Analysis of the economic and ecological feasibility of district heating in a deeply renovated housing estate using THERMOS

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Agenda

- Introduction to case study
- Aim of the study
- Method
- Scenario and input data
- Results
- Findings

Introduction to case study

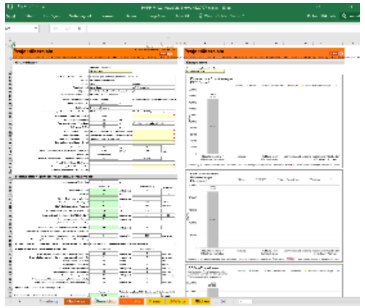
- Housing estate “Südtirolersiedlung” in city of Bludenz
  - Built between 1943 and 1962
  - 80 buildings (mainly multi family houses) with 397 flats
  - energetically almost in original condition (except windows changed in 80s)
  - ≈ 24.000 m² living space on ≈ 63.000 m² land area
  - Low rents and low income
  - Mostly heated with individual stoves, no central heat distribution system (Biomass, Oil, Electricity, few gas connections)
  - Hot water via electric boiler

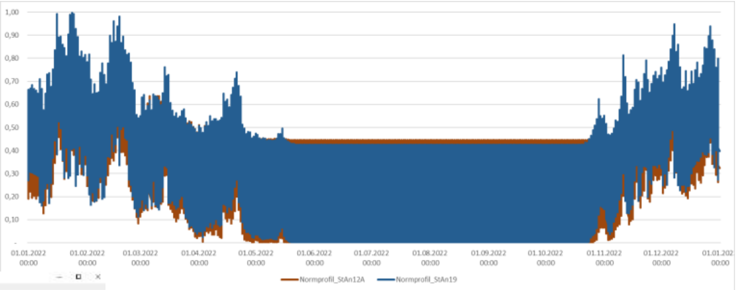
Aim of study

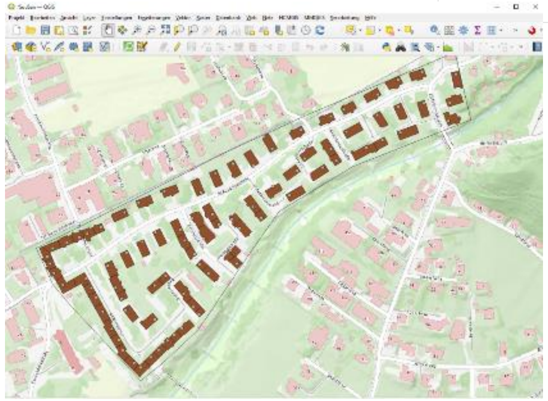
- Analyse if the housing estate is suitable (economic/ecological advantages) for supply via a heating network (in comparison to decentral heat pumps) after extensive renovation options have been carried out?

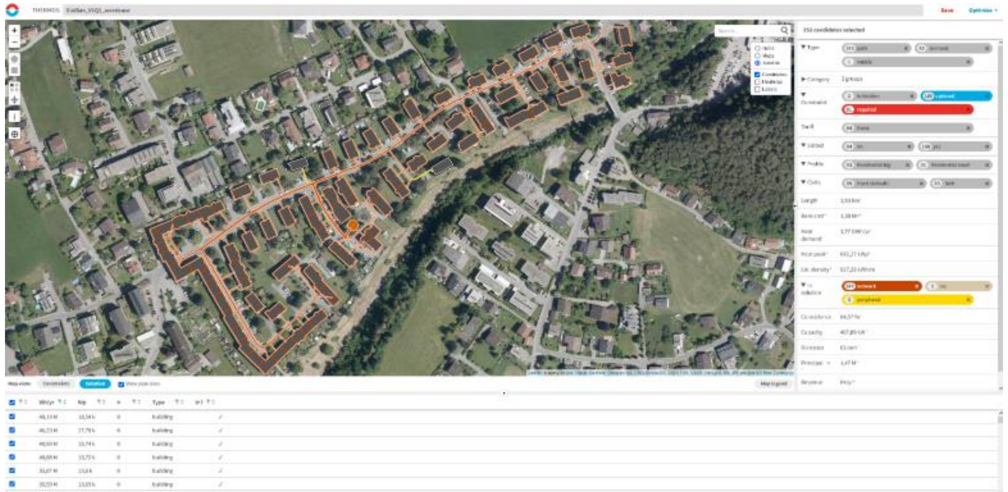
Method

- Detailed analysis and calculation for the refurbishment of two demonstration buildings
    - Calculation of refurbishment options with PHPP
      https://passivehouse.com/04_phpp/04_phpp.htm
    - Simulation of load profiles with IDA ICE
      https://www.equa.se/en/ida-ice
- Demonstration building data mapped to building shapes and streets attributed with QGIS
  https://qgis.org/en/site/
- Calculation of optimal network design and supply optimization with Thermos Tool
  https://tool.thermos-project.eu/









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Scenario and input data - buildings

- Three areas with two energetic qualities
  - Delivered Energy (heat @ exchanger)

Area	Very high quality Q1		High quality Q2	
Historically valuable	85 kWh/m²	33 W/m²	100 kWh/m²	39 W/m²
Partly valuabla	**65 kWh/m²**	**25 W/m²**	85 kWh/m²	33 W/m²
New buildings	45 kWh/m²	17 W/m²	55 kWh/m²	21 W/m²

- Two densification scenarios

Area	Slightly densification V1	Higher densification V2
Historically valuable	No densification	
Partly valuabla	Additional living space in attic (≈+10%)	
New buildings	Additional floor (≈+10%)	High densification (≈ +50%)

- Overall area

Indikato	Min heating demand (Q1V1)	Max heating demand (Q2V2)
Floor area (act. 25 300 m²)	27 176 m²	29 458 m²
Heating demand	1.77 GWh/a	2.35 GWh/a
Heat load	680 kW	900 kW

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Scenario and input data – network & supply

Input - network		Q1V1_wc	Q1V1_ref	Q2V2_ref	Q2V2_BAT Best Available Technology
Supplied energy demand	[GWh/yr]		1,71	2,26	
Overall accounting period	[yr]		40		
Discount value	[%]		3%		
Capital cost pipework + supply station	[yr] | [%]		40 | 3%		
Capital cost building connection	[yr] | [%]		20 | 3%		25 | 3%
Pipe capacity and loss (8°C ground)	[°C]	90°C | 60°C	70°C | 40°C		
Pumping energy and cost	[%] | [c/kWh]		1% | 30		

Input - supply		Q1V1_wc	Q1V1_ref	Q2V2_ref	Q2V2_BAT Best Available Technology	Q2V2_11f 11c feed in electricity	Q2V2_10e 10c electricity price
HOB wood chips	LT | eff_{th} | IK_h | $O\&M_{fix}$ | $O\&M_{var}$	20yr | 89% | 810 €/$_{kW}$ | 37 €/$_{kW}$ | 4 €/$_{MWh}$			25yr | 110% | 710 €/$_{kW}$ | 33 €/$_{kW}$ | 3 €/$_{MWh}$		
CHP wood chips	LT | eff_{th} | eff_{el} | IK_h | $O\&M_{fix}$ | $O\&M_{var}$	20yr | 61%$_{th}$ | 12%$_{el}$ | 1500 €/$_{kW}$ | 65 €/$_{kW}$ | 2 €/$_{MWh}$			25yr | 83%$_{th}$ | 14%$_{el}$ | 1000 €/$_{kW}$ | 43 €/$_{kW}$ | 2 €/$_{MWh}$		
HP air source	LT | eff_{th} | IK_h | $O\&M_{fix}$ | $O\&M_{var}$	15yr | 275% | 1900 €/$_{kW}$ | 3 €/$_{kW}$ | 4 €/$_{MWh}$			25yr | 290% | 1430 €/$_{kW}$ | 2 €/$_{kW}$ | 3 €/$_{MWh}$		
Heat storage	LT | eff_{store} | IK	30yr | 96% | 180 €/$_{kWh}$			40 yr | 98% | 180 €/$_{kWh}$		
Price wood chips	[EUR / MWh]		50				
Price electricity	[EUR / MWh]		300				100
Feed in electricity	[EUR / MWh]		100			110	
CO_2 wood chips	[g/kWh]		10				
CO_2 electricity	[g/kWh]	188/135/94/76/68/74/72/86/135/160/181/198(*)					

(*) monthly CO_2 factors from Ploß et. al 2022 http://www.energieinstitut.at/pdfviewer/Low-Cost-nZEB-2022

- Network costs (per dimension and surface) taken from Handbook on Planning of District Heating Networks https://www.verenum.ch/index_QMDH.html
  - Main pipes in streets (hard ground)
  - House connection pipes in field (soft ground)
- Cost and technology data for heat supply from Danish Technology catalogue (DEA)
  - Investment and dispatch optimization with 3 fictitious producer technologies + storage
  - 2 type-days per month from hourly load profiles
- Fictitious heat supply location

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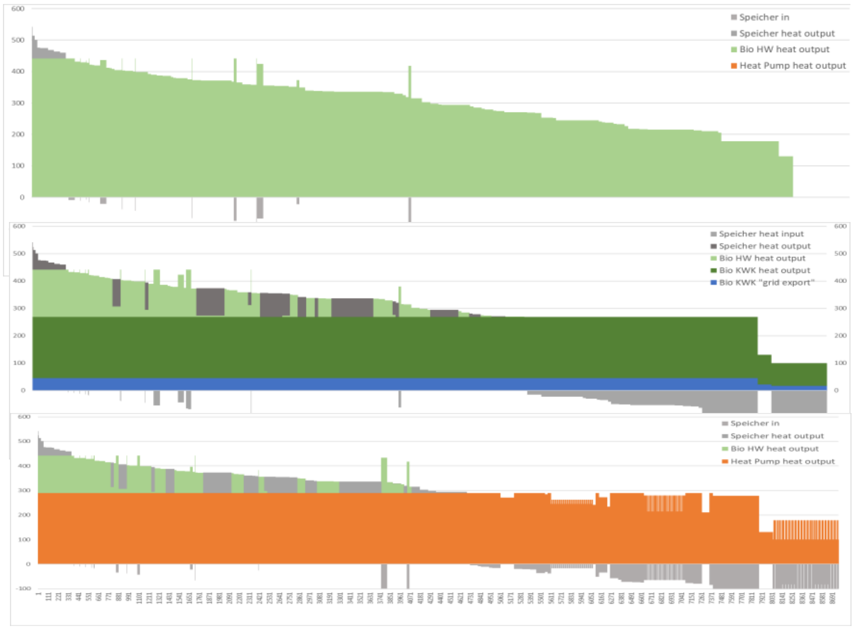
Results



Network results	Unit	Q1V1_wc	Q1V1_ref	Q2V2_ref	Q2V2_BAT Best Available Technology
Network length	[m]		**1890**		
Supplied Energy	[GWh/yr]		1,71	2,26	
network losses	[GWh/yr]	0,26	0,18	0,19	
	[%]	13%	10%	8%	
Total capital cost network (40yr)	[Mio. EUR]	2,97	2,96	3,04	2,86
Total O&M cost network (40yr)	[Mio. EUR]	0,24	0,23	0,29	0,29
LCH distribution	[c/kWh]	4,68	4,67	3,68	3,48
CO_2 (pumping)	[t/yr]	4,87	4,68	6,06	6,06
	[g/kWh]	2,47	2,48	2,47	2,47

Supply results	unit	Q1V1_wc	Q1V1_ref	Q2V2_ref	Q2V2_BAT Best Available Technology	Q2V2_11f 11c feed in electricity	Q2V2_10e 10c electricity price
HOB Wood chip capacity	[GWh/yr]	338	333	444	442	174	56
CHP Wood chip capacity		0	0	0	0	268	0
HP Air source capacity		0	0	0	0	0	386
Storage capacity		243	260	304	314	314	314
Storage in-out capacity		100	100	100	100	100	100
Total capital cost (40yr)		0,64	0,63	0,83	0,68	0,84	1,24
Total opex cost (40yr)		0,81	0,79	1,05	0,87	0,90	0,4
Total fuel cost (40yr)	[GWh/yr]	4,39	4,21	5,46	4,42	5,70	3,36
Total el revenues (40yr)	[%]	0	0	0	0	1,60	0
	[m]						
heat production	[Mio. EUR]	1,96	1,88	2,44	2,44	2,58	2,45
LCH produced	[Mio. EUR]	7,45	7,49	7,52	6,13	5,66	5,09
LCH supplied	[c/kWh]	8,54	8,23	8,12	6,60	6,46	5,53
CO_2 (supply)	[t/yr]	22	21	27	22	29	192
	[g/kWh]	11,22	11,17	11,07	9,02	11,24	78,37

- Higher network temperature (Q1V1_wc)
  → higher losses, same distribution costs, higher LCOH supplied
- More energy supplied due to lower thermal standard (Q2V2_ref)
  → same losses, lower distribution costs, same LCOH supplied
- Better technology assumptions (Q2V2_BAT)
  → lower LCOH distribution and supply
- 1c higher el. feed in tariff of 11c/kWh (Q2V2_11f)
  → makes CHP feasible and leads to lower LCOH supplied
- Low electricity price of 10c/kWh (Q2V2_10e)
  → makes HP feasible and leads to lowest LCOH supplied

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Findings

- Supply via district heating seems feasible despite high energetic quality of buildings
  - Levelized distribution costs 3.5 - 4.7 c/kWh
  - Higher uncertainty of generation costs 5.5-8.5 c/kWh
  - No invest subsidies included
- Similar range than decentral supply via individual heat pumps
  → non-monetary aspects may be decisive

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