COST EFFECTIVE DANISH DH CASES CONTRIBUTION TO SUBTASK B

RAMBOLL ENERGY
ANDERS DYRELUND

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CONTENT

Infrastructure networks

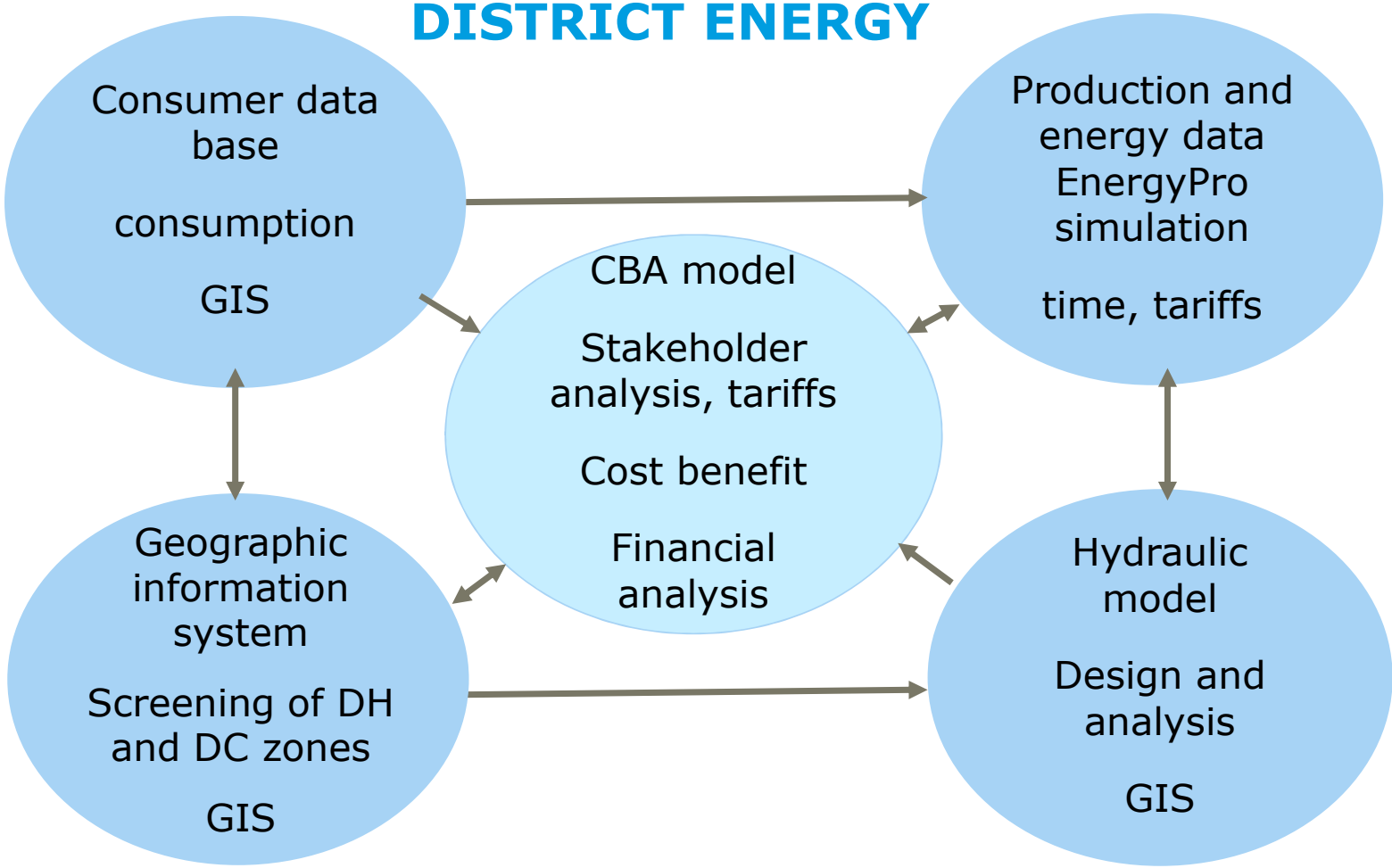
- Tårnby District Heating, from gas boilers to district heating (DH)
- Høje Taastrup DH, from chillers to district cooling (DC) network with storage
- Høje Taastrup DH, from centralized to decentralized supply of DH end-users for DH and DC
- Danish Building and Property Agency, from campus network to city DH
- Greater Copenhagen DH, Integration of local DH systems and available production in a city

CONTENT (2)

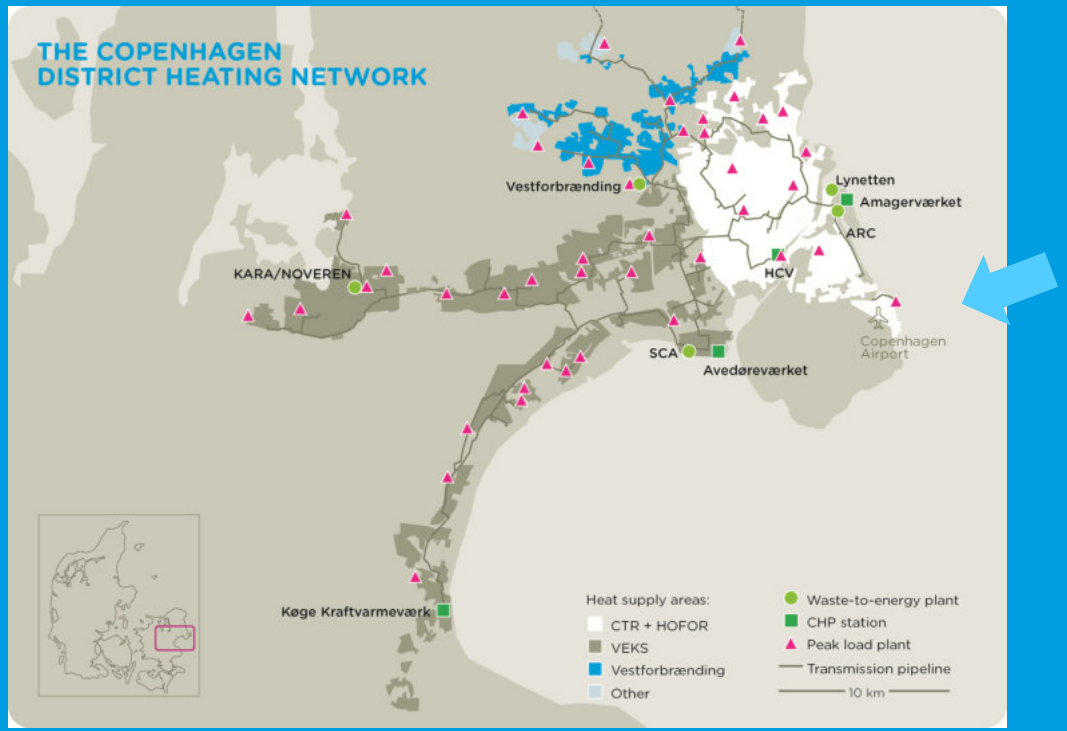
Production cases

- Nymindegab military campus: from oil to local CHP based on biogas
- Gram DH, Solar heat, electric boiler, heat pump, gas CHP,
- Technical University of Denmark, Campus, electric boiler, gas CC CHP, heat pump
- Silkeborg DH, Solar heat, gas CC CHP, heat pump
- Waste incineration, ARC Copenhagen
- Biomass CHP, HOFOR Copenhagen
- Tårnby DH, Heat pump to combined DH and DC and surplus heat from waste water

MODEL AND METHODOLOGY FOR PLANNING DISTRICT ENERGY



TÅRNBY DH, FROM GAS BOILERS TO DH PART OF THE GREATER COPENHAGEN DISTRICT HEATING SYSTEM



TÅRNBY DISTRICT HEATING

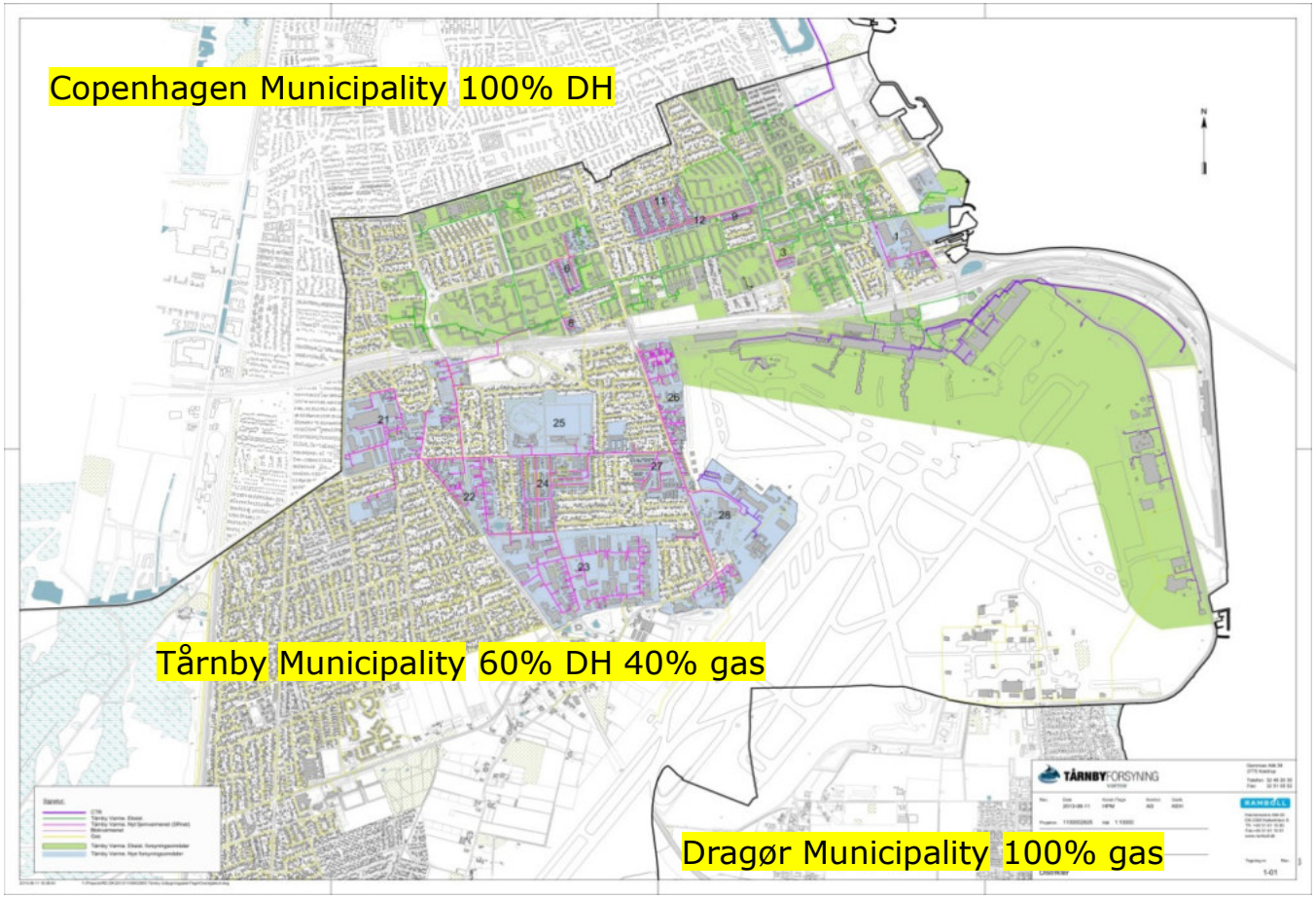
Owned by Tårnby Municipality

Established in 1985, replace oil

Heat from the heat transmission company, CTR,Tårnby Municipality is co-owner of CTR

Zoning of the networks:

- Green districts: DH system established in 1985
- Blue districts: Planning to shift from gas to DH around 2020
- District with-out colour: One-family houses: an option to shift from gas boilers to DH or to heat pumps in 2030-2050



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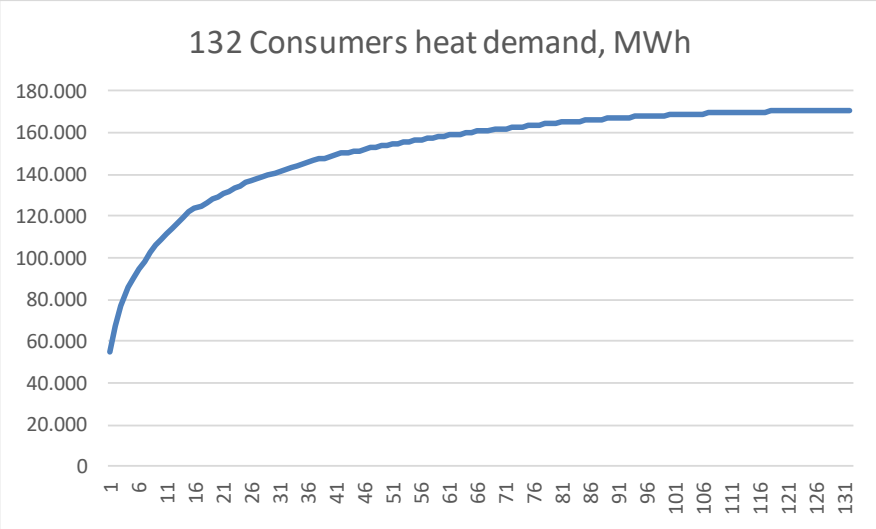
DATA FOR TÅRNBY DH

- 132 consumers, incl. Copenhagen Airport campus
- 178 GWh annual heat production
  - 168 GWh annual heat sale, of which 55 to the airport
  - 9,5 GWh annual heat loss, equal to 5,3%
  - 8,5 GWh annual heat loss for new pipes, calculated
  - 12,7 GWh losses incl. Airport network, equal to 7%
  - 11,7 GWh inkl. the network of the airport campus
- 28 km DH network, DN20-DN500 + 10 km airport
- Normal supply temperature 75-95 dgr.C
- Normal return temperature 50 dgr.C
- Preinsulated pipes from 1985, survalience system
- Remaining life-time of the network? 50 years more ?
- Heat exchanger between DH and campus is removed



- Maximal demand **60 MW**
- Heat capacity to the network
  - Heat exchanger transmission: 60 MW
  - Local back-up oil boiler 60 MW
  - Planned heat pump DH&DC 6 MW

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PLAN FOR EXTENSION OF THE DH SYSTEM

- Strategic developement of the DH system
- The key figure ”investment in network” divided by ”heat sale” is a good indicator
- Due to low density heat load and longer network per heat sale
- Therefore, heat losses is also a good indicator

Development of Tårnby DH	**Demand**	**Network invest.**	**Key figure**	**Heat loss**	**Alternative**
Districts	MWh	1000 DKK	1000DKK/MWh	%	individual
First network in 1985	115.909	253.079	2,2	6,8%	gas boiler
Campus in long-term development	54.953	74.175	1,3	5,6%	oil boiler
Total incl. Campus	**170.862**	**327.254**	**1,9**	**6,3%**	
First extension 2020	30.838	42.594	1,4	5,0%	gas boiler
New urban development	5.635	17.826	3,2	10,4%	heat pump
Second extension 2025?	11.201	41.147	3,7	11,0%	gas boiler
Total without small houses	**218.535**	**428.821**	**2,0**	**6,6%**	

HØJE TAASTRUP DH, FROM CHILLERS TO DISTRICT COOLING (DC) NETWORK WITH STORAGE

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PROJECT PROPOSAL APPROVED

- Screening model to identify the potential
- Total long-term project approved
  - Interconnected DC grid
  - Heat pump for combined DH and DC, with no curtailment of heat
  - Chilled water storage
  - ATES system
  - Share of heat storage pit
- First stages in operation in 2018:
  - Heat pump in 3 steps to Copenhagen Markets whole sale vegetables etc.
  - Energy plant prepared for extension to maximal capacity

HØJE TAASTRUP DH, FROM CENTRALIZED TO DECENTRALIZED SUPPLY OF DH END-USERS FOR DH AND DC

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THE DH AND DC DIRECTLY TO THE END-USER

- DH to each appartment in the building
- DC to each tenant in Copenhagen Markets for vegetables and flowers
- If the building or campus owner wants to avoid internal heating and cooling systems, DH and DC are can be delivered directly to individual end-users. The only condition is
  - Stop valves and a heat meter
  - Agreement between building owner and utility on ownership of pipes in the buildings, and level of insulation

DANISH BUILDING AND PROPERTY AGENCY, FROM CAMPUS STEAM TO CITY DH

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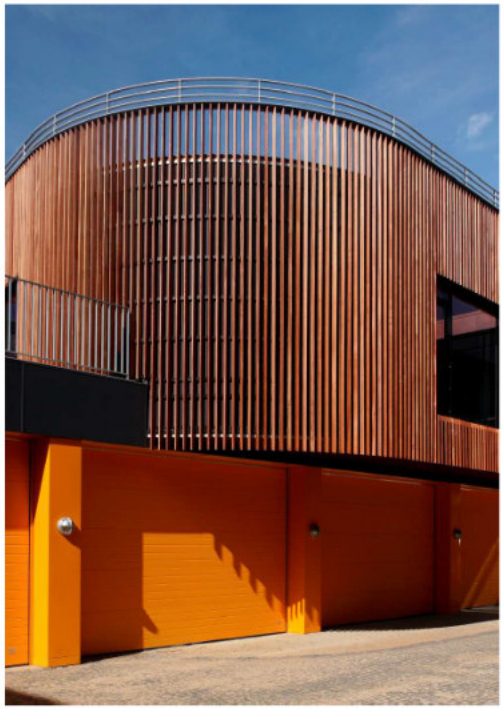
THE CAMPUS OWNER

One of Denmark's largest public property enterprises and developers

- We administer approximately 4 million m^2 properties
- 3 million m^2 state-owned properties used as offices and by universities – with a value exceeding DKK 37 billions (EUR 4.9 billions)
- 1.3 million m^2 private leases
- Operating revenue; DKK 3 billions per year (EUR 0.4 billions)
- Construction expenses; DKK 3 billions per year (EUR 0.4 billions).
- Approximately 230 employees



BYGNINGSSTYRELSEN

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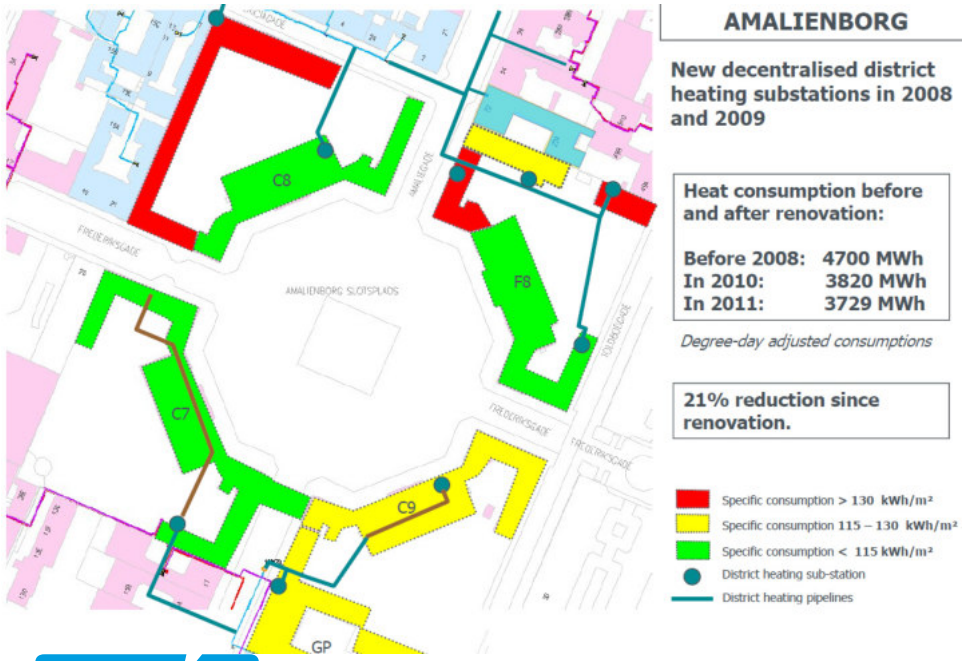
THE QUEENS PALADS

- 1951 from a centalized boiler to DH steam
- 2009 from 4-pipe system and steam to DH directly to 9 local substations
- Active energy management via the DH system



AMALIENBORG

New decentralised district heating substations in 2008 and 2009

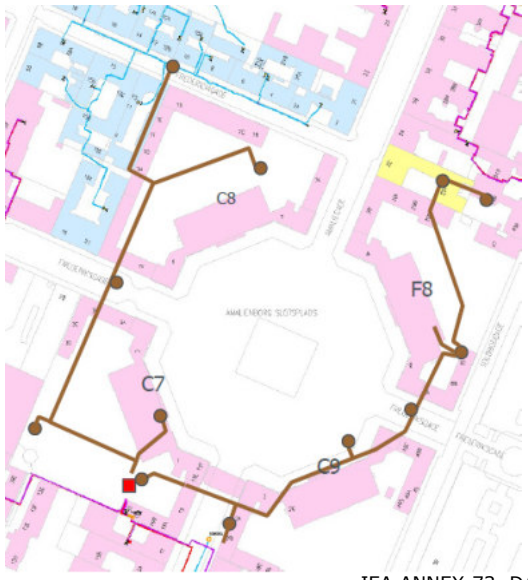
Heat consumption before and after renovation:

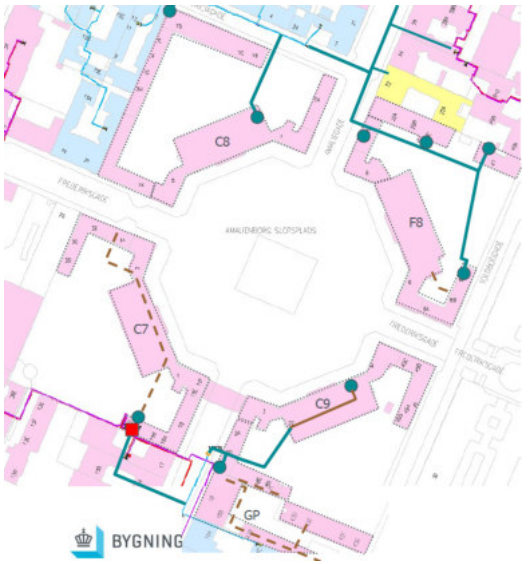
Before 2008:	**4700 MWh**
In 2010:	**3820 MWh**
In 2011:	**3729 MWh**

Degree-day adjusted consumptions

21% reduction since renovation.

Specific consumption > 130 kWh/m²
Specific consumption 115 – 130 kWh/m²
Specific consumption < 115 kWh/m²
District heating sub-station
District heating pipelines





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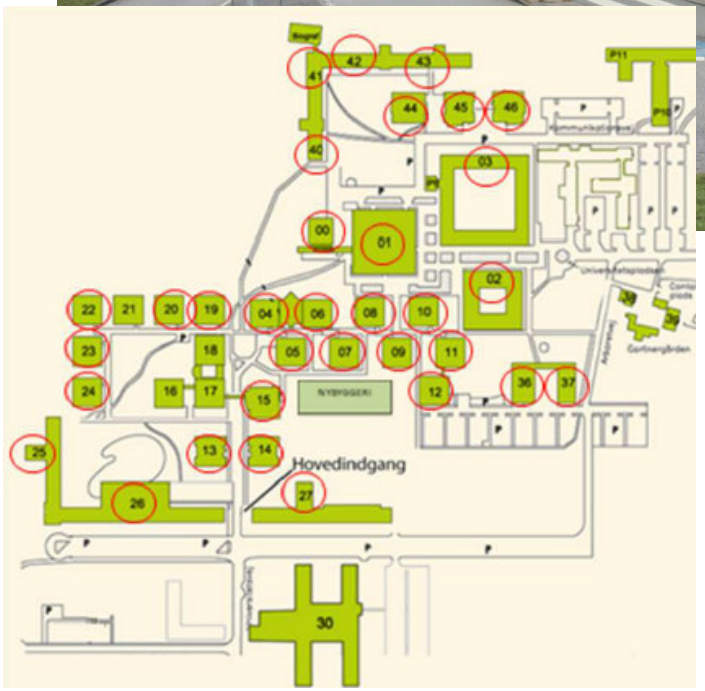
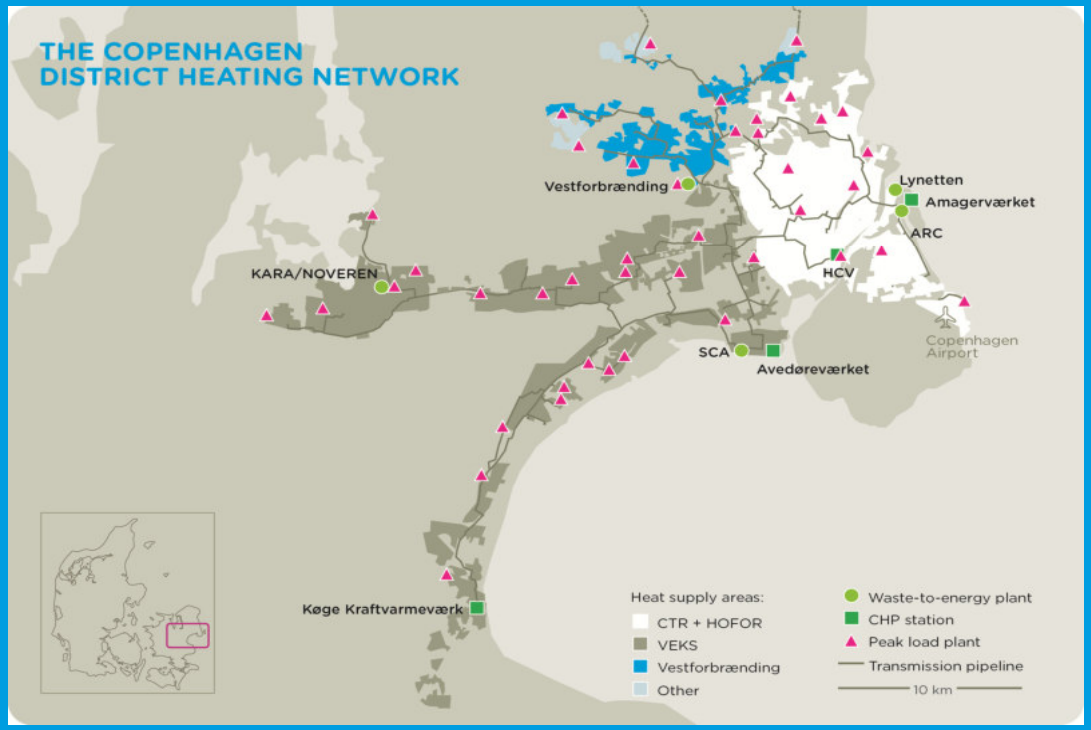
ROSKILDE UNIVERSITY

- 1970: oil boiler plant and local network to 33 building substations
- 1988: from oil boiler to DH
- 2012 City DH network replaces the campus network and 33 new substations are established
- From 2,4 km to 2,0 km pipes
- Smaller dimensions
- Heat loss savings 1.500 MWh (25%)
- More efficient energy management from campus owner via the DH system



GREATER COPENHAGEN DH, INTEGRATION LOCAL DH SYSTEMS AND AVAILABLE PRODUCTION IN A CITY



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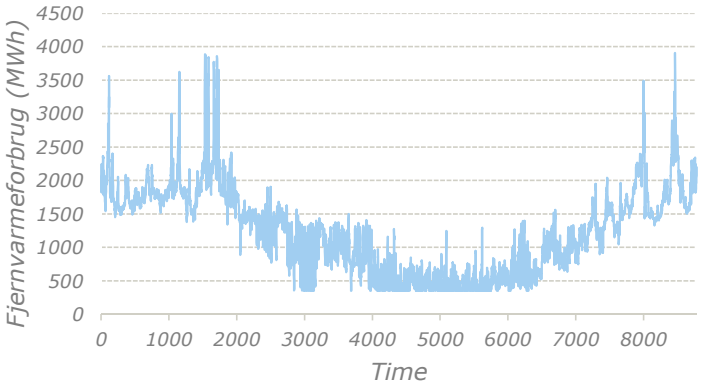
INTEGRATING 3 HEAT TRANSMISSION DH AND 20 DISTRIBUTION DH AND CAMPUSSES WITH PRODUCTION

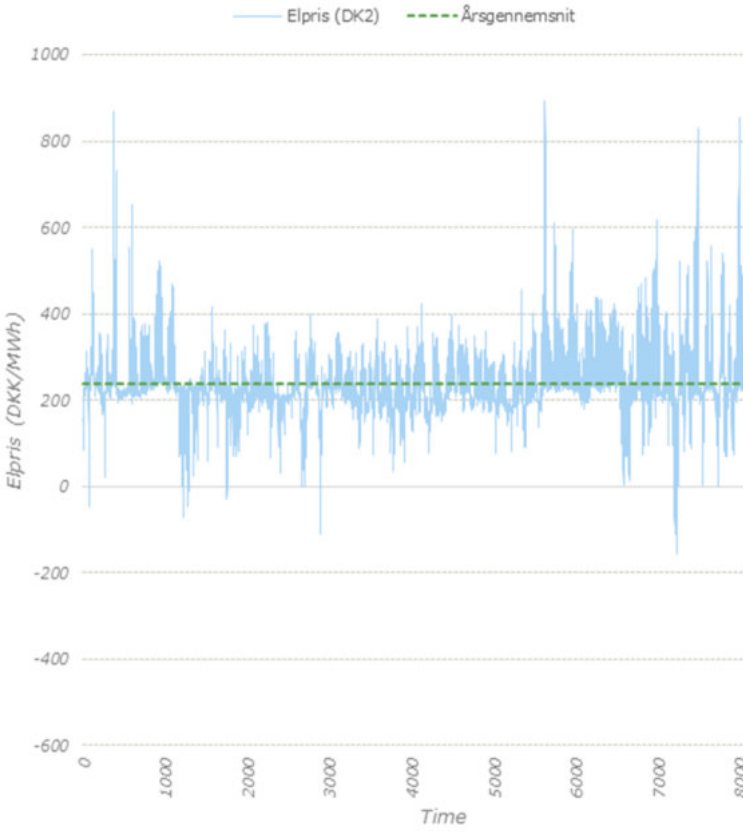
Greater Copenhagen DH&C, in year	**2018**	**2038**
Supplied population	1 million	
Supplied heated floor area million m2	70	80 ?
Heat production in average, GWh	10.800	10.800
Waste to energy CHP	30%	30%
Biomass CHP	62%	50%
Heat pumps, electric boilers	0%	17%
Biomass boilers, or CHP by-pass	2%	2%
Peak boilers, gas, oil,	6%	1%
District cooling combined with heat, GWh	0	330
Heat storage volume 1000 m3	75	2,000
Cols storage volume in 1000 m3	4	110

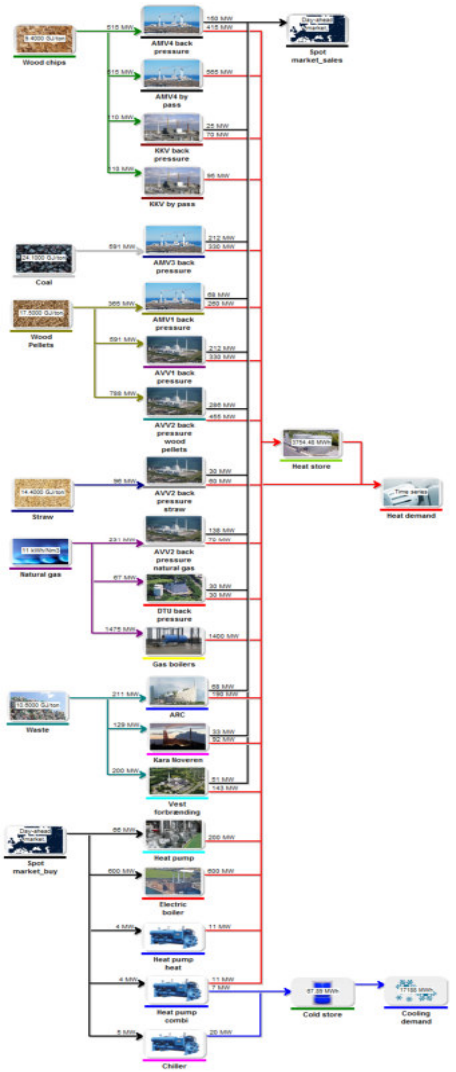
SIMULATION OF HEAT AND ELECTRICITY WITH ENERGYPRO

Simulation of the heat production on hourly basis for a typical year

- Heat load profile for the system
- Electricity price profile, NORDPool market







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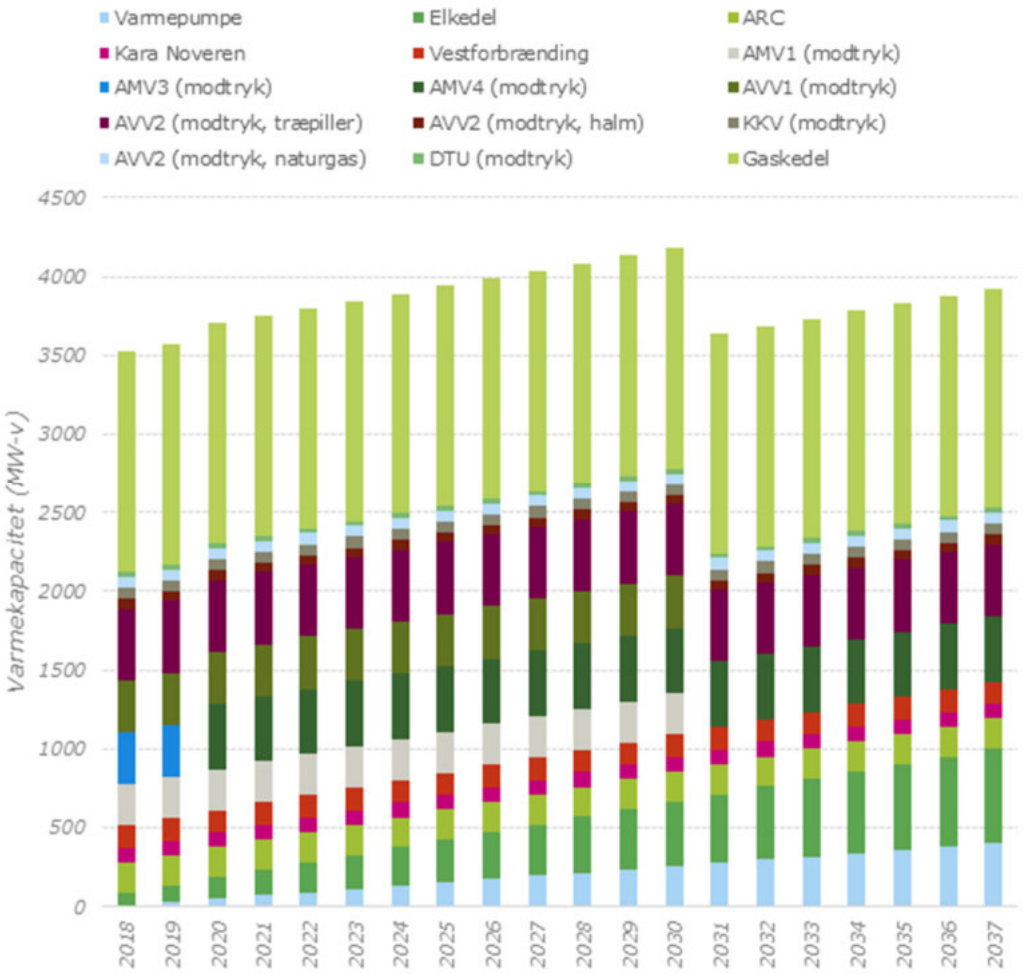
DEVELPMENT OF PRODUCTION CAPACITY

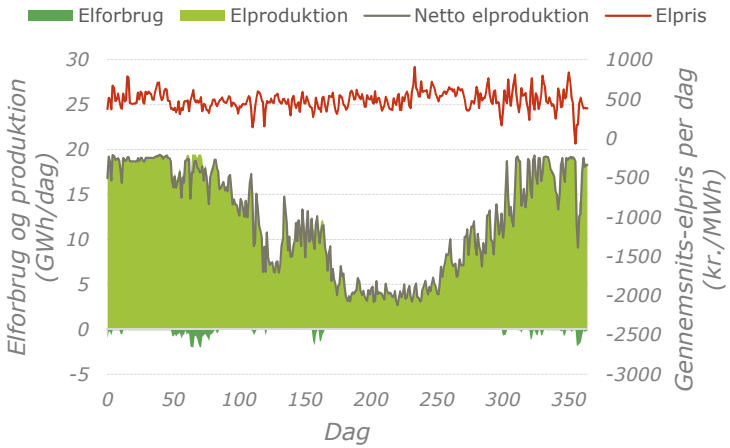
- Existing CHP from gas and coal to biomass
- New 400 MW heat wood chip fuelled CHP will start in 2020

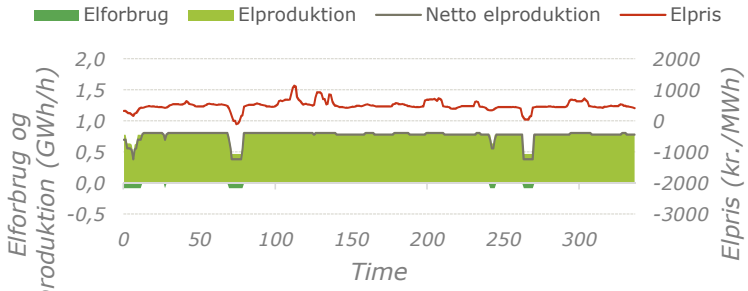
- Our prognosis for 2018-2038:
- 400 MW heat pumps
- 800 MW electric boilers
- 2 million m3 thermal storage



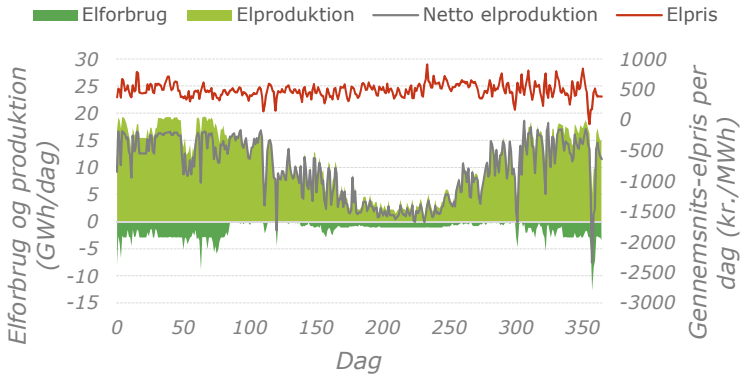
RESILIENT POWER GENERATION WITHOUT THERMAL LOSSES DEMAND RESPONSE, NO RES IS CURTAILED

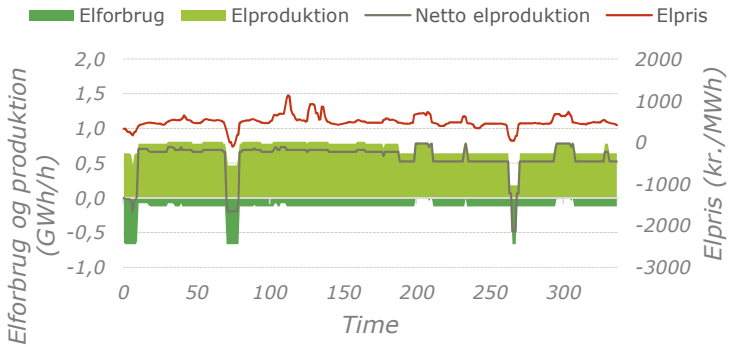
- 2018
  - 365 days
  - 300 hours





- 2038
  - 365 days
  - 300 hours

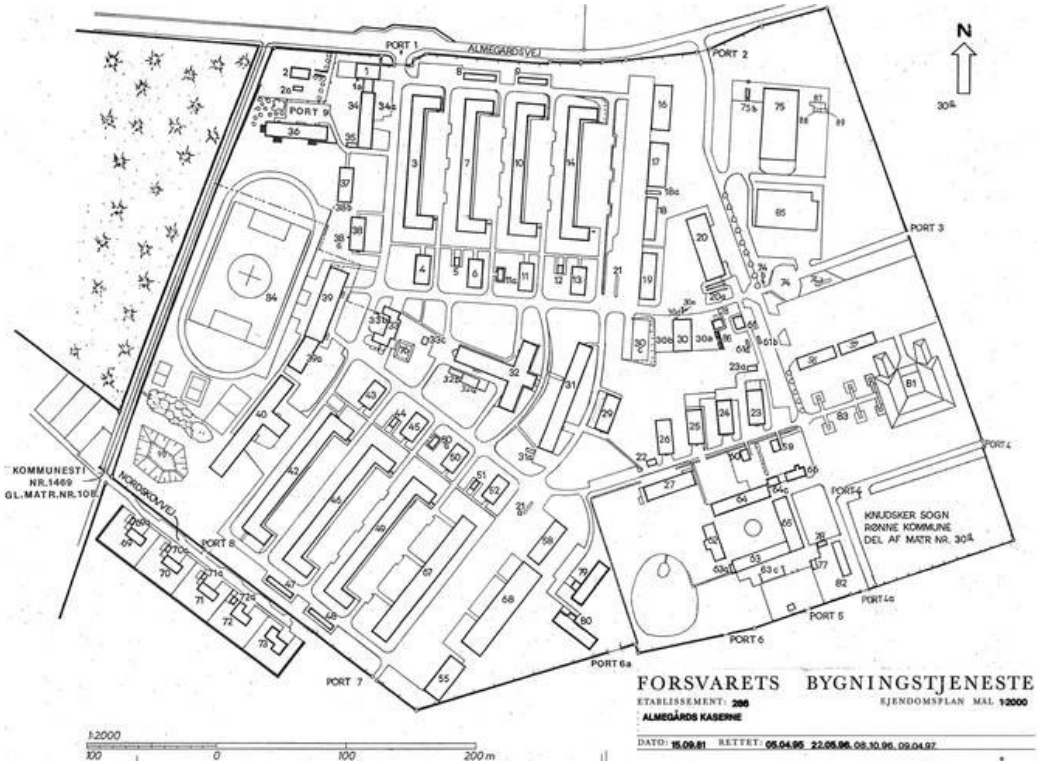




NYMINDEGAB MILITARY CAMPUS: FROM OIL TO LOCAL CHP BASED ON BIOGAS

FROM OIL TO BIO GAS CHP AT THE NYMINDEGAB CAMPUS

- Nymindegab is a military installation in Jutland covering approximately 2.96 km^2.
- There are 24 buildings in the installation and it houses Home Guard training facilities
- Originally, the buildings were connected to a campus pre-insulated pipe DH system, supplied with an oil boiler.
- Recently a biogas fueled gas engine has been installed to supply the base load
- The biogas is produced at a near-by biogas plant processing bio waste from the farming



GRAM DH, SOLAR HEAT, ELECTRIC BOILER, HEAT PUMP, GAS CHP,

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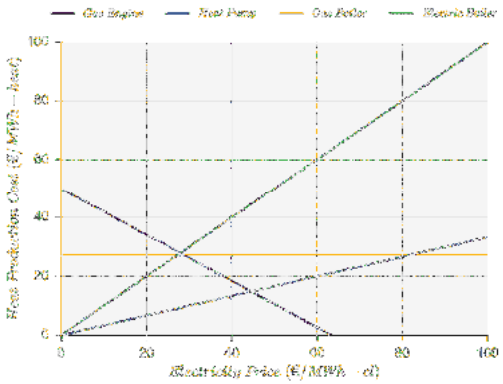
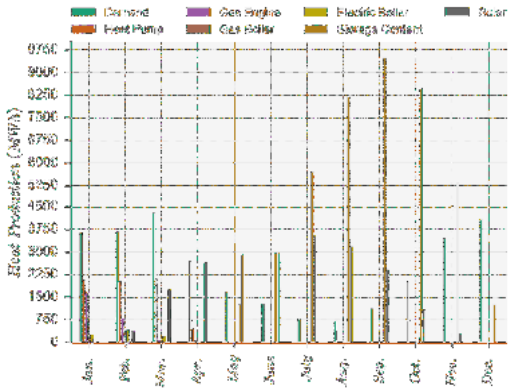
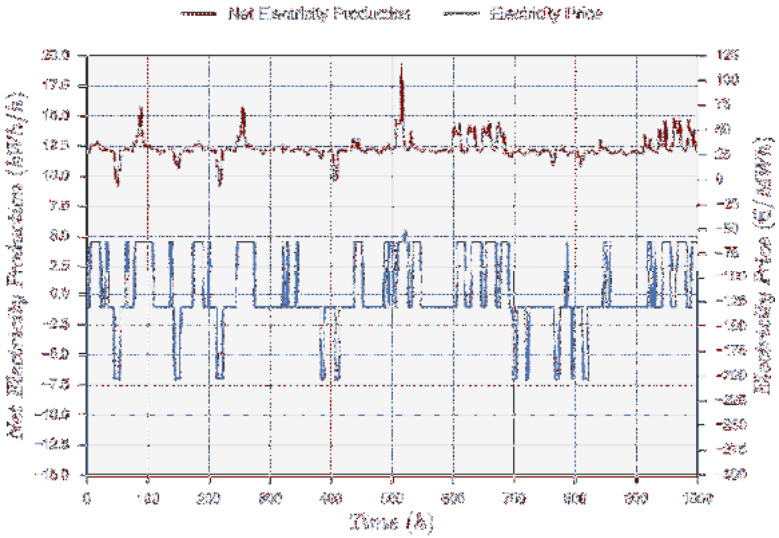
STRONG DEMAND RESPONS – ACTS AS A VIRTUAL BATTERY

- Heat production 30 GWh
- 120,000 m3 heat storage pit
- 44,000 m2 solar panels (61%)
- A 10 MW electric boiler (15%)
- A 900 kW heat pump (8%)
- Industrial surplus heat (8%) and
- A 5 MWe/6 MWth CHP gas engine (8%)
- Gas boilers for spare capacity (0%)

- ENREGYPro for planning
- MENTOR PLANNER for daily operation







TECHNICAL UNIVERSITY OF DENMARK, CAMPUS, ELECTRIC BOILER, GAS CC CHP, HEAT PUMP

DTU CAMPUS, LONG-TERM PLAN ELEC-TRICITY, DH AND DC TO ALL BUILDINGS

2017

- Gas fuelled CC plant 30 MW elec./30 MW heat
- Total efficiency of the plant 90%
- Heat storage tank 8.000 m3

2020

- Gas fuelled CC plant 30 MW elec./30 MW heat
- Interconnected to the City DH part of Greater Copenhagen
- Electric boiler at CHP plant 40 MW
- Heat pump to DC system 3,4 MW cold / 4,4 MW heat

Towards 2050

- Building floor area increases significantly
- Heat demand increases slightly and lower return temperature
- Cooling demend increases significantly
- New heat pump capacity to combined heating and cooling
- Chilled water storages
- Ground source cooling

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IEA ANNEX 73, DANISH CASES FOR COST EFFECTIVE DH AND DC
170418

SILKEBORG DH, SOLAR HEAT, GAS CC CHP, HEAT PUMP

MUNICIPAL OWNED DH SYSTEM IN SILKEBORG
ANNUAL HEAT TO THE NETWORK: 400 GWH

Before

- Gas fuelled CC plant 108 MW elec./85 MW heat
- Total efficiency of the plant 87%
- Heat storage tank 2*16.000 m3
- Heat production from CHP 80 GWh
- Heat production boilers 320 GWh

From 2017

- Gas fuelled CC plant 106 MW elec./120 MW heat
- Total efficiency of the plant 102%
- Heat storage tanks 4 x 16.000 m3 = 64.000 m3
- Large-scale solar heating 156.000 m2 (world largest in 2018)
- Absorption heat pumps 25 MW cooling capacity
- Heat production solar 70 GWh
- Heat pump from solar 10 GWh
- Heat production CHP 210 GWh
- Heat pump condensation 30 GWh
- Heat production boilers 80 GWh

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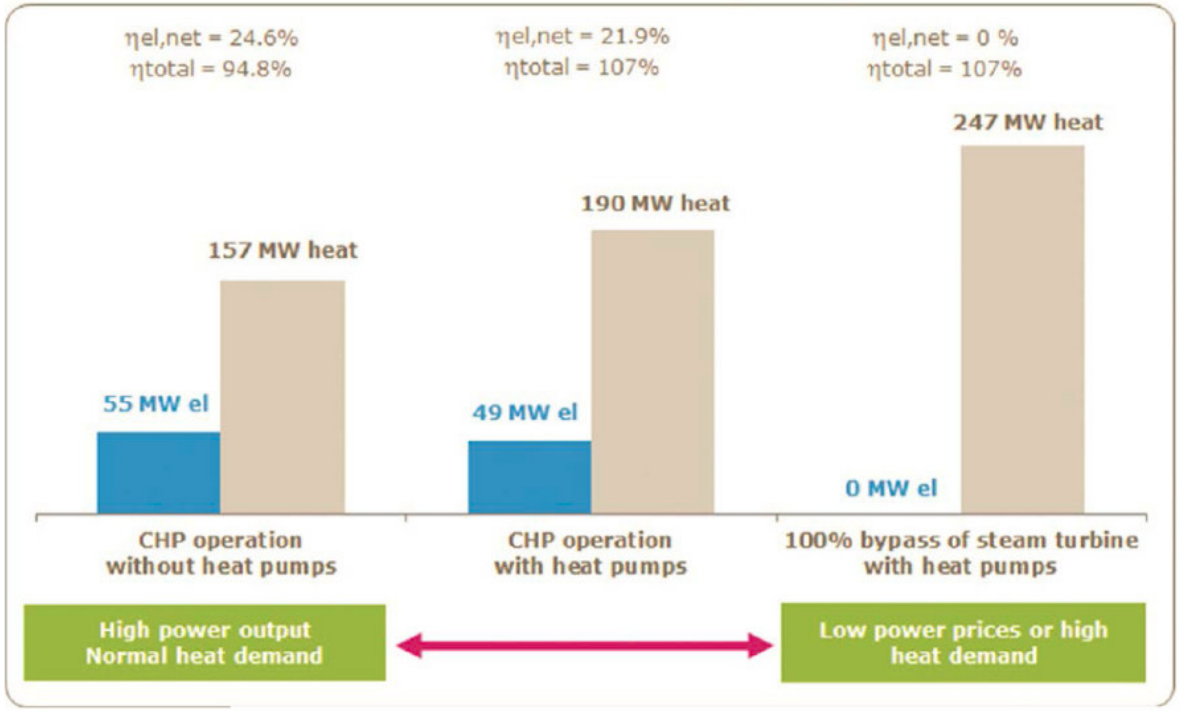
WASTE INCINERATION, ARC COPENHAGEN

ARC COPENHILL – NO WASTE TO BE DUMPED AT LANDFILLS ENERGY PRODUCTION - FLEXIBILITY - AND LIVEABILITY



Credit: BIG

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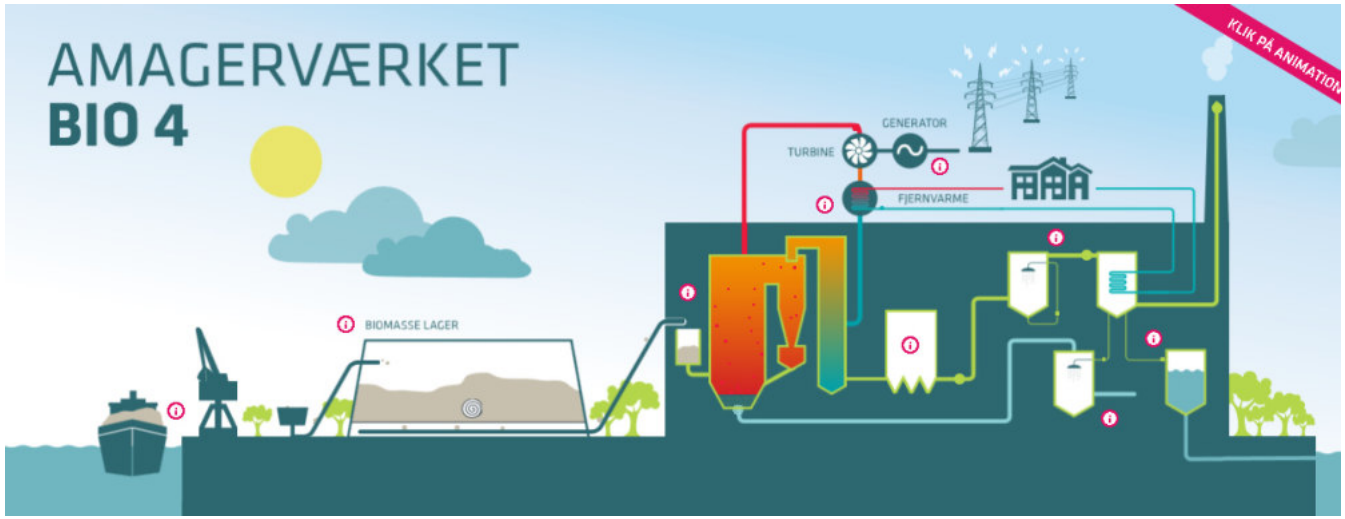
BIOMASS CHP, HOFOR COPENHAGEN

HOFOR, MUNICIPAL OWNED MULTI UTILITY, OWNER OF DH, DC, CHP, GAS, WATER AND WASTE WATER

- Amagerværket Bio4 CHP plant under construction
- Fluidized bed boiler
  - Heat pump flue gas condensation
  - Low quality wood chip
  - 500 MW fuel capacity
  - 110% total efficiency
- Maximal power:
  - 150 MW electricity
  - 400 MW heat
  - Minimal power:
  - 0 MW electricity
  - 550 MW heat



TÅRNBY DH, HEAT PUMP TO COMBINED DH AND DC AND SURPLUS HEAT FROM WASTE WATER

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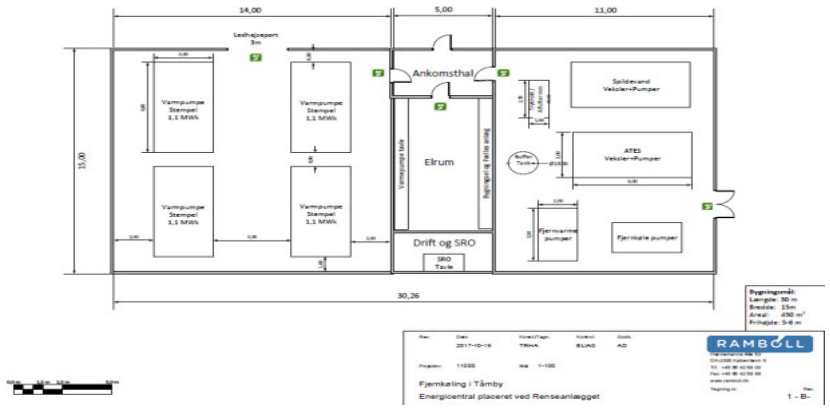
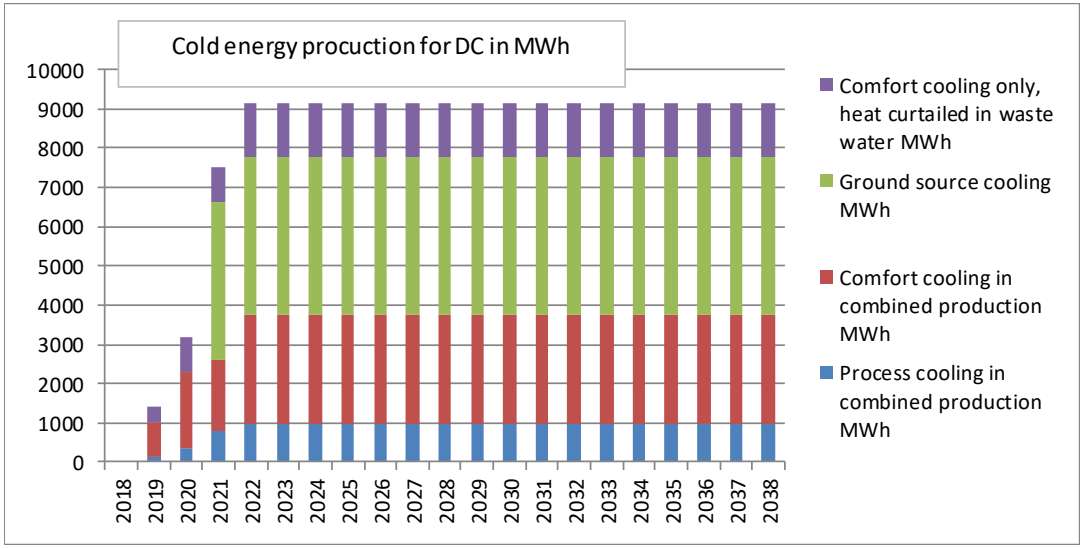
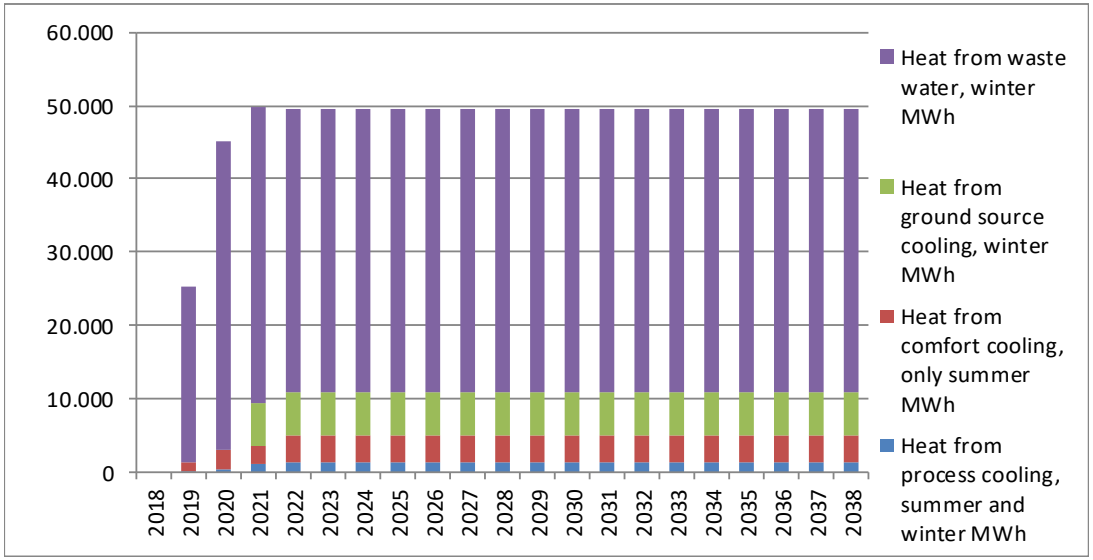
COST EFFECTIVE DISTRICT HEATING AND COOLING

Symbiosis between DH and DC

- No installations for production in buildings
- Heat pump serves two purposes:
  - Generate cooling capacity in summer
  - Produces efficient heat in winter







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QUESTIONS ?

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