COST EFFECTIVE DANISH DH CASES
CONTRIBUTION TO SUBTASK B
RAMBOLL ENERGY
ANDERS DYRELUND
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

- Nymind egab 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

- Consumer data base
  - consumption
  - GIS

- Geographic information system
  - Screening of DH and DC zones
  - GIS

- CBA model
  - Stakeholder analysis, tariffs
  - Cost benefit
  - Financial analysis

- Production and energy data
  - EnergyPro simulation
  - time, tariffs

- Hydraulic model
  - Design and analysis
  - GIS
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

Copenhagen Municipality 100% DH
Tårnby Municipality 60% DH 40% gas
Dragør Municipality 100% gas
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, survialence 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
PLAN FOR EXTENSION OF THE DH SYSTEM

- Strategic development 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

<table>
<thead>
<tr>
<th>Development of Tårnby DH</th>
<th>Demand MWh</th>
<th>Network invest 1000 DKK</th>
<th>Key figure 1000DKK/MWh</th>
<th>Heat loss %</th>
<th>Alternative individual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Districts</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>First network in 1985</td>
<td>115.909</td>
<td>253.079</td>
<td>2,2</td>
<td>6,8%</td>
<td>gas boiler</td>
</tr>
<tr>
<td>Campus in long-term development</td>
<td>54.953</td>
<td>74.175</td>
<td>1,3</td>
<td>5,6%</td>
<td>oil boiler</td>
</tr>
<tr>
<td><strong>Total incl. Campus</strong></td>
<td><strong>170.862</strong></td>
<td><strong>327.254</strong></td>
<td><strong>1,9</strong></td>
<td><strong>6,3%</strong></td>
<td></td>
</tr>
<tr>
<td>First extension 2020</td>
<td>30.838</td>
<td>42.594</td>
<td>1,4</td>
<td>5,0%</td>
<td>gas boiler</td>
</tr>
<tr>
<td>New urban development</td>
<td>5.635</td>
<td>17.826</td>
<td>3,2</td>
<td>10,4%</td>
<td>heat pump</td>
</tr>
<tr>
<td>Second extension 2025?</td>
<td>11.201</td>
<td>41.147</td>
<td>3,7</td>
<td>11,0%</td>
<td>gas boiler</td>
</tr>
<tr>
<td><strong>Total without small houses</strong></td>
<td><strong>218.535</strong></td>
<td><strong>428.821</strong></td>
<td><strong>2,0</strong></td>
<td><strong>6,6%</strong></td>
<td></td>
</tr>
</tbody>
</table>
HØJE TAASTRUP DH, FROM CHILLERS TO DISTRICT COOLING (DC) NETWORK WITH STORAGE
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
THE DH AND DC DIRECTLY TO THE END-USER

- DH to each apartment 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 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

We buy, rent, build, develop, maintain and energy optimise buildings
THE CAMPUS OWNER

One of Denmark's largest public property enterprises and developers

- We administer approximately 4 million m² properties
- 3 million m² state-owned properties used as offices and by universities – with a value exceeding DKK 37 billions (EUR 4.9 billions)
- 1.3 million m² 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
THE QUEENS PALADS

- 1951 from a centralized 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
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

THE COPENHAGEN DISTRICT HEATING NETWORK

Heat supply areas:
- CTR + HOFOR
- VEKS
- Vestforbrændning
- Other

- Waste-to-energy plant
- CHP station
- Peak load plant
- Transmission pipeline

10 km
### 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
DEVELOPMENT 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

IEA ANNEX 73, DANISH CASES FOR COST EFFECTIVE DH AND DC
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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 km².

• 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,
**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%)

- ENREGYPPro for planning
- MENTOR PLANNER for daily operation
TECHNICAL UNIVERSITY OF DENMARK, CAMPUS, ELECTRIC BOILER, GAS CC CHP, HEAT PUMP
DTU CAMPUS, LONG-TERM PLAN ELECTRICITY, 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 demand increases significantly
- New heat pump capacity to combined heating and cooling
- Chilled water storages
- Ground source cooling
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
WASTE INCINERATION, ARC COPENHAGEN
ARC COPENHILL – NO WASTE TO BE DUMPED AT LANDFILLS
ENERGY PRODUCTION - FLEXIBILITY - AND LIVEABILITY

Credit: BIG
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

[Image of Amagerværket Bio4 CHP plant]
TÅRNBY DH, HEAT PUMP TO COMBINED DH AND DC AND SURPLUS HEAT FROM WASTE WATER
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
THANK YOU FOR YOUR ATTENTION

QUESTIONS ?

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