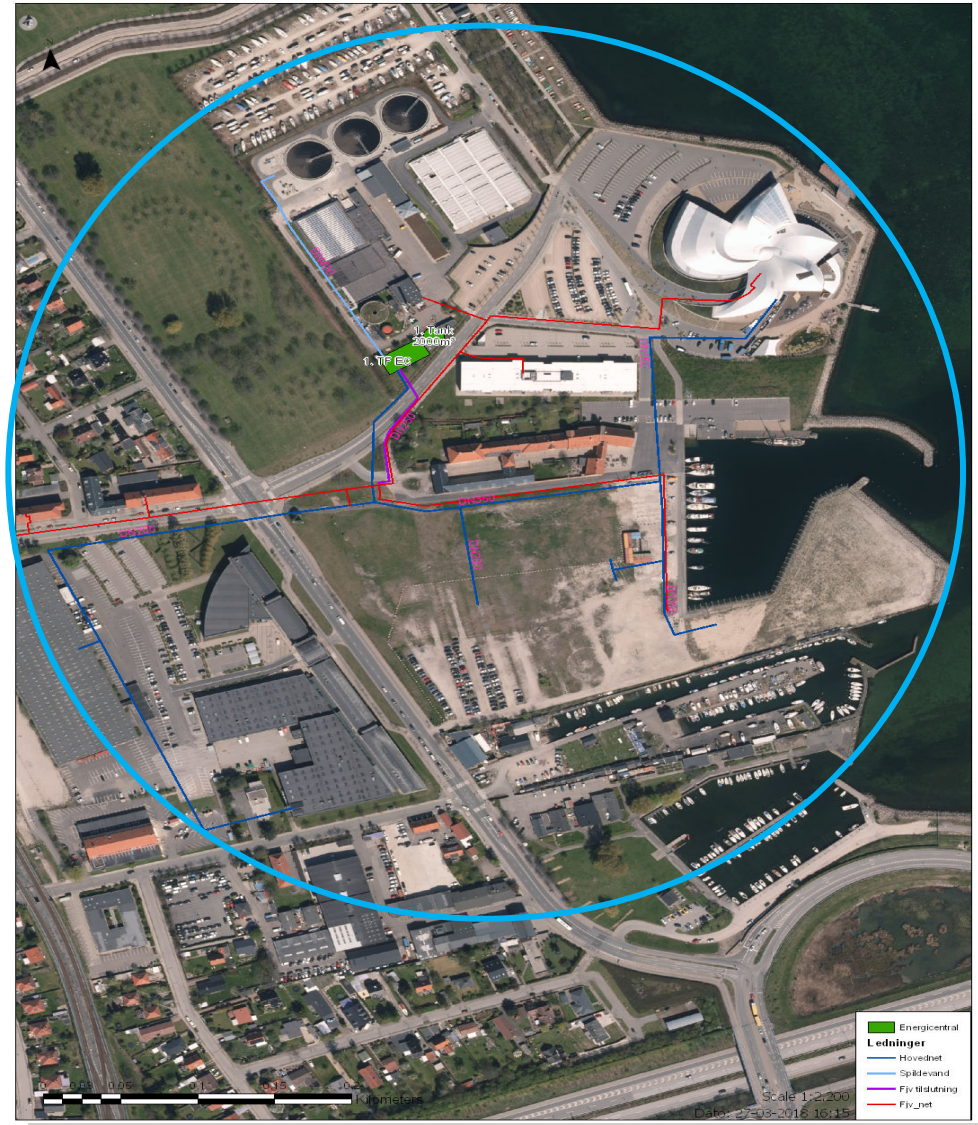
DISTRICT COOLING IN TAARNBY STAGE 2 FULLY DEVELOPED

- Cooling demand in stage 2 — 9,5 MWc / 9.000 MWhc
- Capacity demand to network — 8 MWc expected
- Installed capacity — 9,3 MWc incl. back-up
  - *Ground source cooling* — *2,0 MWc / 4.000 MWhc*
  - *Heat pump cooling* — ***4,8 MWc** / 5.000 MWhc*
  - *Heat pump heating* — *6,5 MW_{heat} / 50,000 MWh_{heat}*
  - *2.000 m3 chilled water tank* — *>2,5 MWc / 0 MWhc*
- Heat Pump heating — efficiency compared to basecase
  - *Cogeneration heat/cold* — *7.000 MWh COP=6*
  - *Ground source* — *5.000 MWh COP=4,5*
  - *From waste water* — *38.000 MWh COP=3*



See case 1 out of 8 in publication from EU, February 2021:
https://publications.jrc.ec.europa.eu/repository/handle/JRC123771

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DC SAVES INVESTMENTS AND COSTS

- Investments cooling baseline 97 mill. DKK
- Investment in DC project 81 mill. DKK
  - DC plant incl. building 55 mill. DKK
  - DC storage tank 4 mill. DKK
  - DC network 19 mill. DKK
  - Connection to DH network 3 mill. DKK
  - Including transformer to 10 kV to save costs
- Stage 1 only (no stage 2 is worst case for financing)
  - NPV Benefit for the society 60 mill. DKK
  - NPV Benefit consumers and utility 23 mill. DKK
- Stage 1 and 2
  - NPV Benefit, society 103 mill. DKK
  - NPV Benefit, consumers and utility 60 mill. DKK (90 mill.)

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WHY IS THIS PROJECT A GOOD CASE TO MAKE CITIES SMARTER AND MORE LIVEABLE

- Focus on energy solutions which reduce costs and improves environment and resilience in cities
- Focus on municipal commitment in order to implement the solutions to the benefit of the consumers and for integrating energy and environment in one utility
- Focus om municipal co-operation
- Focus on sector integration, which opens for smart city solutions across following sectors:
  - The energy sectors: Electricity, District heating, District cooling and gas
  - The environment sectors: Waste water and ground water resources
  - The building sector: Ferring and Scandic go for sustainability as being a part of the community
- The symbiosis between
  - heat pump for combined DH&C and
  - heat pump for generating heat from waste water
  - is the key to cost effectiveness and bankability, in particular for the difficult stage 1.

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THANK YOU FOR YOUR ATTENTION

QUESTIONS

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