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FEDERAL FACILITIES COUNCIL

ENERGY MASTER PLANNING FOR RESILIENT PUBLIC COMMUNITIES – VIRTUAL TRAINING WORKSHOP

October 13-16, 2020

Best Practices from Denmark - 4 cases

Anders Dyrelund, Ramboll

IEA EBC Annex 73 Task C – EUDP Denmark

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
  - World leading within several energy services
- 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

CONTENT

Energy Policy and Legal framework

Overall result of the energy planning and further development in Denmark

4 cases:

- Greater Copenhagen – the integrated district heating system in a metropol
- Taarnby – one of the local communities in Greater Copenhagen
- The Technical University of Denmark – one of campusses in Greater Copenhagen
- Gram, Toftlund and many other small communities

ENERGY POLICY AND LEGAL FRAMEWORK

Denmark - a reaction on the oil crizes (resiliency at national level)

- 1976 Electricity Supply Act – since 1976 only optimal CHP – no power-only plants
- 1979 Heat Supply Act – cost effectiveness, reduce dependence on oil, planning obligation
- 2020 Energy Policy to eliminate dependency on all fossil fuels

EU – inspired by Danish experience

- Energy Efficiency Directive – obligation to plan for district heating and cooling, promote CHP
- Renewable energy Directive – obligation to plan for district heating and cooling, promote RES
- Building Directive – nearly zero buildings taking into account that DH&C can transfer CHP and RES

EU and Denmark – overall energy policy objectives

- Cost-effectiveness in order to increase welfare and competitiveness
- Resiliency at national level being less dependent on imported fuels from……
- Go green

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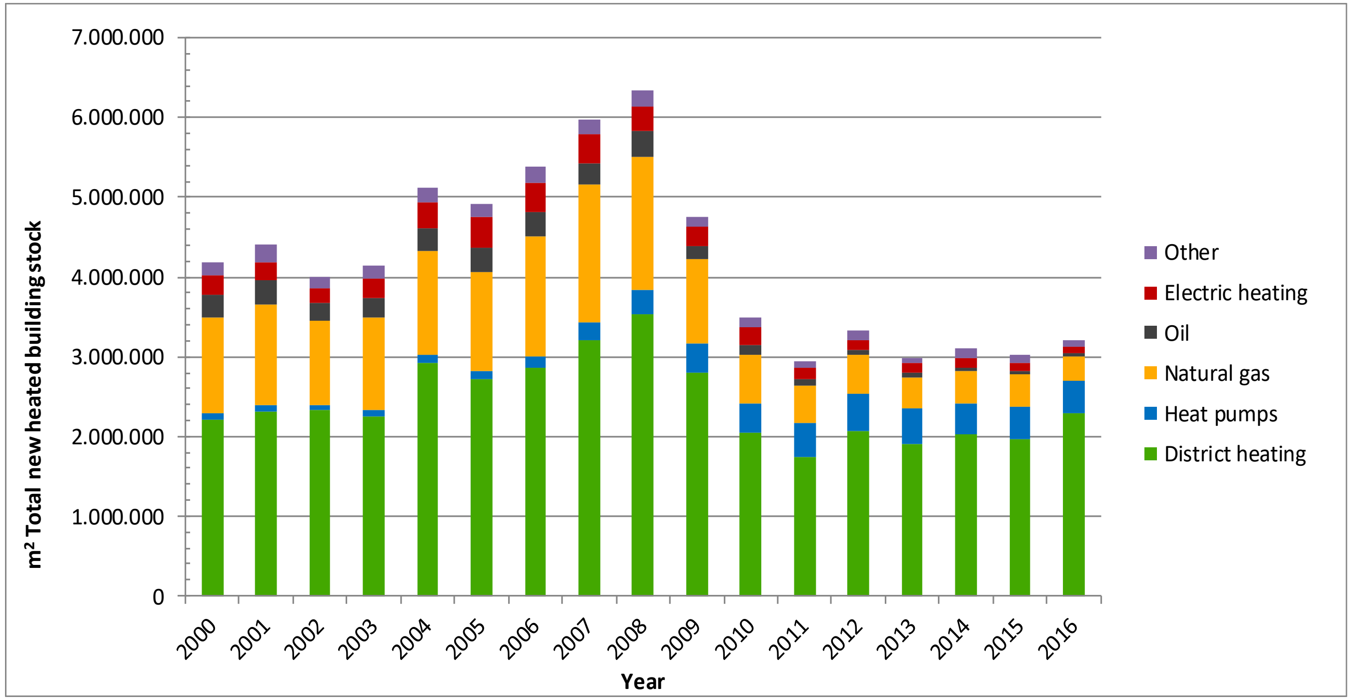
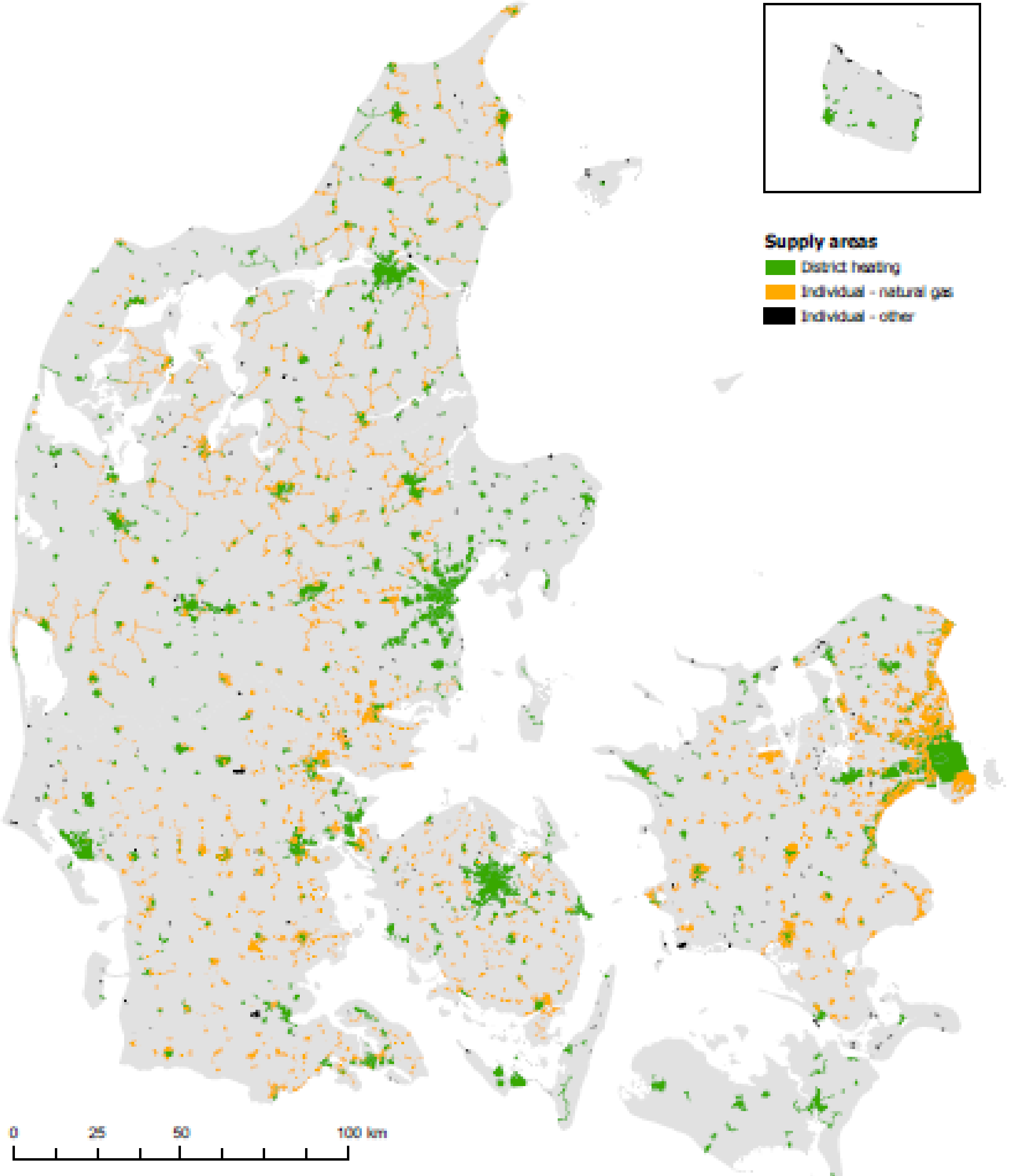
HEAT SUPPLY STATUS 2018

- Zoning of natural monopoly grids DH and gas
- 65% DH and 15% gas
- 75% of new buildings to DH, 25% to gas/heat pumps



HEAT SUPPLY IN URBAN AREAS



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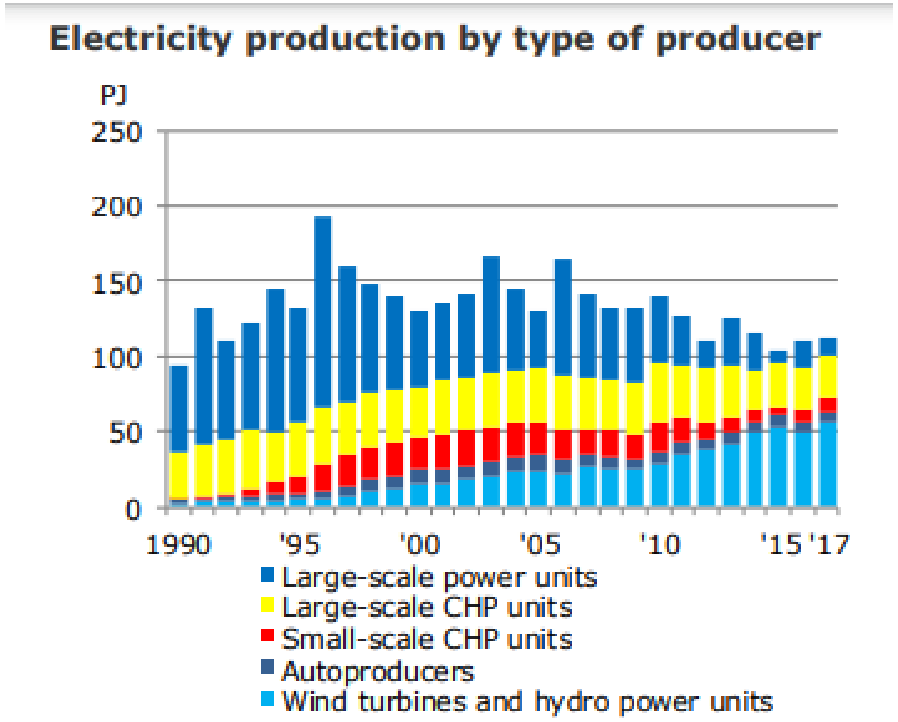
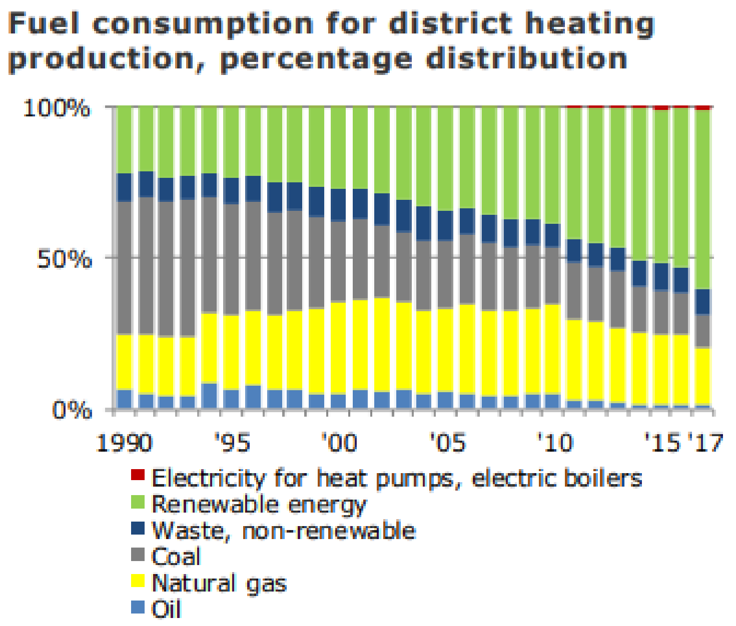
HEAT PRODUCTION, STATUS 2018

- The CHP potential fully utilized (almost no thermal power-only generation of power – no cooling losses
- All waste is used for energy (no energy wasted at landfills, help other countries to process waste)
- Coal at large CHP plants is reduced and replaced by wood chip and wood pellets (temporary)

- Around 40% of all heat to DH is surplus energy which else would be wasted from power plants
- 60% of all heat is based on fuels of which more than 50% are renewable energy sources





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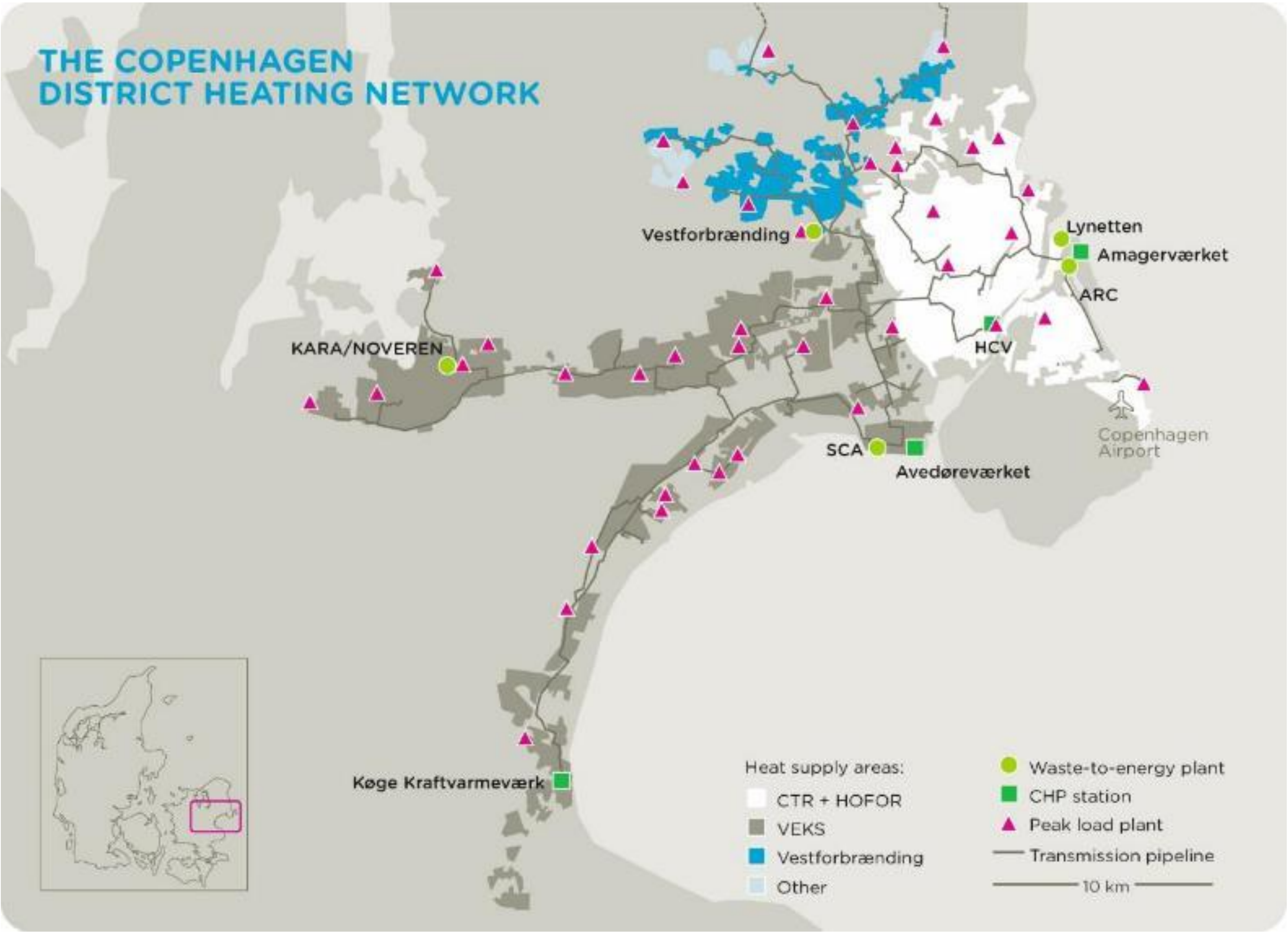
See also case 1 in this publication from EU:
http://publications.jrc.ec.europa.eu/repository/bitstream/JRC104437/study%20on%20efficient%20dhc%20systems%20in%20the%20eu%20-dec2016_final%20-%20public%20report6.pdf

MANY UTILITIES CO-OPERATE IN ONE INTEGRATED SYSTEM

- 20 local governments
- 3 heat transmission companies
- 20 distribution companies
- Local democratic ownership of all companies
- Except few private producers and a state-owed CHP



4 large DH utilities: CTR.dk HOFOR.dk VEKS.dk VESTFOR.dk

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THE SYSTEM IS IN A TRANSITION FROM FOSSIL FUELS TOWARDS EFFICIENT USE OF CHP, WASTE AND WIND ENERGY

1970

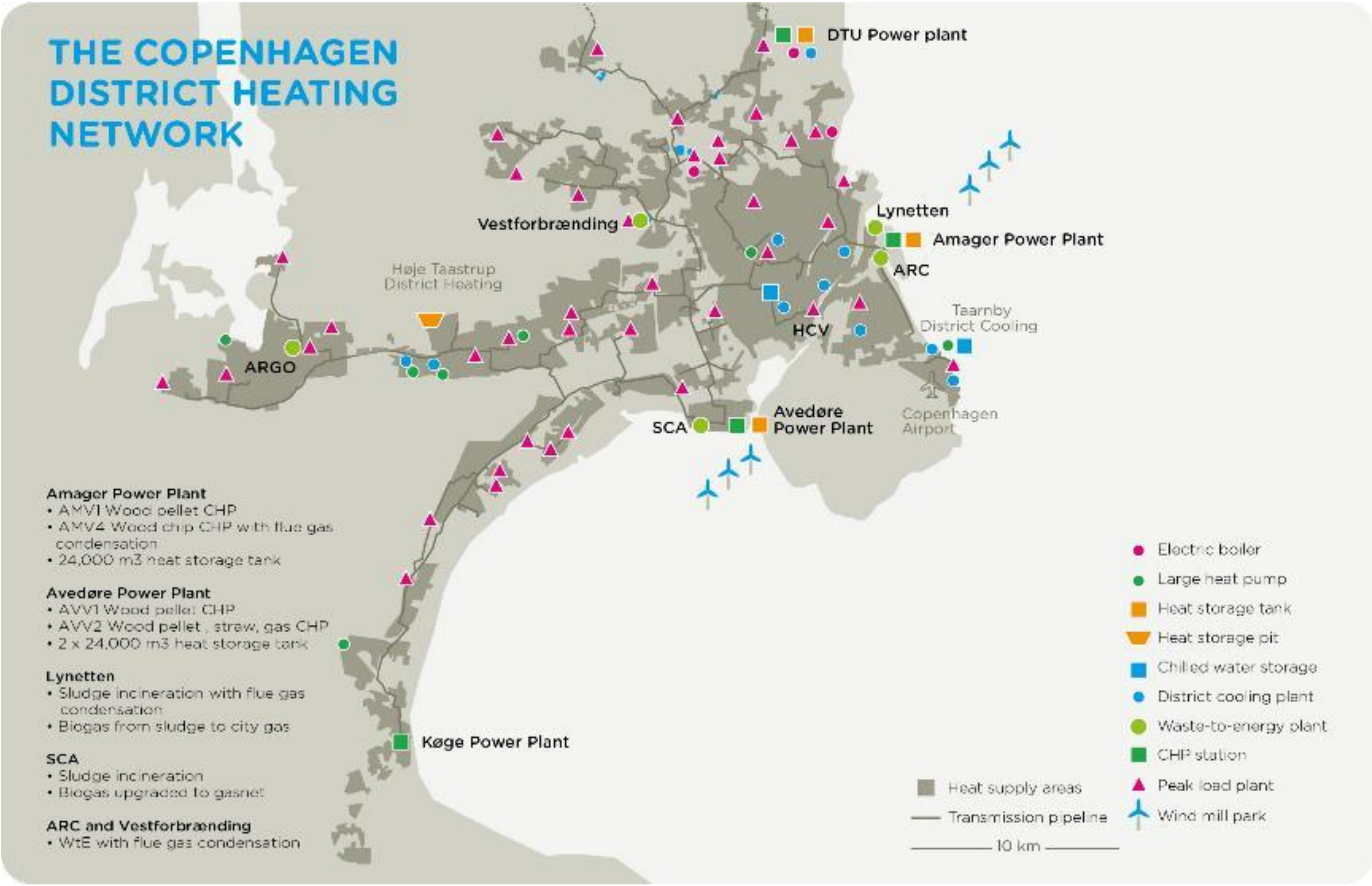
- low share of DH
- Steam and high temp
- 100% oil

2010

- More DH at lower temp.
- Waste, coal and gas CHP

2020

- Steam system closing
- From coal to biomass
- More DC and heat pumps



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AVEDORE CHP PLANT ESTABLISHED IN 1990 AT A NEW SITE CLOSE TO THE HEAT MARKET

- 1990 AVV1 330 MW heat from coal fuelled CHP plant
- 2000 AVV2 500 MW heat from gas CC and straw fuelled plant
- 2 x 24.000 m3 heat storage tanks
- 2020 from coal to wood pellets

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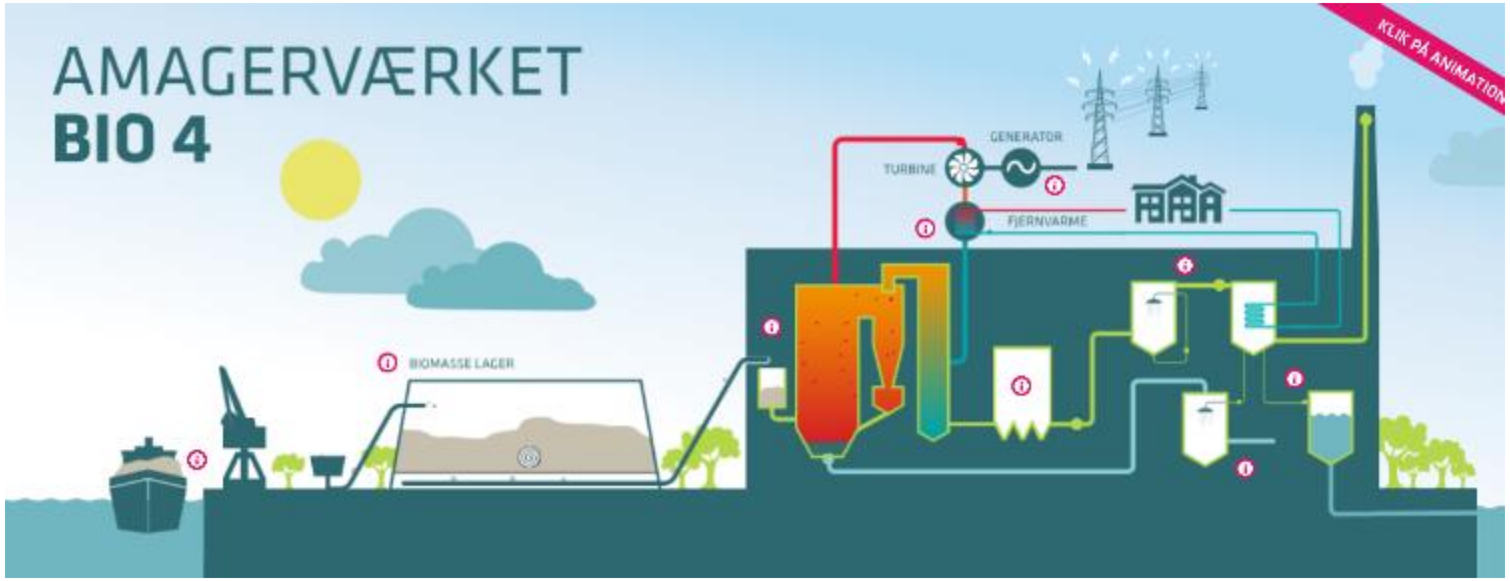
NEWEST CHP PLANT OWNED BY HOFOR, MUNICIPAL MULTI UTILITY, (DH, DC, CHP, GAS, WATER AND WASTE WATER)

- Amagerværket BIO4 CHP plant, in operation 2020
- 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



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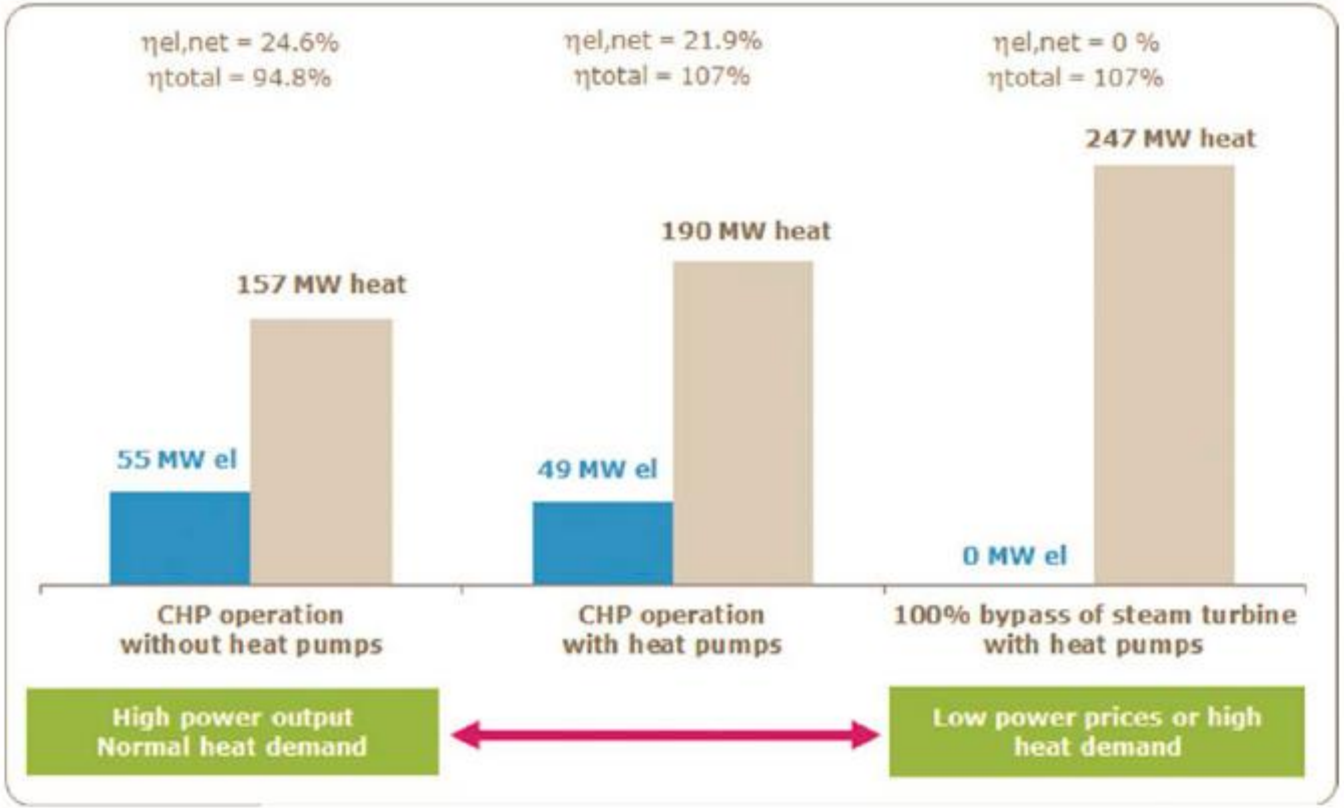
NEWEST WASTE FOR ENERGY PLANT, ARC COPENHILL – OWNED BY MUNICIPAL PARTNERSHIP COMPANY



Credit: BIG

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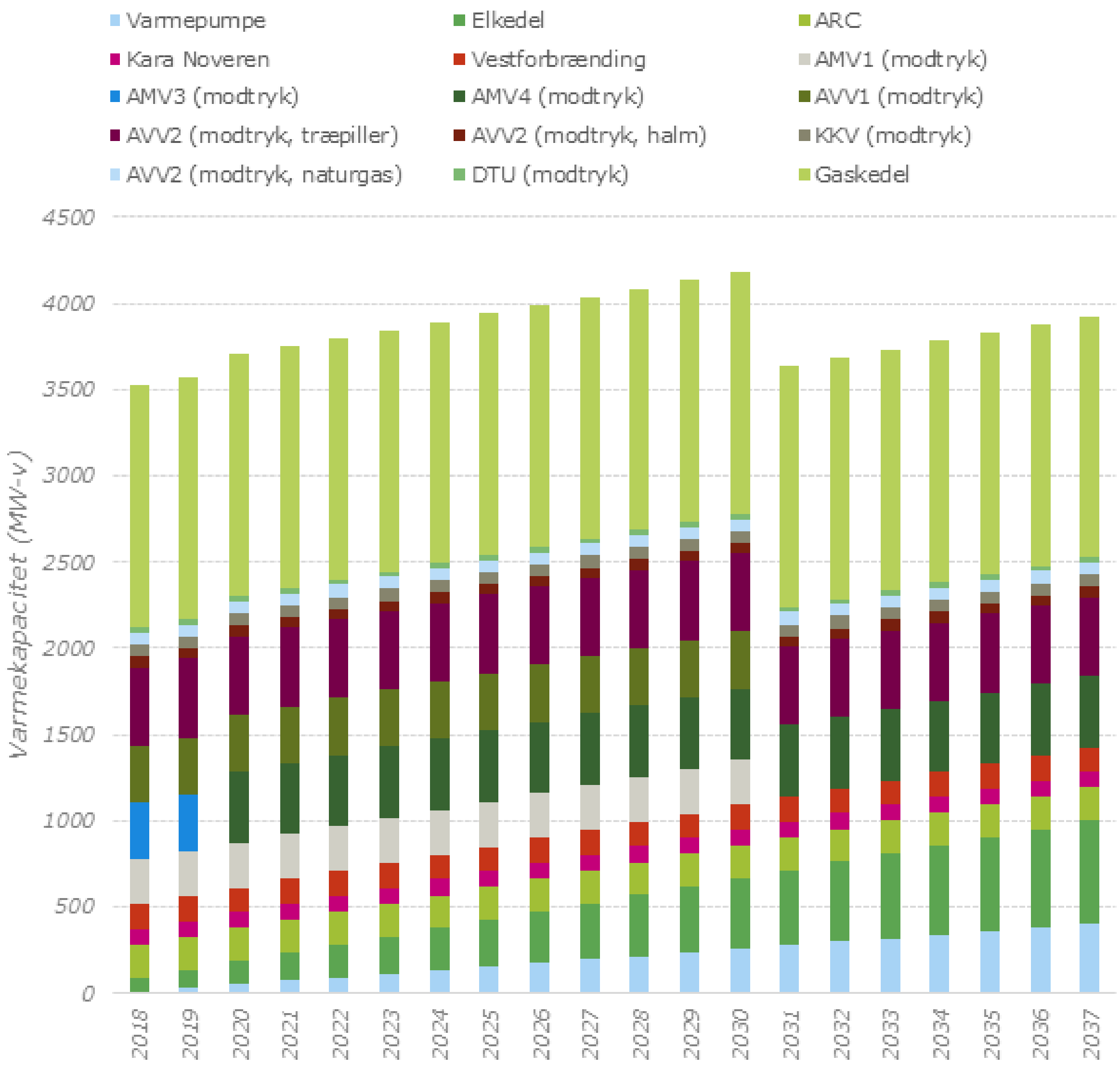
DEVELOPMENT OF PRODUCTION CAPACITY

- Existing CHP from gas and coal to biomass in 2019
- New 400 MW heat wood chip fuelled CHP will start in 2020

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



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ESTIMATED DEVELOPMENT OF PRODUCTION IN BRIEF

Greater Copenhagen DH&C, in year	2018	2038
Supplied population, millions	1	1.1?
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
Cold storage volume in 1000 m3	4	110

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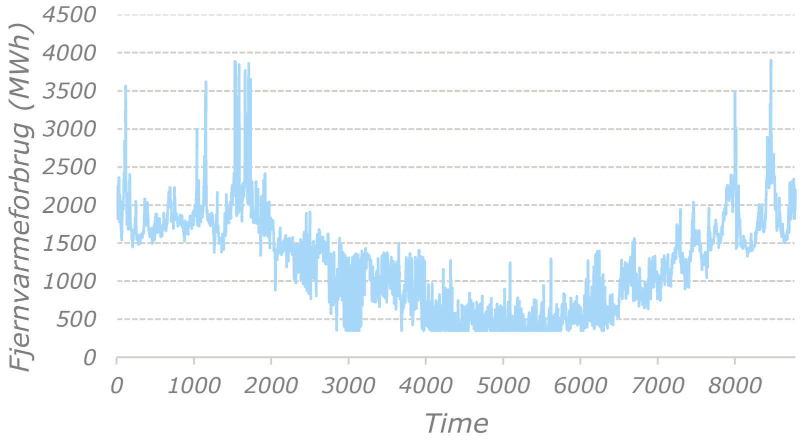
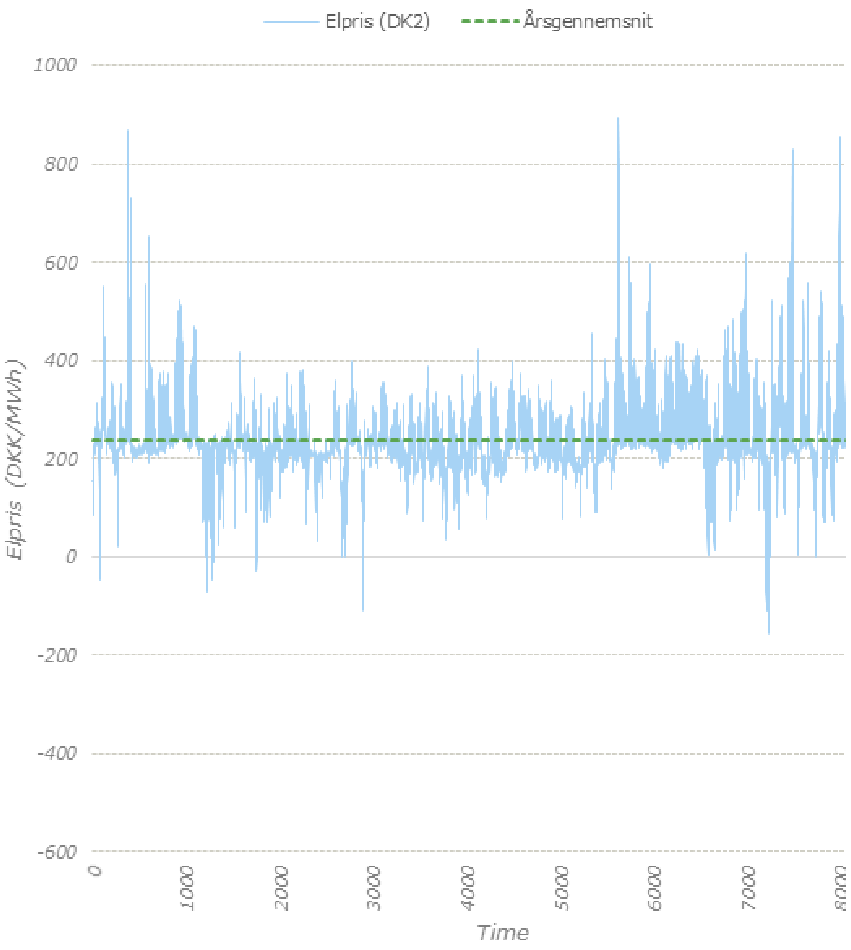
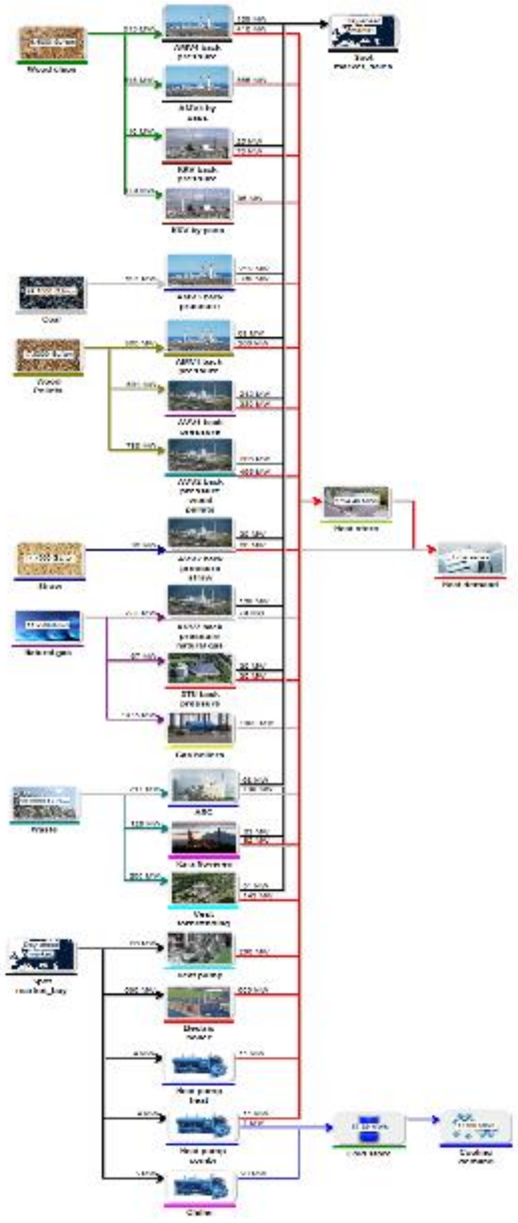
SIMULATION OF HEAT AND ELECTRICITY IN THE SYSTEM WITH ENERGYPRO

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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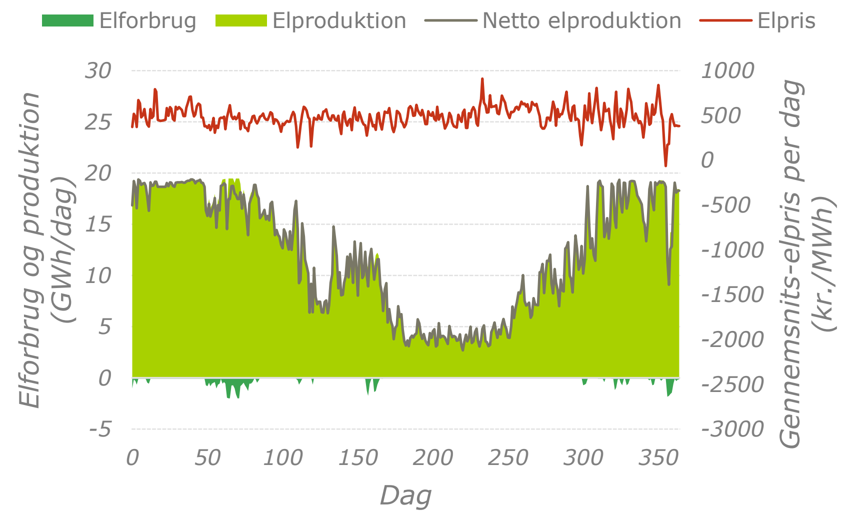
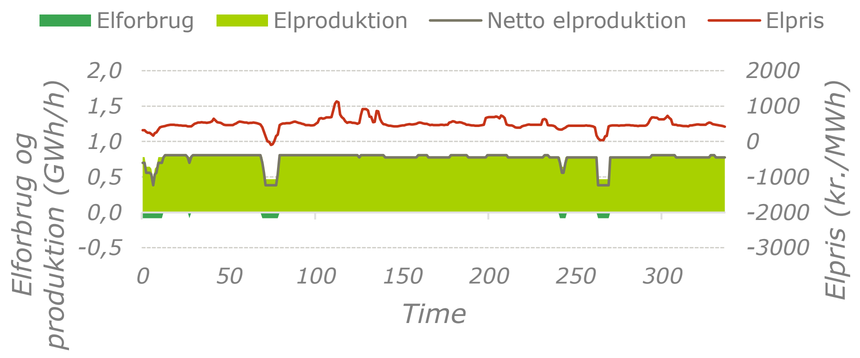
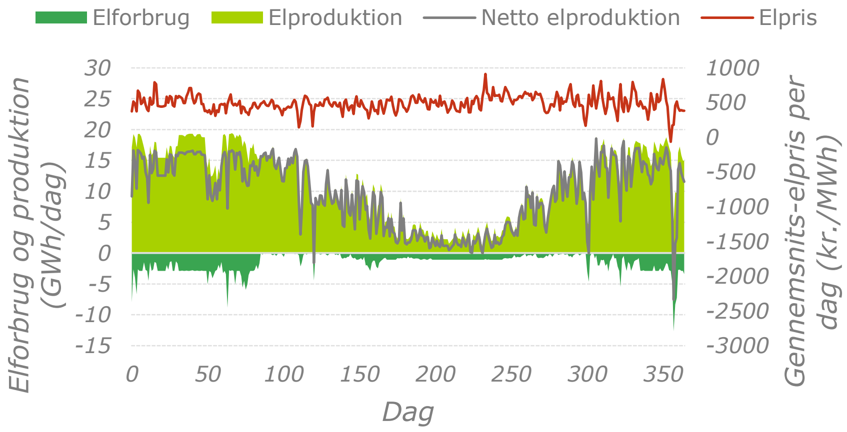
RESILIENT POWER GENERATION WITHOUT THERMAL LOSSES DEMAND RESPONSE, NO WIND OR SOLAR PV IS CURTAILED

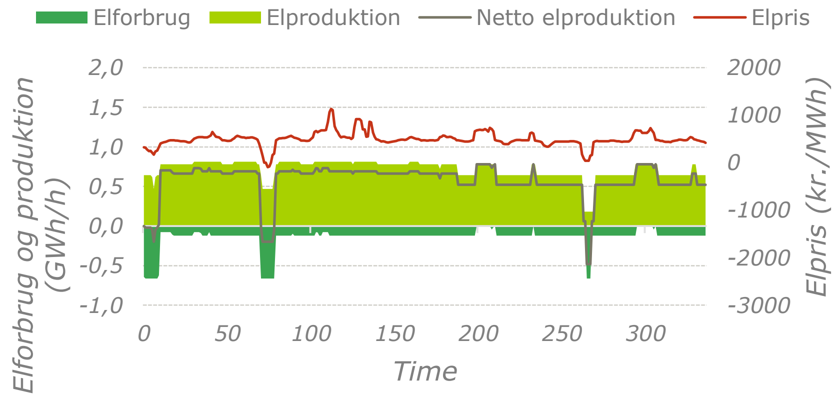
- 2018
  - 365 days
  - 300 hours





- 2038
  - 365 days
  - 300 hours





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ENERGY MASTER PLANNING IN TAARNBY 1980-2030
MUNICIPAL OWNED PUBLIC UTILITY

1980

- 100% oil boilers in Taarnby

1985 optimal zoning of new DH and gas grid

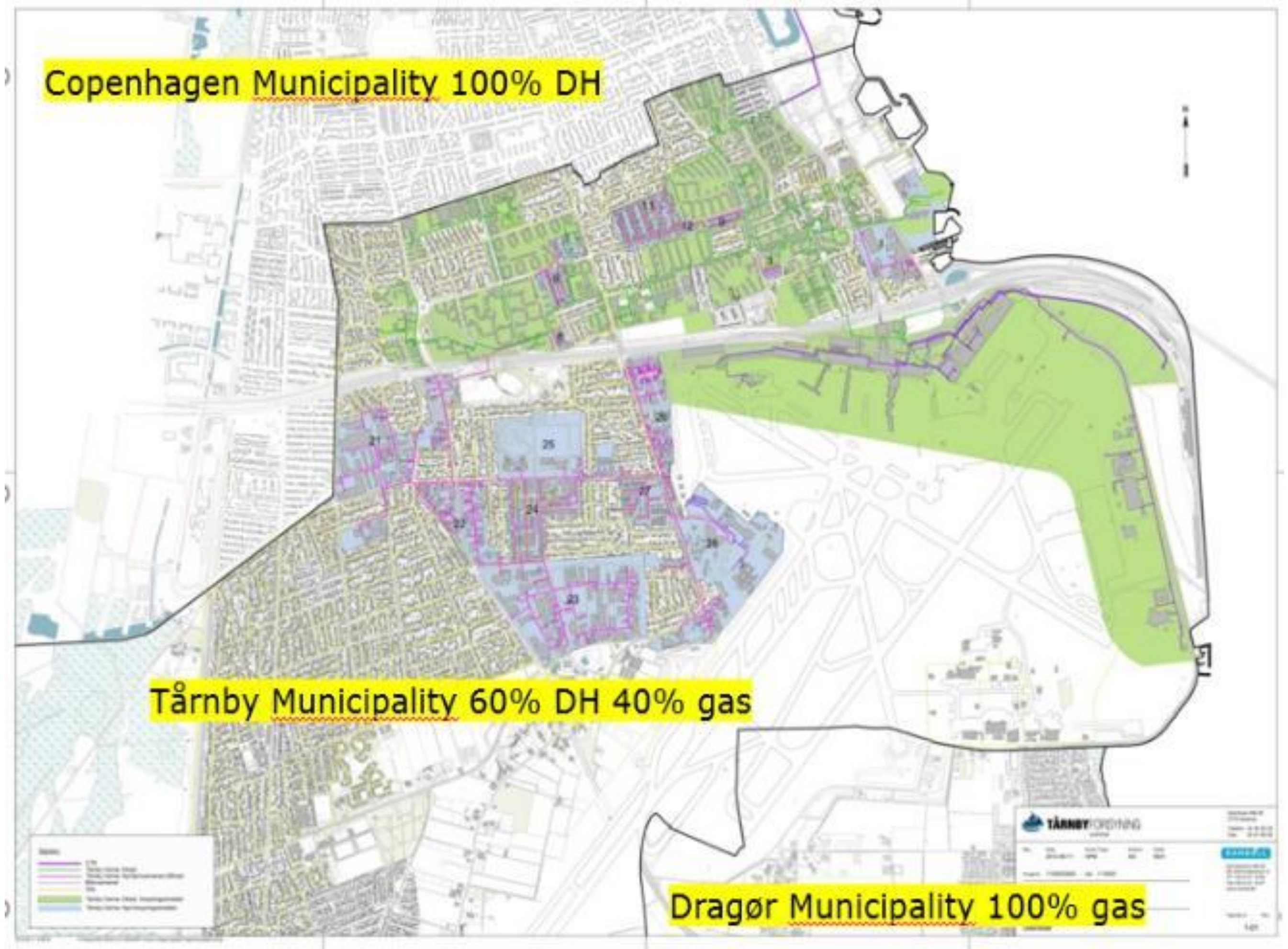
- 60% to hot water DH, large buildings (green)
- 40% to gas, single family houses (no color)

2020

- Urban development next to metro station, 100% DH and a new DC system combined with DH and wastewater
- Integration of DH with airport campus grid

2020-2030

- Second stage of the DC project ground water
- More DH to replace gas boilers (blue)
- New small DH system based on heat pump, heat storage, gas boilers and electric boilers



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KEY FIGURES OF THE DH SYSTEM FOR INTEGRATING DC

DH demand 170 GWh (growing)

Heat losses in network 6%

60 MW Maximal capacity demand

6 MW minimum capacity summer

95% production from waste and biomass CHP + 5% from boilers

60 MW back-up boiler at the airport

6,5 MW heat pump capacity extracting heat from cooling and waste water

In summer, all buildings can be supplied from heat pump, at 70 dgr.C

In winter, the temperature to consumers is boosted with heat from CTR


Waste water treatment plant – the basins are covered and the air is cleaned to avoid bad smell
Blue Planet, aquarium
New head quarter of Ferring DK
Energy plant and tank (green) located at the waste water plant
Second stage, hotel and office
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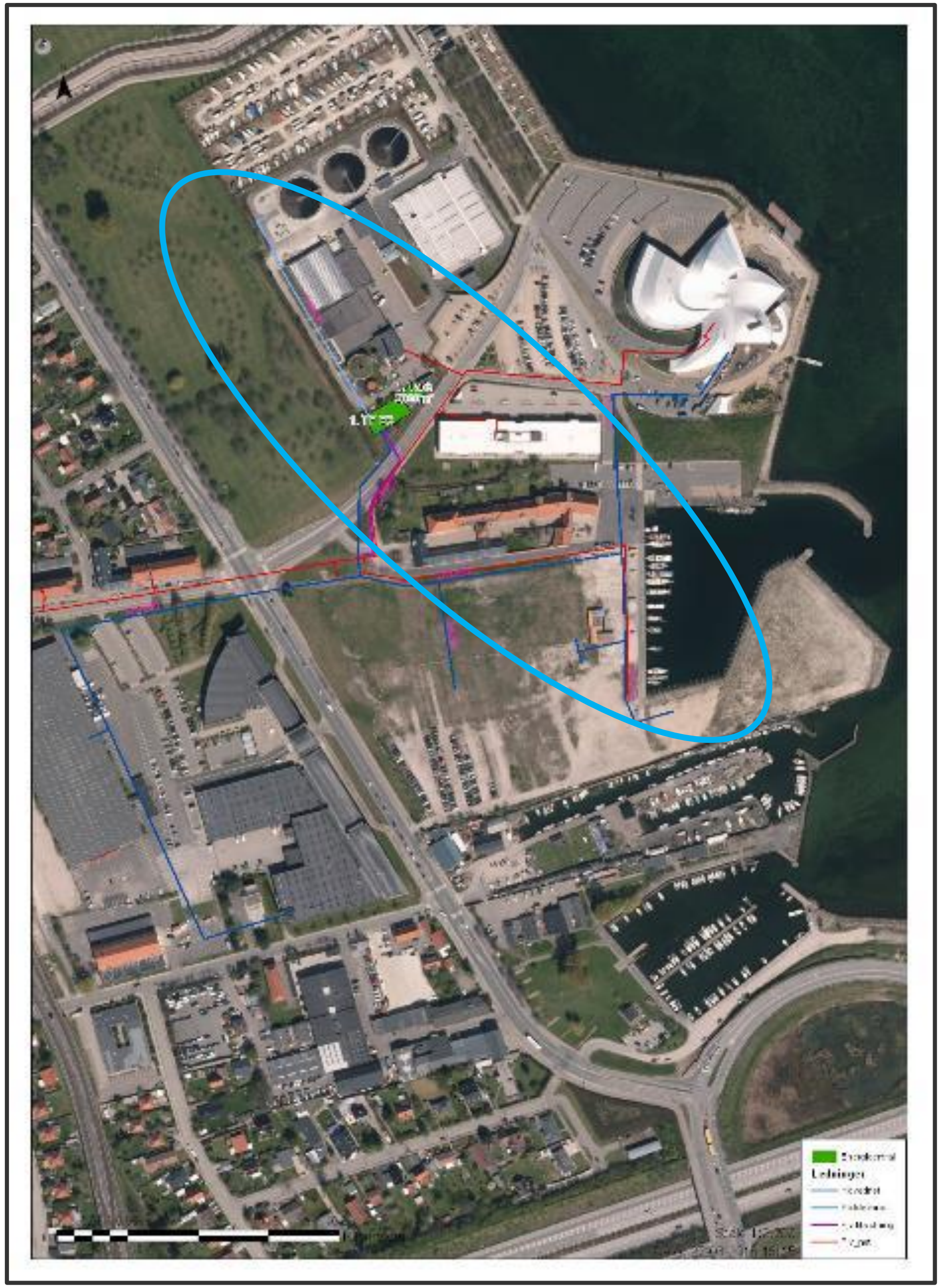
Photo animation with the aim to show the impact of the installation in the urban environment for approval of land-use plan

DISTRICT COOLING IN TAARNBY STAGE 1 IN 2020

- Cooling demand in stage 1 — 4,3 MW-c / 4.500 MWh-c
- Capacity demand to network — 4,0 MW-c ?

- Installed capacity — 7,3 MW-c incl. back-up
  - *Heat pump cooling* — *4,8 MW-c / 4.500 MWh-c*
  - *2.000 m3 chilled water tank* — *2,5 MW-c / 0 MWh-c*
- Heat Pump heating — 7 MW-h, 50,000 MWh-h
  - *Cogeneration heat/cold* — *6.500 MWh-h COP=6*
  - *From waste water* — *43.500 MWh-h COP=3,5*

- DH pipe connection to DH network
- PEH pipe connection to the treated waste waster



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DISTRICT COOLING IN TAARNBY STAGE 2 FULLY DEVELOPED

- Cooling demand in stage 2 — 9,5 MW-c / 9.000 MWh-c
- Capacity demand to network — 8 MW-c ??
- Installed capacity — 9,3 MW-c incl. back-up
  - *Ground source cooling* — *2,0 MW-c / 4.000 MWh-c*
  - *Heat pump cooling* — ***4,8 MW-c*** */ 5.000 MWh-c*
  - *2.000 m3 chilled water tank* — *>2,5 MW-c / 0 MWh-c*

- Heat Pump heating — 7 MW-h, 50,000 MWh-h
  - *Cogeneration heat/cold* — *7.000 MWh-h COP=6*
  - *Ground source* — *5.000 MWh-h COP=6*
  - *From waste water* — *38.000 MWh-h COP=3,5*

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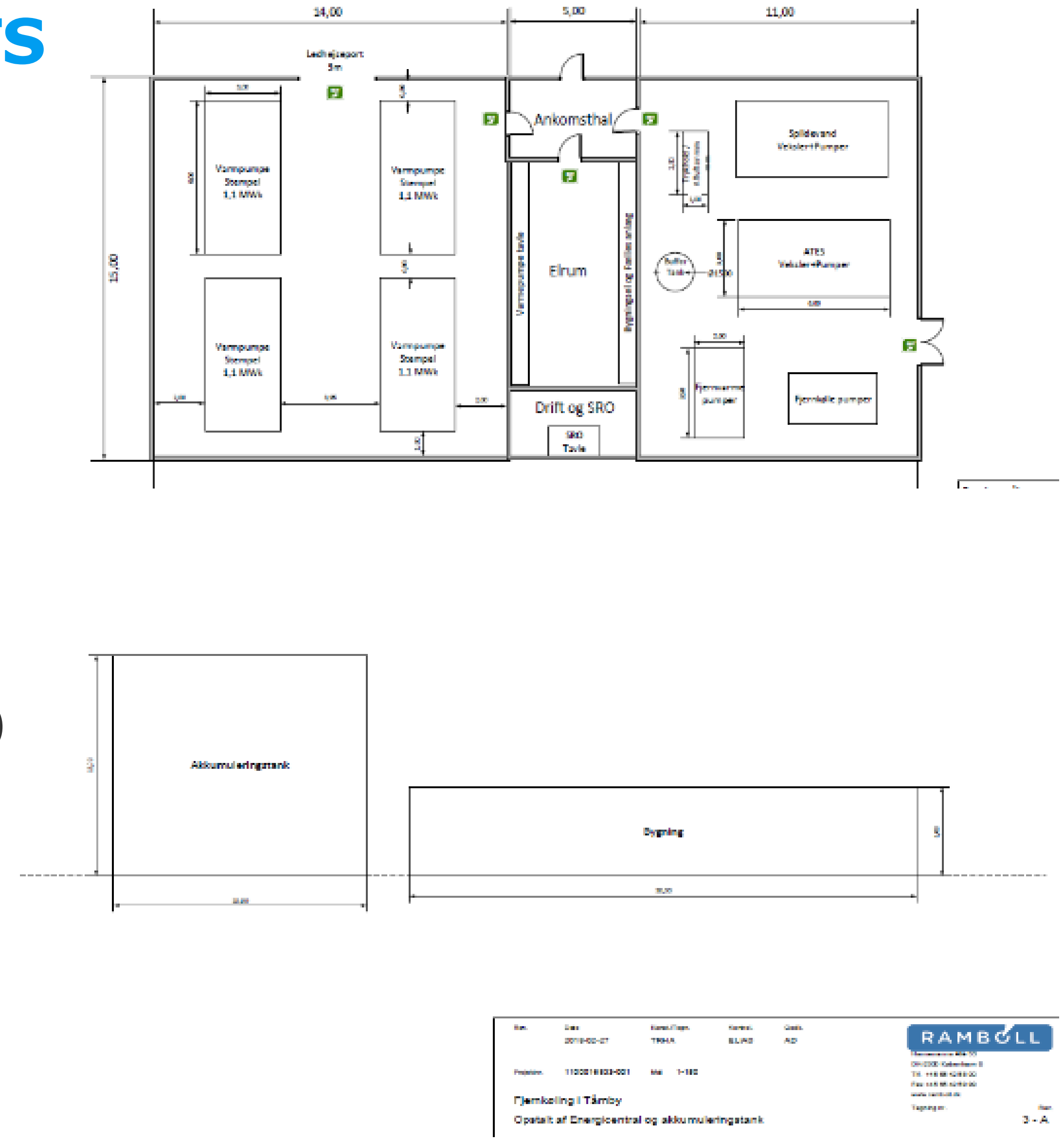
DC SAVES INVESTMENTS AND COSTS

- 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 in total
  - NPV Benefit for the society 103 mill. DKK
  - NPV Benefit consumers and utility 60 mill. DKK



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 Scanport 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.

2020 SUCCESSFUL TEST OPERATION OF THE HEAT PUMP

THE HEAT PUMPS AND PUMPS IN 5 LOOPS

1. From the tank to consumers
2. From heat pumps to the tank
3. From the heat pumps to district heating
4. From waste water out-let to heat pumps
5. From ground water to heat pumps

THE DISTRICT HEATING AND COOLING NETWORKS

- DH and DC in the same trench saves cost
- No-dig method can save cost and space
- Twin pipes saves cost and space
- Good co-operation saves cost and time (the crane from the building contractor helps to put the pipes in place)



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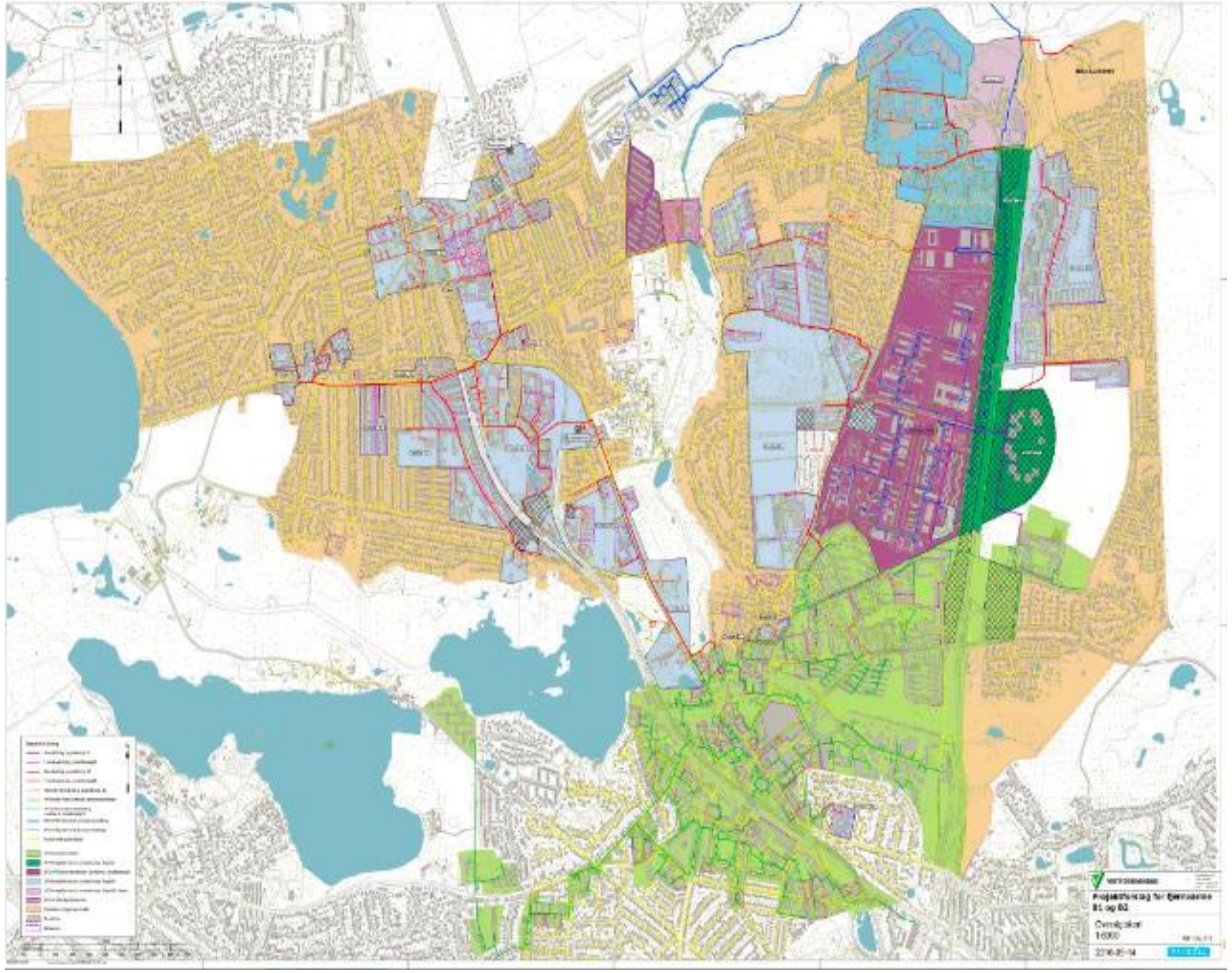
THE ROLE OF THE CAMPUS IN THE ENERGY MASTER PLANNING IN THE LOCAL COMMUNITY

- 1960 Campus DH network
- 1960 30 MW Heavy fuel oil boilers
- 1985 Coal dust fuelled CHP (test)
- 1990 Conversion of boilers to gas
- 1995 30 MW Gas CC CHP at DTU
- 1995 Heat transmission network from CHP to DTU and local DH company
- 2010 Gas CC operate in the market
- 2017 Heat transmission network interconnected to Greater Copenhagen district heating system
- Extension of the DH around DTU



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

1995
- Gas fuelled CC plant 33 MW elec./30 MW heat
- Total efficiency of the plant 90%
- Heat storage tank 8.000 m3

2017
- Gas fuelled CC plant 33 MW elec./30 MW heat
- Interconnected to the City DH part of Greater Copenhagen
- Electric boiler at CHP plant 40 MW

2030
- Heat pump to DC system 3,4 MW cold / 4,4 MW heat
- 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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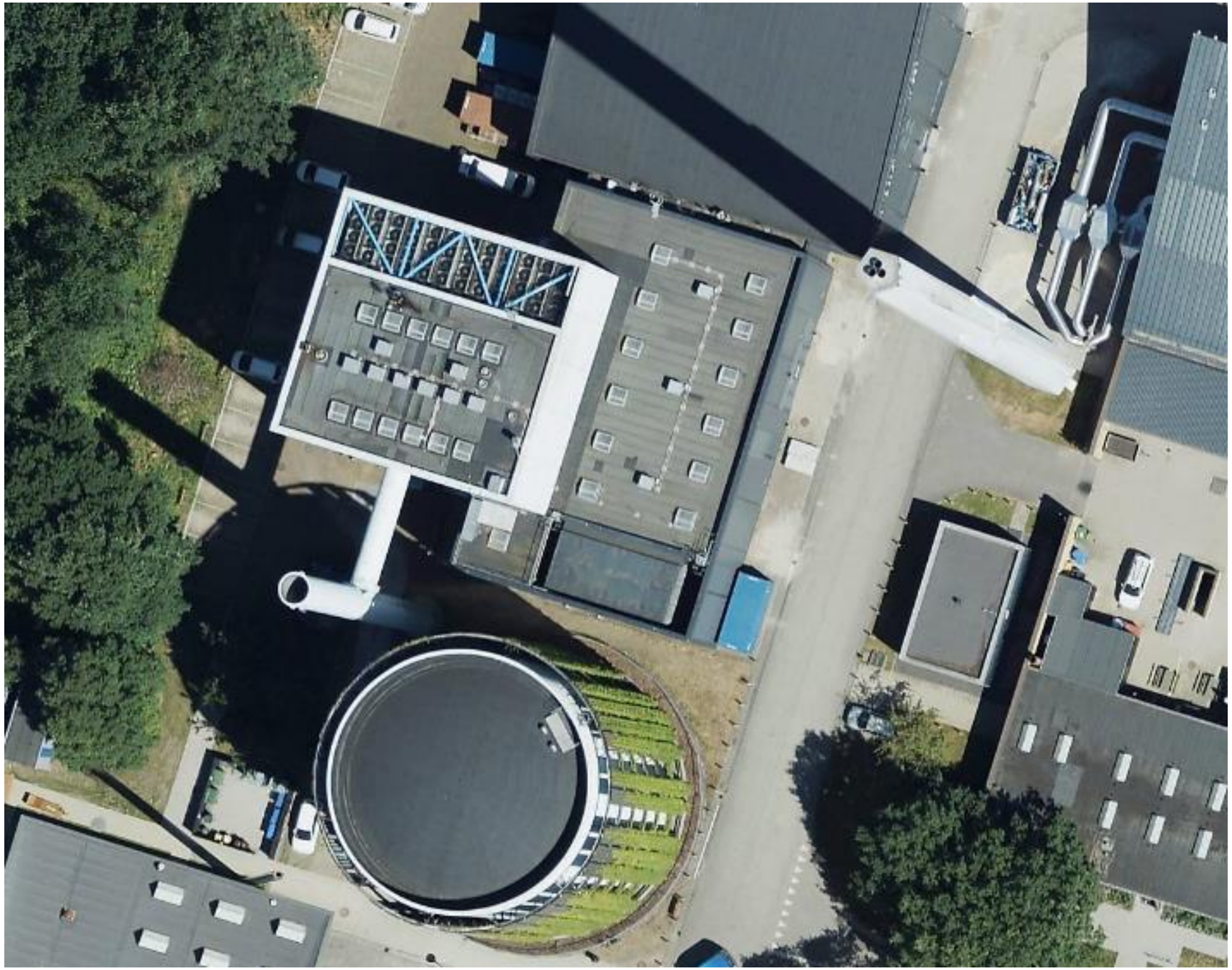

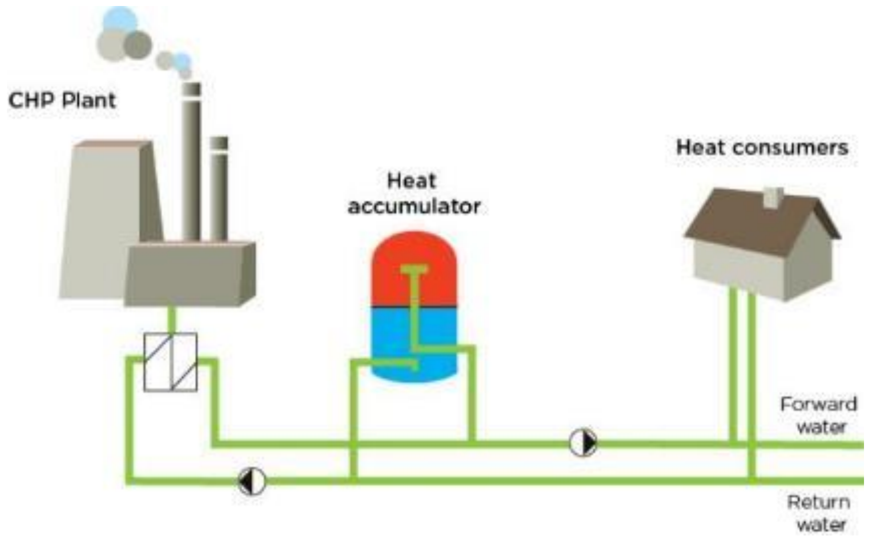
CHP Plant
Heat accumulator
Heat consumers
Forward water
Return water

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THE ROLE OF MORE THAN 200 SMALL CONSUMER OWNED COMPANIES AMONG THEM GRAM, TOFTLUND, JÆGERSPRIS

- 1970 typical heavy fuel oil
- 1975 look for sources to replace oil
- 1985 gas boilers or biomass
- 1995 gas CHP engines
- 2000 solar water heating up to 20% at around 100 plants
- 2010 solar up to 50% at 5 plants
- 2010 gas CHP on the market
- 2020 integration of wind
  - Electric boilers
  - Large heat pumps

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TYPICAL CONCEPT FOR LARGE SCALE SOLAR

5 has more than 50% solar heating

100 has around 20% solar heating

Typical system design:

- Heat production 30 GWh (% share)
- 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%)

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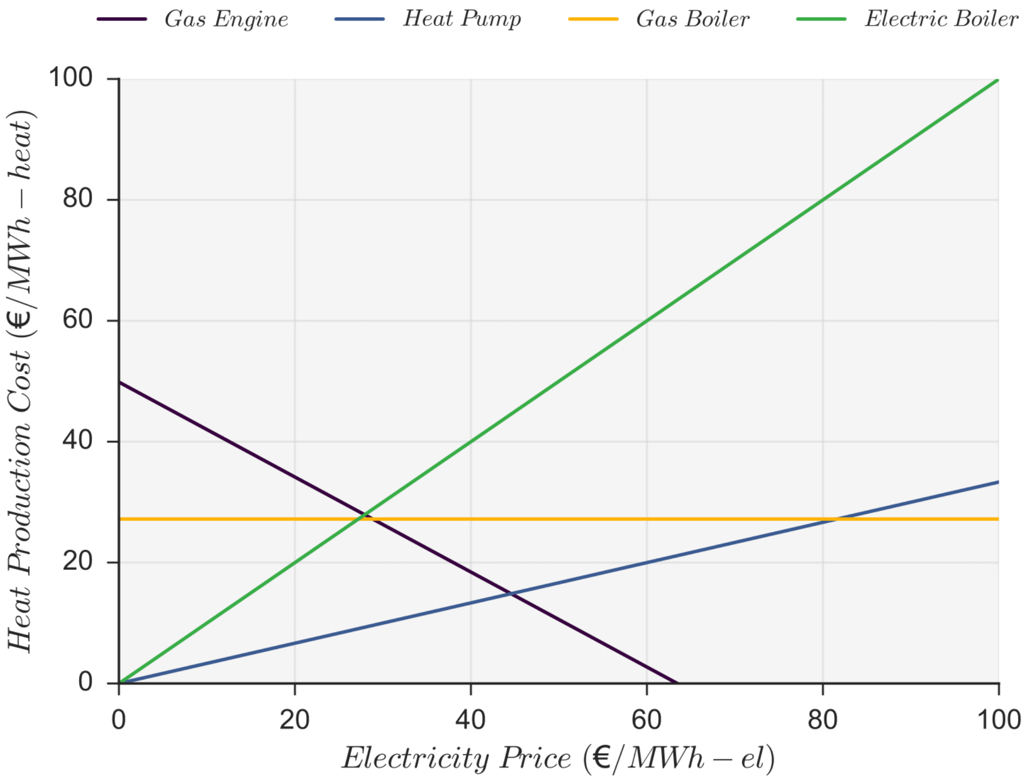
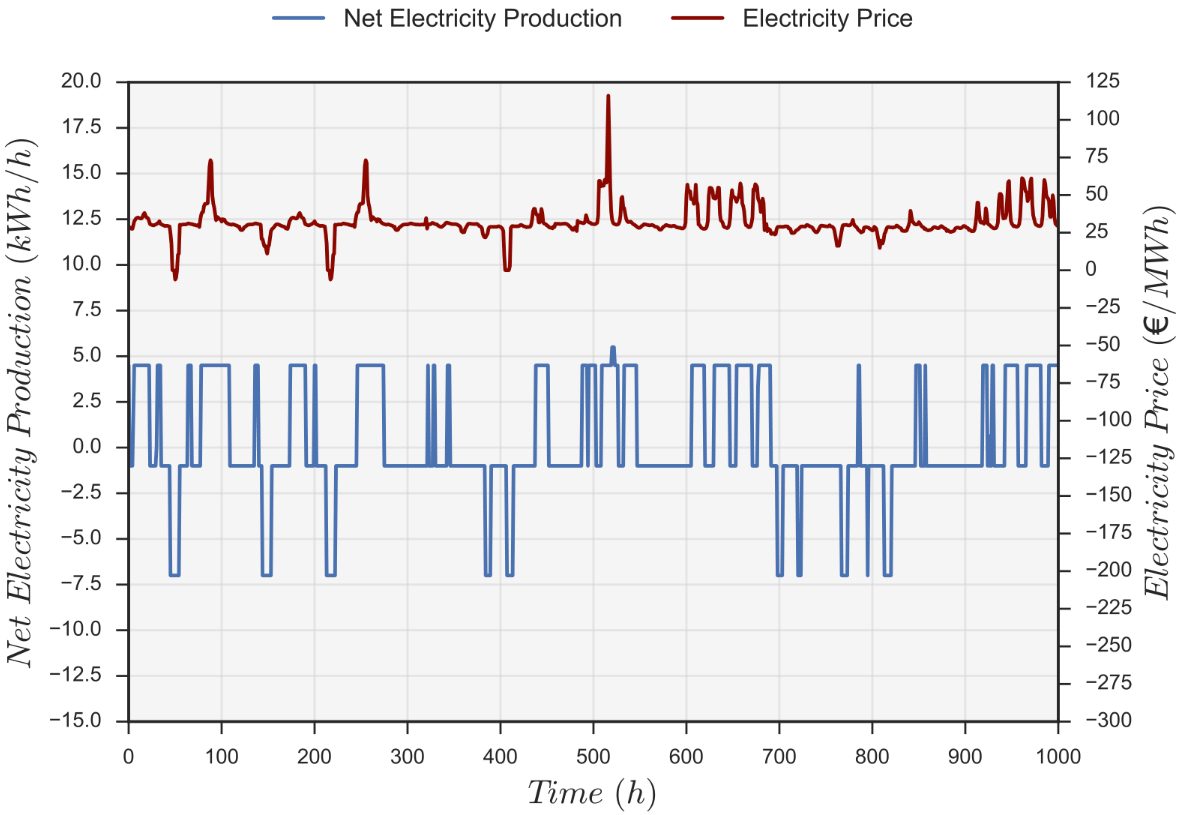
SYSTEM RESPONSE ON FLUCTUATING ELECTRICITY PRICES ACTING LIKE A VIRTUAL BATTERY





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