Hybrid System Design Considerations:

Finding the Right Balance

Presenters: Robert M. Neimeier / Ramboll

Joseph DiSanto, P.E., / Ramboll

Decarbonization

Balancing technology and cost efficiency in the green transition

NY-Geo – April 9, 2024

Joseph DiSanto, Senior Energy Engineer

Robert Neimeier, Client & Market Officer, Energy

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Bright ideas.
Sustainable change.

Purpose

Learning Objectives

01 Holistic energy system planning that is cost effective

02 Technology and cost considerations for baseload and peak load thermal operation needs

03 The importance of thermal energy storage for optimizing equipment operation in a renewable energy grid

04 Short-term and long-term energy transition considerations for bridging fossil fuels to low-carbon energy production technologies

Agenda

1. Holistic energy system planning
2. Baseload, peaking, and backup thermal strategy
3. Role of thermal energy storage
4. Electric capacity assessment
5. Project examples

Holistic energy system planning

Holistic Planning

Thermal energy network potential

Decarbonization influences and considerations

Goal

- Decarbonization solutions that are pragmatic
- Equitable
- Flexible
- Resilient

Heat sources

- Air
- Ground
- Wastewater
- Waste heat
- Cooling…..

Equipment

- Heat pumps
- Refrigerants
- Storage (thermal, battery)
- Piping
- System integration

Electrical grid

- Timing of renewable/carbon free energy build out and integration
- Future price fluctuations from intermittent solar and wind
- Influences – data centers/AI growth, increased cooling demand

Funding

- Grants
- Incentives

Workforce development

- Jobs
- Training
- O&M

Alternative fuels

- RNG
- Biofuels

Uncertainty

- Gas constrained areas
- Gas moratoriums
- Electric grid constrained areas
- Carbon tax

Baseload, Peaking, and Backup Strategy

Base load/peaking technologies

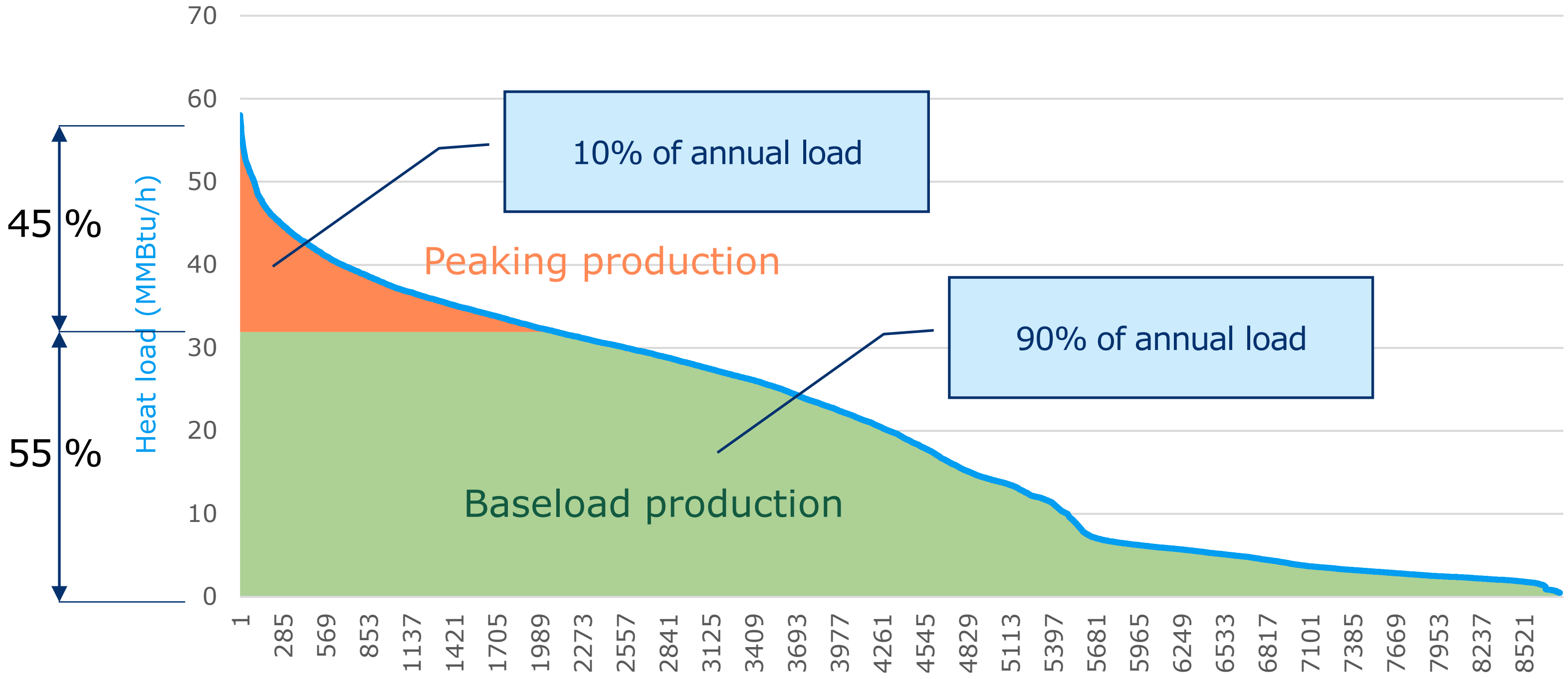
Some baseload technologies characteristics

- 55% of peak demand covers approx. 90% of annual load
- High Capital Expenditure (CapEx) (should operate many hours annually)
- Should have low fuel costs

Some peaking/backup technologies characteristics

- 45% of peak demand covers 10% of annual load
- Low CapEx (*e.g.*, boiler)
- High technology reliability (backup)
- High fuel supply reliability
- Higher fuel costs

Base Load vs Peak Load



Example Heat Load

Potential heat sources

Potential heat sources/sinks	Heat source quality
Industrial waste heat (sources could close)	High
Wastewater treatment facilities (effluent)	Medium
Heat rejection from cooling (e.g., process or comfort)	Medium
Heat rejection from refrigeration	Medium
Aquifer thermal energy storage (ATES)	Medium
Geothermal (closed loop boreholes)	Low/medium
Ambient air	Low
Sewer heat recovery (influent)	Low
Surface water	Low
Electric substations	Low
Subway tunnels (ambient or dewatering)	Low

Technology Screening

Technologies evaluated on

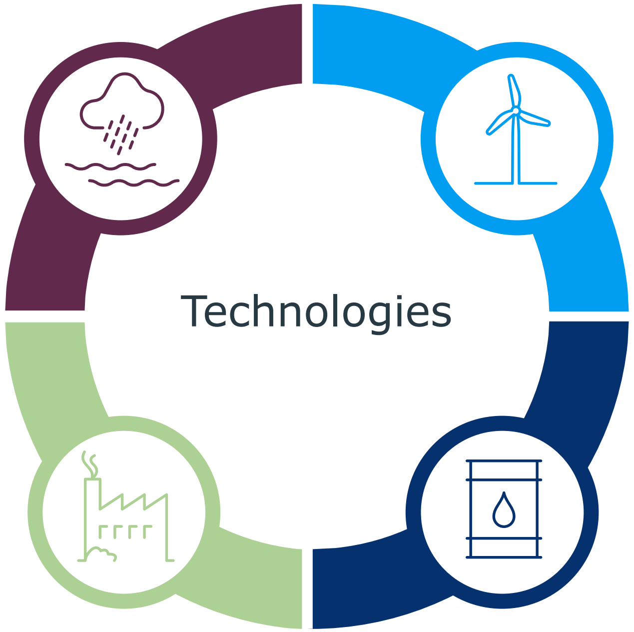
- Ability to meet the long-term GHG goals
- Capital Expense (CapEx)
- Operating Expense (OpEx)
- System integration

Electrification Technologies

- Heat pumps (ground source, air source, wastewater)
- Electric boilers

Renewable Technologies

- Wind turbine
- Solar PV
- Biofuels* (biomass, bio-oil)



Fossil Technologies

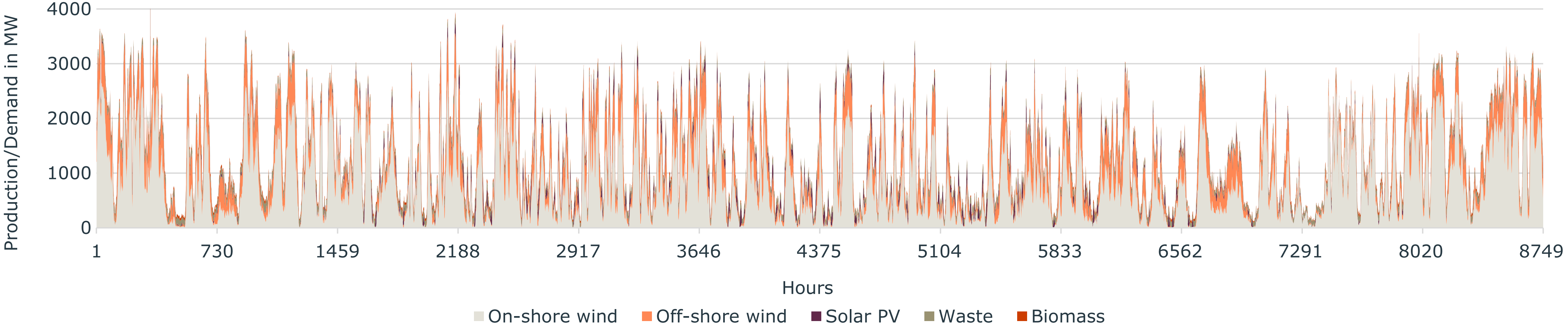
- Natural gas boilers
- Fuel oil

Energy Storage

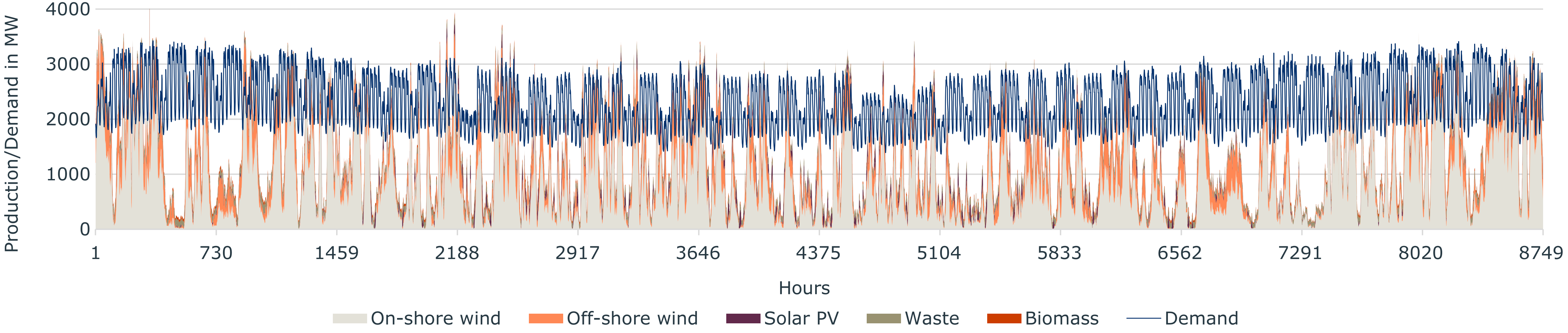
- Tank thermal energy storage (TES)
- Borehole thermal energy storage (BTES)
- Aquifer thermal energy storage (ATES)

The role of thermal energy storage

Renewable Power Production, DK-West 2015



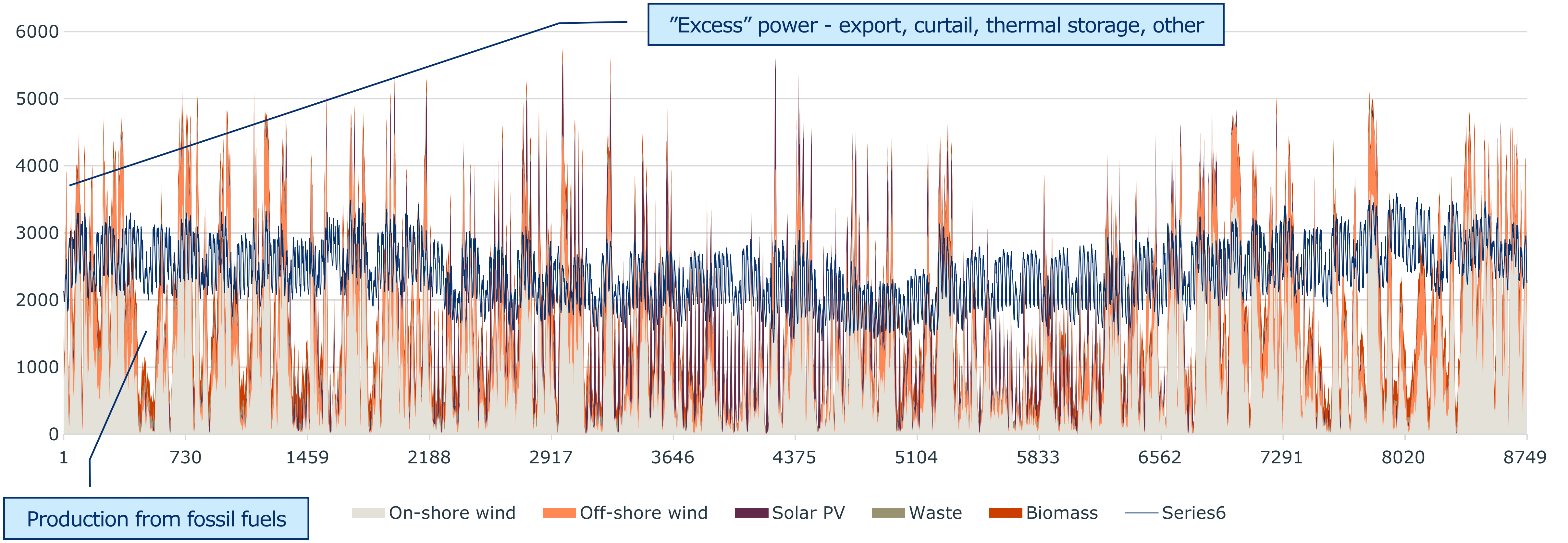
Renewable Power Production, DK-West 2015



The need for thermal storage

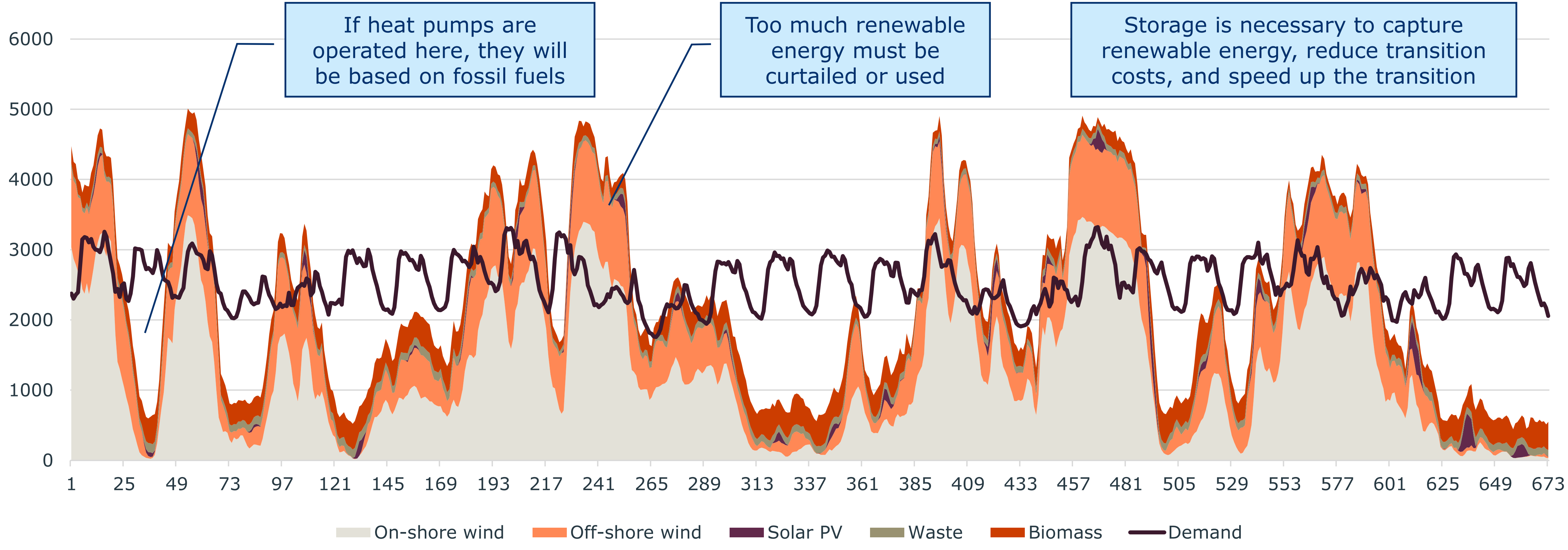
	Renewable production	Share of demand
Onshore Wind	9,356	44.3%
Off-shore wind	4,705	22.3%
Solar PV	2,158	10.2%
Waste	579	2.7%
Biomass	1,541	7.3%
Total	18,338	86.8%

Renewable Power Production, DK-West 2023



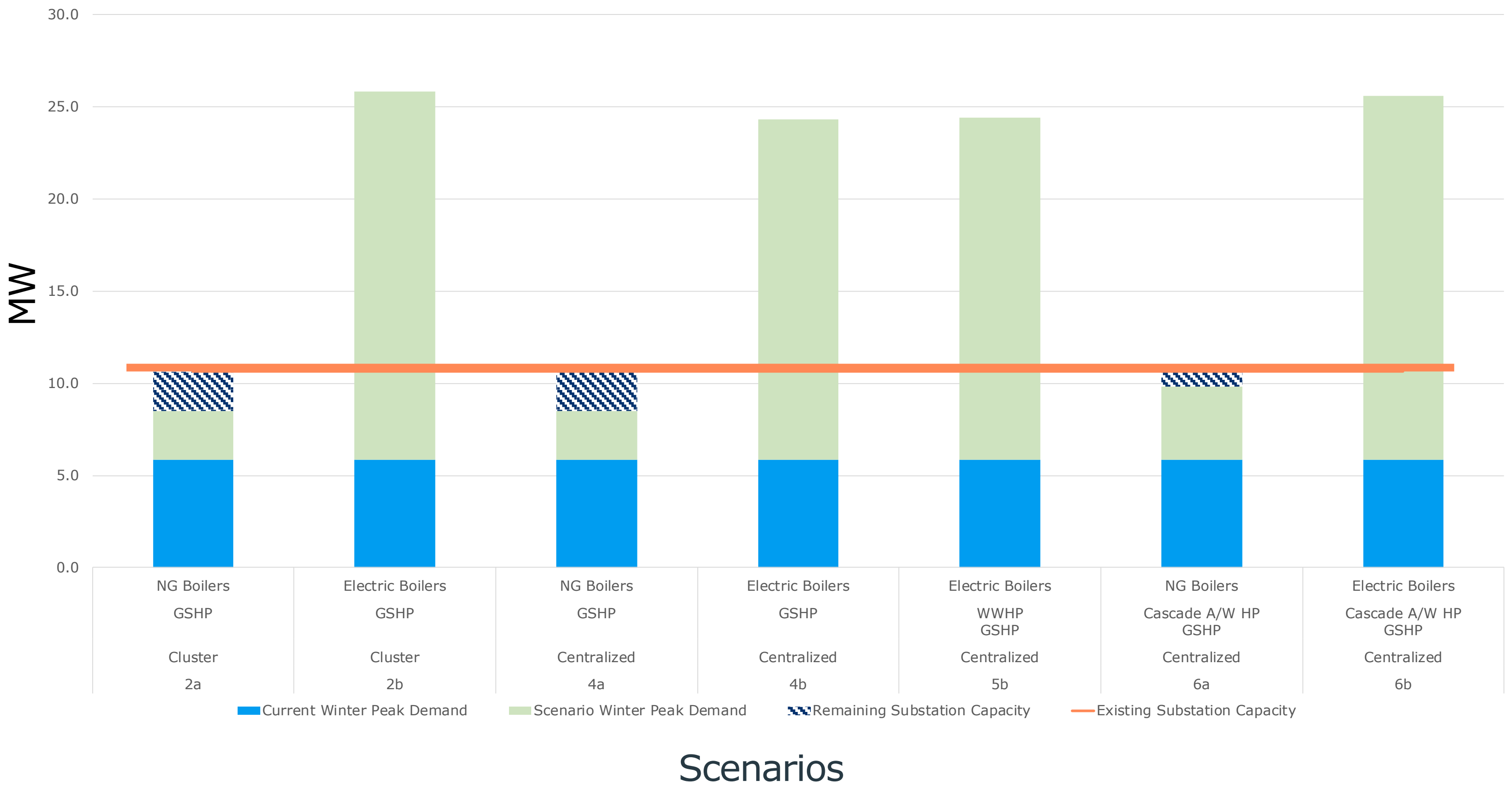
The need for storage, February 2023

Renewable Power Production, DK-West February 2023



Electric Capacity Assessment

Electrical Capacity Assessment



Potential need for electrical upgrades on

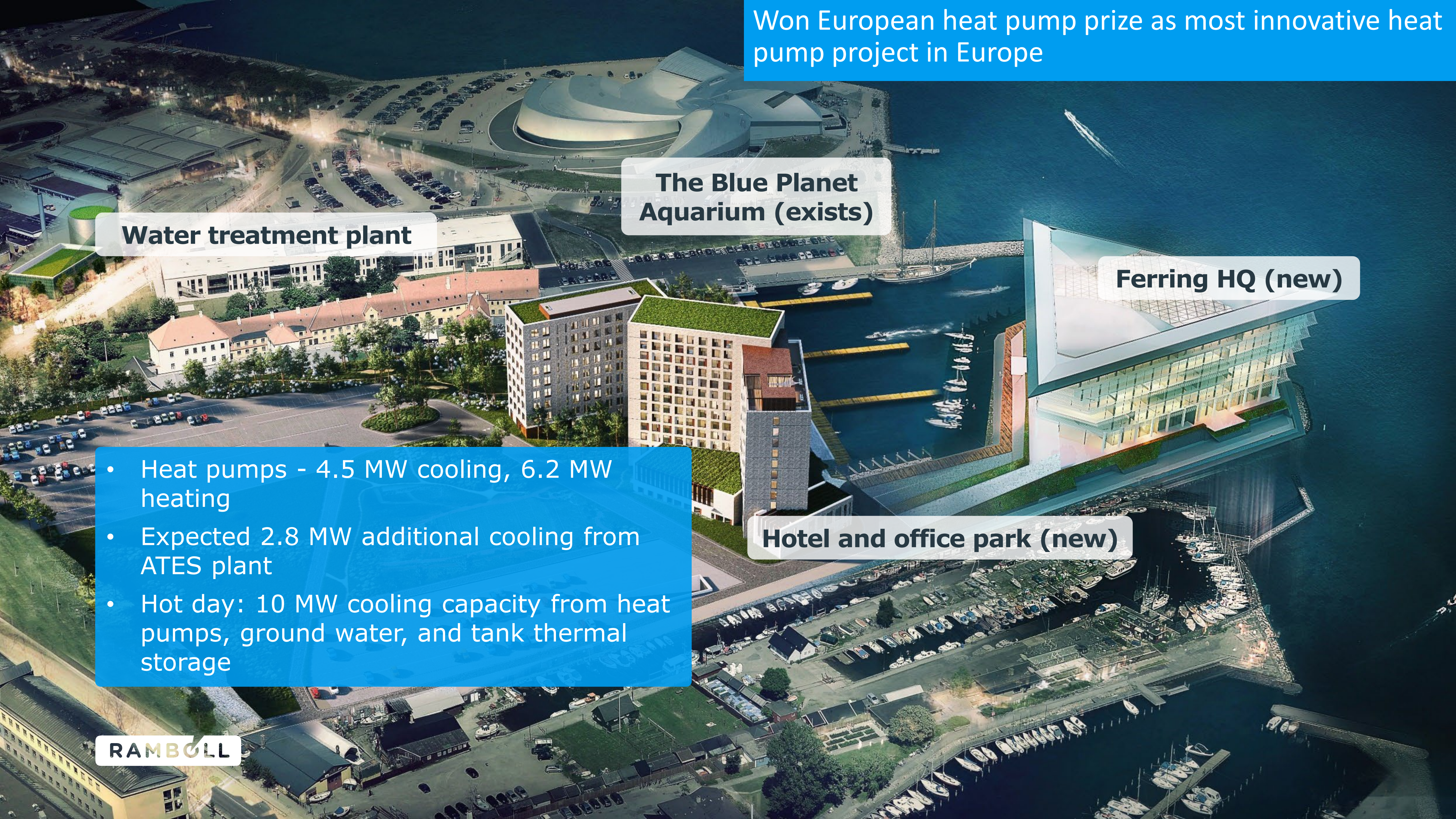
- Building level
- Campus level
- Utility level

Project examples

Taarnby Municipality DK

Cost-effective low carbon district energy system

Won European heat pump prize as most innovative heat pump project in Europe



- Heat pumps - 4.5 MW cooling, 6.2 MW heating
- Expected 2.8 MW additional cooling from ATES plant
- Hot day: 10 MW cooling capacity from heat pumps, ground water, and tank thermal storage

Taarnby Municipality, DK – District heating and cooling

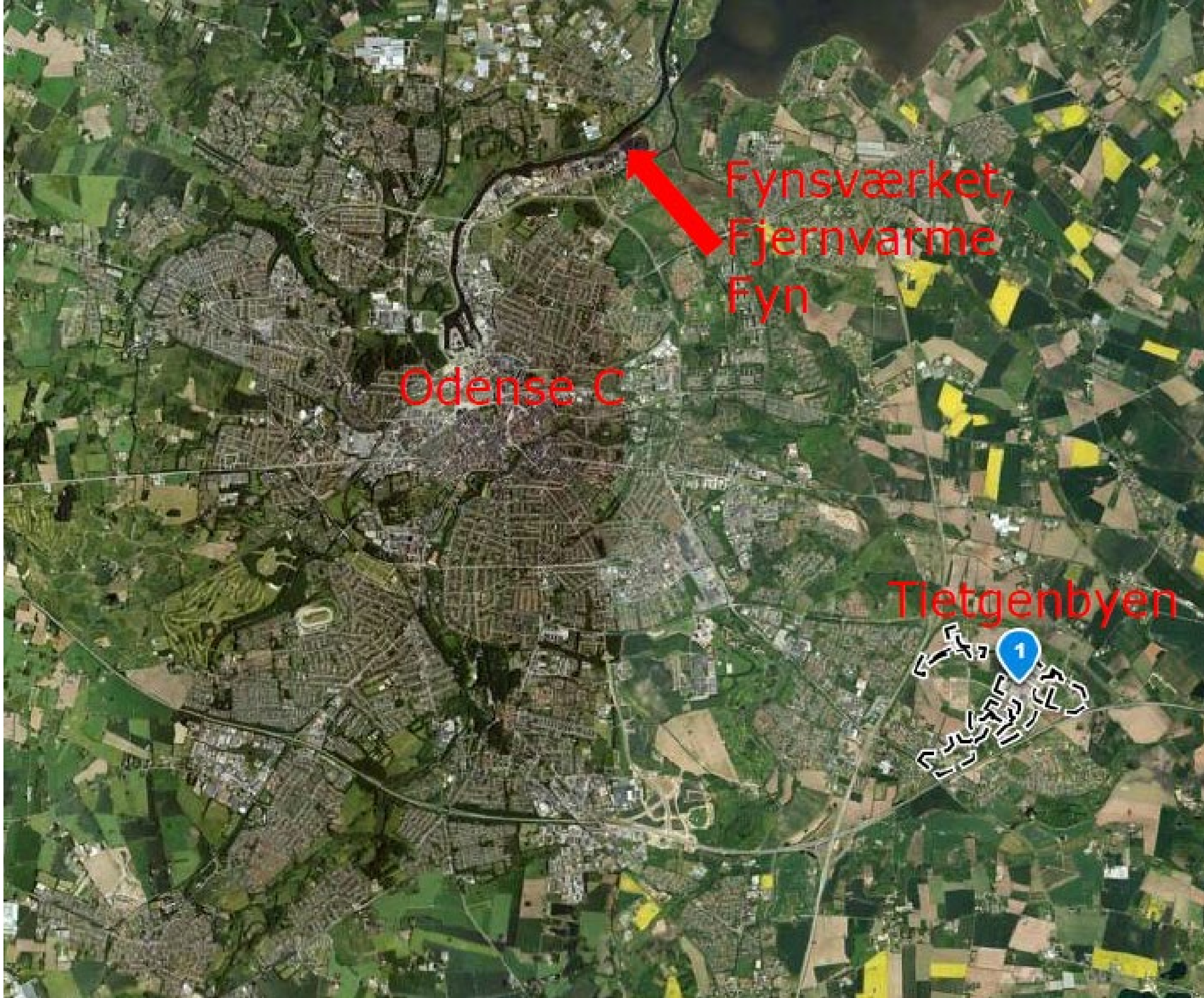
- Compliments existing district heating system that produces cost-effective energy based on many heat sources: (*e.g.*, cogeneration, residual waste, biomass, solar thermal, thermal storage, and natural gas)
- Hotels and offices need cooling
- During summer, heating produced from production of cooling
- During limited cooling demand, heat extracted from wastewater
- Ground source cooling (ATES) (Planned)
    - Heat in the winter while cooling the groundwater
    - Groundwater - free cooling in summer
- 528K gallon (2,000 m3) chilled water thermal storage tank
    - Operational optimization according to hourly electricity prices and wastewater availability
    - Adds flexibility and resiliency
- Energy plant located at Taarnby Forsyning's existing WWTP, cheaper land, saving 25% investment costs

Meta Data Center Odense, DK

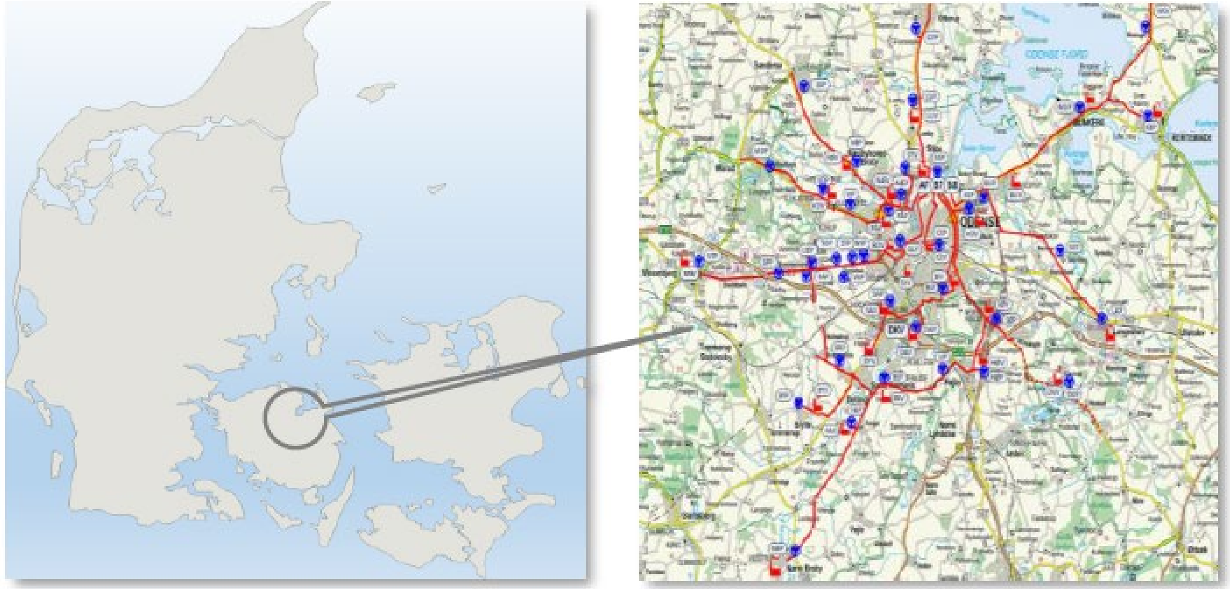
Surplus heat to district energy system

Location

- Odense: Birthplace of Hans Christian Andersen
- Population of 180,000
- Fynsværket – Fjernvarme Fyn's cogeneration plant – approx. 5 mi from the Meta site in Tietgenbyen
- Data center and heat pump plant are located in Tietgenbyen



Odense district heating network - Meta data center feeds into



Distribution

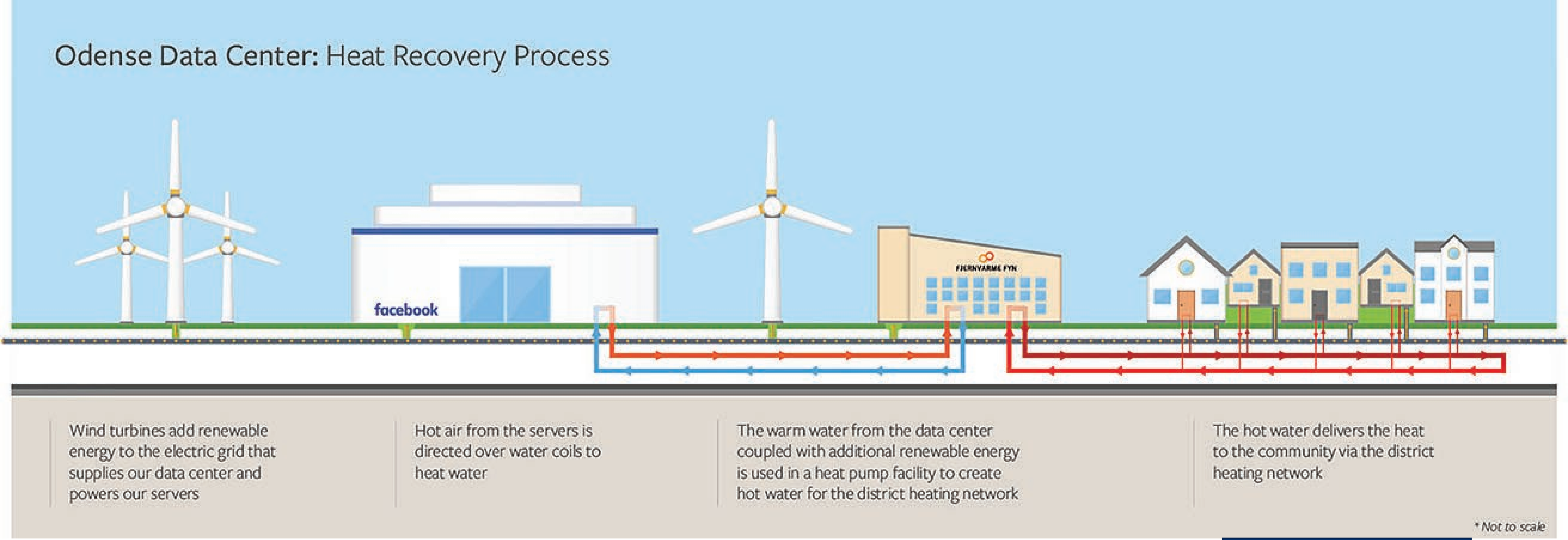
- 65,000 connections/meters
- 75 mi transmission lines (176-194 °F)
- 1,370 mi distribution lines (158-167 °F)

Replacing with heat pumps, electric boilers, and biomass boilers

Productions units

- Coal CHP (unit 7): 1,099/1,672 MMbtu/h (power/heat), 200,000 t_{met} coal/yr
  - Coal is phased out as per spring 2024
  - Substituted by: Large HP's, electric boiler, seasonal storage etc. Until these technologies are ready in 2030, very limited heat will be produced from n-gas.
- Straw CHP (unit8): 109/300 MMbtu/h (power/heat), 200,000 t_{met} straw/yr
- Waste CHP (unit 11-13): 68/358 MMbtu/h (power/heat), 300,000 t_{met} waste/yr
- Wood Chips CHP (DKV): 80,000 t_{met} wood chips/yr
- Oil and Gas peak and reserve load (24 units)
- Small scale industrial surplus heat (~10 suppliers)
- Hyper scale datacenter (Meta): 136 MMbtu/h heat pumps)

The system

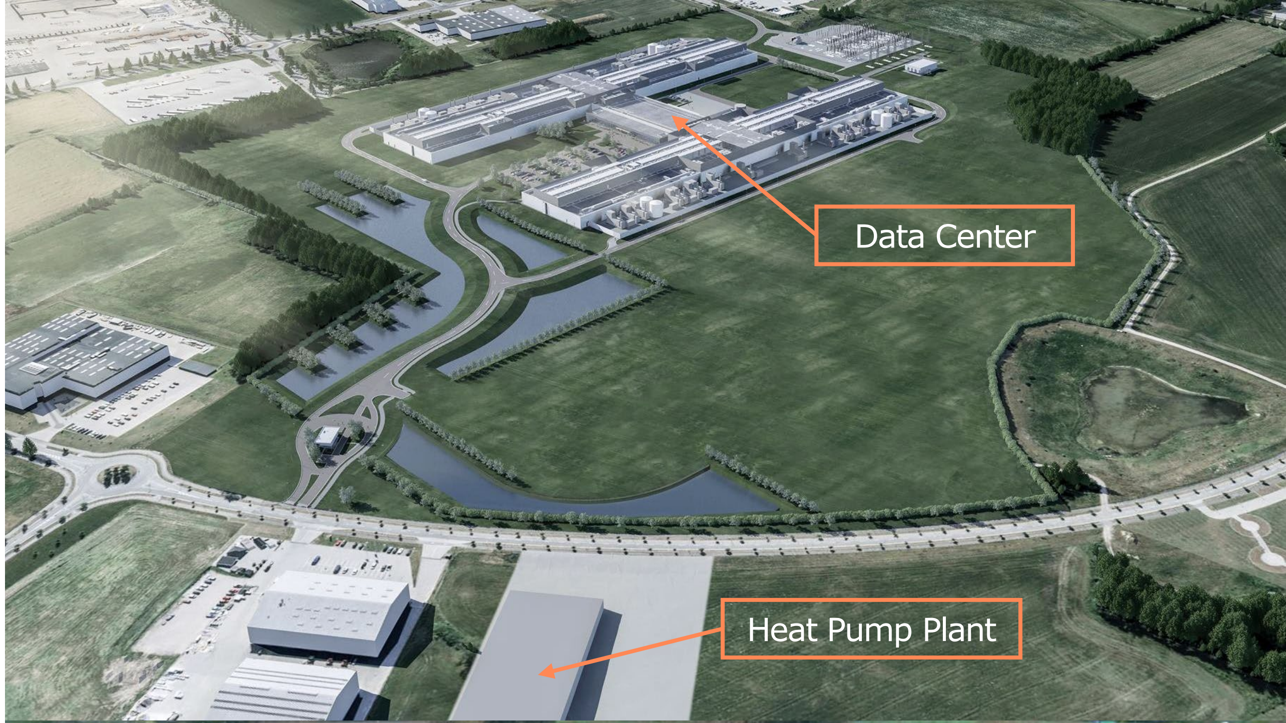


Source: Meta

Meta data center and waste heat recovery plant

Key figures

- Combined heating and cooling with heat pumps
- 85 + 51 MMBtu/h waste heat from a hyperscale data center
- 340,000 MMBtu heat per year to the district heating network. Nearly 7,000 households in the city of Odense will be heated up by the plant.
- 9 heat pumps (3 x 3 in cascade):
- 167°F in supply to DH
- 113°F in return from DH (54°F delta)
- 59°F in supply to Meta
- 81°F in return from Meta (22°F delta)
- COPheat for heat pumps = 4.8 – 5.2
- In operation P1:Nov 2019 / P2:Nov 2022
- *Client: Fjernvarme Fyn (District Heating Utility)*



SUNY Oswego

Clean Energy Master Plan


Lake Ontario
Electric Generation Plant
Wastewater Treatment
Electric substation transformers
Geothermal Borefields
Ground mount solar or wind turbine
OSWEGO STATE UNIVERSITY OF NEW YORK
FRANKLIN SQUARE HISTORIC DISTRICT
Oswego

SUNY Oswego - TEN Configuration Analysis

	BaU	2a/2b	4a/4b	5b	6a/6b
District Type	**Existing systems – centralized steam**	**4G Cluster (2-pipe)**	**4G Centralized (2-pipe)**	**4G Centralized (2-pipe)**	**4G Centralized (2-pipe)**
Fuel/Heat source	Fossil fuel (FF)	Geothermal	Geothermal	Wastewater, geothermal	Air, geothermal
Baseload Technology	FF furnaces/boilers	Heat pumps (HPs)	HPs	HPs	HPs
Peaking Technology	FF furnaces/boilers	Electric or FF boilers	Electric or FF boilers	Electric	Electric or FF boilers
Backup fuel/ heat source	FF furnaces/boiler	FF Boilers	FF Boilers	FF Boilers	FF Boilers
Cooling	AC unit, chillers	HPs	HPs	HPs	HPs
Tank thermal energy storage	No	Yes	Yes	Yes	Yes

OSWEGO
STATE UNIVERSITY OF NEW YORK

SUNY Oswego

Cluster C – Central Heating Plant

~~Cluster E – Mackin~~

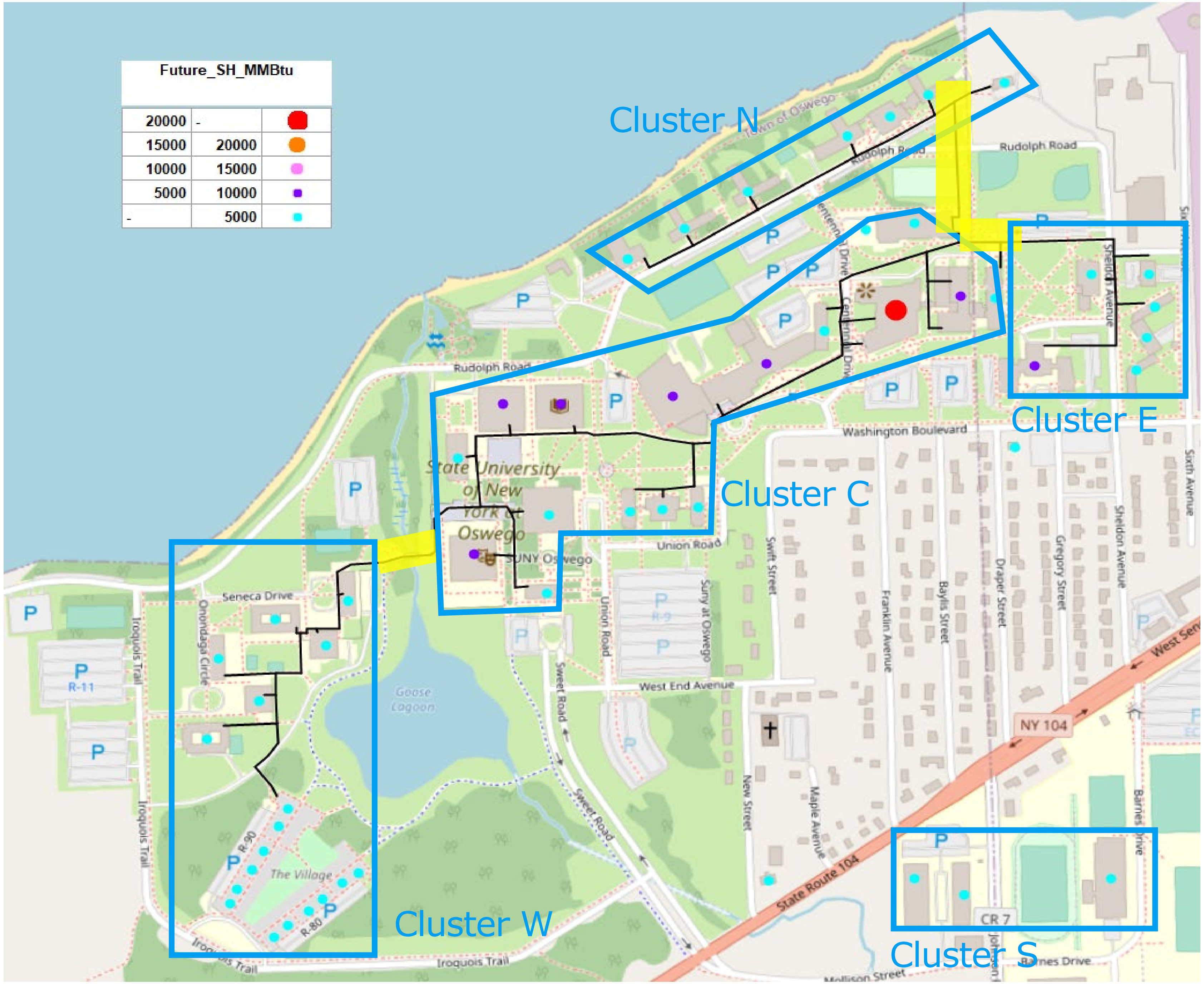
~~Cluster N – Riggs~~

~~Cluster W – Little Page DH~~

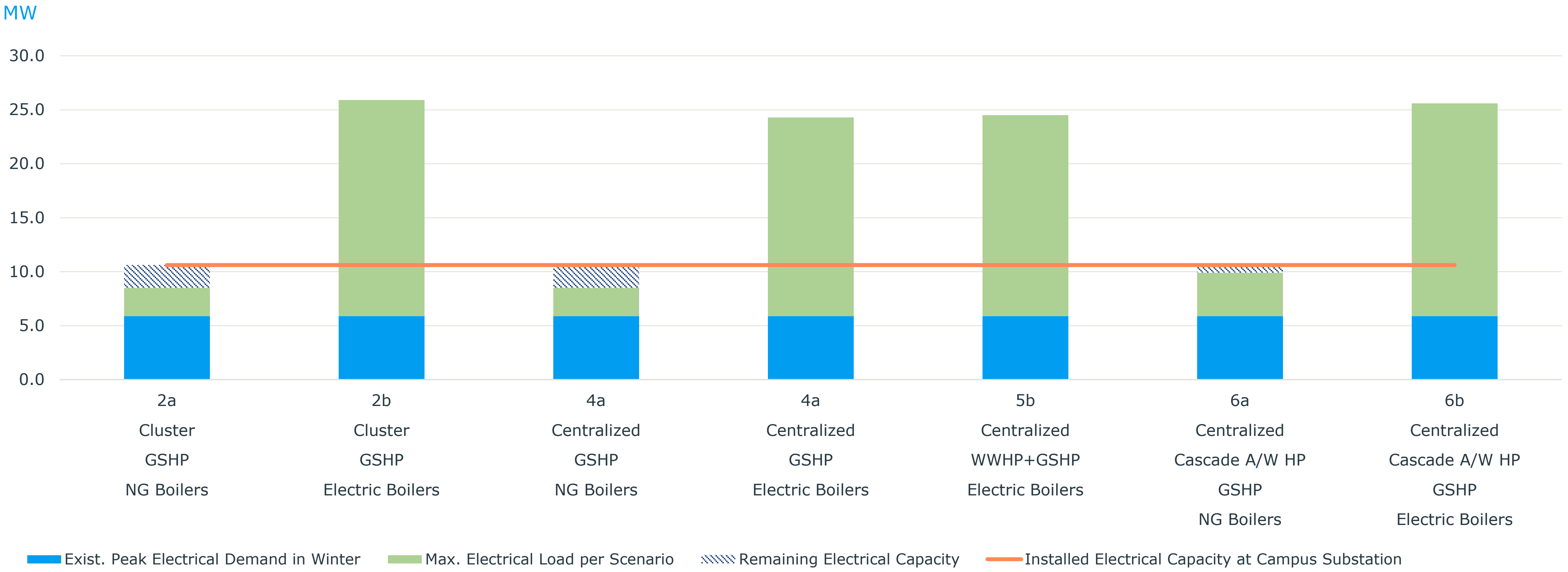
Cluster S – Laker

Considerations:

- Space for heat pumps and distribution equipment
- Backup boilers
- Redundancy

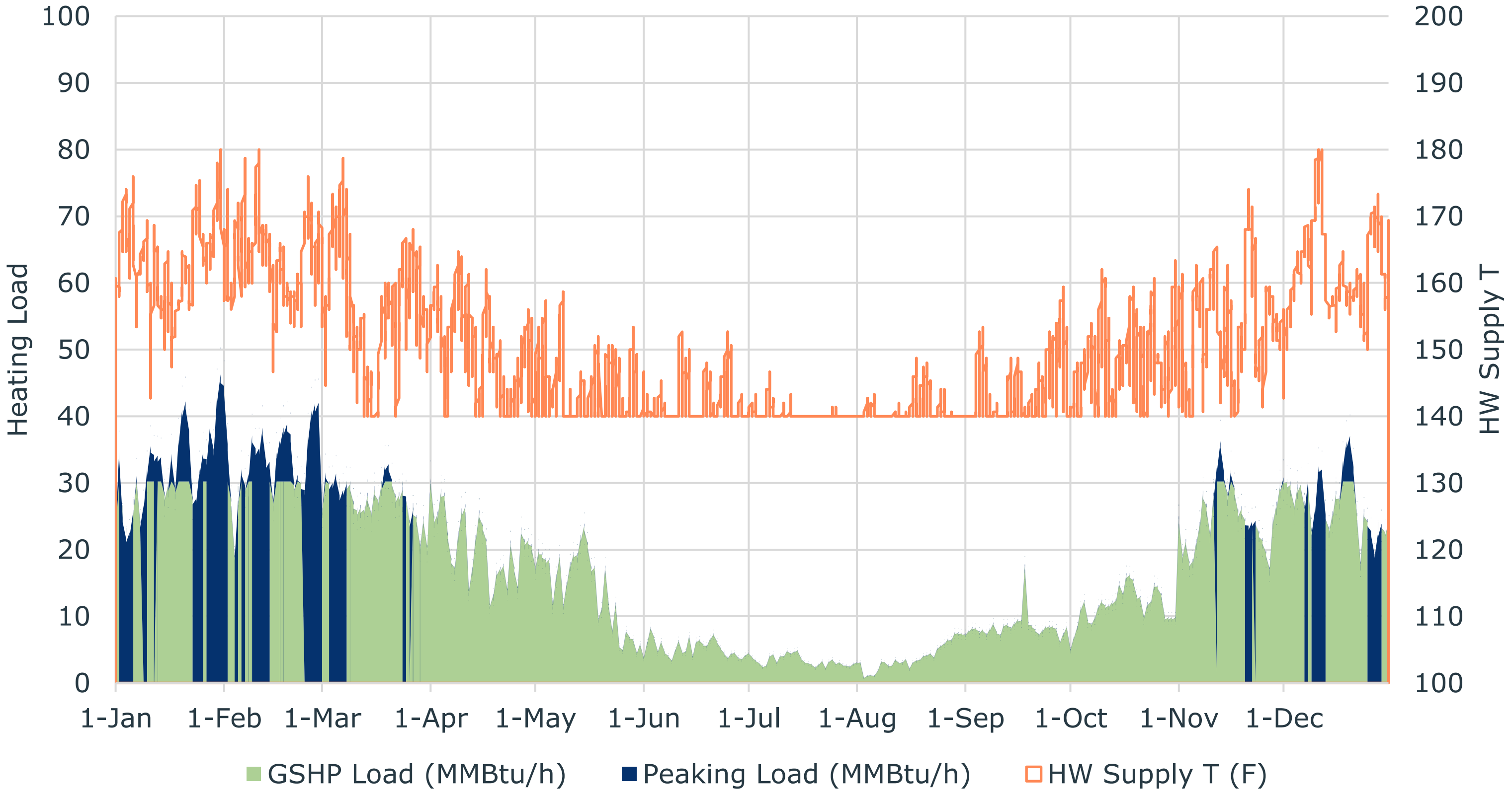


Peak electrical demand impact



Are Building Upgrades Needed for LTW?

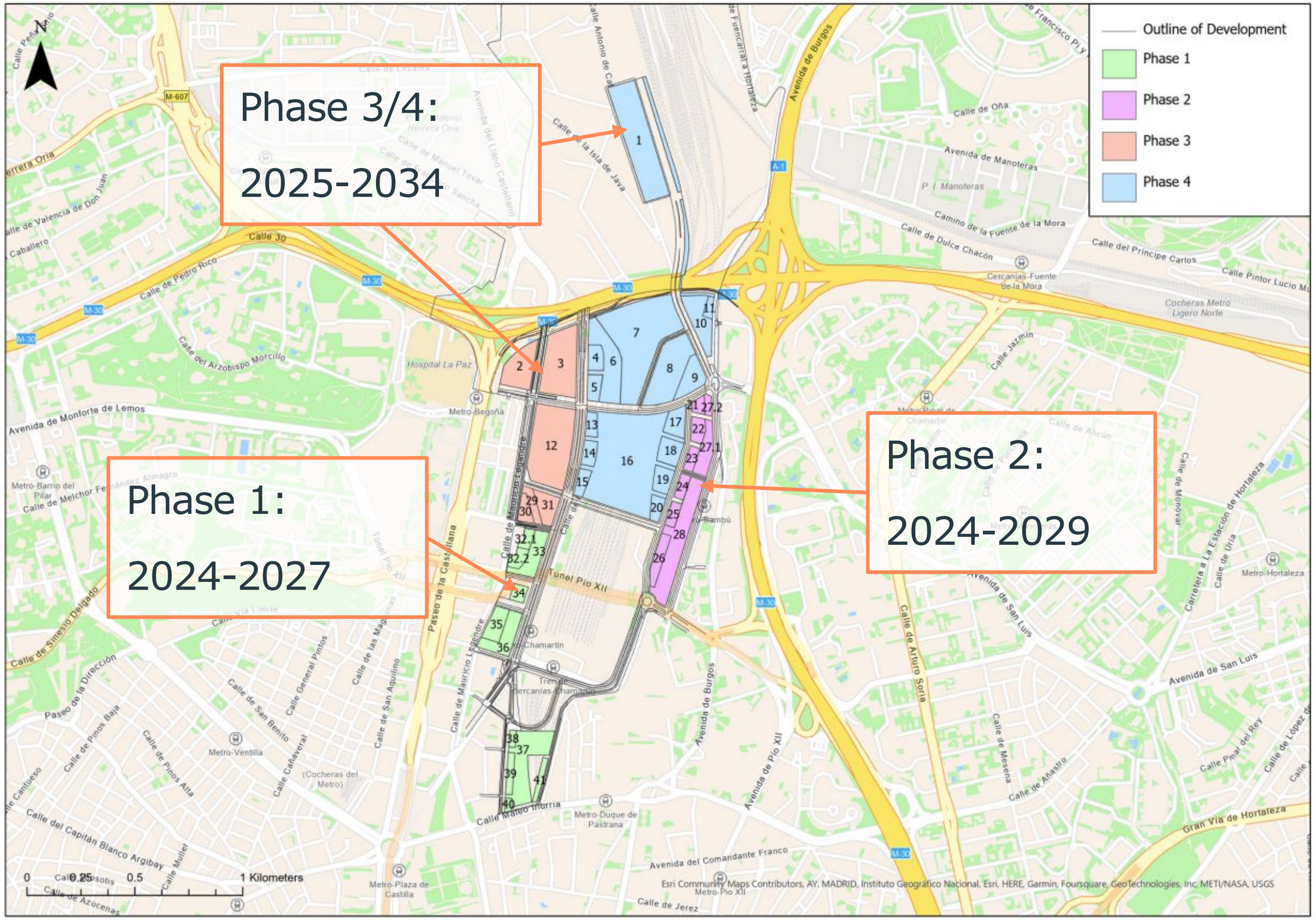
GSHP Cutoff = 165 F



- HW Reset from 180F @ 0F to 140F @ 60F
- GSHP operates 90% of the year
  - Produces up to 165F
  - Provides 80% of the annual load
- Peaking Boilers operate 10% of the year
  - Produces HW from 165F to 180F
  - Provides 20% of the annual load
- Building upgrades would lower LTW distribution temperature
  - More hours of GSHP operation
  - Improves efficiency of GSHP

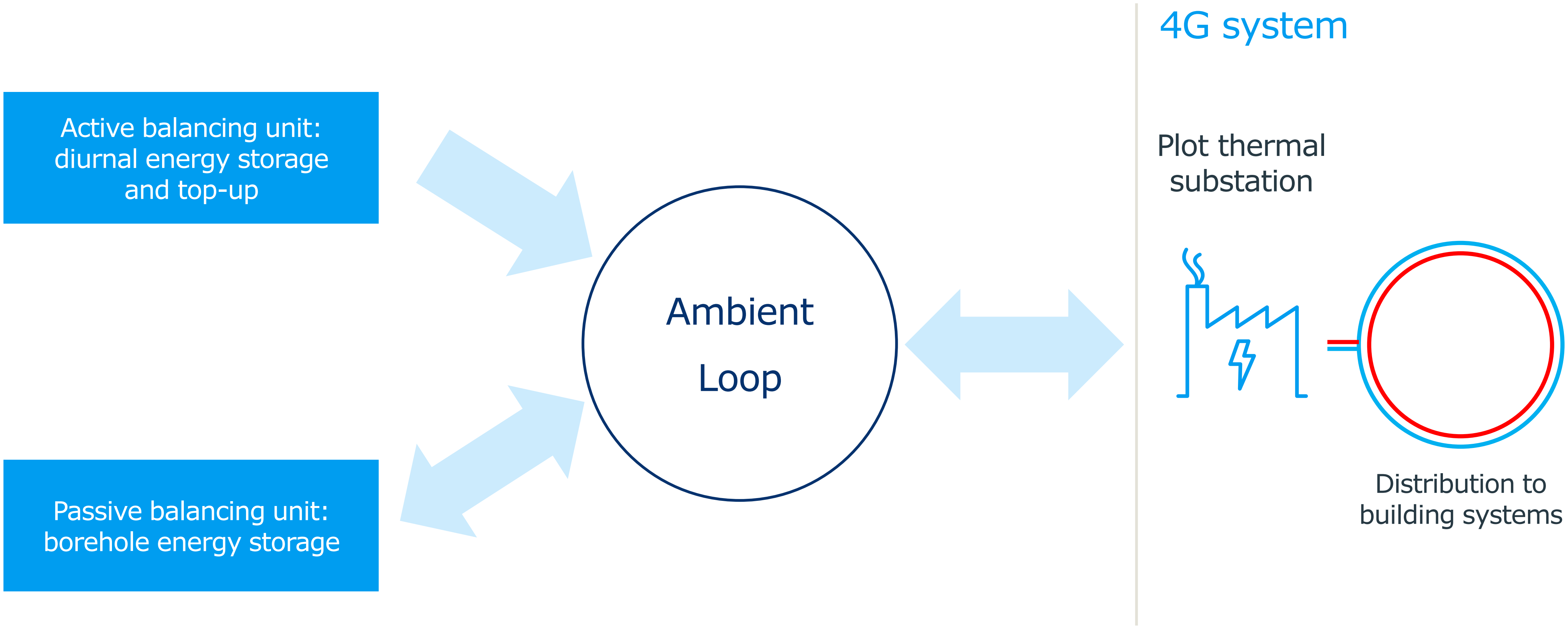
Madrid ambient system

Phases in the Madrid project

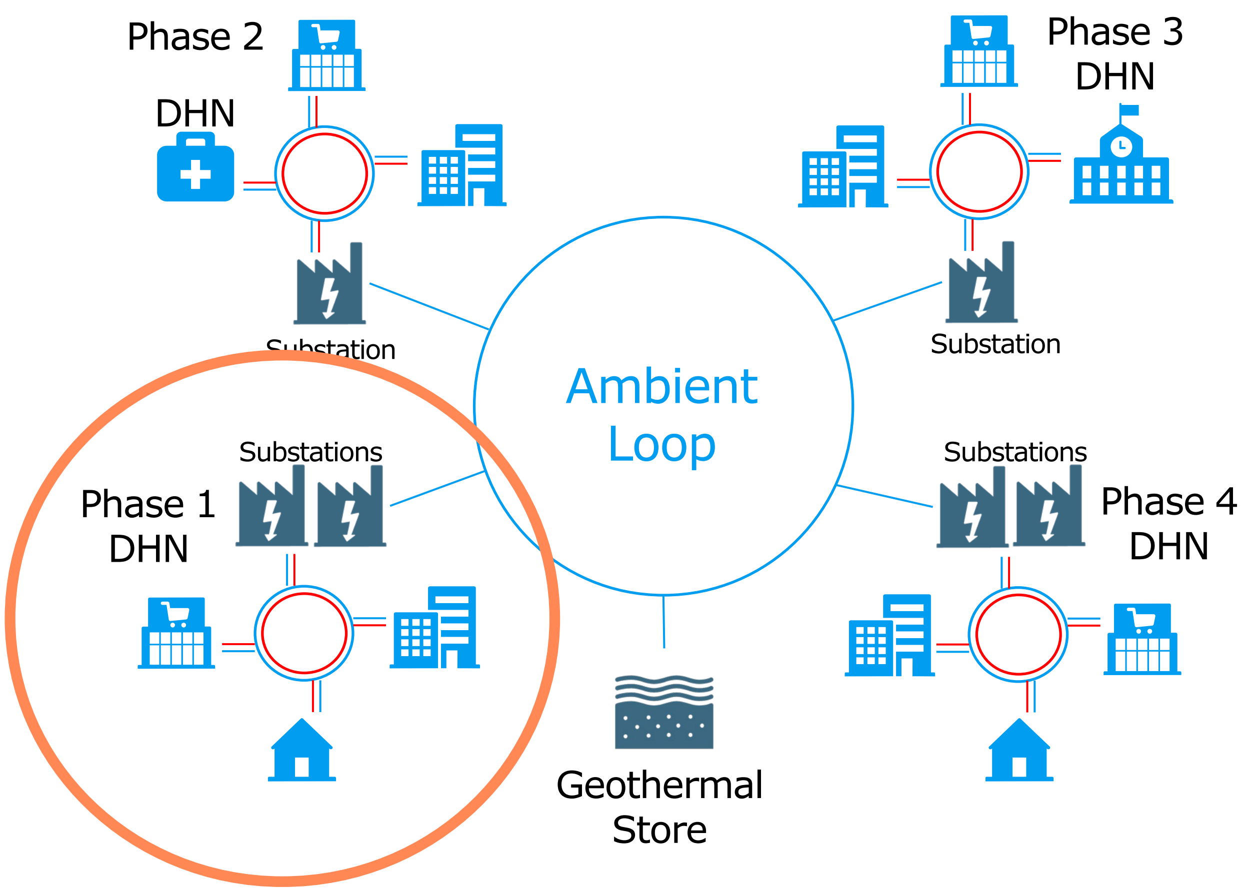


Phase	Plot	Uses	Heat (MWH)	Coolth (MWH)
1	32.1	Residential/Commercial	-297.5	183.6
	38	Residential/Commercial	-288.1	157.3
	39	Residential/Commercial	-708.2	387.3
	32.2	Commercial/Offices	-466.7	487.8
	35	Commercial/Offices	-3848.5	3996.7
	40	Commercial/Offices	-55.5	68.6
2	21	Commercial/Offices	-531.0	593.8
	22	Commercial/Offices	-928.0	1004.9
	23	Commercial/Offices	-678.9	747.9
	25	Commercial/Offices	-771.2	839.2
	26	Commercial/Offices	-2424.8	2545.6
	24	Health	-309.6	270.2
3	3	Commercial/Offices	-8372.5	8699.2
	12	Commercial/Offices	-9949.5	10469.9
	31	Commercial/Offices	-2975.0	3080.6
	2	Educational	-896.8	972.3
	30	Educational/Civic	-189.3	252.6
4	4	Residential/Commercial	-951.0	464.8
	5	Residential/Commercial	-798.1	393.9
	9	Residential/Commercial	-1622.9	815.7
	13	Residential/Commercial	-674.8	340.5
	14	Residential/Commercial	-772.7	385.9
	15	Residential/Commercial	-728.3	356.1
	17	Residential/Commercial	-1145.9	572.6
	18	Residential/Commercial	-1216.7	581.6
	19	Residential/Commercial	-991.2	479.3
	20	Commercial/Offices	-918.8	983.5
	1	Community Services	-1995.6	2467.0
	10	Sport	-261.9	362.4
	7	Community Services/Sports/Civic	-2055.7	2953.6
Annual loads (MMBtu/yr)			**163,000**	**156,000**

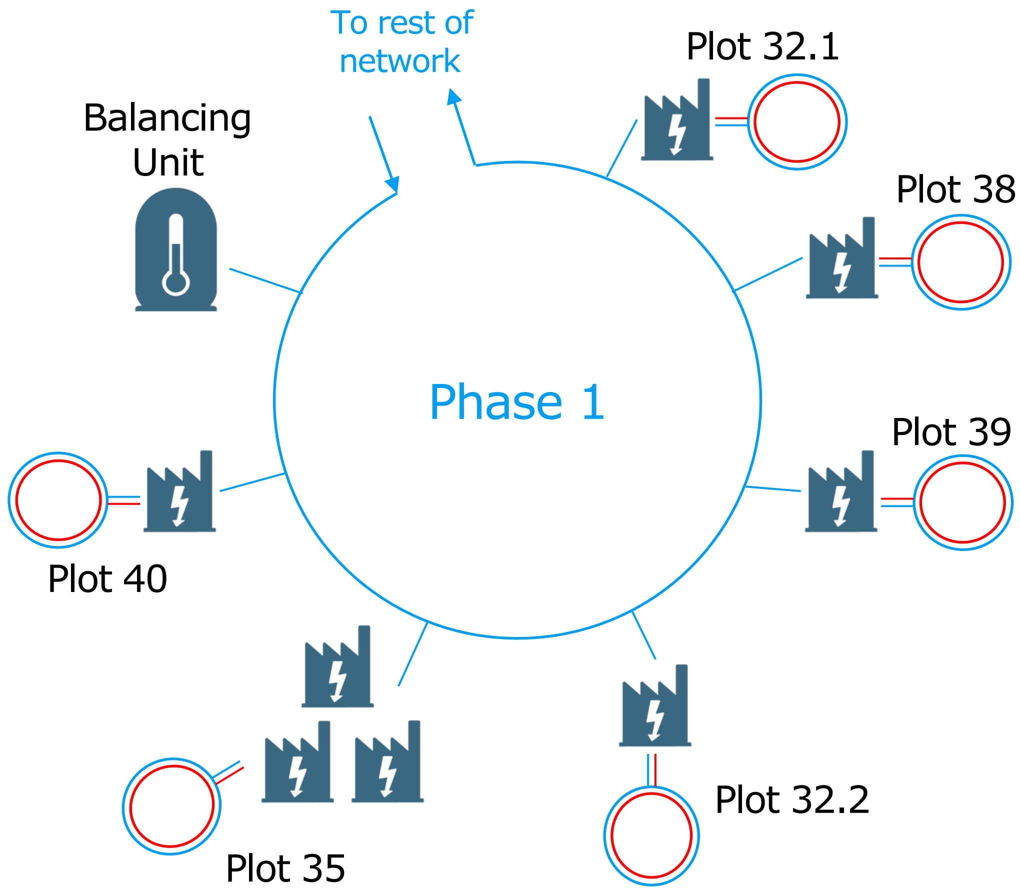
Approach for the project



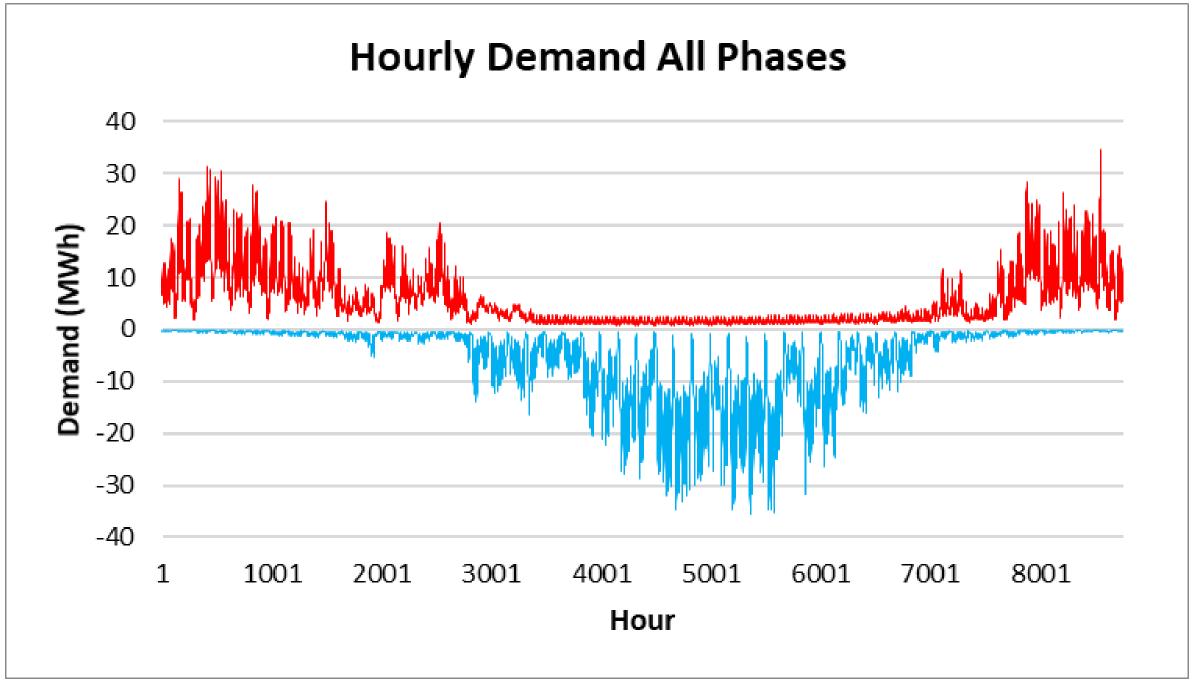
Network Configuration 1

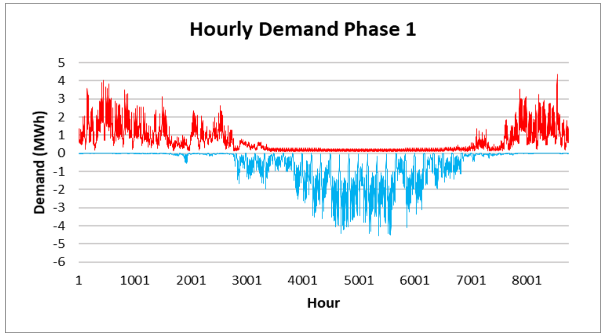


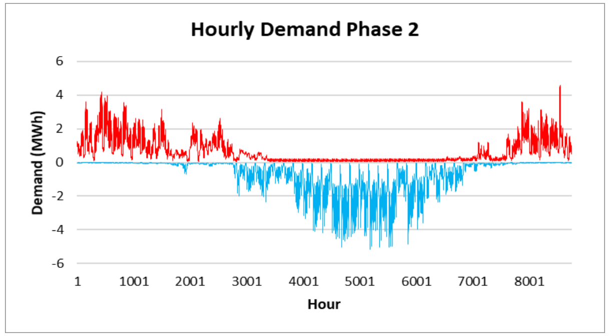
Network Configuration 2, only Phase 1

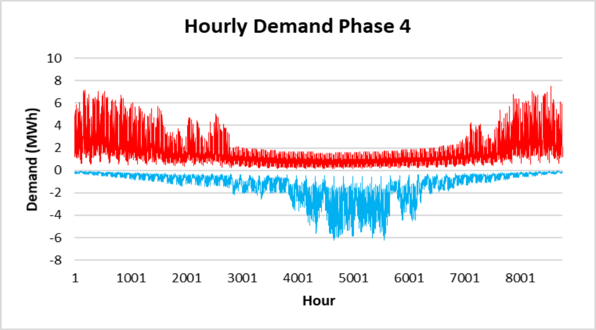


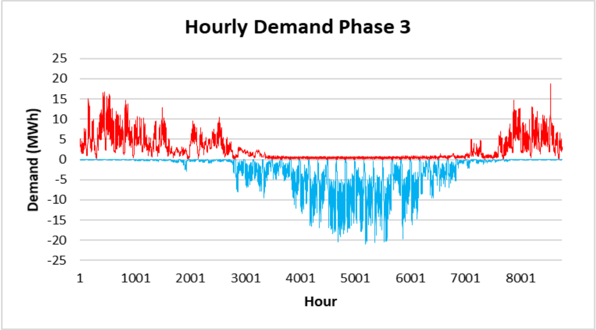
Hourly Demand





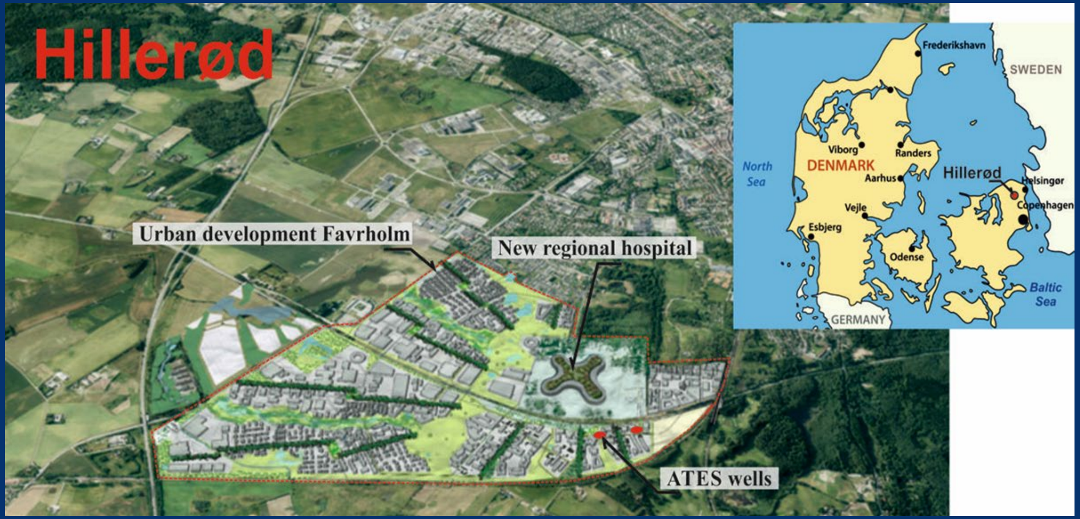






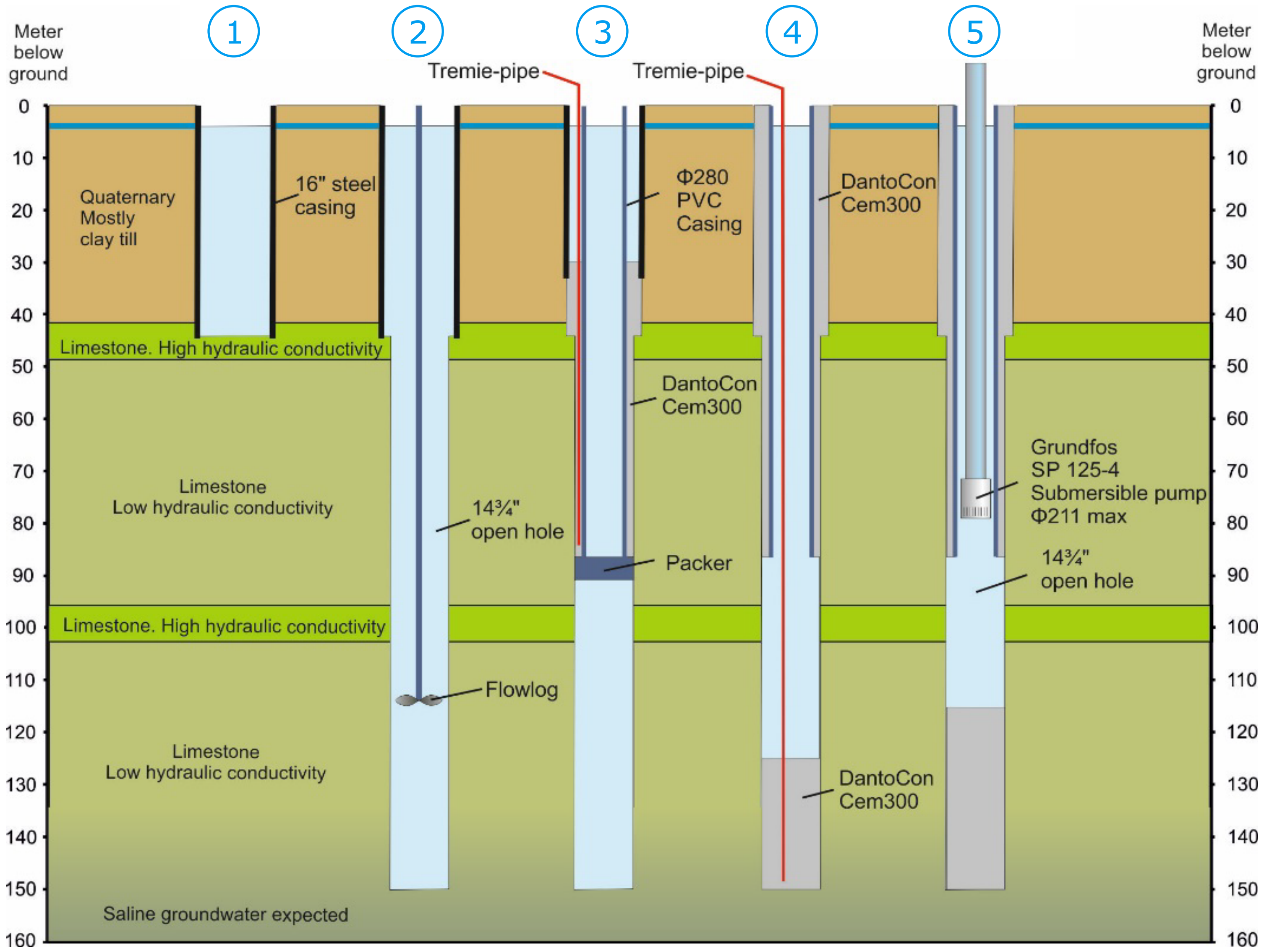
Aquifer Thermal Energy Storage Hillerod, Denmark

District cooling in new urban development



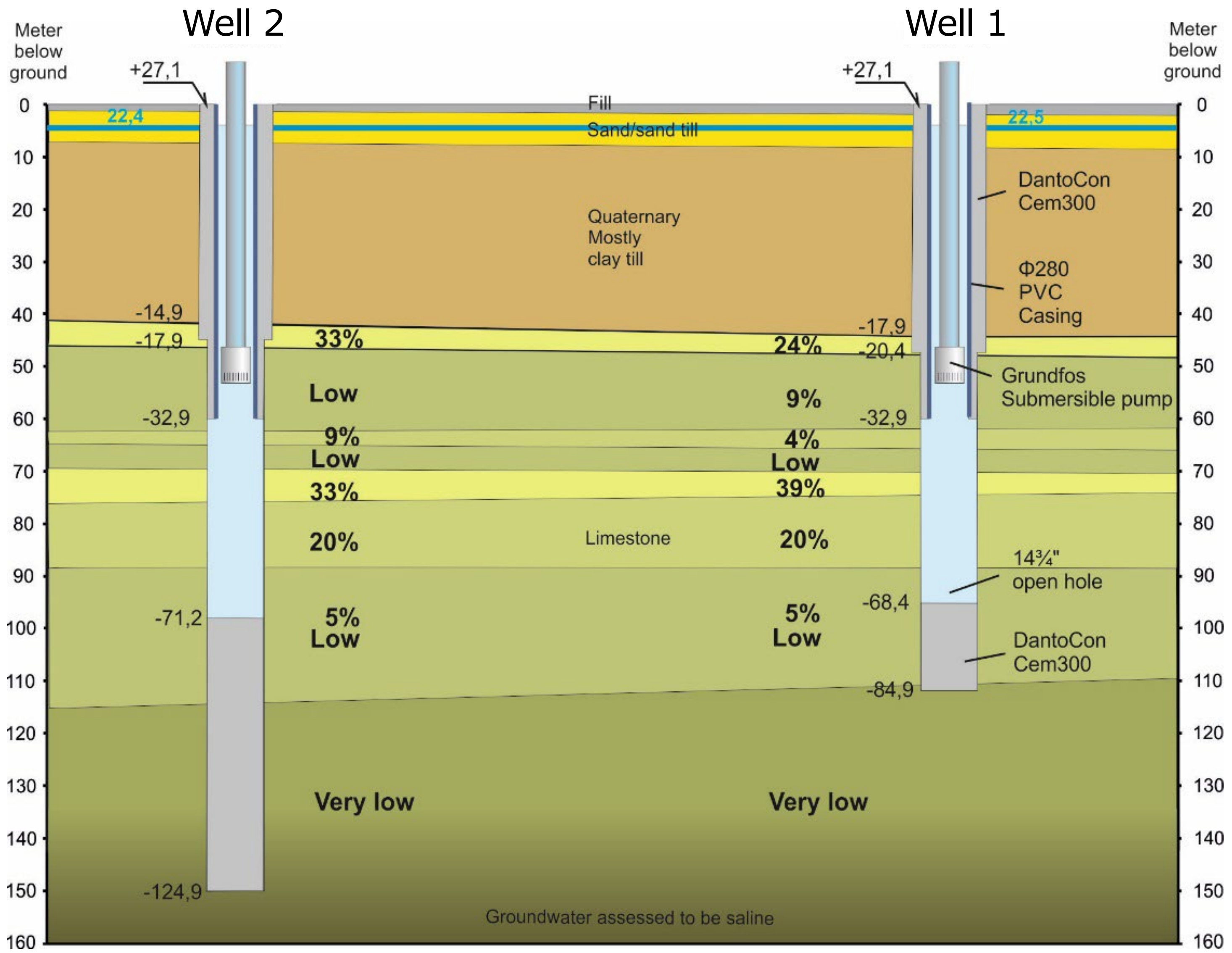
Drilling Strategy

- Time series in five phases of the drilling



Final ATES well design

- Logging of flows from the geophysical borelog
- Pct. indicating the shares of the total flows
- Initially to depth of 124.9 m (400 ft), but yield was too low. Therefore, hole is casted in the bottom
- Final bottom is approximately 71 meters (232 ft)



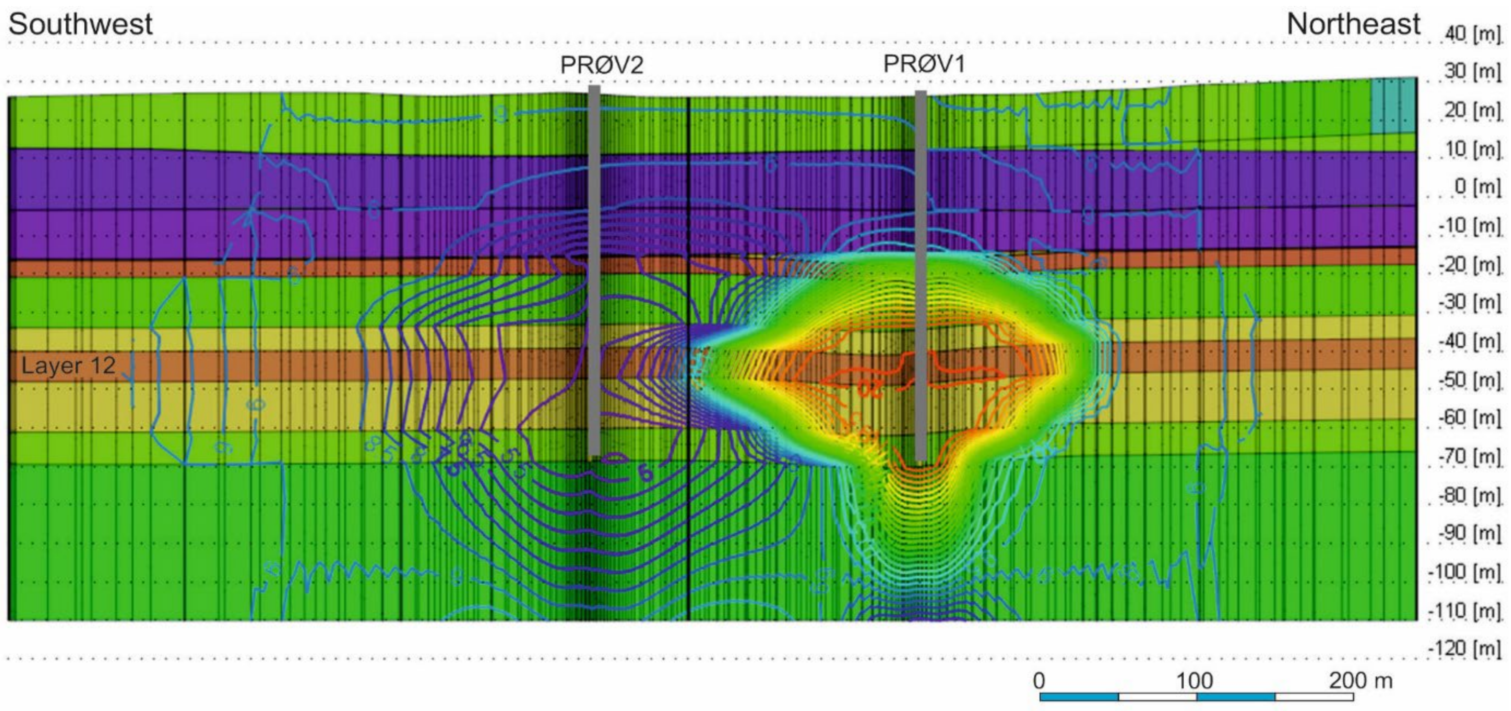
Hydraulic Tests

Hydraulic tests carried out

- Specific capacity tests in both wells
  To assess the potential maximum yield and decide the flow rates for the subsequent tests
- Step-drawdown pumping tests both wells
  To evaluate well and aquifer losses and derive the well equation and assess whether the wells should be further developed by acidification
- Three-day pumping test in Well 2 with simultaneous injection in Well 1
  To assess the aquifer parameters, the transmissivity T and the storage capacity S

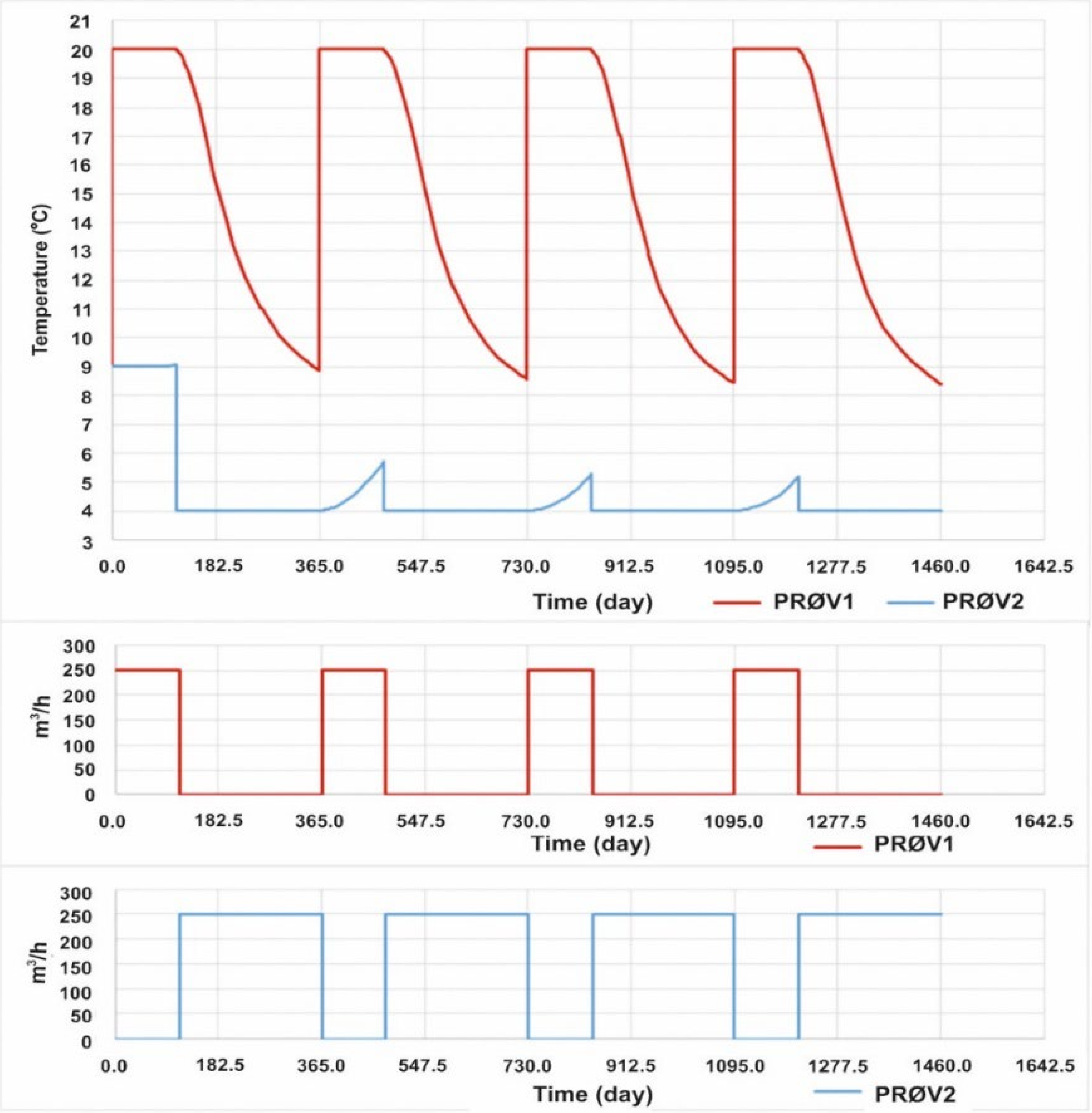
3D-Groundwater Model Calibration and Simulations

- Temperature changes after 3 years of operation
- High yielding boreholes, tested at high flow
- Conclusion from test is that flow need to be reduced and/or additional boreholes are needed
- Client added two additional pairs



General Conclusions

- One ATES well pair produces roughly the same amount of energy as 40 closed loop GSHP wells
- Well design and maintenance are important factors for an effective, long-lasting system
- Careful consideration needs to be taken to avoid thermal break-through
- The permitting process for ATES is significantly more complex than for GSHP



Energy Transition Considerations

Understanding the complexity of transforming to clean energy

Phasing

Converting from steam to hot water

Building improvements, HVAC upgrades

Using existing assets during transition

New electrification production technologies; thermal storage needs

Operational

Operation of technologies dependent of external influences (fuel/electricity)

Co-production for heating and cooling

Expected fluctuation in electricity prices due to intermittent production

New skills required from operational staff

Thank you!

Joe DiSanto, PE
Senior Energy Engineer, Energy
joseph.disanto@ramboll.com

John Florning
Chief Planning Engineer, Energy
jnf@ramboll.com

Rob Neimeier
Client & Market Officer, Energy
rob.neimeier@ramboll.com

Learning Outcomes - Questions

1. What are the attributes of a baseload and peaking strategy?
2. What are the benefits of tank thermal energy storage (TES)?
3. For SUNY Oswego, approximately what percentage of the campus heat demand is covered by Clusters C and W?

Learning Outcomes - Answers

1. What are the attributes of a baseload and peaking strategy
    a. Cost efficiency, use of existing assets for peaking and emergency, resiliency, redundancy
2. What are the benefits of tank thermal energy storage (TES)?
    a. Creation and storage of heated or chilled water during times when there is abundant renewable energy in the grid and prices are low. Use stored energy during peak times and when renewable energy is low in production.

3. For SUNY Oswego, approximately what percentage of the campus heat demand is covered by Clusters C and W?

    a. 75%

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