HOW TO USE DISTRICT ENERGY SYSTEMS AS A VIRTUAL BATTERY IN MICROGRID SYSTEMS

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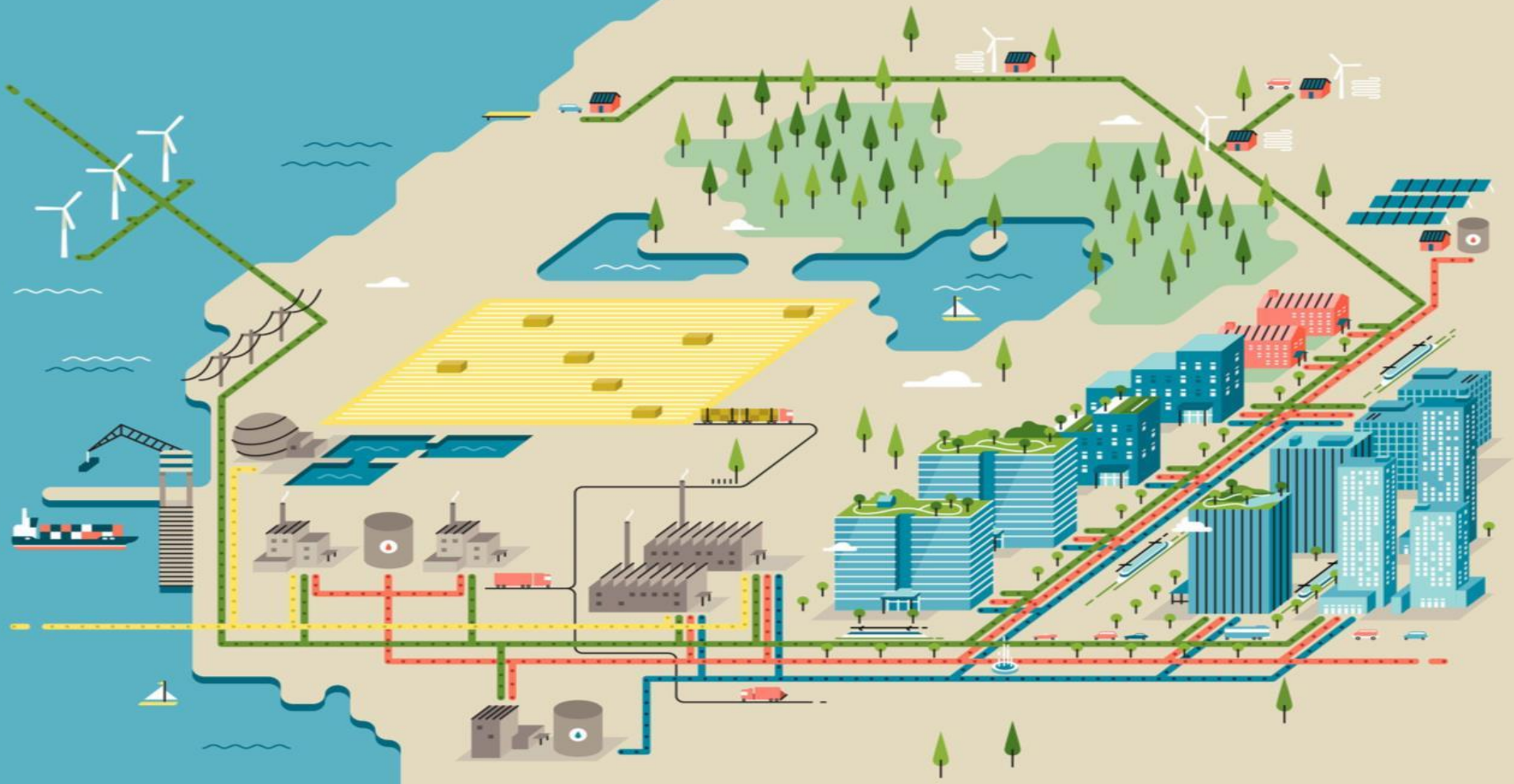
RAMBØLL

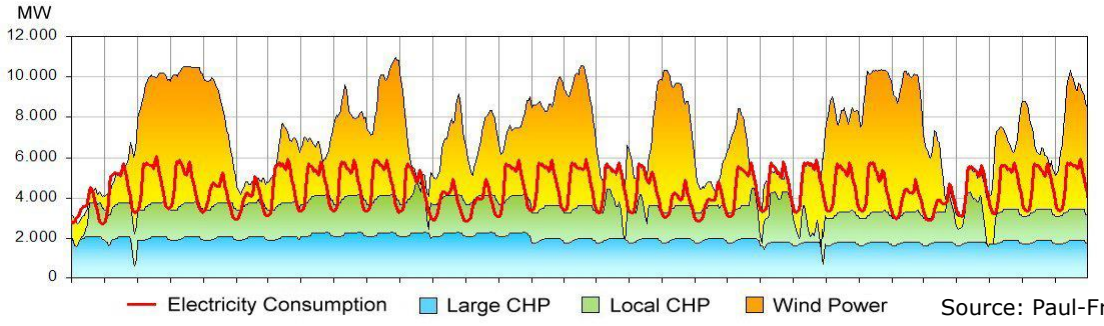
INTEGRATED SMART ENERGY SYSTEM WITH THERMAL STORAGES THAT WORKS LIKE A VIRTUAL BATTERY



MAIN COMPONENT OF THE SMART ENERGY SYSTEM TO INTEGRATE WIND AND SOLAR

- Interconnected grids with storages
  - International power grid, Nordpool market, with some hydro storage
  - National natural gas grid with gas storage
  - City-wide district heating grids with thermal storages
  - Local district cooling grids with thermal storages
  - Buildings with Low-temperature heating and High-temperature cooling
- Conversion technologies (interconnecting the grids)
  - CHP plants
  - Heat pumps for co-generation of heating and cooling
  - Electric boilers
  - Absorption heat pumps
  - P2GAS

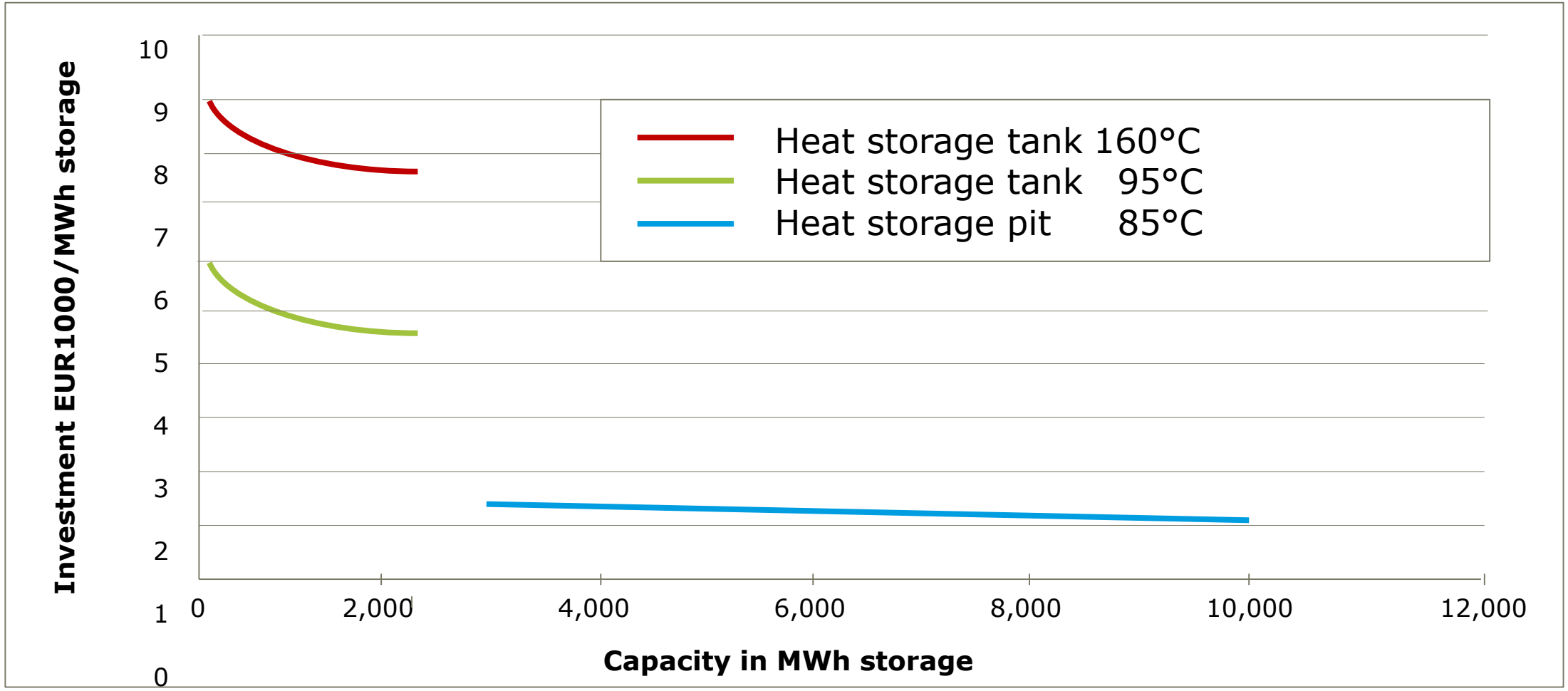
THE THERMAL VIRTUAL ELECTRICITY STORAGE (BATTERY)



Source: Paul-Frederik Bach

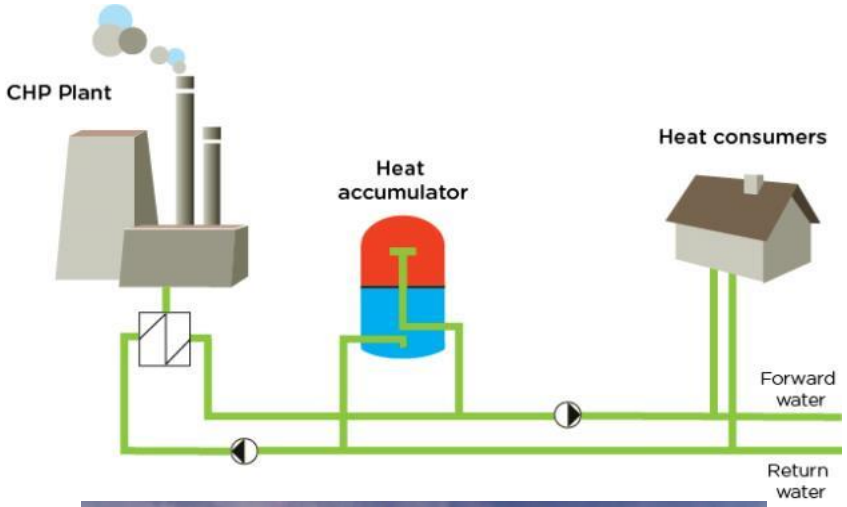
- The baseline
  - Small heat pumps without storage og gas boiler back-up
  - Can-not adjust consumption to the fluctuations of the wind
- The virtual electricity storage
  - DH&C grids
  - Large heat pumps, which can be interrupted
  - Electric boilers, operates only at low price
  - CHP plants, operates only at high price
  - Hot and cold water storage, daily and seasonal

COST OF HEAT STORAGE TANKS AND PITS



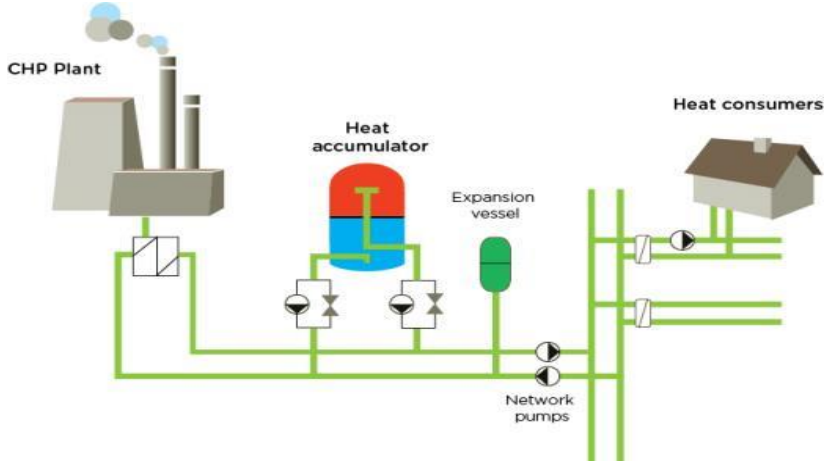
THE SIMPLE HEAT STORAGE TANKS PRESSURELESS AND DIRECT CONNECTION

- All CHP plants have heat storage tanks in Denmark
- Optimize operation of the CHP plant > 8 max load hours
- Can integrate surplus heat from waste, solar, wind etc.
- Optimize the operation of the DH system
- Maintain the pressure
- Provide peak capacity the coldest day
- Fynsværket power plant, Odense
  - 70,000 m^3
  - Direct connection
  - Maximum temp 95°C. 90/40
  - Storage capacity, 3,6 GWh, e.g. 300 MW in 12 hours



ADVANCED HIGH TEMPERATURE HEAT STORAGE TANKS PRESSURIZED AND PRESSURE SECTIONED

- Temperature above 100 °C can be necessary due to consumer needs (poor heating installations),
- But - the larger temperature - the larger investment.
- Pressure sectioning can be necessary due to the pressure level in the DH grid and due to necessary pressure variations at the location
- Pressure sectioning increase costs, but is cheaper and more efficient than a heat exchanger connection
- Avedøre CHP plant, Copenhagen
  - 2 x 24,000 m^3
  - Maximal temp 120 °C actual temp. 105/50
  - Pressure diff: 10 Bar
  - Storage capacity 2,400 MWh, e.g. 300 MW in 8 hours



HEAT STORAGE PITS
PRESSURELESS AND SECTIONED BY HEAT EXCHANGER

- Heat storage pit, an innovative combination of:
  - Landfills for establishing liners to a water proof pit
  - Heat storage tank for diffusers
  - Off shore technology for diffusers and pipes
  - A floating cover (newly developed)
- Impossible to avoid oxygen in the water, therefore sectioned by heat exchanger
- Maximal temp 85 ^{o}C
- Storing weekly or monthly fluctuations
- The driver for this development in Denmark has been to increase share of solar heat up to 60%

HEAT STORAGE PITS
PRESSURELESS AND SECTIONED BY HEAT EXCHANGER

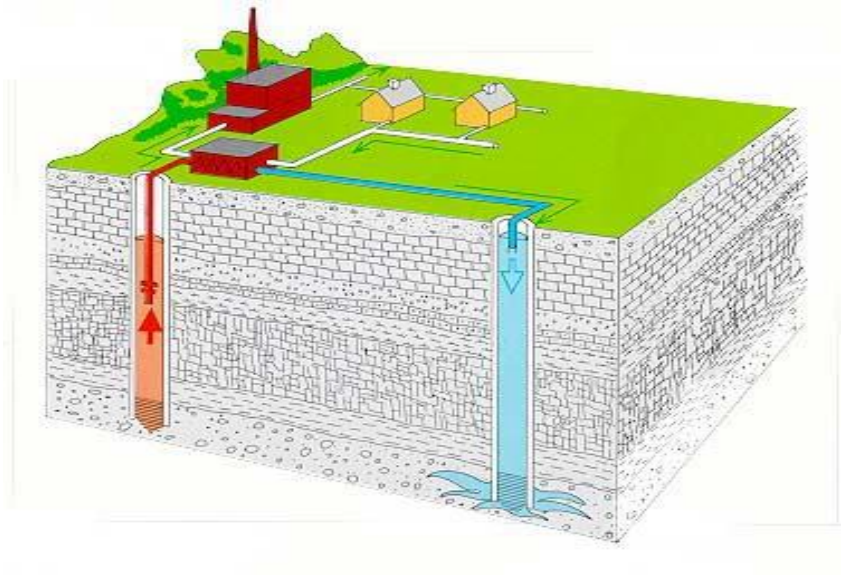
- Test plants with subsidy
  - 10,000 m^3 Test plant in 2010 in Marstal
  - 70,000 m^3 Full-scale test plant 2012 in Marstal
  - 62,000 m^3 Full-scale test plant 2014 in Dronninglund

- Commercially, without subsidy, new floating cover
  - 125,000 m^3 Gram district heating 2015
  - 200,000 m^3 in Vojens district heating 2015
  - 70,000 m^3 in Toftlund district heating 2017
  - 150,000 m^3 in Løgumkloster district heating 2017/18

Several more in the pipeline, may be 100 in 2025

CHILLED WATER STORAGES, REDUCING THE DAILY COOLING PEAKS

- Steel tank, district heating technology
- Concrete chamber, water supply technology, e.g. under new road in Carlsberg city
- Cold water storage, heat storage pit technology
- Ground source cooling (ATES)

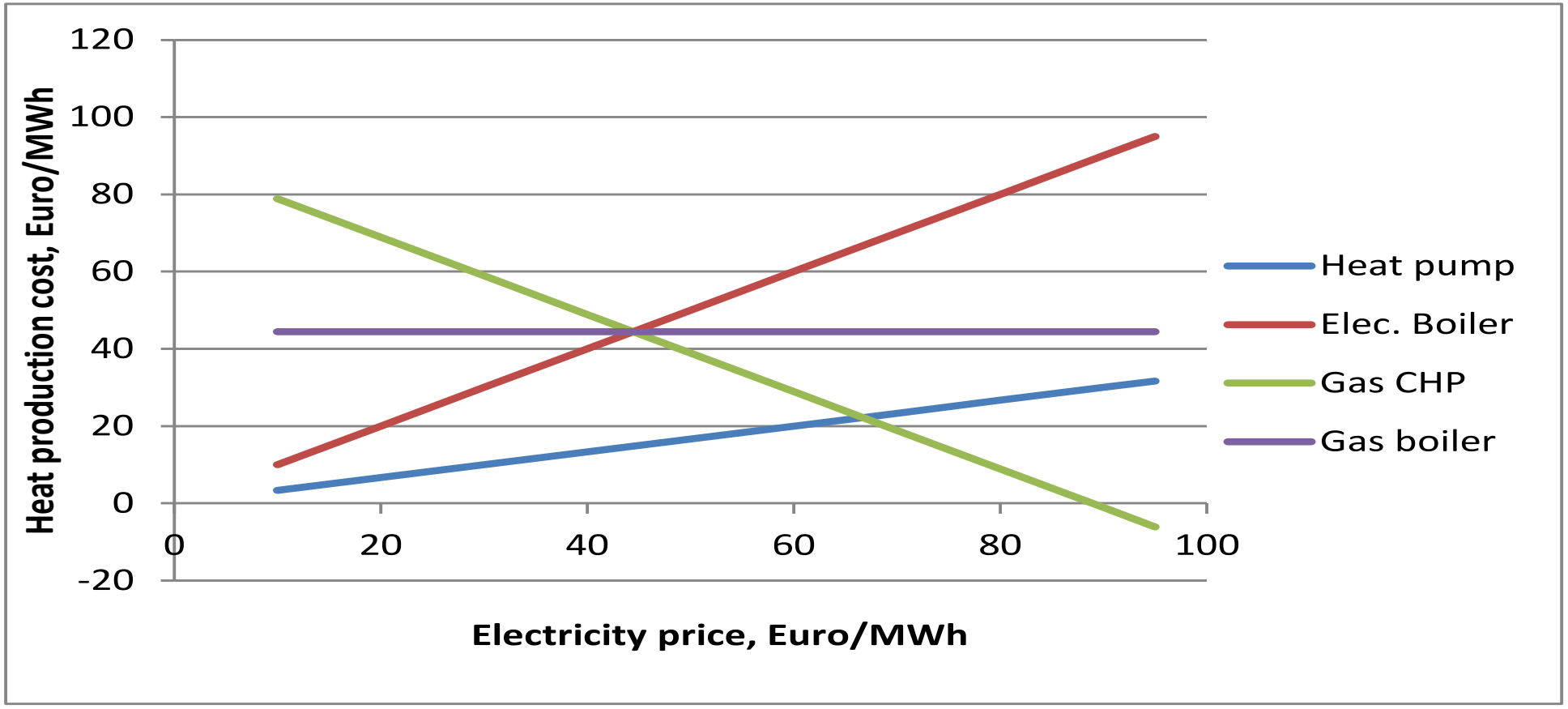


ECONOMY OF SCALE FOR HOT WATER STORAGES EUR/MWH HEAT STORAGE CAPACITY

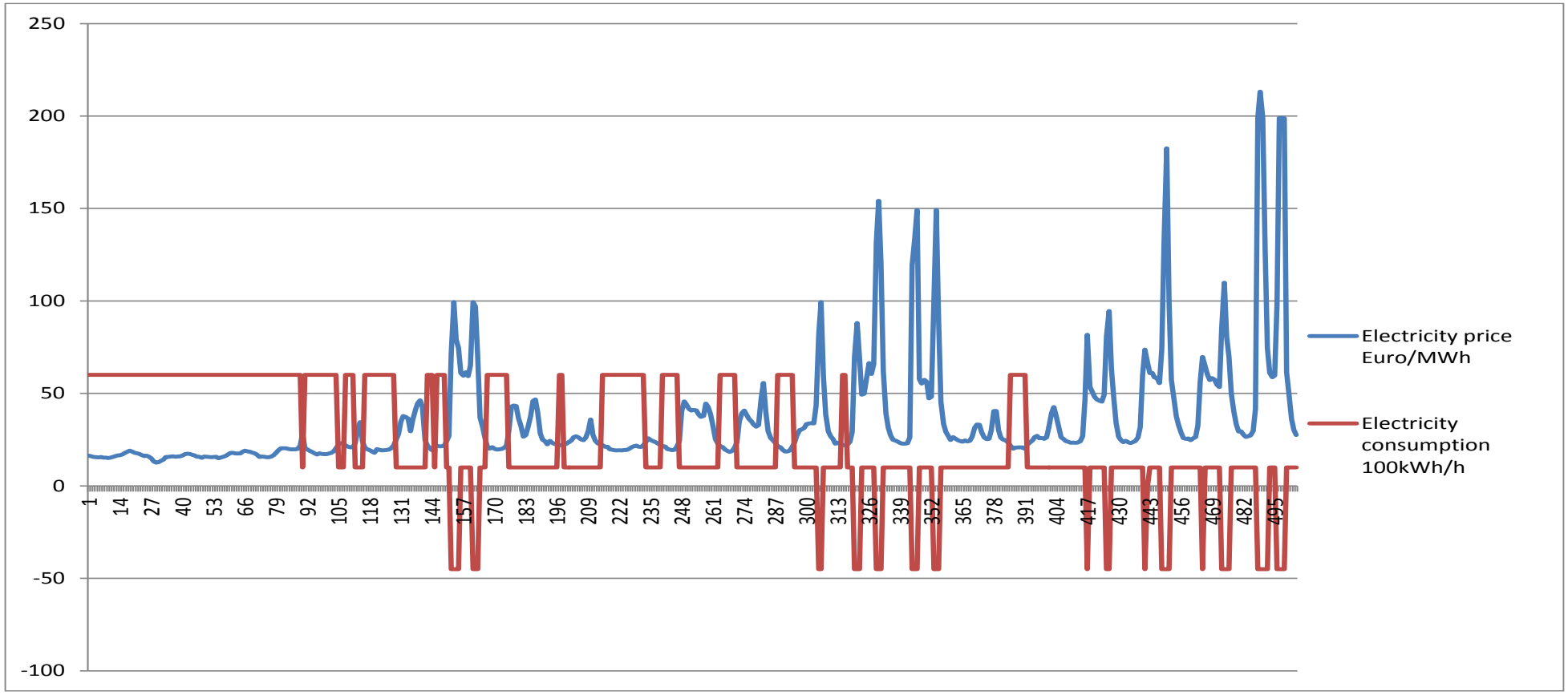
- One family house, 0.16 m^3 300,000
- Large building, 4 m^3 40,000
- DH tank, 160° C 7,000
- DH tank, < 95° C 4,000
- Storage pit, 150,000 m^3 800
- Pit alone, 100,000-200,000 m^3 500
- Marginal extension of the pit 200

- Sources: Henrik Lund and Ramboll

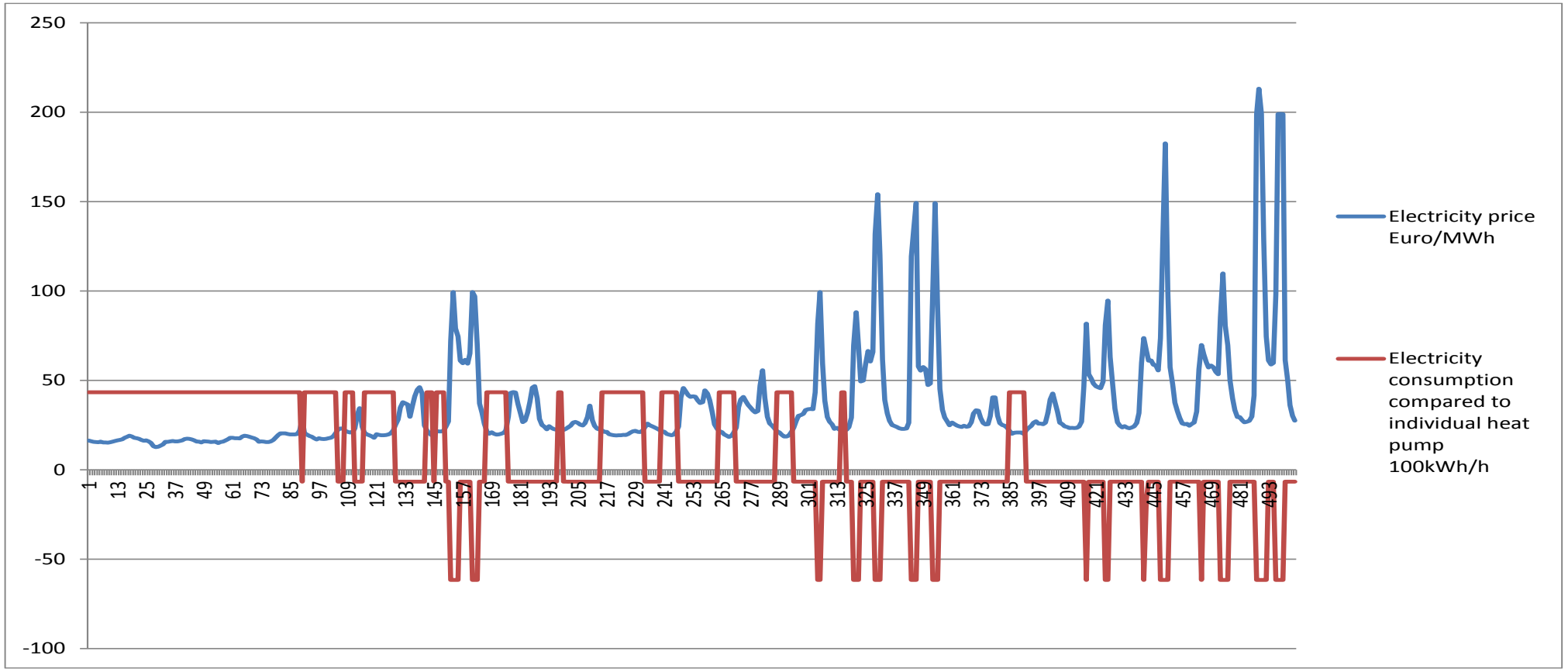
THE VARIABLE COST OF HEAT PRODUCTION DEPENDS ON ELECTRICITY PRICES, GRAM (EXCLUDING TAXES)



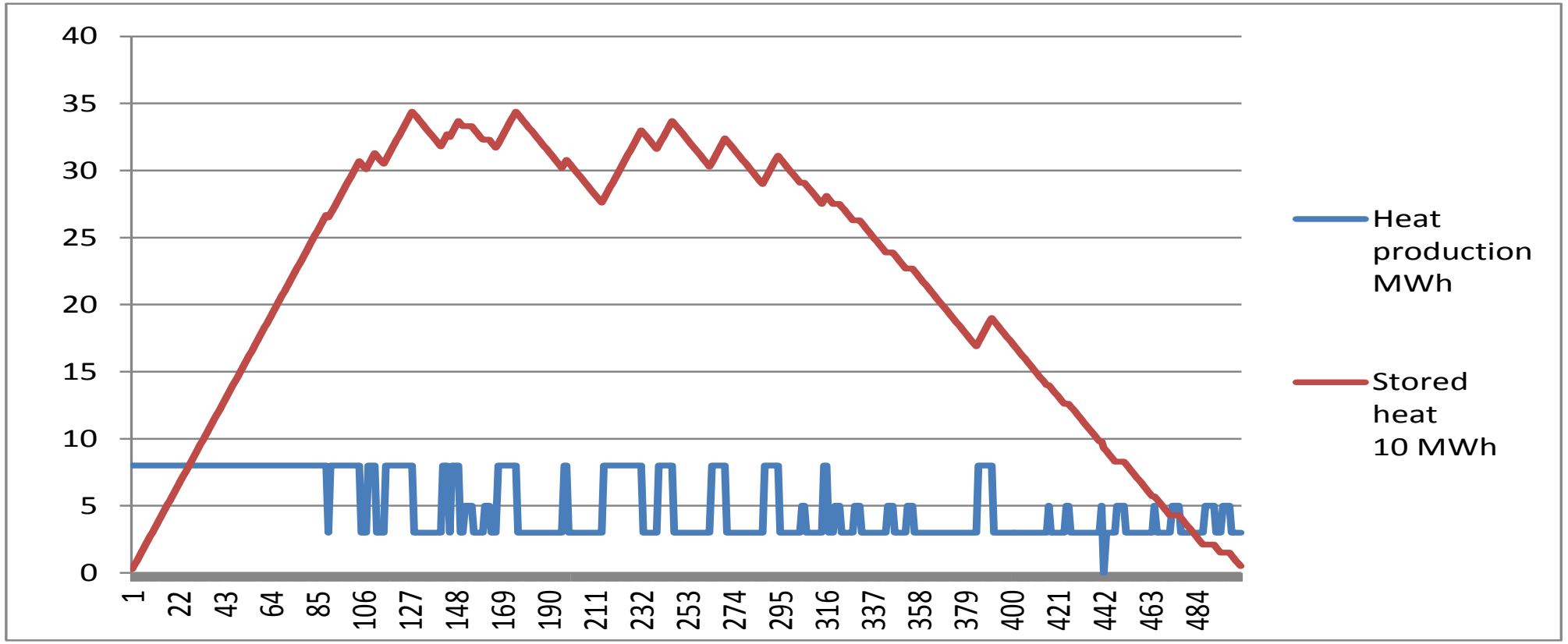
THE ELECTRICITY CONSUMPTION FOR DH RESPONDS TO THE ELECTRICITY PRICES



DH MINUS 1,7 MW_{ELEC} SMALL HEAT PUMPS – IT'S LIKE A VIRTUAL BATTERY



THE HEAT STORAGE BEHIND THE VIRTUAL BATTERY
FOR THIS PERIOD 350 MWH STORAGE IS NEEDED



QUESTIONS & ANSWERS

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