Webinar Digitalization for optimizing integrated district heating systems

Block III: Hybrid energy systems

This Webinar is held in the framework of two international cooperation programs:

IEA DHC Annex TS3 “Hybrid Energy Networks“

IEA DHC Annex TS4 “Digitalisation of District Heating and Cooling“.

9. September 2020

Ralf-Roman Schmidt AIT, Austria, ralf-roman.schmidt@ait.ac.at (leader TS3)

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More information at

https://www.iea-dhc.org/the-research/annexes/2018-2024-annex-ts4/

http://www.iea-dhc.org/the-research/annexes/2017-2020-annex-ts3-draft.html

Fraunhofer
IEE

AIT AUSTRIAN INSTITUTE OF TECHNOLOGY
TOMORROW TODAY

This webinar is recorded

The video file will be available after the webinar on the IEA DHC YouTube channel
https://www.youtube.com/channel/UCuYcqLjJi8thrUJCjzLBaow

We will have a “group photo” at the end of the webinar, so please be prepared to turn on your webcam (participation voluntarily)

Webinar Etiquette

- **The microphone should be muted by default**
  - They should only be switched on if you are speaking.
- **Only one person speaks at a time**.
  - Requests to speak are reported via chat (**"rts"**),
  - the moderator will ask then the speakers to speak.
  - Please state your name and institution before you speak
- **Please turn off your webcam**!
  - No general video transmission in order to reduce the bandwidth.
  - The camera can be used at short notice for spoken contributions.
  - We will make a “group-photo” at the end of each block
- **Caution with humor and sarcasm!**
  - much of the original effect between the lines can be lost

Agenda Block III - Hybrid energy system

15:00	**Testing of technical connections**
15:30	Introduction into the IEA DHC Annex TS3 project (Ralf-Roman Schmidt, AIT)
	Technologies for Hybridisation (Oddgeir Gudmundsson, Danfoss)
	GIS-based automated design of DH networks (Joseph Jebamalai, Comsof)
	Sector coupling between hydrogen and district heating (Hans Böhm, EI Linz)
	Interactive session and Q&A to all presenters
17:00	**End of Block III**

Introduction into the IEA DHC Annex TS3 project

(Ralf-Roman Schmidt, AIT)

IEA DHC Annex TS3: Hybrid Energy Networks - District Heating and Cooling Networks in an Integrated Energy System Context

Introduction into international DHC Annex TS3

Ralf-Roman Schmidt

AIT, Austria

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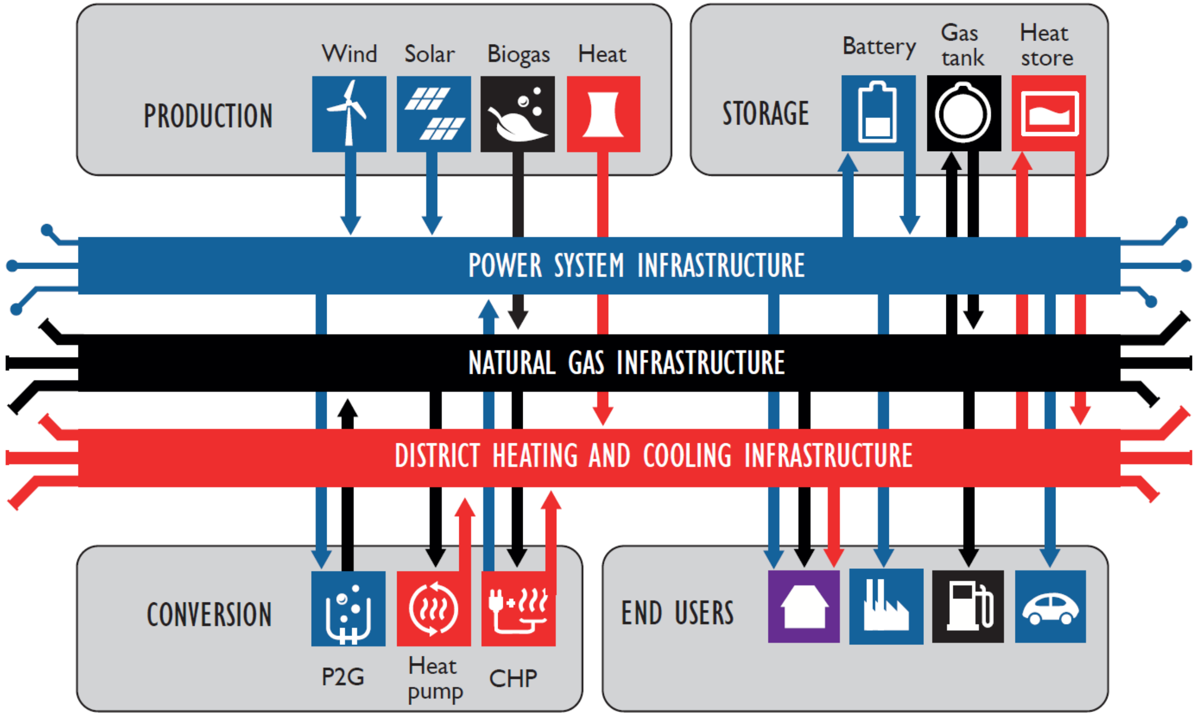
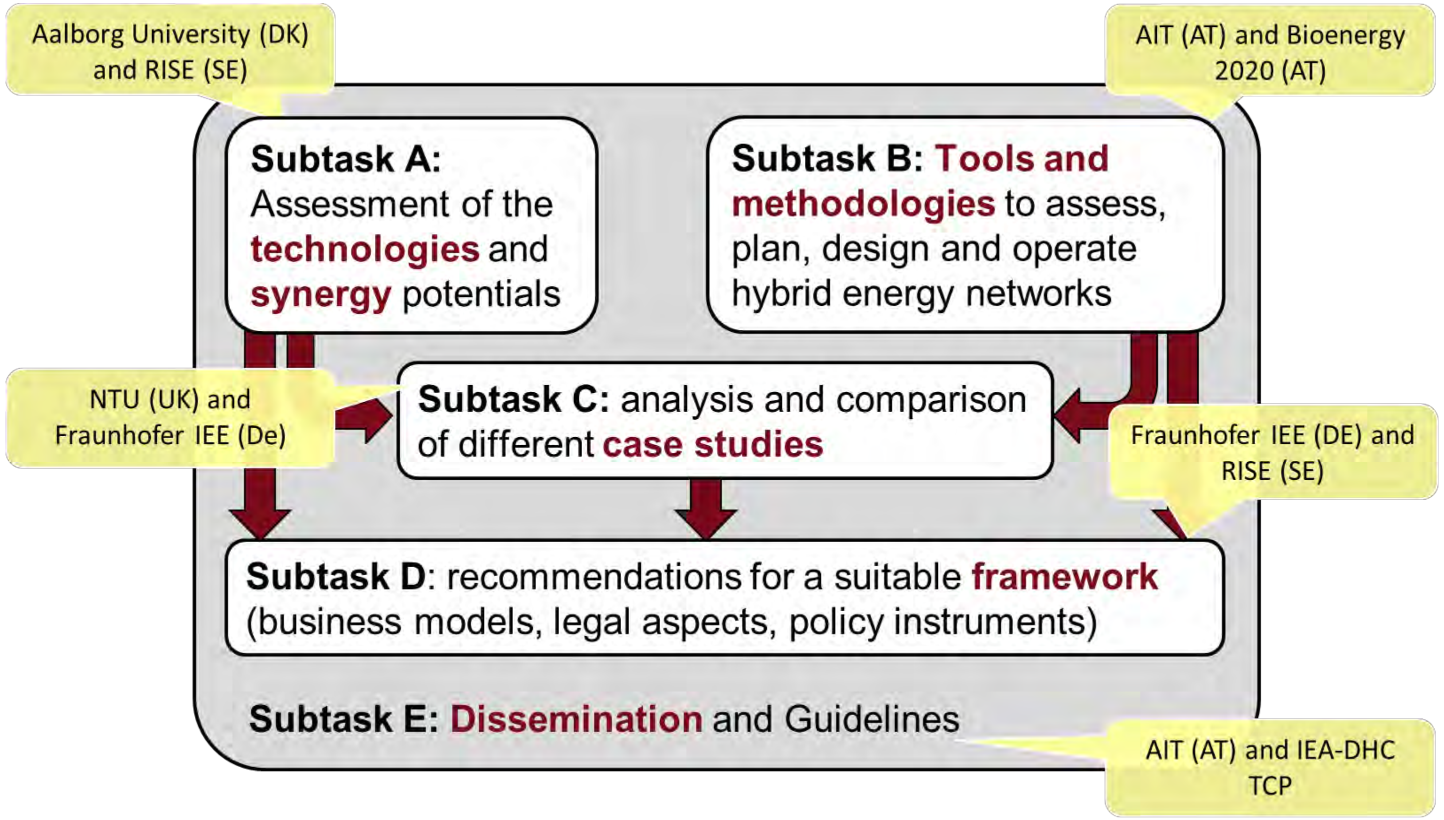
IEA DHC Annex TS3: Background

- The integration of the electricity/ gas grids and heating/ cooling networks is considered as one of the key measures for decarbonizing the energy system (aka “sector coupling”). This
  - triggers important **synergies**, that couldn’t be realised by optimizing the sectors individually.
  - is connected to several **challenges**, such as an increasing competition between the energy domains and a higher complexity.



IEA DHC Annex TS3: aim and structure

- **Aim**: to promote the opportunities and to overcome the challenges for DHC networks in an integrated energy system context. The Annex
  - provides a holistic approach for assessing, planning and operation,
  - considers technical aspects (system configuration, operational strategy) and strategic aspects (business model, regulatory frame).



Aalborg University (DK) and RISE (SE)

AIT (AT) and Bioenergy 2020 (AT)

Subtask A: Assessment of the **technologies** and **synergy** potentials

Subtask B: **Tools and methodologies** to assess, plan, design and operate hybrid energy networks

NTU (UK) and Fraunhofer IEE (De)

Subtask C: analysis and comparison of different **case studies**

Fraunhofer IEE (DE) and RISE (SE)

Subtask D: recommendations for a suitable **framework** (business models, legal aspects, policy instruments)

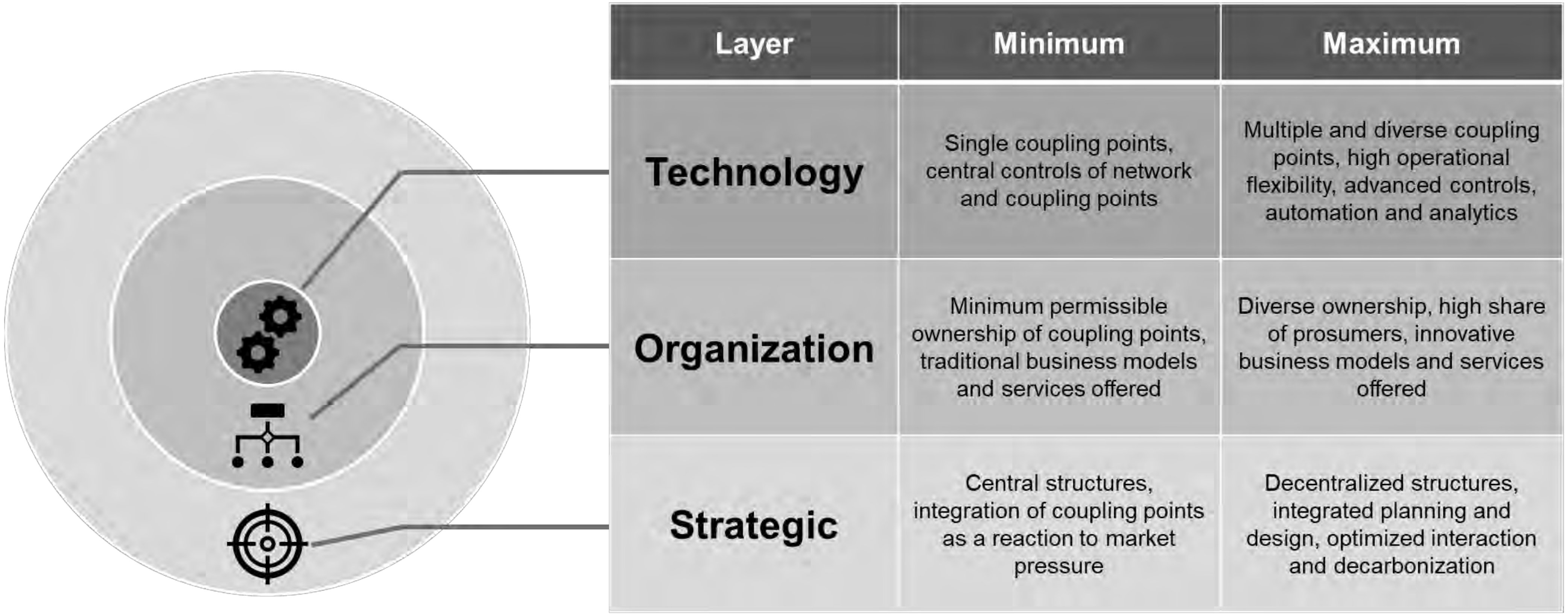
Subtask E: **Dissemination** and Guidelines

AIT (AT) and IEA-DHC TCP

IEA DHC Annex TS3: sector coupling technologies

- **Electric boilers (eBs)**
  - transform electricity into heat (low invest. costs, high temperatures and fast gradients).
  - can be economically viable at very few operating hours (compared to HPs).
- **Power-to-heat and cold (PtH/C) technologies (heat pumps, HPs)**
  - use electricity to move heat from a cool space to a warm space (high conversion efficiency)
  - high dependency of the efficiency on the temperature lift between heat sink and source
  - enable the use of cost-efficient and high capacity thermal storage (high load cycles possible)
- **Power-to-gas (PtG) processes (i.e. electrolysis)**
  - uses electricity to transform water into oxygen and hydrogen.
  - If cost-efficient gas storages are available, cost-efficient seasonal storage is possible
  - recovering the associated waste heat in DHC networks increases its efficiency
- **Combined heat and power (CHP) plants**
  - generate high temperature heat for DHC networks and electricity,
  - hydrogen has a limited applicability in existing gas CHPs

IEA DHC Annex TS3: a classification approch*



Layer	Minimum	Maximum
Technology	Single coupling points, central controls of network and coupling points	Multiple and diverse coupling points, high operational flexibility, advanced controls, automation and analytics
Organization	Minimum permissible ownership of coupling points, traditional business models and services offered	Diverse ownership, high share of prosumers, innovative business models and services offered
Strategic	Central structures, integration of coupling points as a reaction to market pressure	Decentralized structures, integrated planning and design, optimized interaction and decarbonization

***This classification differs from the 4G DHC networks concept (Lund et. al=)**

→ the main characteristic of a HEN is the **integration** between the different networks, and not the supply temperature or the time period where the different generations were dominating.

IEA DHC Annex TS3: Schedule and outcomes

Definition phase	Preparation phase		Working phase					
2017 /Fall	2018 /Spring	2018 /Fall	2019 /Spring	2019 /Fall	2020 /Spring	2020 /Fall	2021 /Spring	2021 /Fall
Austria	Stockholm	Berlin with Industry WS	Stockholm shared WS with ISGAN	France – on invitation by CEA	Online TelCo and public Webinar	Online TelCo and public Webinar	Austria attached to the mission innovation week ?	Denmark – attached to the 4DH / SES conference?

Expected results:

- A **SWOT analyses** of HEN
- An assessment of suitable **technologies** and HEN concepts
- Country reports on national **energy scenarios** (Denmark, Austria …)
- Collection and assessment of international **case studies**
- A review of existing **methods and tools**
- **Best practice guidelines** and online tutorials for planning, designing and operating HEN
- A report on **exergy as evaluation criteria** for HEN
- Development of new **business models**
- Policy papers and recommendation on **market design and regulations**
- **workshops** with local industries
- **Publications and presentations** on various conferences
- a final **guidebook** summarizing the results
- …

Technologies for Hybridisation (*Oddgeir Gudmundsson, Danfoss)*

ENGINEERING
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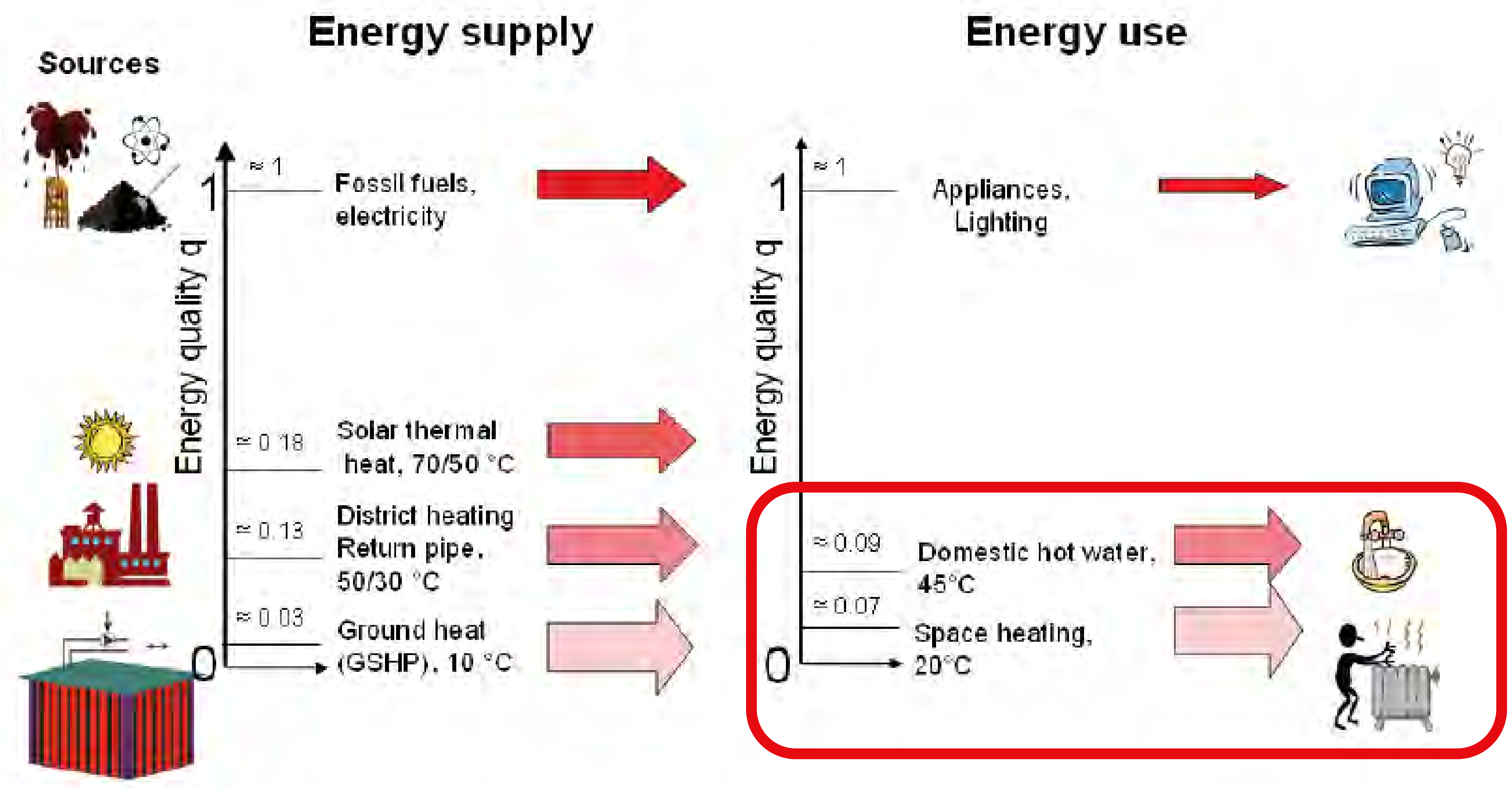
Energy system coupling technologies

Oddgeir Gudmundsson, Director, Projects

Role of district energy in traditional hybrid energy systems

- Traditional district energy: Important service using low quality energy
  - In sense of traditional hybrid energy systems district energy has been the dumping ground of low-quality energy



Source: ECB Annex 49: Low Exergy Systems for High Performance Buildings and Communities. Dietrich Schmidt. 2013.

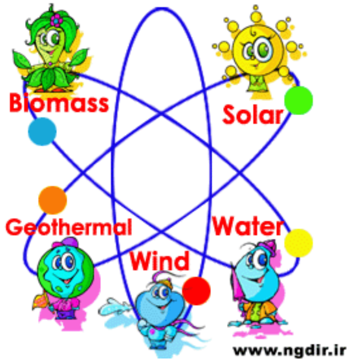
Future energy systems

- The disruptive force of renewable energy

Future energy generation


Source: Vestas Wind Systems A/S

Source: Danfoss A/S



Power demand news of today and tomorrow

RECORD 24 HOURS: WIND TURBINES COVER DENMARK'S POWER DEMAND FOR 24 HOURS

PUBLISHED 23.9.2019 09.36
BY ENERGINET

“15 September 2019 is a milestone for the green transition in Denmark and the first 24-hour period ever of excess wind power production during all hours of the day and night. On Sunday, production from midnight to midnight supplied 130% of demand in Denmark.”

“Early on Sunday morning between 2.00 am and 3.00 am, the wind turbines generated an impressive 60% more electricity than the Danish market demanded.”

These kind of good news will be more and more common!

Technologies to capture and enable maximum usage of excess energy generation

- There are many technologies and solutions available:
  - Batteries
  - District energy systems
  - Heat pumps
  - Thermal storages
  - Load shifting enabling software
  - Power to synthetic fuels
  - Direct electricity to power heaters
  - … and many others

Recap

"15 September 2019 is a milestone for the green transition in Denmark and the first 24-hour period ever of excess wind power production during all hours of the day and night. On Sunday, production from midnight to midnight supplied 130% of demand in Denmark."

"Early on Sunday morning between 2.00 am and 3.00 am, the wind turbines generated an impressive 60% more electricity than the Danish market demanded."

- Different technologies have different benefits and abilities to capture the excess energy being generated at a given time

- In the scope of hybrid energy systems:
  ➔ We are interested in the excess energy that cannot be cost efficiently stored within the same energy system it was generated

Role of district energy in future hybrid energy systems

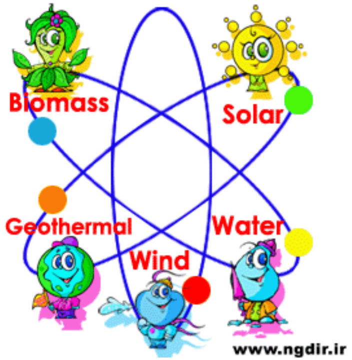
- With decarbonization and focus on energy efficiency district energy is becoming the rising shining star and enabler of cost efficient future renewable based energy systems
  - In combination with thermal storages there is practically no limit on how much excess generated renewable power the systems can absorb
  - It can ramp capacity utilization up/down very fast → Balancing services

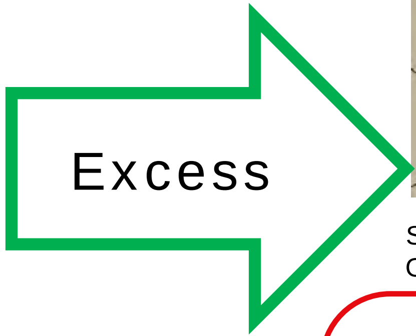
Future energy generation

Source: Danfoss A/S

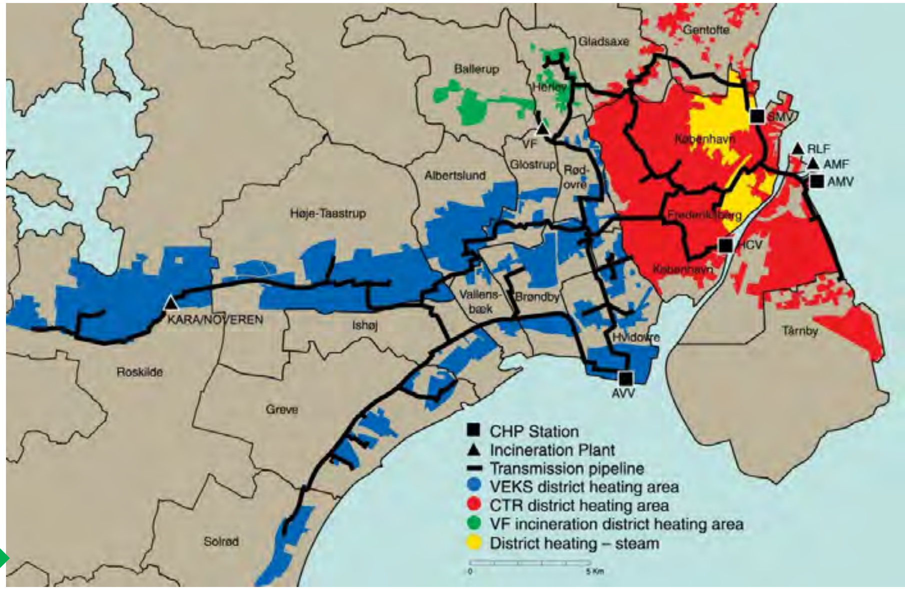
Source: Vestas Wind Systems A/S

Source: Aarhus Vand A/S





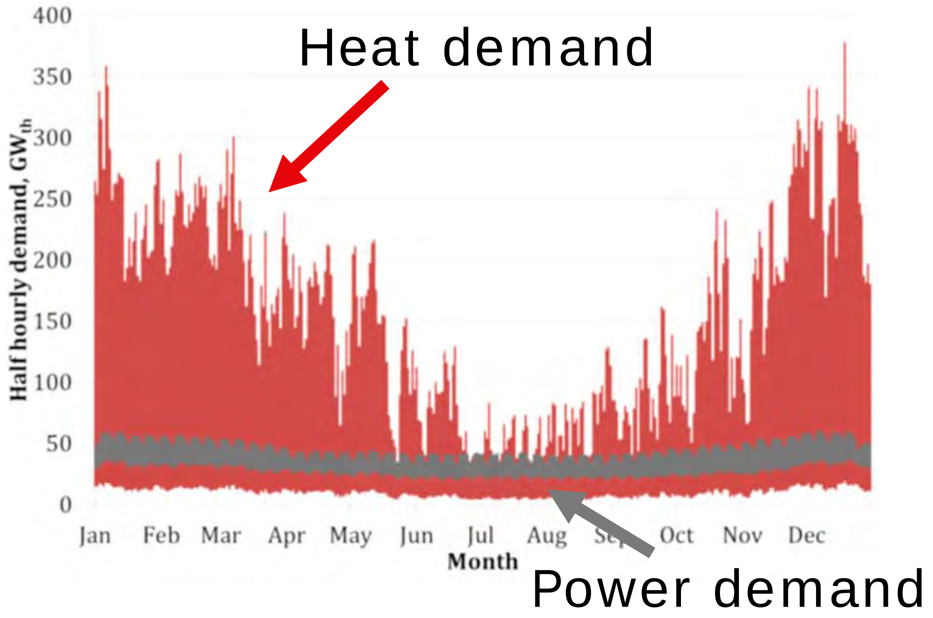
Excess



Source: The District Heating System in Greater Copenhagen Area - in a free power market. Varmelast.dk

Source: Ramboll A/S

Which thermal supply system?



Thermal demand

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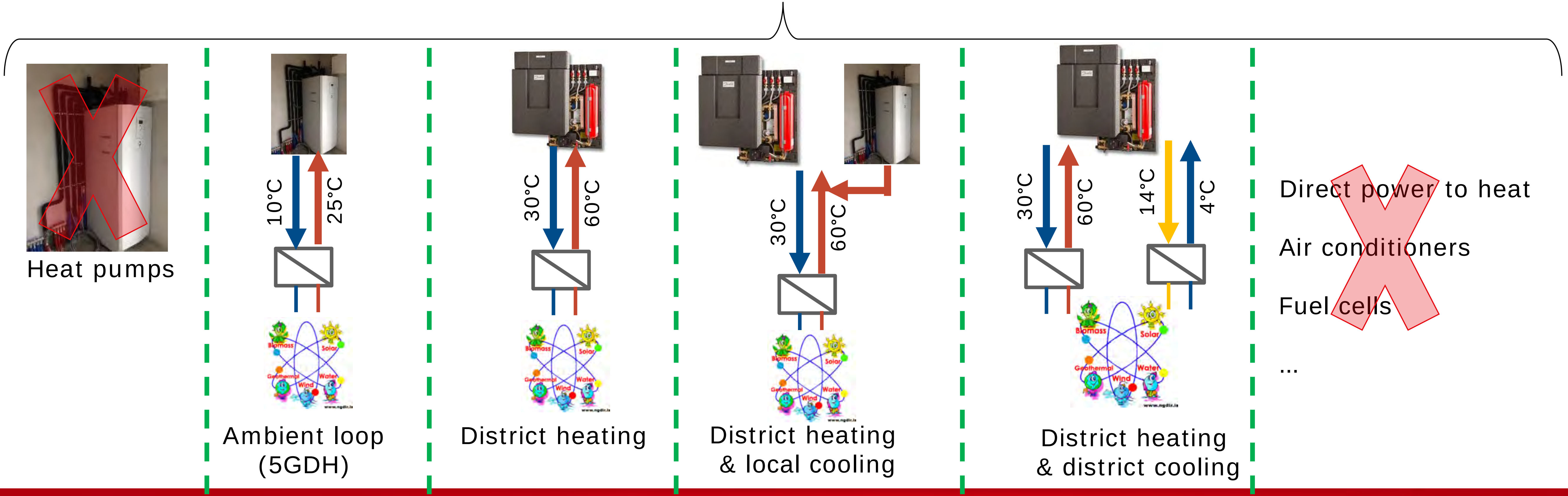


Thermal supply

Heat pumps

Ambient loop (5GDH)

District heating

District heating & local cooling

District heating & district cooling

Direct power to heat

Air conditioners

Fuel cells

...

Different thermal supply methods have different benefits and limitations

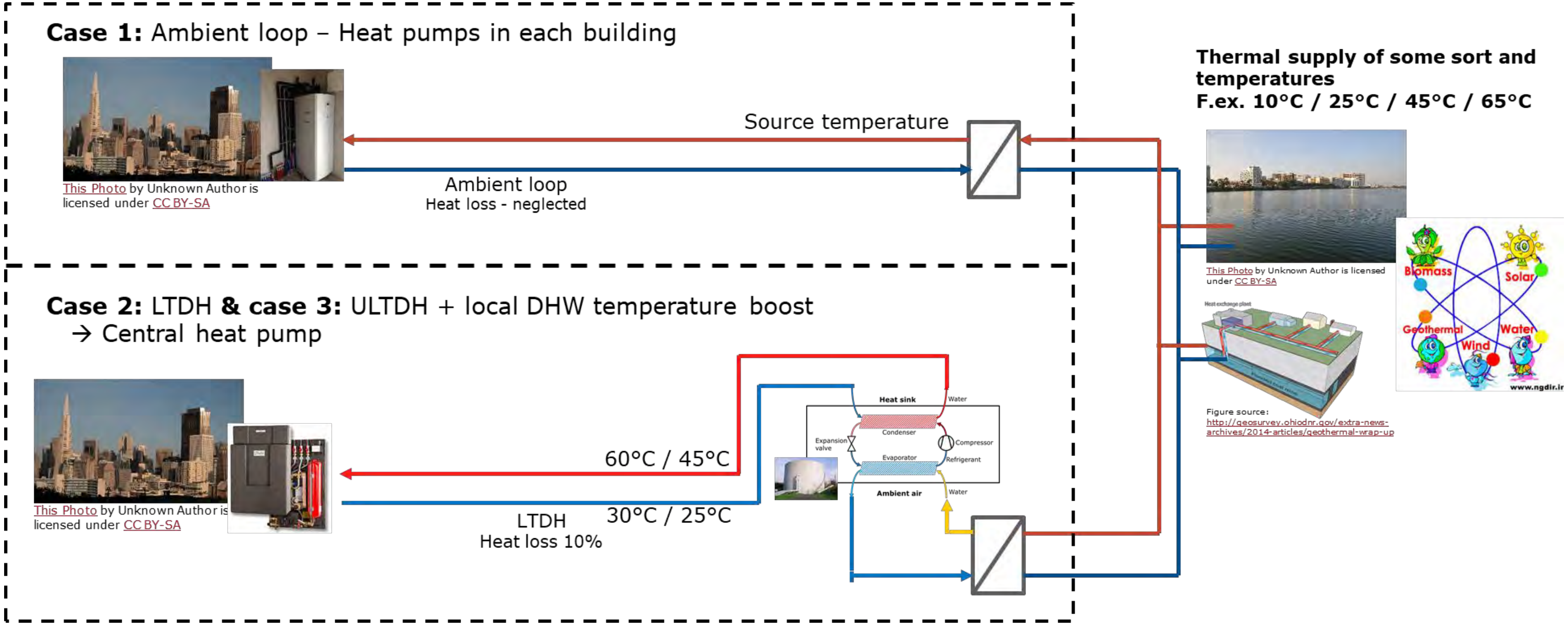
- Communities need to do a heat planning for the future
  - During heat supply planning solutions should be evaluate on a range of metrics:

  - Economics
    - What is the lifecycle cost of the thermal supply?
  - Energy supply security
    - What if the future develops differently than we expect?
  - Flexibility
    - How flexible is the thermal supply to the expected “fuel” input?
  - Robustness
    - Is the supply system able to operate in case of unexpected beating?
  - Reliability
    - How frequently does the thermal supply fail to meet the demands?
  - Resilience
    - How quickly can the supply system recover from a disruption? (climate related, terror/cyber attacks, …)

District energy is simple as well as complex
- Economic example

- District energy is simple: It distributes heat to buildings or extracts heat from buildings

- District energy is complex: It has many stakeholders and has market specific conditions
  - Cost of establishing district energy systems in established district energy countries is “cheap” compared to some new markets



Case 1: Ambient loop – Heat pumps in each building

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Source temperature

Ambient loop
Heat loss - neglected

Case 2: LTDH **& case 3:** ULTDH + local DHW temperature boost
→ Central heat pump

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60°C / 45°C

30°C / 25°C

LTDH
Heat loss 10%

Thermal supply of some sort and temperatures
F.ex. 10°C / 25°C / 45°C / 65°C

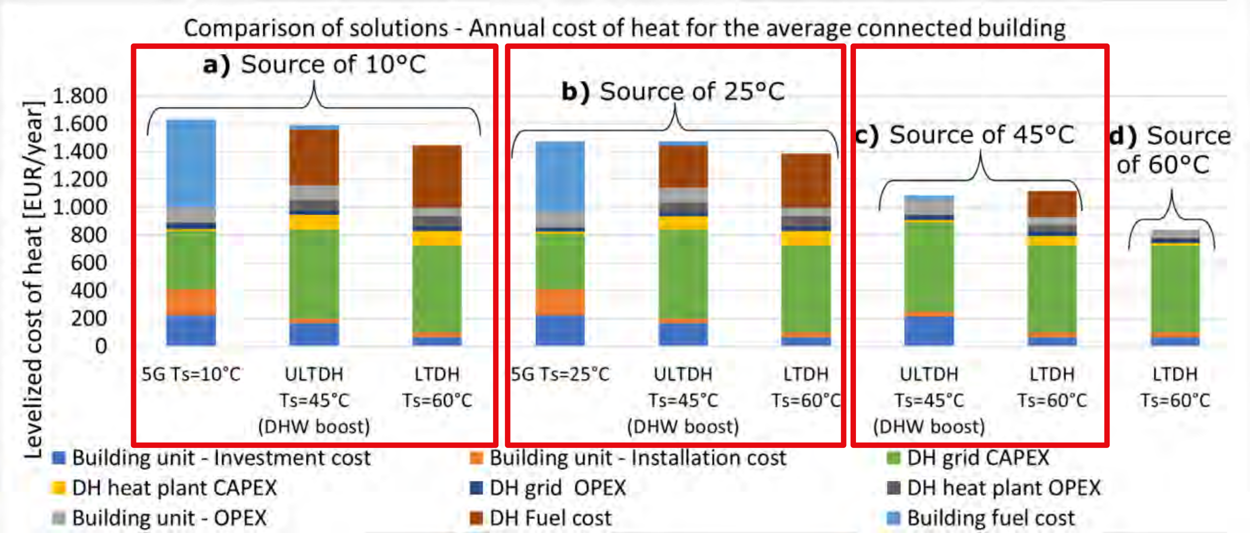
This Photo by Unknown Author is licensed under CC BY-SA

Figure source:
http://geosurvey.ohiodnr.gov/extra-news-archives/2014-articles/geothermal-wrap-up

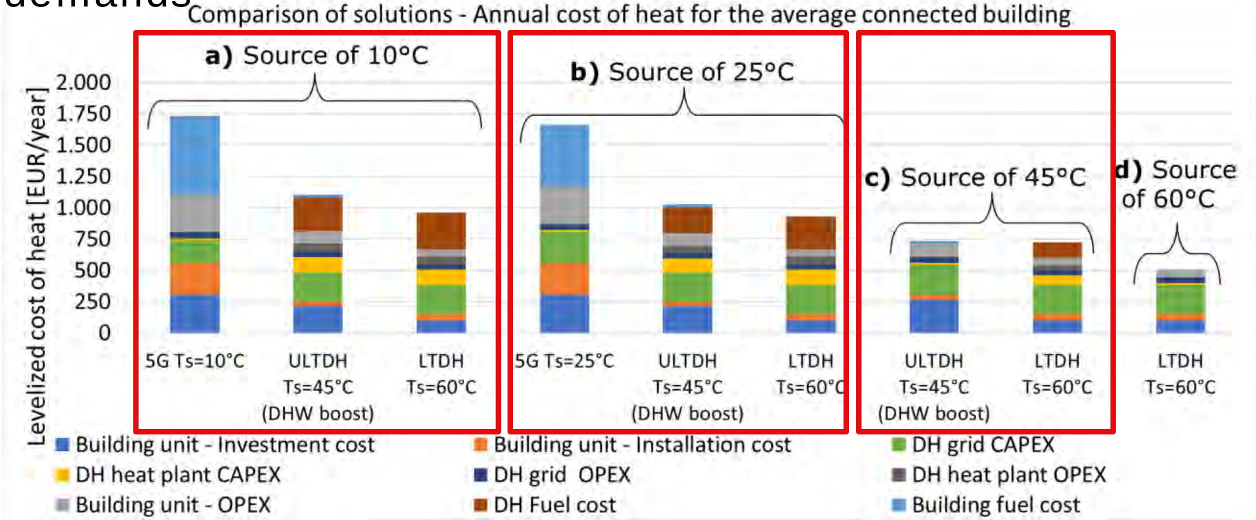
Comparing economics of different solutions for a heat supply in the United Kingdom and Denmark

- The comparison is based on a levelized cost of heating, all main costs inclusive..
  … Except the development of the heat source!

United Kingdom
–11,4 MWh/y space heating and 2 MWh/y DHW demands



Denmark
– 15 MWh/y space heating and 2 MWh/y DHW demands



- The conclusion is that knowledge and experience is the king and queen!
  - New markets need to take advantage of the experience acquired in the established markets

Source: Paper to be published in the Smart Energy Systems conference in Aalborg, October 2020.

Different thermal supply methods have different benefits and limitations

- Communities need to do a heat planning for the future
  - During heat supply planning solutions should be evaluate on a range of metrics:
  - Economics
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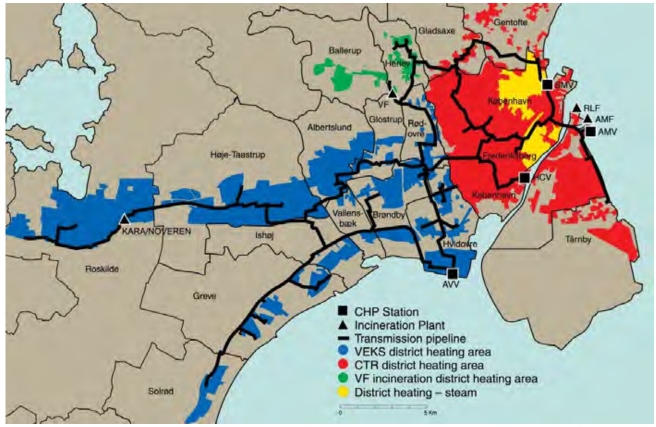
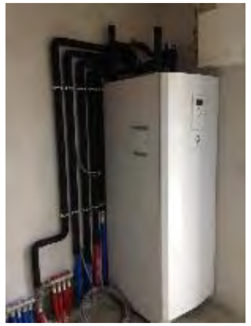
Cities: Low temperature district heating



Source: The District Heating System in
Greater Copenhagen Area - in a free power market. Varmelast.dk

Rural areas:
Winner for most
metrics is:



Heat pumps

Denmark actively takes advantage of district energy to support the future green and sustainable energy system

- The municipality of Aalborg, Denmark, plans to build 1.000.000 m^3 thermal storage to enable maximum energy flexibility to:
  - Support renewable power generation,
  - Balance local power plants,
  - Store industrial waste heat and
  - Surplus heat from local waste incineration.

- The thermal storage will provide the ultimate flexibility to the district heating system supplying 98% of Aalborg city building heating demand.

Aalborg får et af verdens største energilagre

Aalborg Forsyning planlægger at bygge verdens største damvarmelager i Aalborg.

Læs også: Ny leverandør af energianlæg høster små og store ordrer på stribe

- I Aalborg har vi sat os for at spille en afgørende rolle for den grønne omstilling. Vi ser frem til at kunne optimere vores udnyttelse af de vedvarende energikilder med det nye damvarmelager og give aalborggenserne et endnu grønnere produkt, siger vicedirektør for Aalborg Forsyning, Jesper Høstgaard-Jensen.

Efter nedlukningen af Nordjyllandsværket skal damvarmelagerne hjælpe med at opsamle overskudsproduktion fra vindmøller og andre vedvarende energikilder.

Visualisering: Rambøll

Af Maria Berg Badstue Pedersen
3. september 2020 09:04

https://www.energy-supply.dk/article/view/737536/aalborg_far_et_af_verdens_storste_energilagre?ref=newsletter&utm_medium=email&utm_source=newsletter&utm_campaign=daily

Thank you for your attention

Contact information:
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GIS-based automated design of DH networks *(Joseph Jebamalai, Comsof)*

COMSOF
Empower to create

COMSOF HEAT

GIS BASED AUTOMATED DESIGN OF DISTRICT HEATING NETWORKS

Joseph Jebamalai

comsof.com

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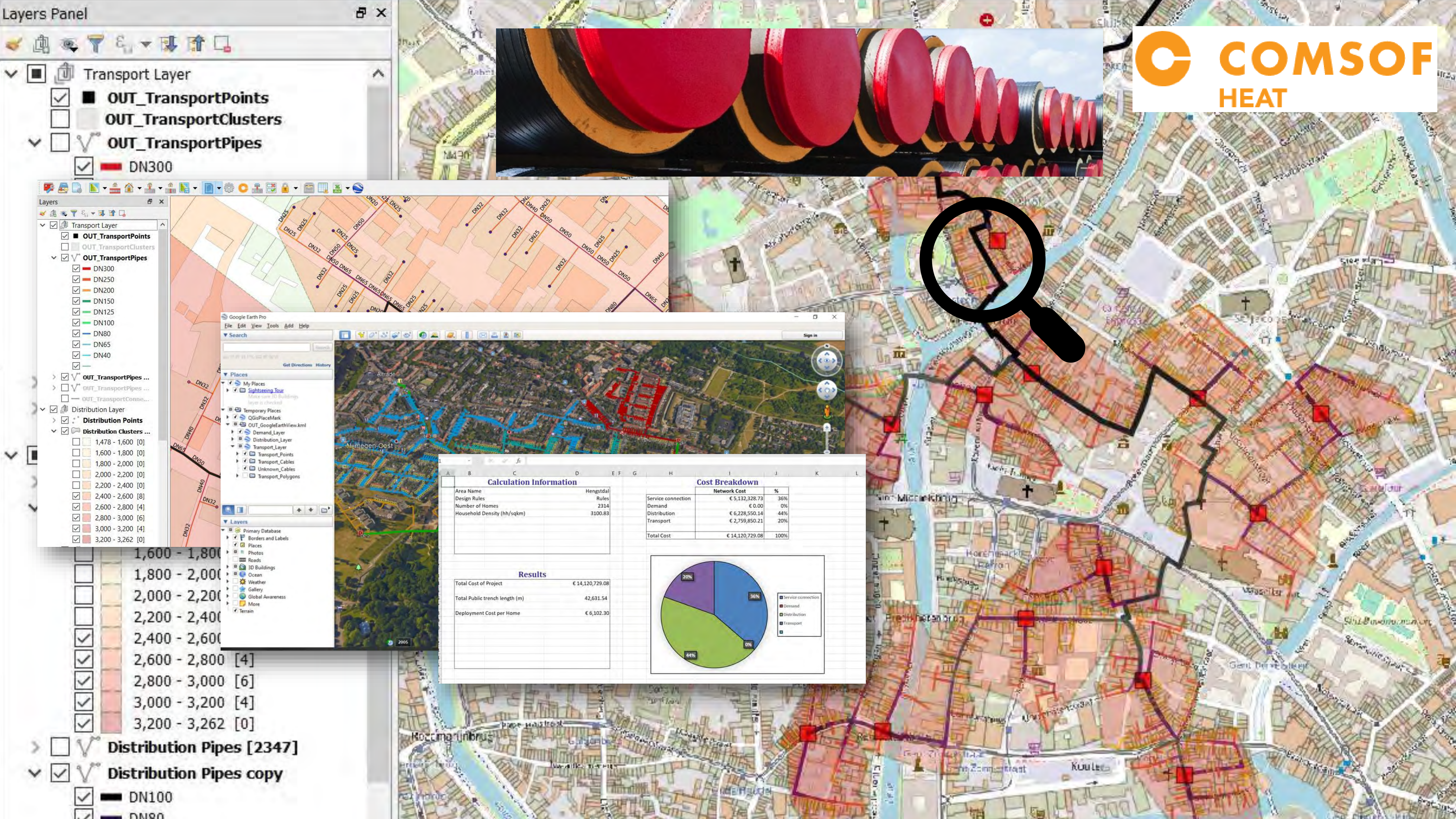


Calculation Information

Area Name	Hengstdal
Design Rules	Rules
Number of Homes	2314
Household Density (hh/sqkm)	3100.83

Cost Breakdown

	Network Cost	%
Service connection	€ 5,132,328.73	36%
Demand	€ 0.00	0%
Distribution	€ 6,228,550.14	44%
Transport	€ 2,759,850.21	20%
Total Cost	€ 14,120,729.08	100%

Results

Total Cost of Project	€ 14,120,729.08
Total Public trench length (m)	42,631.54
Deployment Cost per Home	€ 6,102.30

COMSOF HEAT REFERENCES

ingenium

Nijmegen

GRUNNEGER POWER

fluvius.

hvc.

Royal HaskoningDHV
Enhancing Society Together

Gemeente Rotterdam

KU LEUVEN
FACULTY OF ARCHITECTURE

if
IF Technology **Creating energy**

WITH COMSOF HEAT YOU CAN HANDLE LARGER PROJECTS. FOR A PROJECT WHERE YOU WOULD NEED **THREE MONTHS DESIGN TIME** YOU CAN NOW DO THE SAME CALCULATIONS IN A **NUMBER OF DAYS**, AND WITH **MORE DETAIL**

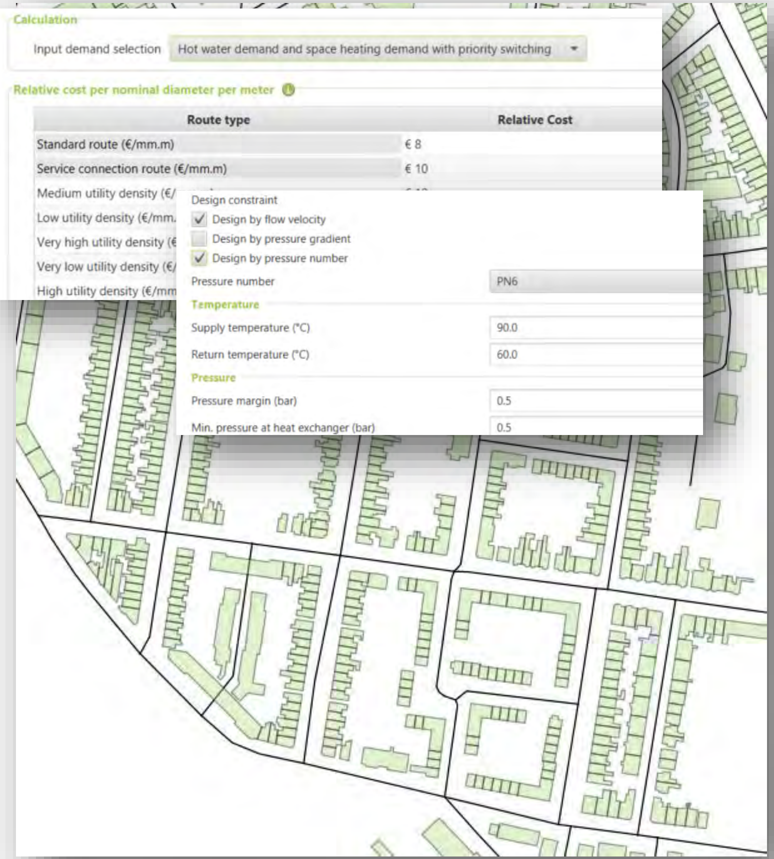
rotterdam engineering

WITH THE AUTOMATED GIS-ANALYSIS OF COMSOF HEAT, YOU GET **QUICK AND AFFORDABLE INSIGHTS** IN NETWORK DESIGN, CAPITAL COST AND MATERIAL NEED. THIS SOFTWARE PROVIDES CONSIDERABLE **MORE RELIABLE CAPITAL COST CALCULATIONS** THAN MANUAL DESIGNS, FOR ONLY A FRACTION OF THE INVESTED LABOR HOURS

OVER MORGEN

PLANNING METHODOLOGY

COMSOF HEAT



Calculation

Input demand selection: Hot water demand and space heating demand with priority switching

Relative cost per nominal diameter per meter

Route type	Relative Cost
Standard route (€/mm.m)	€ 8
Service connection route (€/mm.m)	€ 10
Medium utility density (€/	
Low utility density (€/mm.	
Very high utility density (€	
Very low utility density (€/	
High utility density (€/mm	

Design constraint

☑ Design by flow velocity

☐ Design by pressure gradient

☑ Design by pressure number

Pressure number: PN6

Temperature

Supply temperature (°C): 90.0

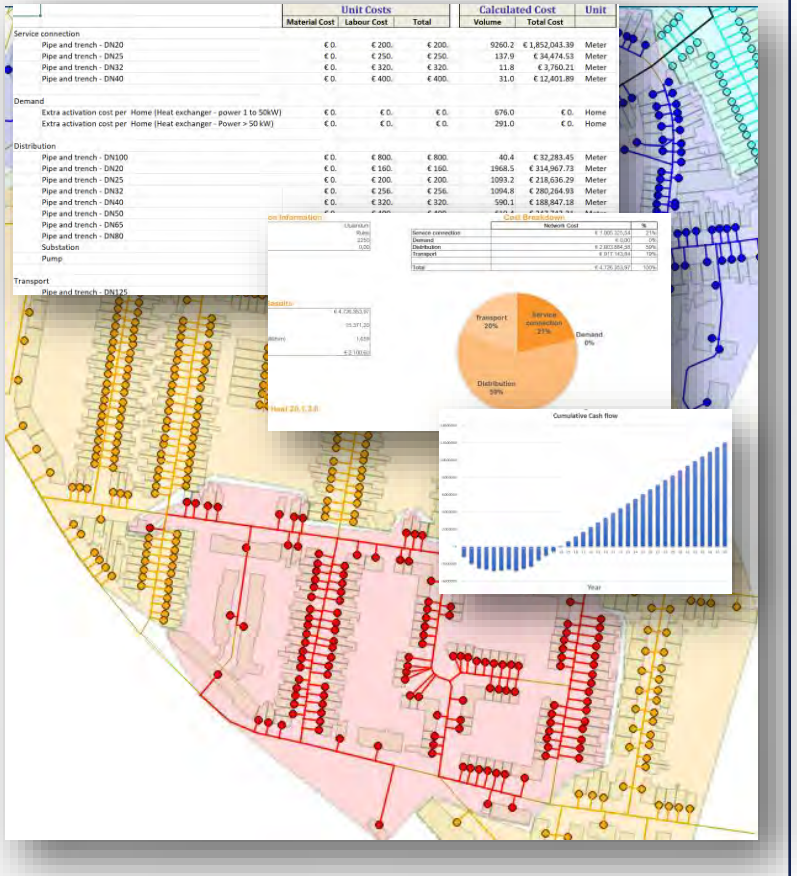
Return temperature (°C): 60.0

Pressure

Pressure margin (bar): 0.5

Min. pressure at heat exchanger (bar): 0.5

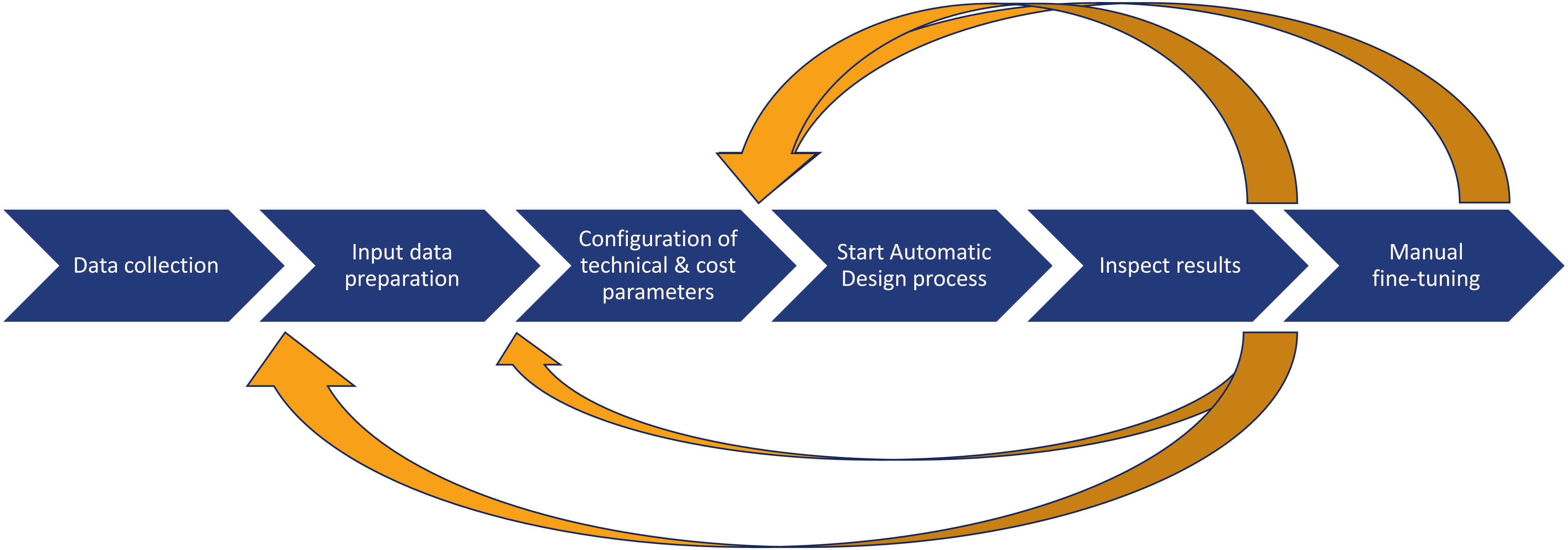
INPUT: GIS, HEAT DEMAND, DESIGN & COST PARAMETERS



	Unit Costs			Calculated Cost		Unit
	Material Cost	Labour Cost	Total	Volume	Total Cost	
Service connection						
Pipe and trench - DN20	€ 0.	€ 200.	€ 200.	9260.2	€ 1,852,043.39	Meter
Pipe and trench - DN25	€ 0.	€ 250.	€ 250.	137.9	€ 34,474.53	Meter
Pipe and trench - DN32	€ 0.	€ 320.	€ 320.	11.8	€ 3,760.21	Meter
Pipe and trench - DN40	€ 0.	€ 400.	€ 400.	31.0	€ 12,401.89	Meter
Demand						
Extra activation cost per Home (Heat exchanger - power 1 to 50kW)	€ 0.	€ 0.	€ 0.	676.0	€ 0.	Home
Extra activation cost per Home (Heat exchanger - Power > 50 kW)	€ 0.	€ 0.	€ 0.	291.0	€ 0.	Home
Distribution						
Pipe and trench - DN100	€ 0.	€ 800.	€ 800.	40.4	€ 32,283.45	Meter
Pipe and trench - DN20	€ 0.	€ 160.	€ 160.	1968.5	€ 314,967.73	Meter
Pipe and trench - DN25	€ 0.	€ 200.	€ 200.	1093.2	€ 218,636.29	Meter
Pipe and trench - DN32	€ 0.	€ 256.	€ 256.	1094.8	€ 280,264.93	Meter
Pipe and trench - DN40	€ 0.	€ 320.	€ 320.	590.1	€ 188,847.18	Meter
Pipe and trench - DN50						
Pipe and trench - DN65						
Pipe and trench - DN80						
Substation						
Pump						
Transport						
Pipe and trench - DN125						

OUTPUT: NETWORK, BOM and COSTS

OPTIMIZE THE DESIGN



Create and compare multiple scenarios

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Empower to create

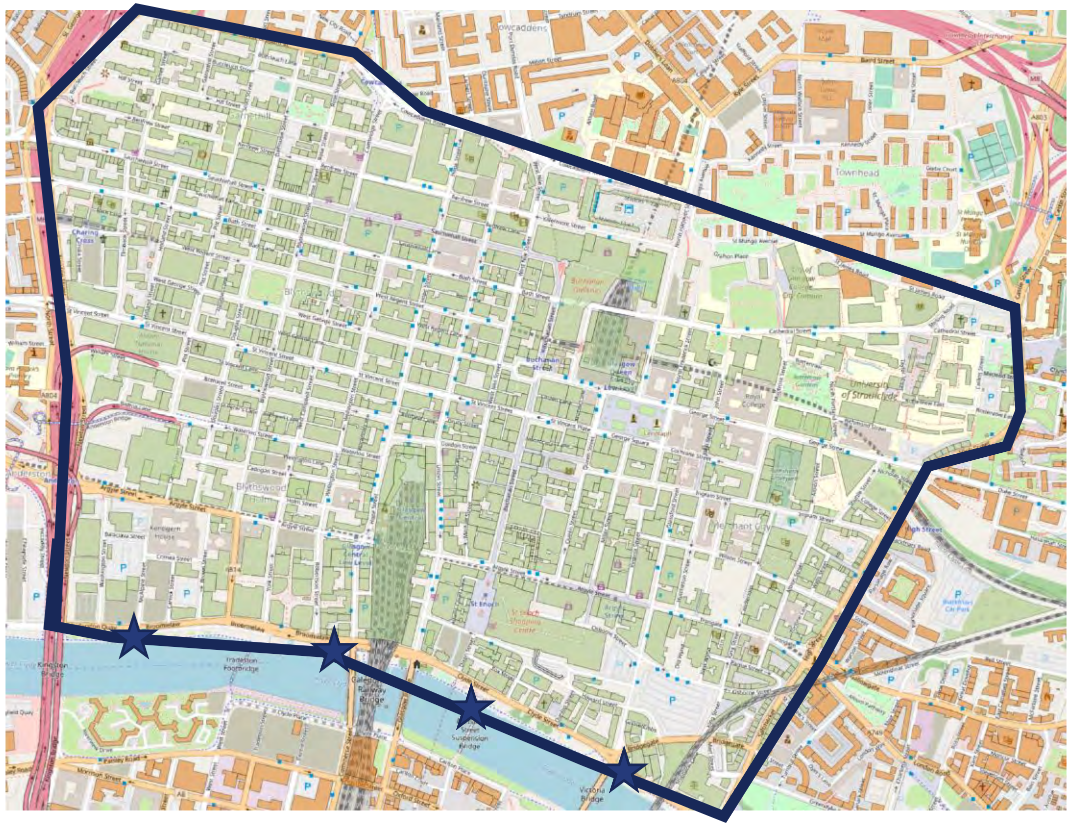
CASE GLASGOW

United Kingdom

GLASGOW PROJECT INFORMATION

District Heating

- Project information
  - Glasgow city centre
  - Extraction of heat from the river with heat pumps. One or more heat pumps will be used to extract heat from the river and feed the city centre of Glasgow with energy for heating of buildings.

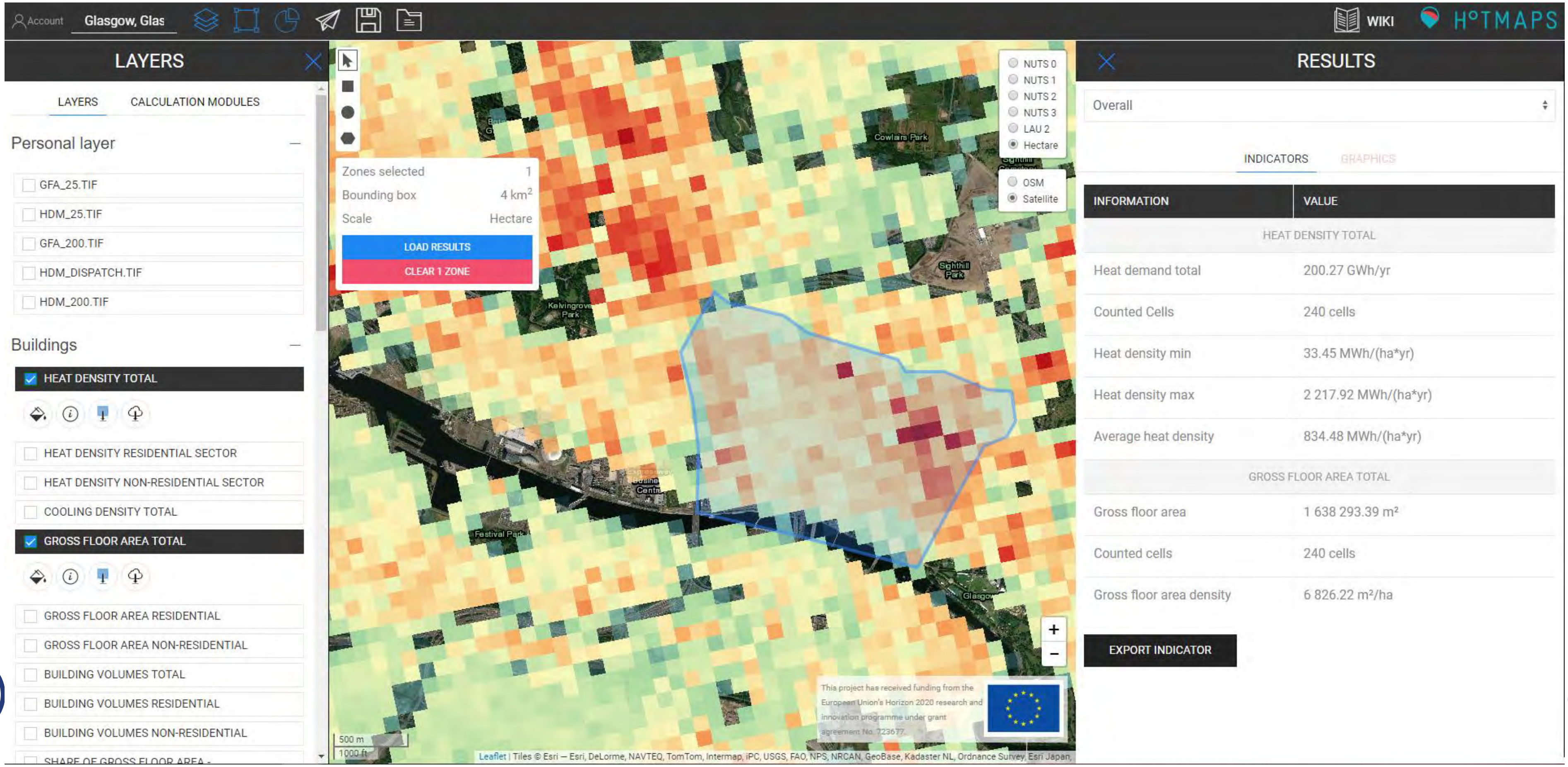


★ Source locations

GIS INPUTS AND HEAT DEMAND DATA

Glasgow

- Digitized map of the area
  - In this case from OpenStreet Map data
  - Including street center lines and building polygons
- Heat demand data
  - Heat demand density and gross floor area density has been extracted from the public website (EU Horizon 2020 project) HOTMAPS.EU



LAYERS

Personal layer

- ☐ GFA_25.TIF
- ☐ HDM_25.TIF
- ☐ GFA_200.TIF
- ☐ HDM_DISPATCH.TIF
- ☐ HDM_200.TIF

Buildings

- ☑ HEAT DENSITY TOTAL
- ☐ HEAT DENSITY RESIDENTIAL SECTOR
- ☐ HEAT DENSITY NON-RESIDENTIAL SECTOR
- ☐ COOLING DENSITY TOTAL
- ☑ GROSS FLOOR AREA TOTAL
- ☐ GROSS FLOOR AREA RESIDENTIAL
- ☐ GROSS FLOOR AREA NON-RESIDENTIAL
- ☐ BUILDING VOLUMES TOTAL
- ☐ BUILDING VOLUMES RESIDENTIAL
- ☐ BUILDING VOLUMES NON-RESIDENTIAL
- ☐ SHARE OF GROSS FLOOR AREA -

Zones selected	1
Bounding box	4 km^2
Scale	Hectare

RESULTS

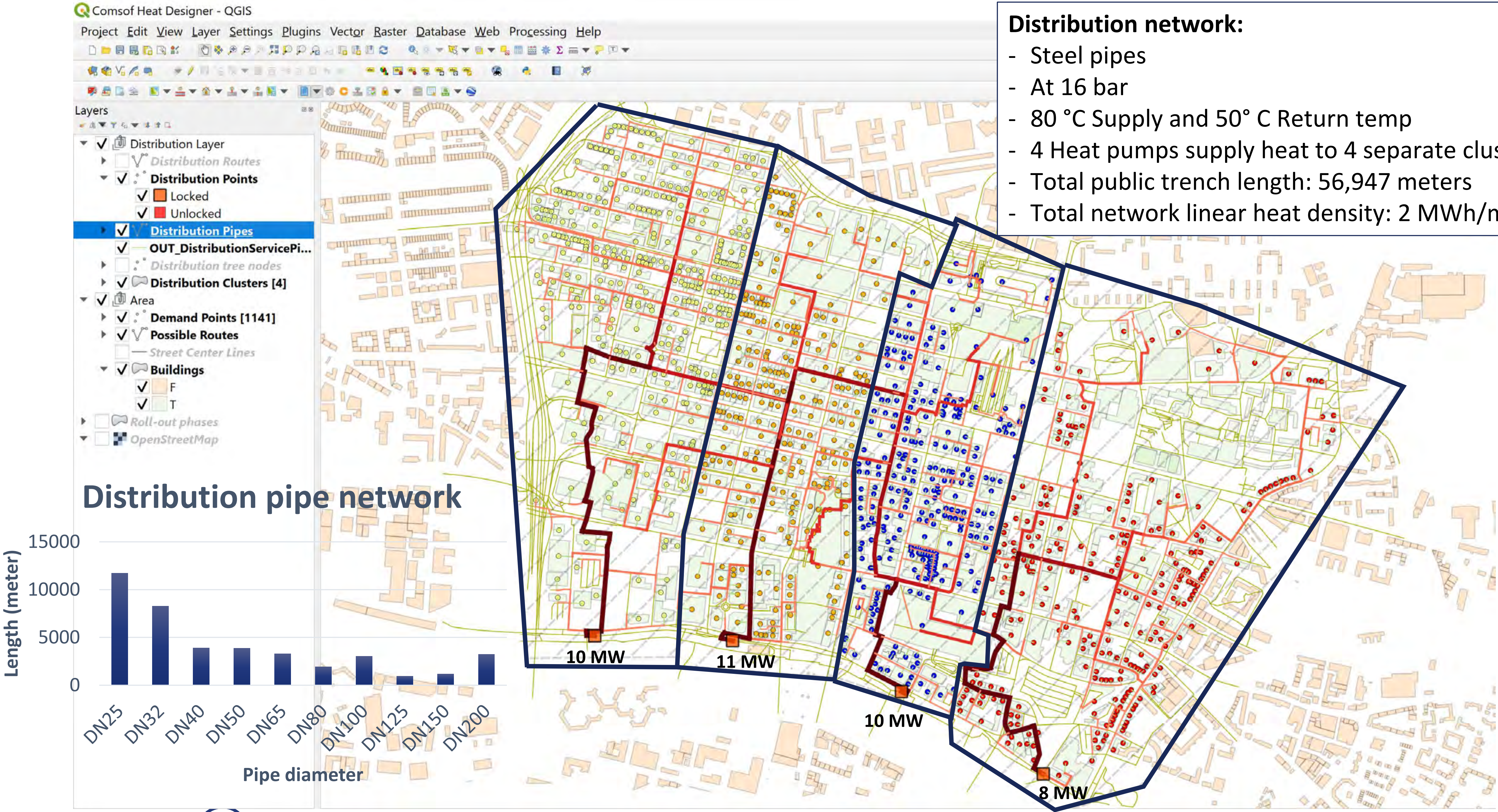
Overall

INDICATORS GRAPHICS

INFORMATION	VALUE
HEAT DENSITY TOTAL	
Heat demand total	200.27 GWh/yr
Counted Cells	240 cells
Heat density min	33.45 MWh/(ha*yr)
Heat density max	2 217.92 MWh/(ha*yr)
Average heat density	834.48 MWh/(ha*yr)
GROSS FLOOR AREA TOTAL	
Gross floor area	1 638 293.39 m²
Counted cells	240 cells
Gross floor area density	6 826.22 m²/ha

Distribution network:

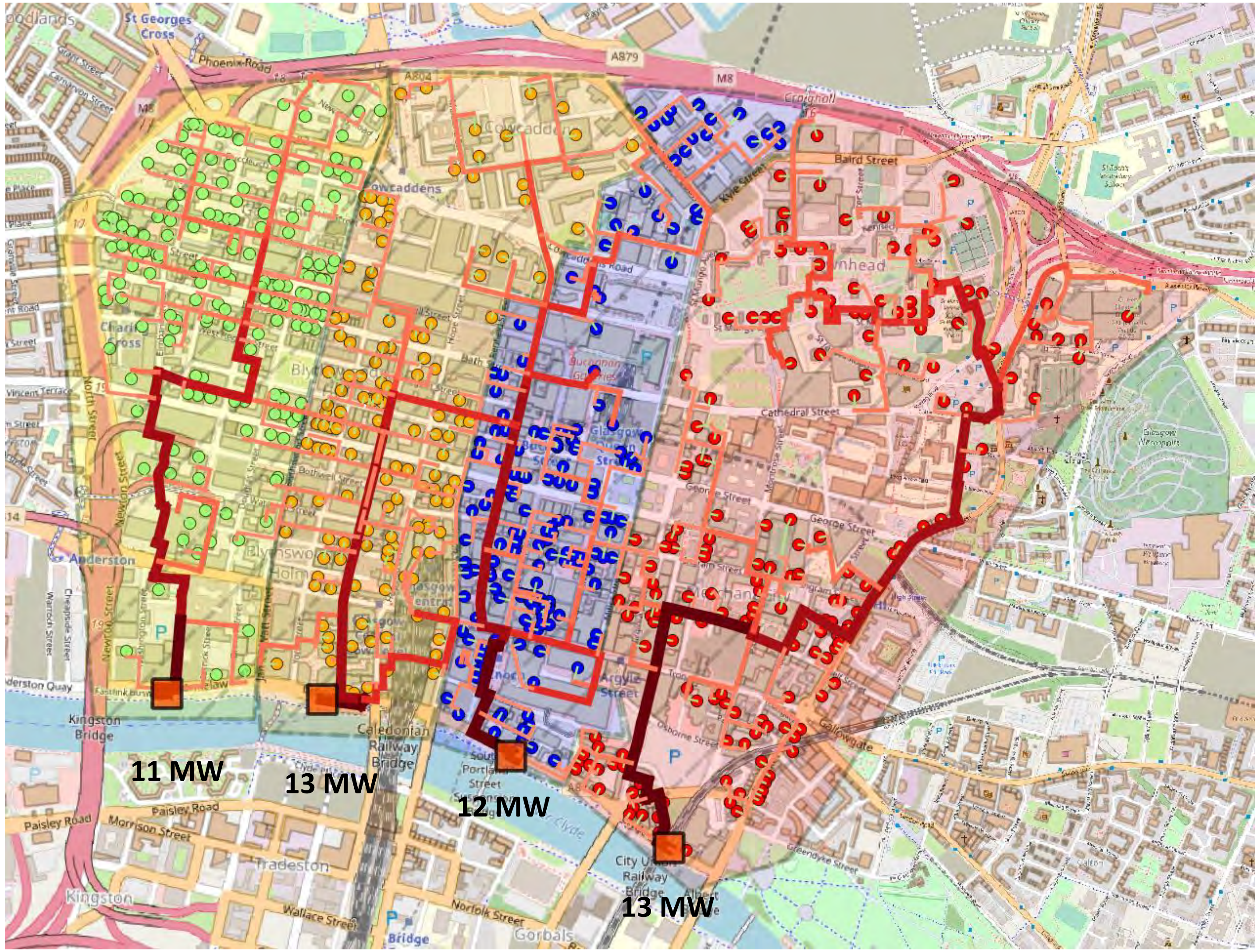
- Steel pipes
- At 16 bar
- 80 °C Supply and 50° C Return temp
- 4 Heat pumps supply heat to 4 separate clusters
- Total public trench length: 56,947 meters
- Total network linear heat density: 2 MWh/m



COMSOF

MODIFIED NETWORK DESIGN

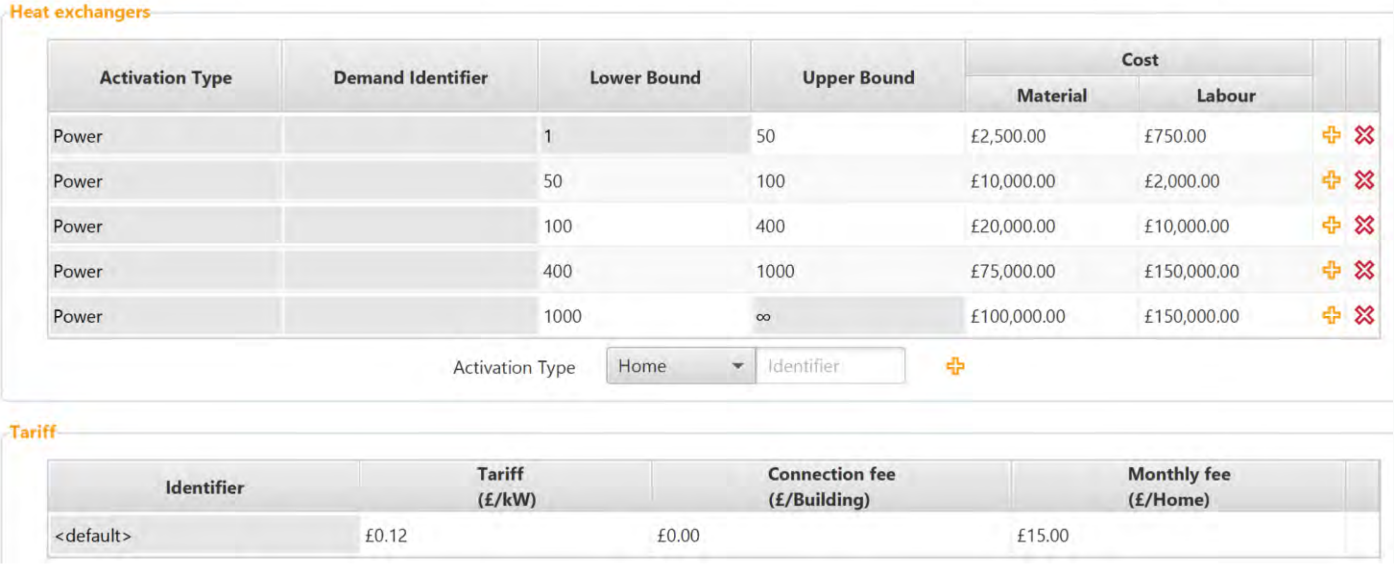
Glasgow



DEPLOYMENT COST CALCULATION (ASSUMPTIONS)

Glasgow

- Based on sample costs per meter pipe network including
  - Excavation
  - Supply & return pipe
  - Welding & installation costs
  - Refill and repair of top layer
  - Project management overhead
- Heat source cost (Heat pump)
  - 1,600,000 GBP / Megawatt
- Intermediate pump cost – 60,000 GBP / Megawatt
- Heat delivery unit cost



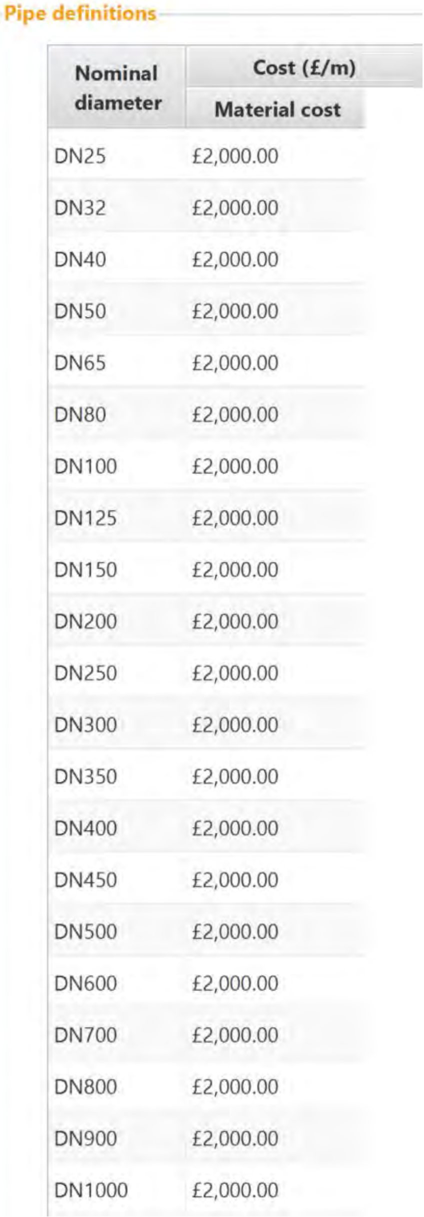
Heat exchangers

Activation Type	Demand Identifier	Lower Bound	Upper Bound	Cost	
				Material	Labour
Power		1	50	£2,500.00	£750.00
Power		50	100	£10,000.00	£2,000.00
Power		100	400	£20,000.00	£10,000.00
Power		400	1000	£75,000.00	£150,000.00
Power		1000	∞	£100,000.00	£150,000.00

Activation Type: Home

Tariff

Identifier	Tariff (£/kW)	Connection fee (£/Building)	Monthly fee (£/Home)
<default>	£0.12	£0.00	£15.00



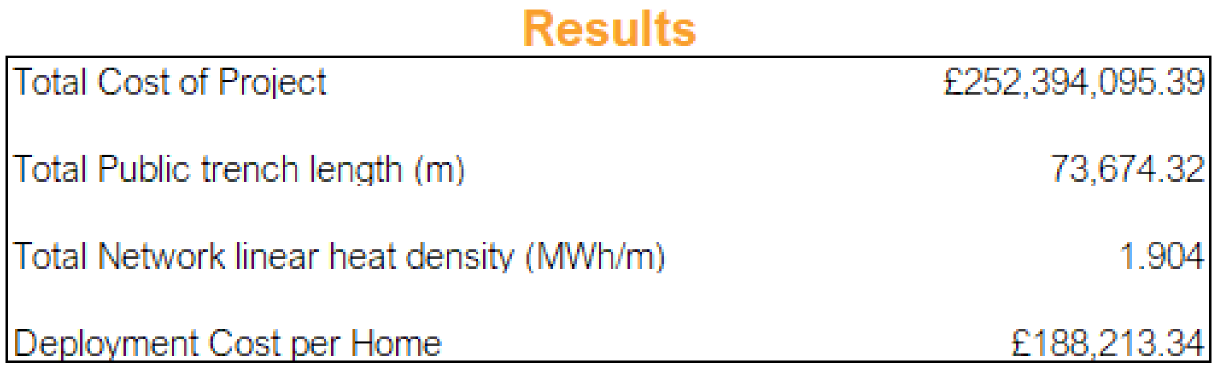
Pipe definitions

Nominal diameter	Cost (£/m)
	Material cost
DN25	£2,000.00
DN32	£2,000.00
DN40	£2,000.00
DN50	£2,000.00
DN65	£2,000.00
DN80	£2,000.00
DN100	£2,000.00
DN125	£2,000.00
DN150	£2,000.00
DN200	£2,000.00
DN250	£2,000.00
DN300	£2,000.00
DN350	£2,000.00
DN400	£2,000.00
DN450	£2,000.00
DN500	£2,000.00
DN600	£2,000.00
DN700	£2,000.00
DN800	£2,000.00
DN900	£2,000.00
DN1000	£2,000.00

RESULTS – 100% UPTAKE

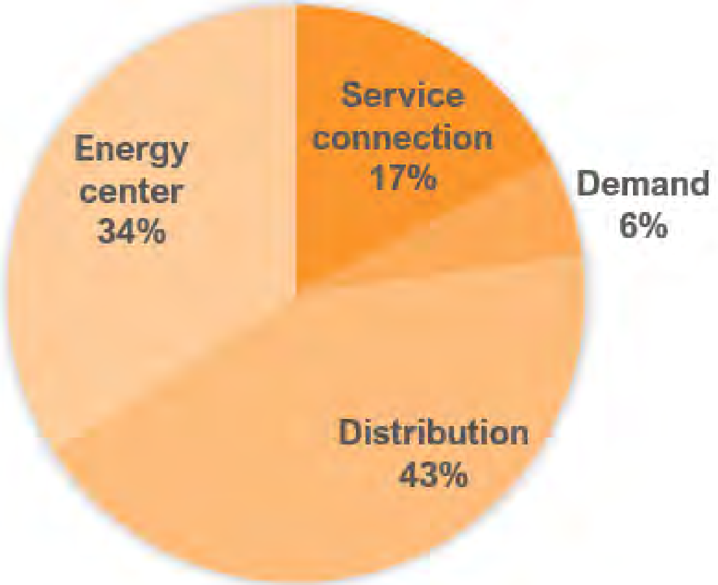
Glasgow

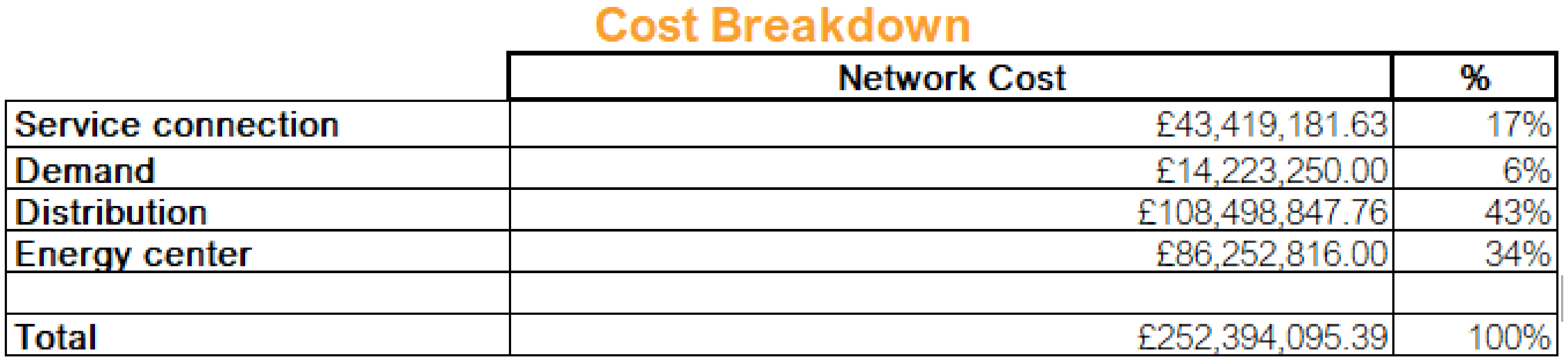
- Cost breakdown



Results

Total Cost of Project	£252,394,095.39
Total Public trench length (m)	73,674.32
Total Network linear heat density (MWh/m)	1.904
Deployment Cost per Home	£188,213.34





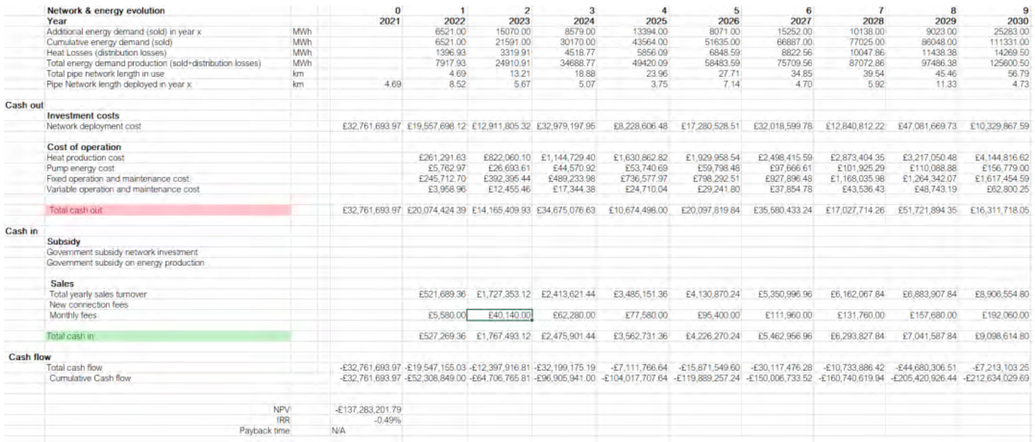
Cost Breakdown

	Network Cost	%
Service connection	£43,419,181.63	17%
Demand	£14,223,250.00	6%
Distribution	£108,498,847.76	43%
Energy center	£86,252,816.00	34%
Total	£252,394,095.39	100%

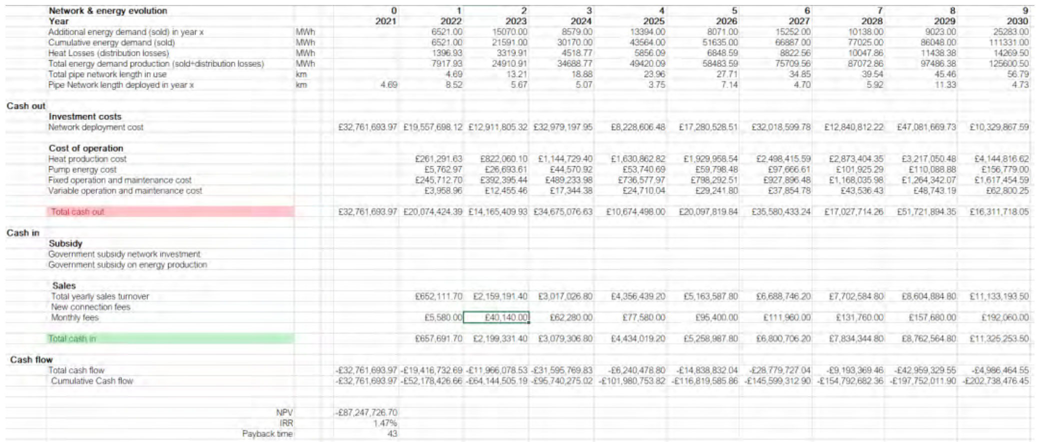
RESULTS WITH 33 GBP AND 15 GBP – COST OF HEAT PRODUCTION

TARIFF – 6p, 8p, 10p, 12p / kWh

33 GBP	NPV	IRR	Payback time
6p	-187,318,676	-3.96	N/A
8p	-137,283,202	-0.49	N/A
10p	-87,247,727	1.47	43
12p	-37,212,252	3	32
15 GBP	**NPV**	**IRR**	**Payback time**
6p	-134,327,755	-0.35	N/A
8p	-84,292,280	1.57	42
10p	-34,256,805	3.08	32
12p	15,778,670	4.4	26



	Network & energy evolution		0	1	2	3	4	5	6	7	8	9
	Year		**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
	Additional energy demand (sold) in year x	MWh		6521.00	15070.00	8579.00	13394.00	8071.00	15252.00	10138.00	9023.00	25283.00
	Cumulative energy demand (sold)	MWh		6521.00	21591.00	30170.00	43564.00	51635.00	66887.00	77025.00	86048.00	111331.00
	Heat Losses (distribution losses)	MWh		1396.93	3319.91	4518.77	5856.09	6848.59	8822.56	10047.86	11438.38	14269.50
	Total energy demand production (sold+distribution losses)	MWh		7917.93	24910.91	34688.77	49420.09	58483.59	75709.56	87072.86	97486.38	125600.50
	Total pipe network length in use	km		4.69	13.21	18.88	23.96	27.71	34.85	39.54	45.46	56.79
	Pipe Network length deployed in year x	km	4.69	8.52	5.67	5.07	3.75	7.14	4.70	5.92	11.33	4.73
Cash out												
	Investment costs											
	Network deployment cost		£32,761,693.97	£19,557,698.12	£12,911,805.32	£32,979,197.95	£8,228,606.48	£17,280,528.51	£32,018,599.78	£12,840,812.22	£47,081,669.73	£10,329,867.59
	Cost of operation											
	Heat production cost			£261,291.63	£822,060.10	£1,144,729.40	£1,630,862.82	£1,929,958.54	£2,498,415.59	£2,873,404.35	£3,217,050.48	£4,144,816.62
	Pump energy cost			£5,762.97	£26,693.61	£44,570.92	£53,740.69	£59,798.48	£97,666.61	£101,925.29	£110,088.88	£156,779.00
	Fixed operation and maintenance cost			£245,712.70	£392,395.44	£489,233.98	£736,577.97	£798,292.51	£927,896.48	£1,168,035.98	£1,264,342.07	£1,617,454.59
	Variable operation and maintenance cost			£3,958.96	£12,455.46	£17,344.38	£24,710.04	£29,241.80	£37,854.78	£43,536.43	£48,743.19	£62,800.25
	Total cash out		£32,761,693.97	£20,074,424.39	£14,165,409.93	£34,675,076.63	£10,674,498.00	£20,097,819.84	£35,580,433.24	£17,027,714.26	£51,721,894.35	£16,311,718.05
Cash in												
	Subsidy											
	Government subsidy network investment											
	Government subsidy on energy production											
	Sales											
	Total yearly sales turnover			£521,689.36	£1,727,353.12	£2,413,621.44	£3,485,151.36	£4,130,870.24	£5,350,996.96	£6,162,067.84	£6,883,907.84	£8,906,554.80
	New connection fees											
	Monthly fees			£5,580.00	£40,140.00	£62,280.00	£77,580.00	£95,400.00	£111,960.00	£131,760.00	£157,680.00	£192,060.00
	Total cash in			£527,269.36	£1,767,493.12	£2,475,901.44	£3,562,731.36	£4,226,270.24	£5,462,956.96	£6,293,827.84	£7,041,587.84	£9,098,614.80
Cash flow												
	Total cash flow		-£32,761,693.97	-£19,547,155.03	-£12,397,916.81	-£32,199,175.19	-£7,111,766.64	-£15,871,549.60	-£30,117,476.28	-£10,733,886.42	-£44,680,306.51	-£7,213,103.25
	Cumulative Cash flow		-£32,761,693.97	-£52,308,849.00	-£64,706,765.81	-£96,905,941.00	-£104,017,707.64	-£119,889,257.24	-£150,006,733.52	-£160,740,619.94	-£205,420,926.44	-£212,634,029.69
		NPV	-£137,283,201.79									
		IRR	-0.49%									
		Payback time	N/A									



	Network & energy evolution		0	1	2	3	4	5	6	7	8	9
	Year		**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
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	Total energy demand production (sold+distribution losses)	MWh		7917.93	24910.91	34688.77	49420.09	58483.59	75709.56	87072.86	97486.38	125600.50
	Total pipe network length in use	km		4.69	13.21	18.88	23.96	27.71	34.85	39.54	45.46	56.79
	Pipe Network length deployed in year x	km	4.69	8.52	5.67	5.07	3.75	7.14	4.70	5.92	11.33	4.73
Cash out												
	Investment costs											
	Network deployment cost		£32,761,693.97	£19,557,698.12	£12,911,805.32	£32,979,197.95	£8,228,606.48	£17,280,528.51	£32,018,599.78	£12,840,812.22	£47,081,669.73	£10,329,867.59
	Cost of operation											
	Heat production cost			£261,291.63	£822,060.10	£1,144,729.40	£1,630,862.82	£1,929,958.54	£2,498,415.59	£2,873,404.35	£3,217,050.48	£4,144,816.62
	Pump energy cost			£5,762.97	£26,693.61	£44,570.92	£53,740.69	£59,798.48	£97,666.61	£101,925.29	£110,088.88	£156,779.00
	Fixed operation and maintenance cost			£245,712.70	£392,395.44	£489,233.98	£736,577.97	£798,292.51	£927,896.48	£1,168,035.98	£1,264,342.07	£1,617,454.59
	Variable operation and maintenance cost			£3,958.96	£12,455.46	£17,344.38	£24,710.04	£29,241.80	£37,854.78	£43,536.43	£48,743.19	£62,800.25
	Total cash out		£32,761,693.97	£20,074,424.39	£14,165,409.93	£34,675,076.63	£10,674,498.00	£20,097,819.84	£35,580,433.24	£17,027,714.26	£51,721,894.35	£16,311,718.05
Cash in												
	Subsidy											
	Government subsidy network investment											
	Government subsidy on energy production											
	Sales											
	Total yearly sales turnover			£652,111.70	£2,159,191.40	£3,017,026.80	£4,356,439.20	£5,163,587.80	£6,688,746.20	£7,702,584.80	£8,604,884.80	£11,133,193.50
	New connection fees											
	Monthly fees			£5,580.00	£40,140.00	£62,280.00	£77,580.00	£95,400.00	£111,960.00	£131,760.00	£157,680.00	£192,060.00
	Total cash in			£657,691.70	£2,199,331.40	£3,079,306.80	£4,434,019.20	£5,258,987.80	£6,800,706.20	£7,834,344.80	£8,762,564.80	£11,325,253.50
Cash flow												
	Total cash flow		-£32,761,693.97	-£19,416,732.69	-£11,966,078.53	-£31,595,769.83	-£6,240,478.80	-£14,838,832.04	-£28,779,727.04	-£9,193,369.46	-£42,959,329.55	-£4,986,464.55
	Cumulative Cash flow		-£32,761,693.97	-£52,178,426.66	-£64,144,505.19	-£95,740,275.02	-£101,980,753.82	-£116,819,585.86	-£145,599,312.90	-£154,792,682.36	-£197,752,011.90	-£202,738,476.45
		NPV	-£87,247,726.70									
		IRR	1.47%									
		Payback time	43									

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CASE KORTRIJK

Multiple sources

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CASE STUDY - INPUTS

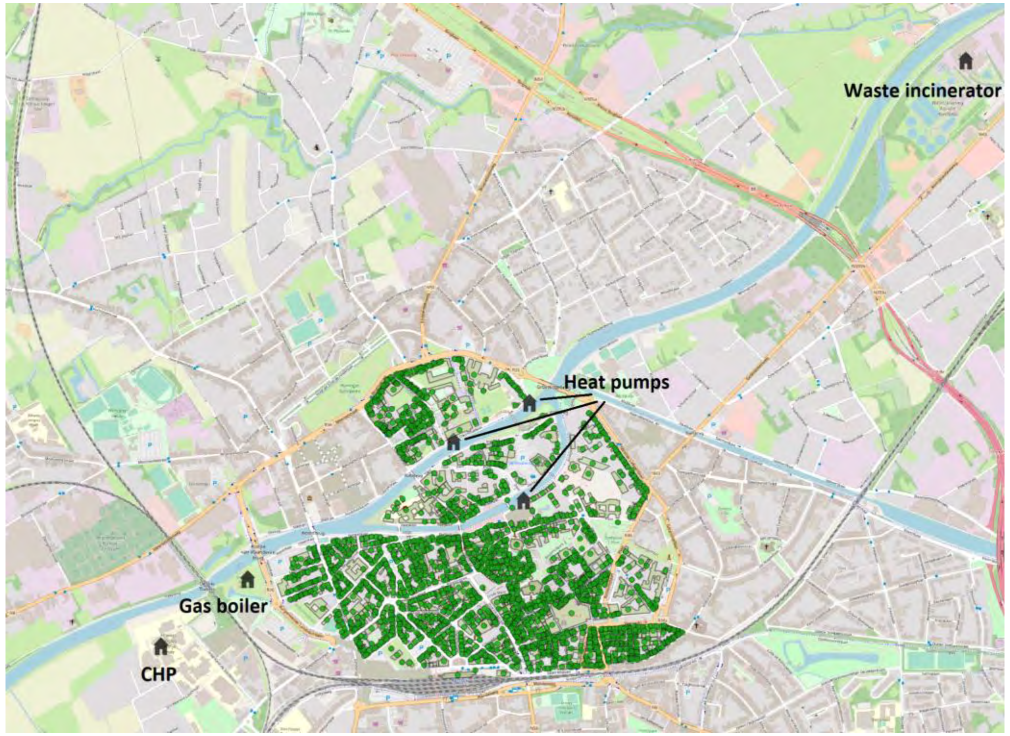
Selected 2328 buildings and heat source – Kortrijk, Belgium

BUILDING INPUTS:

- Open source street level gas consumption data
  - Mapped street level to building level using building area ratio
- Building types are categorized as
  - Residential
  - Commercial
  - Industrial
- Load factors → Estimation of peak demand

HEAT SOURCE:

- IMOG, waste incineration plant
  - 2 km from the network
  - Incinerate 65,000 tons of municipal waste per year
- Heat pumps → 3 units
- Gas boiler
- Combined heat and power (CHP) plant



Case study area

CASE STUDY - INPUTS

Selected 2328 buildings and heat source – Kortrijk, Belgium

HEAT SOURCE ATTRIBUTES:

Source type	Capacity (MW)	Investment cost (€/MW)	Energy production cost (€/MWh)	CO2 released (t per MWh)
Waste incineration	13	-	6	0.6
Heat pump	6	600,000	50	0.075
CHP	2	-	14	0.42
Gas boiler	4	150,000	42	0.5

CASE STUDY – NETWORK

2 - layer network and intermediate results

2 – LAYER NETWORK:

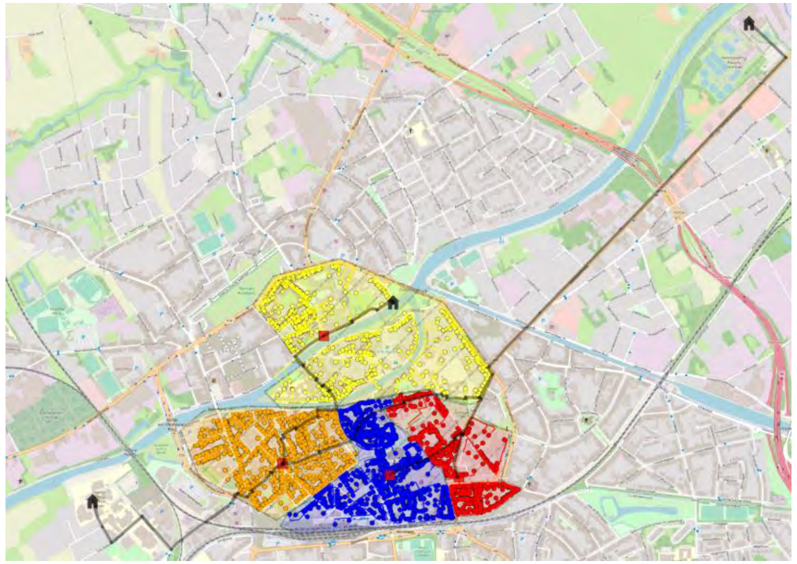
- Transport network → Source to substations
  - Multiple source design method
  - 80/50 temperature level

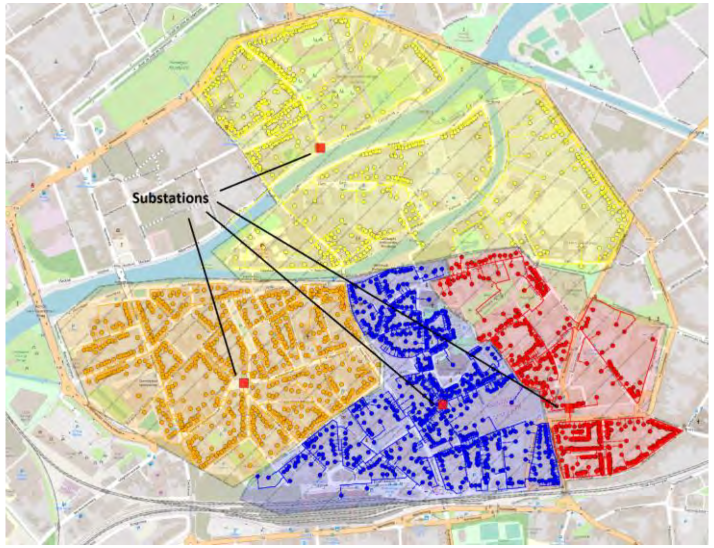
- Distribution network → Substation to buildings
  - Branched network design method
  - 70/40 temperature level

- Network sizing
- Cost estimation

INTERMEDIATE RESULTS:

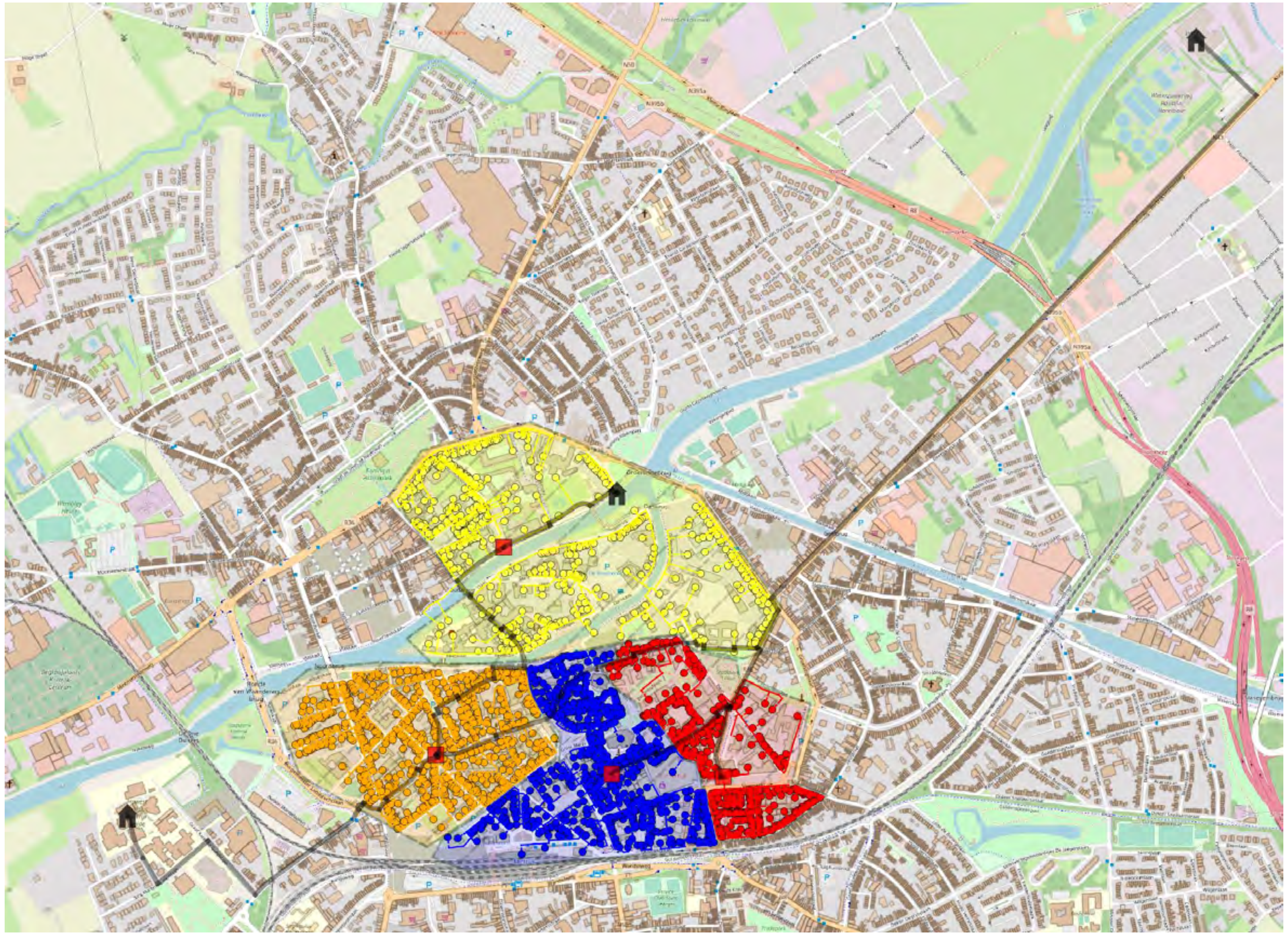
- Clusters with substation locations
- Simultaneous demand of each substation





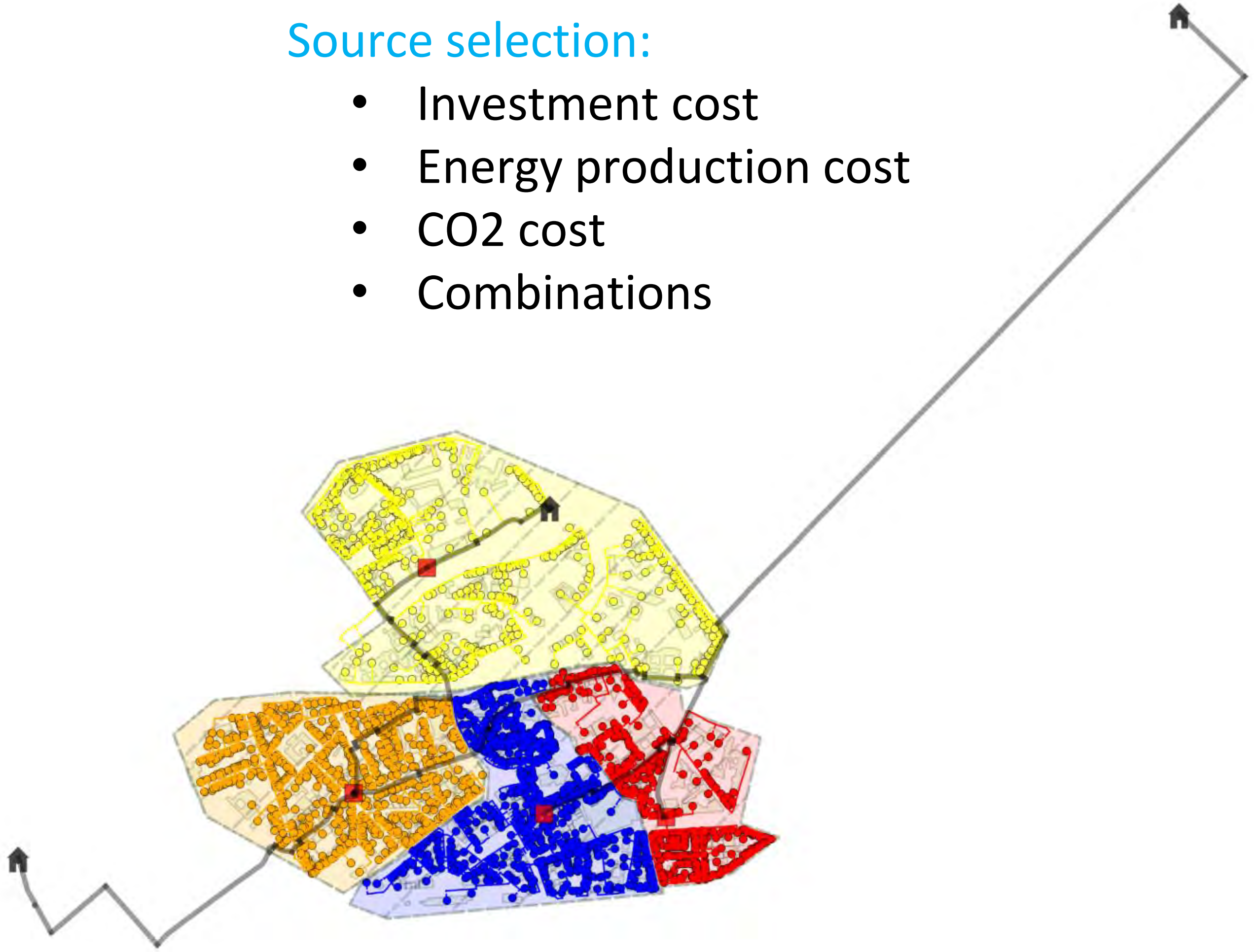
SCENARIOS – OPTIMAL SOLUTION

3 sources selected



DESIGN SCENARIO – SOURCE SELECTION

Supply is greater than demand

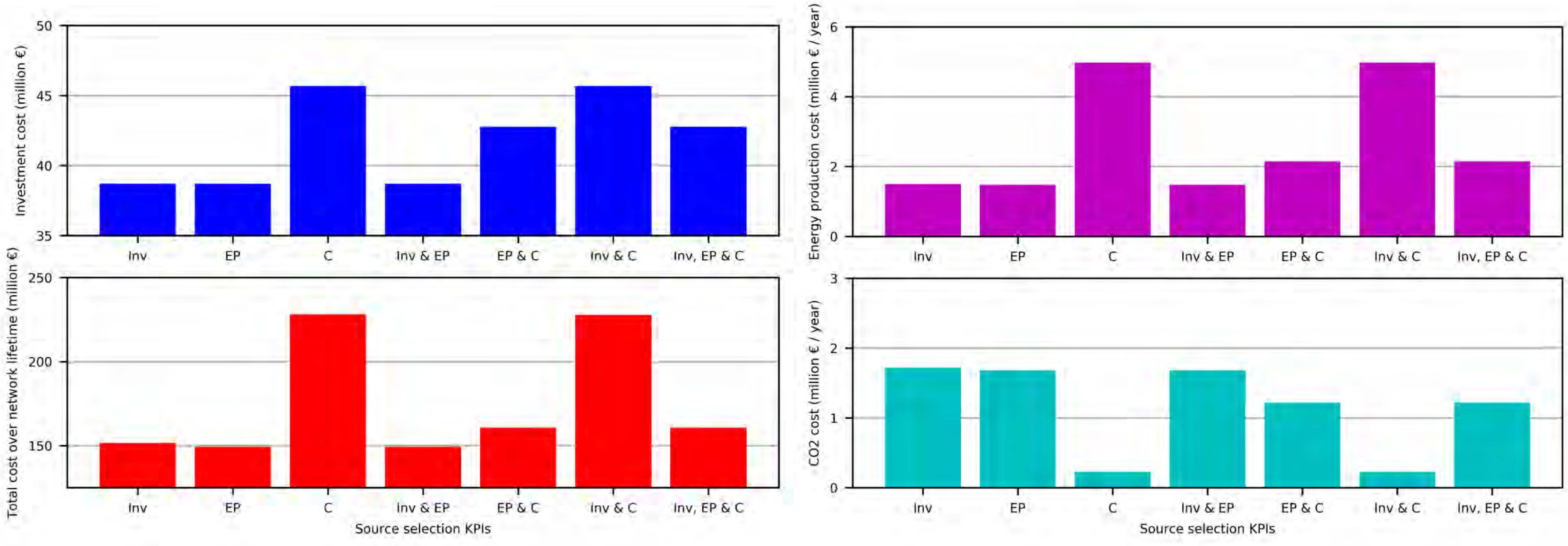


Source selection:

- Investment cost
- Energy production cost
- CO2 cost
- Combinations

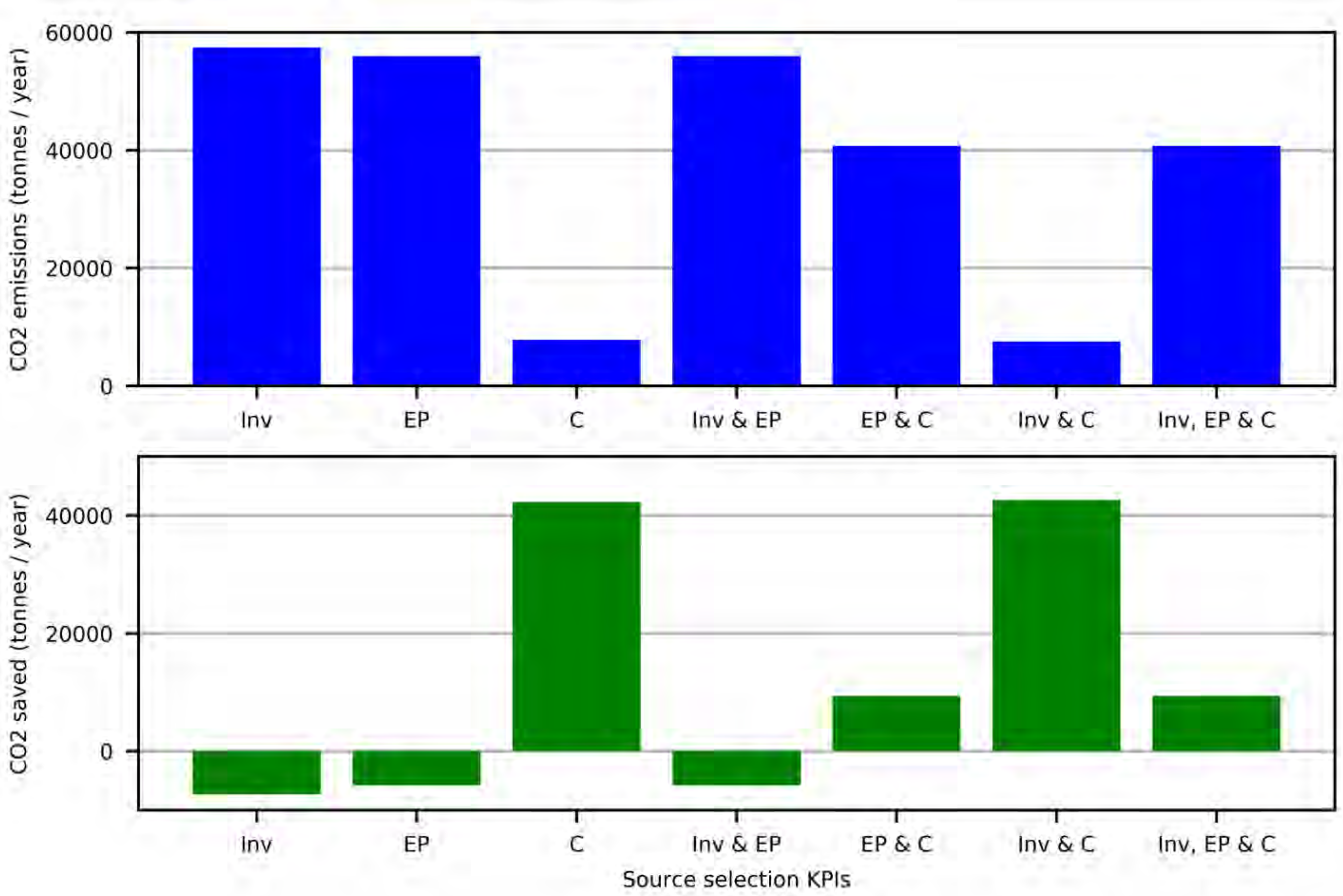
SCENARIOS

Source selection



SCENARIOS

Source selection



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Sector coupling between hydrogen and district heating *(Hans Böhm, El Linz)*

ENERGIEINSTITUT
an der Johannes Kepler Universität Linz

JOHANNES KEPLER
UNIVERSITÄT LINZ

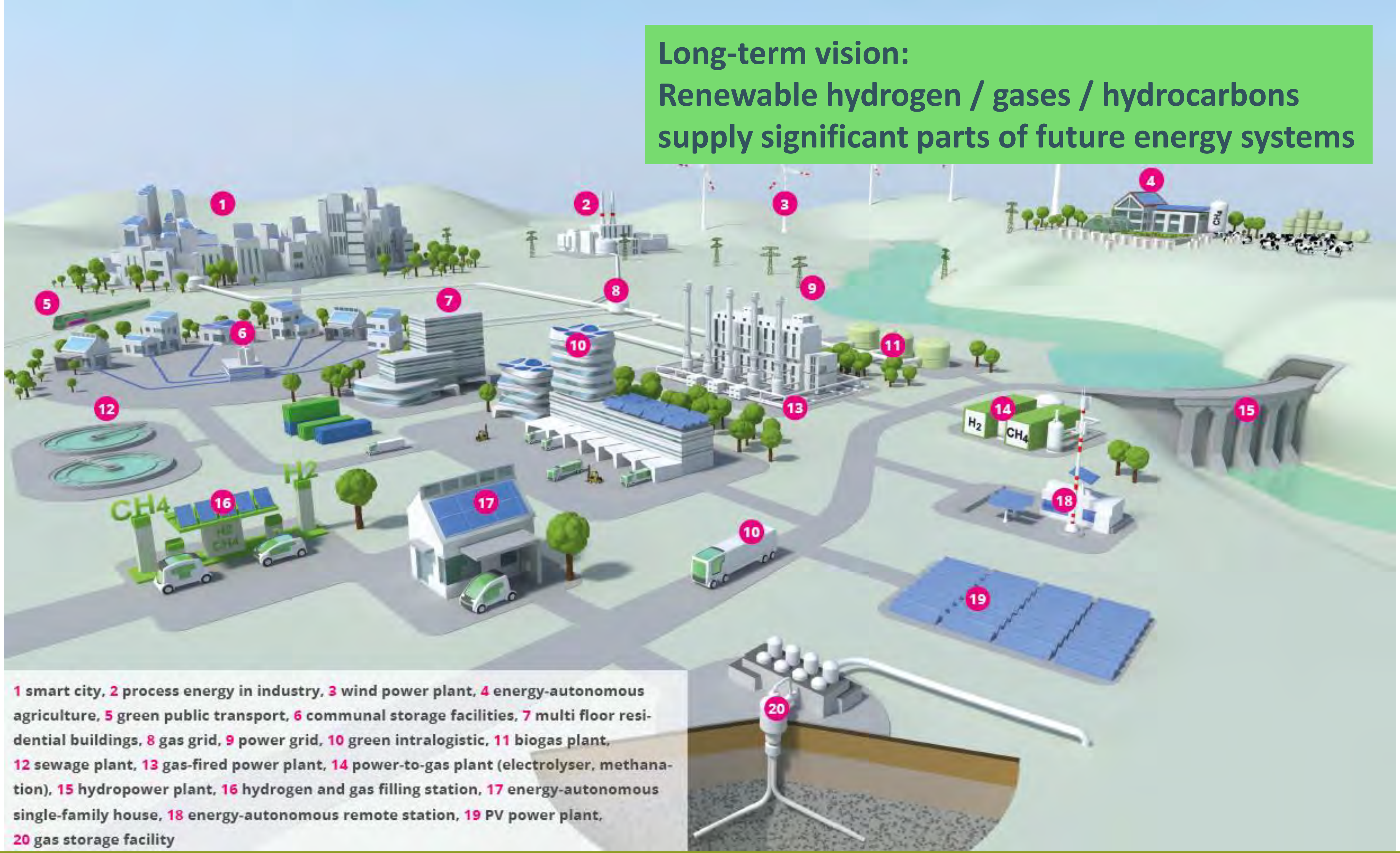
Selected aspects of sector coupling between hydrogen and district heating

DI Hans Böhm

IEA DHC TS3 – Industry workshop: digitalization and hybrid energy

Altenberger Straße 69, HF-Gebäude, 3. Stock , A-4040 Linz | Tel.:+43-732 / 24 68 - 5656 | email: office@energieinstitut-linz.at | www.energieinstitut-linz.at

Long-term vision:
Renewable hydrogen / gases / hydrocarbons supply significant parts of future energy systems

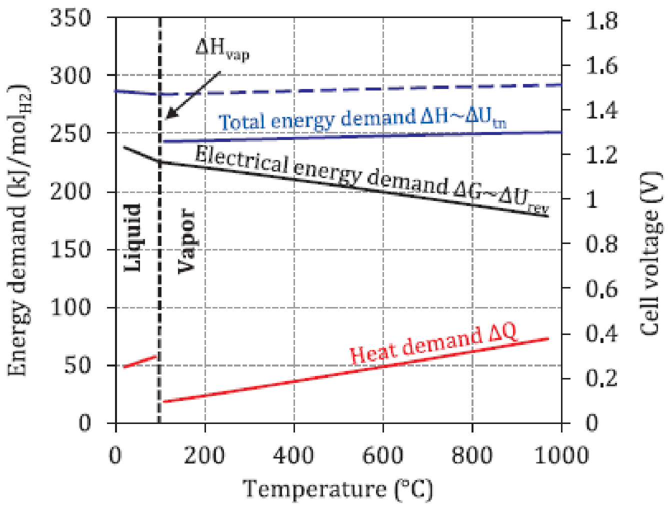


1 smart city, **2** process energy in industry, **3** wind power plant, **4** energy-autonomous agriculture, **5** green public transport, **6** communal storage facilities, **7** multi floor residential buildings, **8** gas grid, **9** power grid, **10** green intralogistic, **11** biogas plant, **12** sewage plant, **13** gas-fired power plant, **14** power-to-gas plant (electrolyser, methanation), **15** hydropower plant, **16** hydrogen and gas filling station, **17** energy-autonomous single-family house, **18** energy-autonomous remote station, **19** PV power plant, **20** gas storage facility

Integrating hydrogen and power-to-gas in district heating

Electrolysis

- Electrolysers are the main technology to bring hydrogen and its derivatives into the future energy system by producing hydrogen from renewable electricity.
- Can be categorised in “low-temperature” and “high-temperature” electrolysis.
- Heat supply or demand is depending on the type and mode of operation.



Low-temperature electrolysis: operated above thermoneutral voltage → requires external cooling

High-temperature electrolysis: can also be operated below thermoneutral voltage → requires external heat input

Source: Buttler, A., Spliethoff, H. Current status of water electrolysis for energy storage, grid balancing and sector coupling via power-to-gas and power-to-liquids: A review. Renewable and Sustainable Energy Reviews 2018;82:2440–54.

Integrating hydrogen and power-to-gas in district heating

Electrolysis – SoA and technology options

Electrolysis cell type	Operating temperature	Typical stack size	Electric efficiency (LHV)	Advantages	Disadvantages
Polymer Electrolyte Membrane (PEMEC)	50(20)-80°C	<1 MW	50-60%	• Short start-up (cold: minutes, warm: seconds) • High load flexibility (0-100%)	• Pt-grade catalysts • Sensitivity to impurities
Alkaline (AEC)	60(30)-90°C	<5 MW	50-60%	• High lifetime • Low efficiency degradation	• Electrolyte management
Solid Oxide (SOEC)	500-900°C	<100 kW	75-90%	• High efficiency • High load flexibility • Reversibility	• High degradation / short lifetimes (pre-commercial) • Long start-up (cold start)

- **LT-electrolysers** encourage a usage in **spatially close applications** and/or where temperature level is of secondary importance (e.g. swimming pools or hospitals)
- Heat intense industries are expected to use **HT-electrolysis with thermal integration** for on-site hydrogen production for better efficiency → this could lead to **increased heat demands in future district heating grids**.
- **Downstream synthesis** processes can provide additional **waste heat at elevated** temperatures for further utilization (e.g. methanation @ 200-300°C)

Source: Energieinstitut an der JKU Linz

Integrating hydrogen and power-to-gas in district heating

Fuel Cells – SoA and technology options

Fuel cell type	Operating temperature	Typical stack size	Electric efficiency (LHV)	Applications	Advantages	Challenges
Polymer Electrolyte Membrane (PEMFC)	<120°C	<100 kW	60% (direct H_2)	• Backup power • Portable power • Distributed generation • Transportation	• Reduced corrosion • Low temperature • Quick start-up and load following	• Expensive catalysts • Sensitive to fuel impurities
Alkaline (AFC)	<100°C	<100 kW	60%	• Military • Space • Backup power • Transportation	• Lower cost components • Low temperature • Quick start-up	• Sensitive to CO_2 • Electrolyte management / conductivity
Phosphoric Acid (PAFC)	**150–200°C**	<500 kW	40%	• Distributed generation	• **Suitable for CHP** • Increased tolerance to fuel impurities	• Expensive catalysts • Long start-up time • Sulfur sensitivity
Molten Carbonate (MCFC)	**600–700°C**	<3 MW	50%	• Electric utility • Distributed generation	• High efficiency • Fuel flexibility • **Suitable for CHP**	• High temperature corrosion and lifetime • Long start-up time • Low power density
Solid Oxide (SOFC)	**500–1,000°C**	<2 MW	60%	• Auxiliary power • Electric utility • Distributed generation	• High efficiency • Fuel flexibility • Solid electrolyte • **Suitable for CHP**	• High temperature corrosion and lifetime • Long start-up time

Source: based on Lindorfer, J., et al. (2020). Fuel Cells: Energy Conversion Technology. In: Future Energy (Third Edition), Letcher, T. (Ed.), Elsevier, 2020

Gas infrastructure is still required in a sustainable energy system

from an Austrian perspective

- National **renewable electricity potentials do not cover the Austrian consumption** – neither profile- nor balance-related.
- The trade-off of electricity demand and supply primarily requires short- (days) and **long-term (seasonal) storage** capacities.

→ For seasonal storage **hydrogen (and derivatives) are essential**

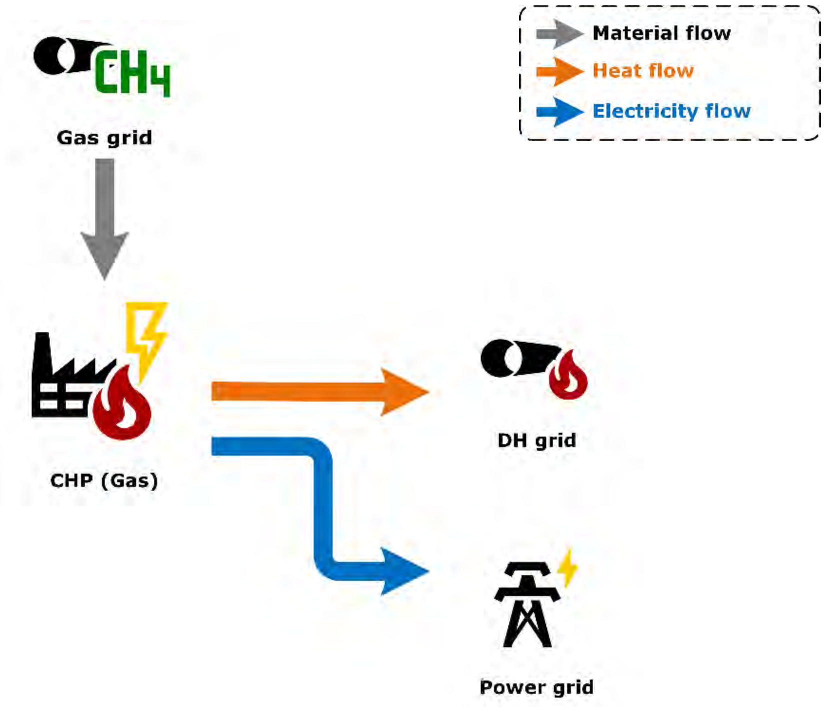
- In the future sustainable energy system today's gas infrastructure still supplies …

• **Renewable gas CHP**	(as backup)
• Industrial consumers	(energy carrier & feedstock)
• Other consumers	(e.g. heavy-duty transport, etc.)

National potentials for renewable power are insufficient to cover demands. Thus, the focus has to be on primary energy efficiency, which requires the **operation of CHP plants**.

Integration of hydrogen in district heating

using the example of CHP

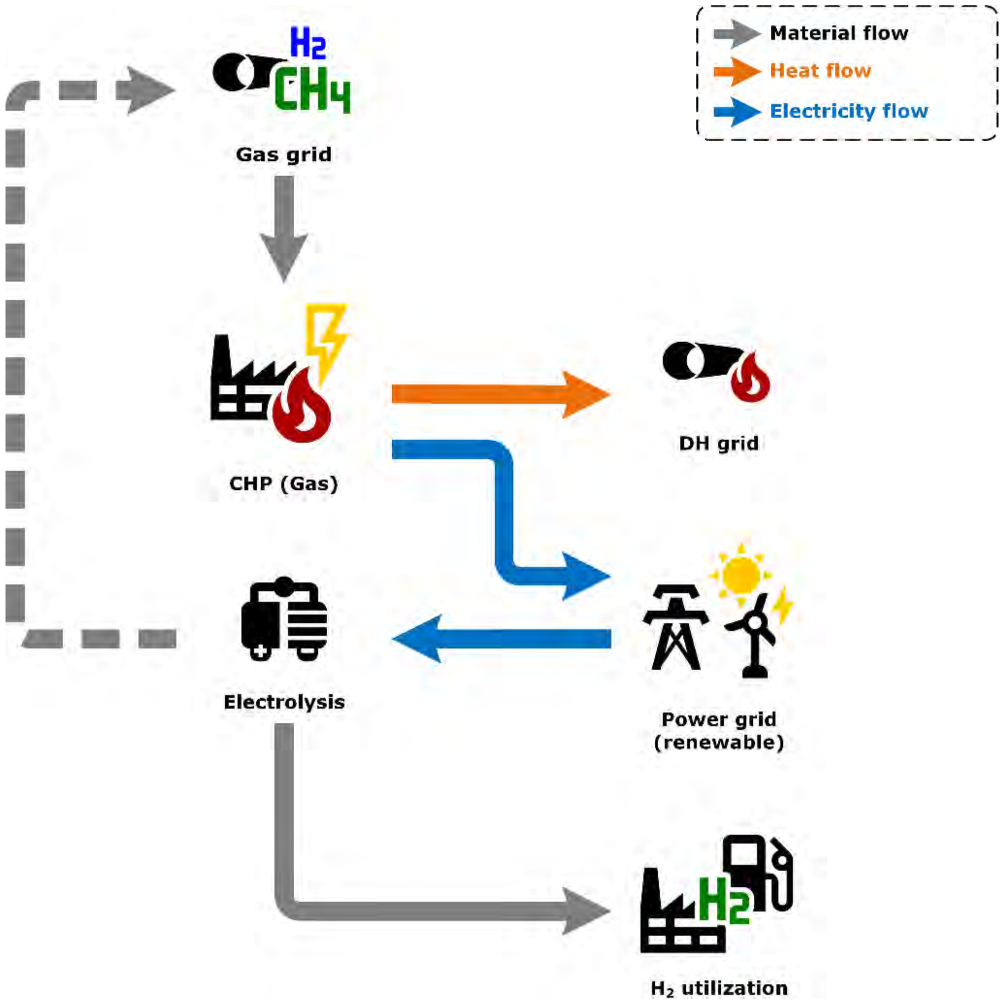


1. Conv. CHP connected to gas, heat and power grid

Source: Energieinstitut an der JKU Linz

Integration of hydrogen in district heating

using the example of CHP



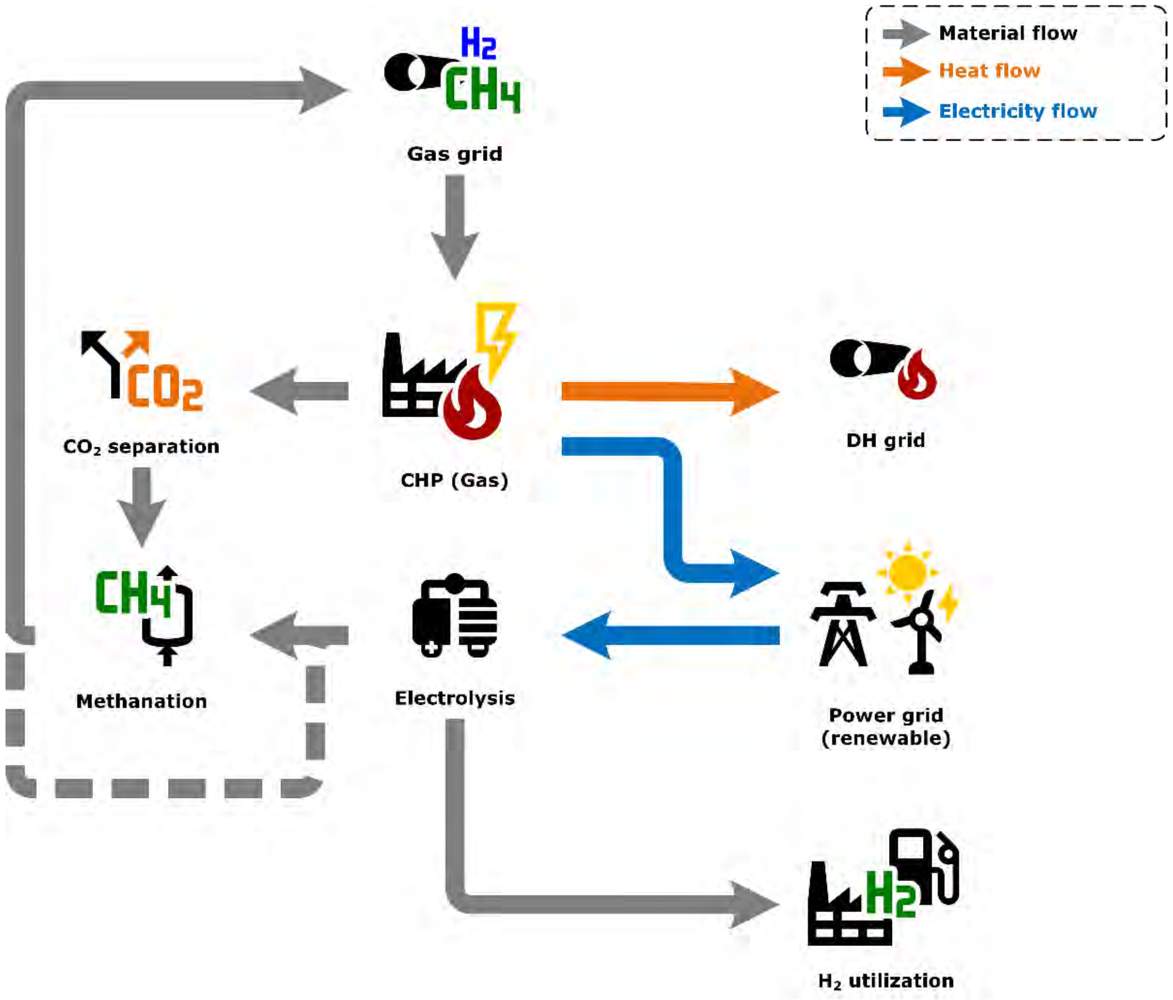
1. Conv. CHP connected to gas, heat and power grid
2. **Production of “green” H_2** for industry, mobility and energy applications

Temporal separation of gas/hydrogen production and usage (seasonal shift)!

Source: Energieinstitut an der JKU Linz

Integration of hydrogen in district heating

using the example of CHP



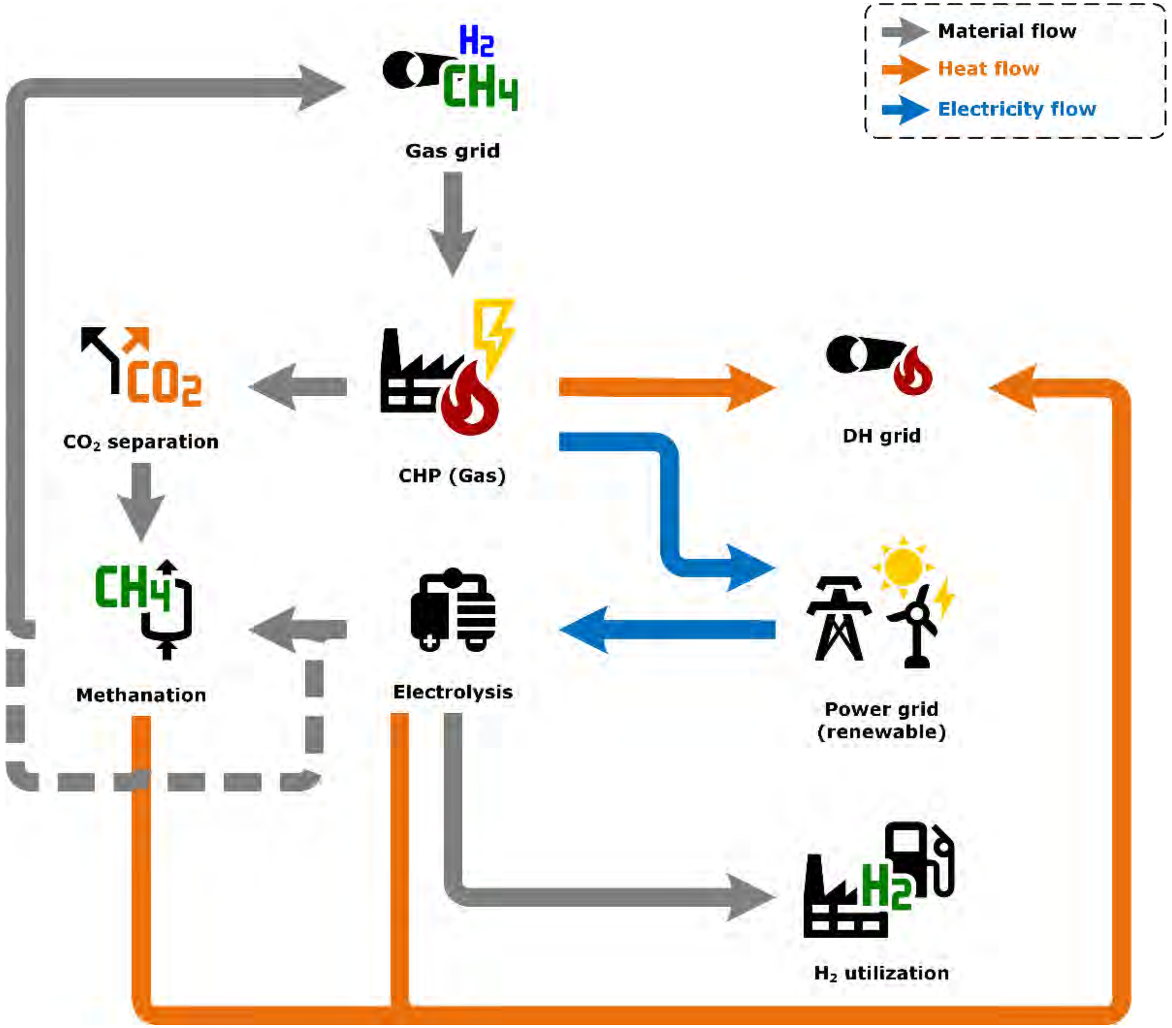
1. Conv. CHP connected to gas, heat and power grid
2. **Production of "green" H_2** for industry, mobility and energy applications
3. Utilization of H_2 and CO_2 for production of renewable energy carriers → **carbon cycle economy**

Temporal separation of gas/hydrogen production and usage (seasonal shift)!

Source: Energieinstitut an der JKU Linz

Integration of hydrogen in district heating

using the example of CHP



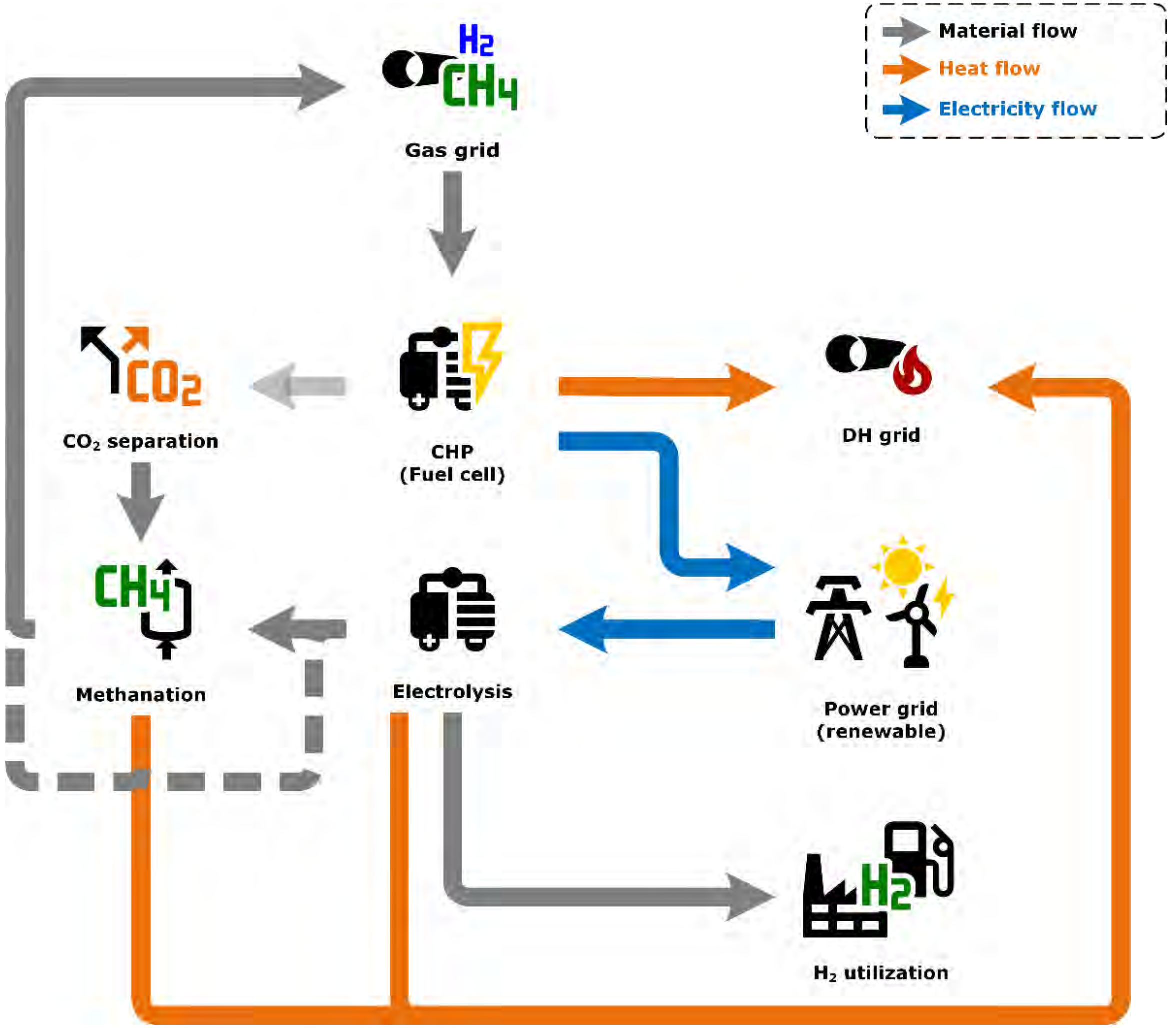
4. Optimized waste heat utilization of power-to-X processes and **integration in heating grids**

Temporal separation of gas/hydrogen production and usage (seasonal shift)!

Source: Energieinstitut an der JKU Linz

Integration of hydrogen in district heating

using the example of CHP



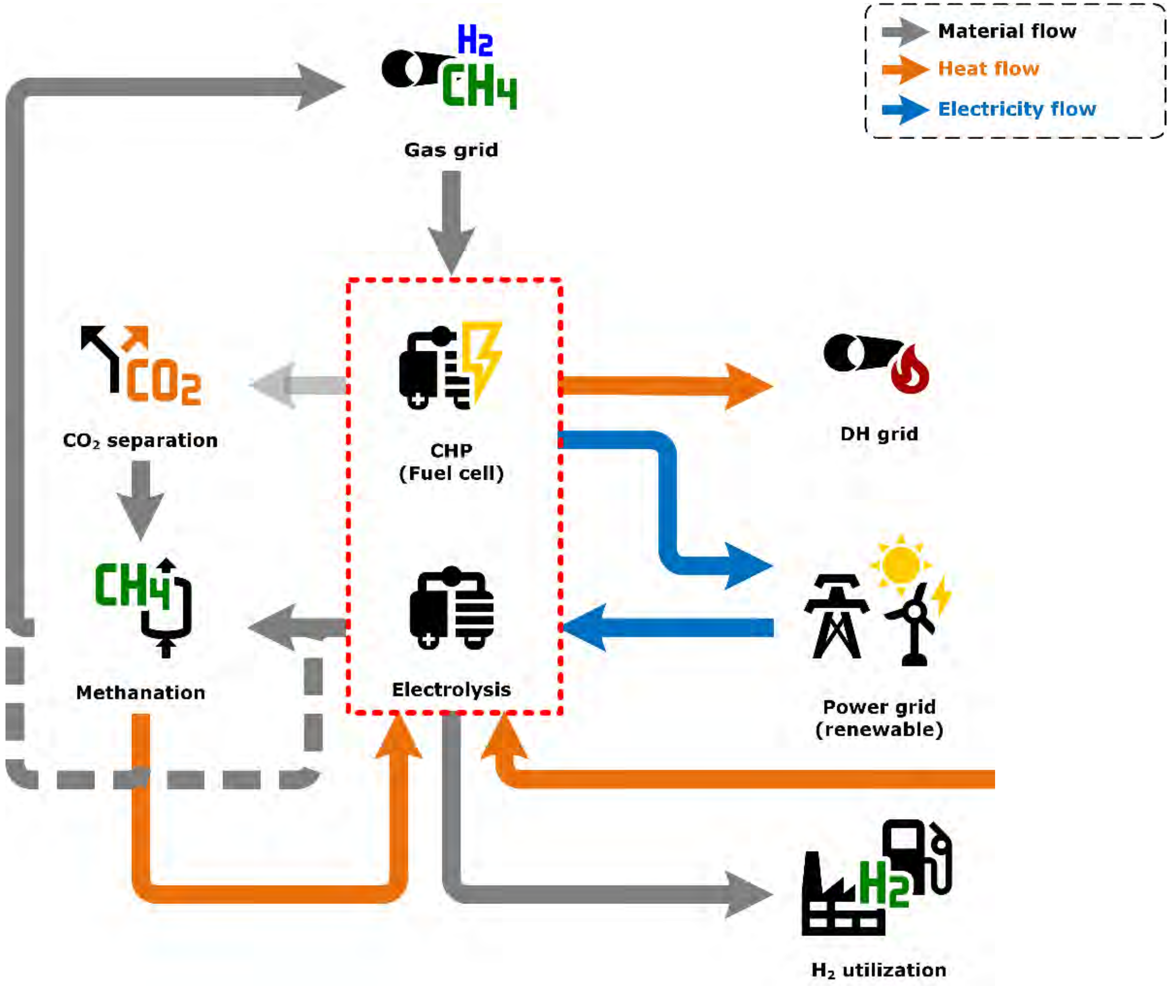
4. Optimized waste heat utilization of power-to-X processes and **integration in heating grids**
5. **Substitution of conventional CHP** by large-scale fuel cells → direct usage of H_2

Temporal separation of gas/hydrogen production and usage (seasonal shift)!

Source: Energieinstitut an der JKU Linz

Integration of hydrogen in district heating

using the example of CHP



4. Optimized waste heat utilization of power-to-X processes and **integration in heating grids**
5. **Substitution of conventional CHP** by large-scale fuel cells → direct usage of H_2
6. Implementing **reversible fuel cells** (rSOFC) → **optimizing** operating hours and **plant costs**

Temporal separation of gas/hydrogen production and usage (seasonal shift)!

Source: Energieinstitut an der JKU Linz

Options for direct integration of power-to-gas applications in heating grids

1. Alkaline and PEM electrolysers provide a **waste heat potential of about 10-25%** of their nominal capacity at temperatures of **60-80 °C.**
2. **Downstream synthesis** processes provide additional sources of heat at elevated temperatures, e.g. catalytic methanation **@ 250-300 °C** in the range of 15% of the processed gas.
3. Operating temperatures of **HT-electrolysis are in the range of 500-1,000 °C** and can be a **heat source or drain** depending on the mode of operation.
4. **Fuel cells** can be (and are already) used as micro-CHP for decentralized **electricity and heat supply**. Future large-scale implementations could substitute conventional CHP plants in **H_2-/SNG-based energy systems.**

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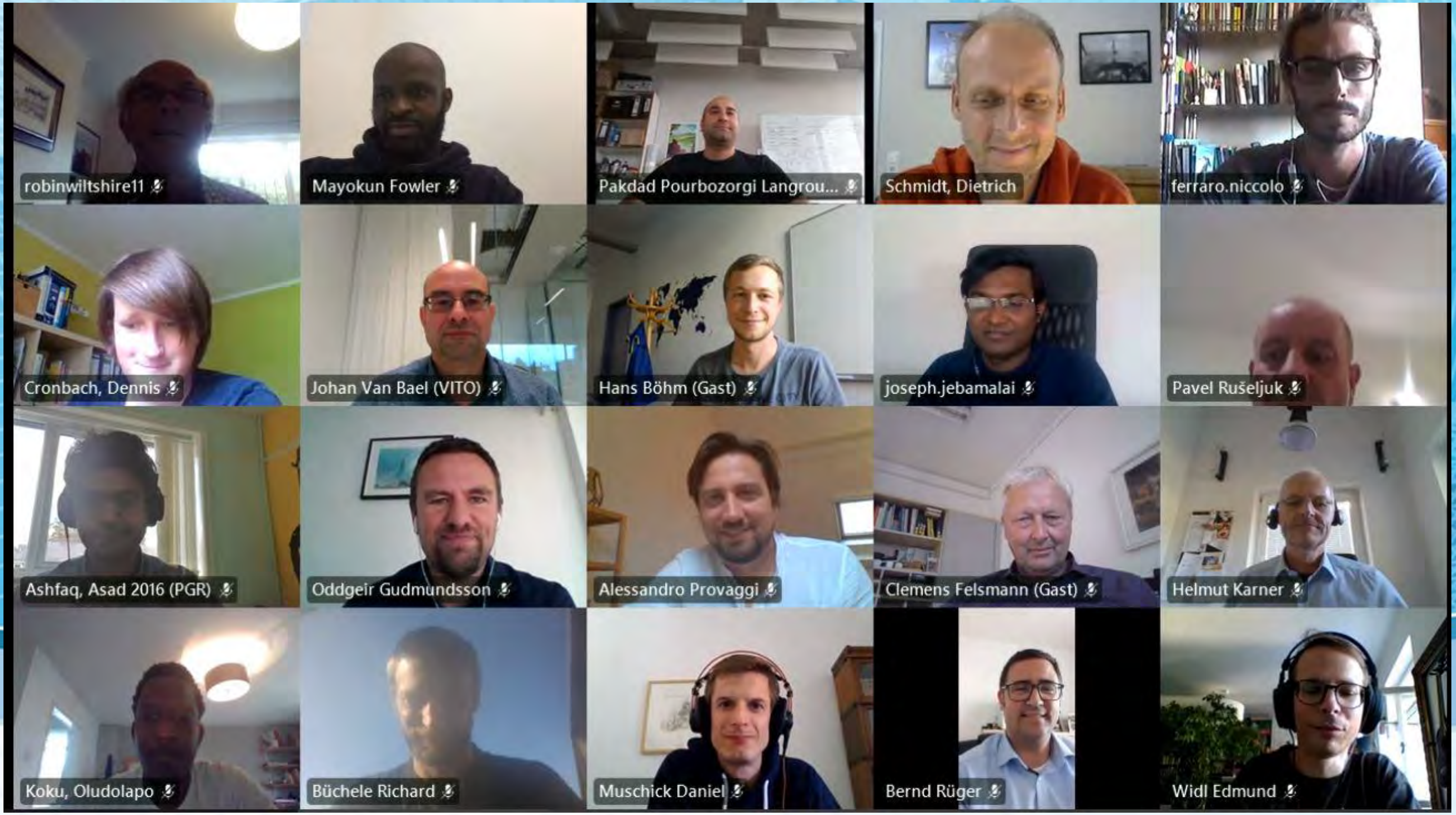
Thanks for your attention!

Q&A to all presenters

Group photo

+ many others without webcam
(in total about 50 participants)



Summary and next steps

- We will make the **recording of the webinar** available on the IEA DHC YouTube channel https://www.youtube.com/channel/UCuYcqLjJi8thrUJCjzLBaow and send out the **presentation slides**

- If you want to **join the IEA DHC Annex TS3 or TS4**, please contact
  - Ralf-Roman Schmidt, ralf-roman.schmidt@ait.ac.at (leader TS3)
  - Dietrich Schmidt, dietrich.schmidt@iee.fraunhofer.de (leader TS4)
  - AND: contact your national IEA DHC representative for funding opportunities https://www.iea-dhc.org/home/

Thank you for your attention!

Webinar Digitalization for optimizing integrated district heating systems - Block III

9. September 2020

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Dietrich Schmidt, Fraunhofer IEE, Germany, dietrich.schmidt@iee.fraunhofer.de (leader TS4)

More information at

https://www.iea-dhc.org/the-research/annexes/2018-2024-annex-ts4/

http://www.iea-dhc.org/the-research/annexes/2017-2020-annex-ts3-draft.html

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