IEBB 1.5 ACTIVITEIT 2: LAGERE TEMPERATUREN: AFGIFTESYSTEMEN

ANDRIES VAN WIJHE

YASIN BULUT

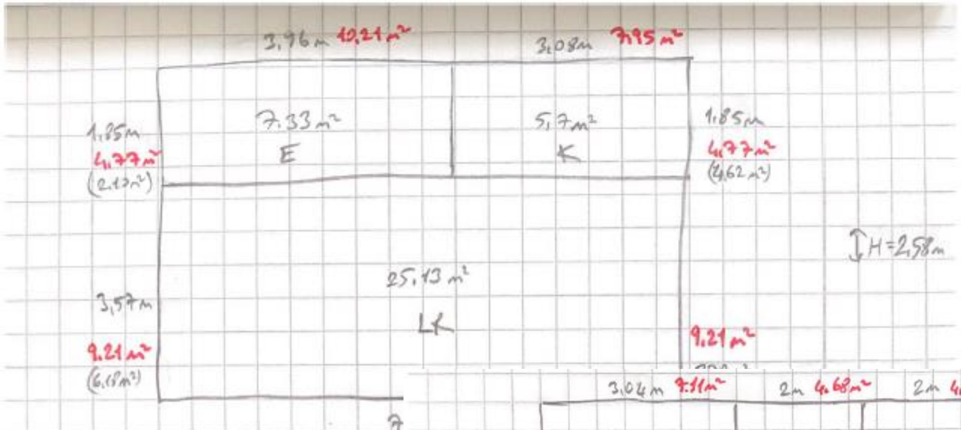
EFFECT OF THERMOSTAT NIGHT SETBACK ON REQUIRED HEATING WATER TEMPERATURE AND ENERGY SAVING

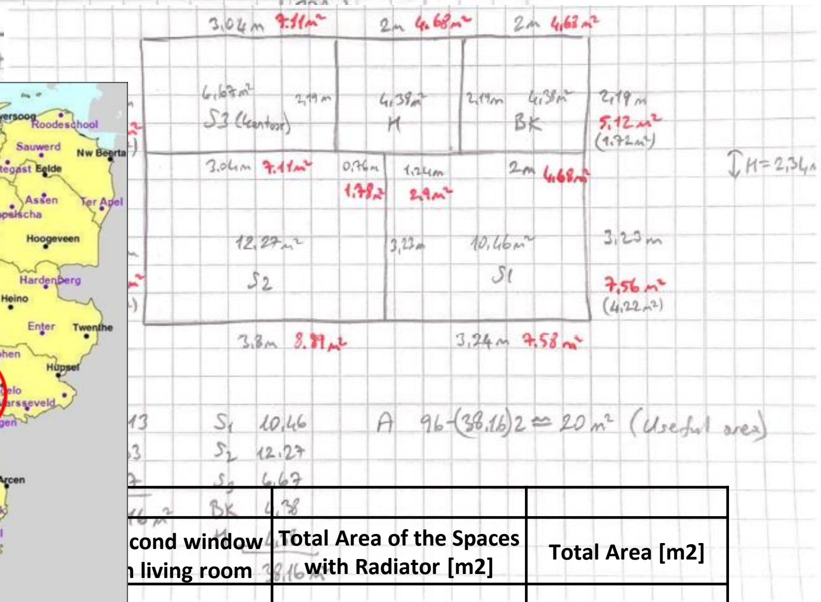
- Heat networks benefit from a lower heating water temperature in terms of heat generation efficiency and transport losses.
- Lower heating water temperature results in lower heat output in hydronic heating circuits such as radiators,
- Using night setback on a heating system reduces the overall energy consumption of a heating system but increases the required heat output of the heating system.
- There is a discrepancy between increasing efficiency of the heat generation in the heat network and energy saving by using a night setback.

- **In this work: a study is done to explore this for a typical Dutch house,**

THE HOUSE

- A multizone dynamic house model was based on house geometry, observations from a site visit, building regulations (bouwbesluit) and assumptions on user behavior (VLA).
- A model of a heating system was coupled to the house.
- A validation study was done to check if the dynamic behavior of the building and heating system is on par with monitoring data.





woning NR: 2										
Type of space	Verkeersruimte	Leefruimte (bv. woonkamer, kantoor)	Slaapruimte	Slaapruimte	Sanitaire ruimte	[illegible]	[illegible]	cond window n living room	Total Area of the Spaces with Radiator [m2]	Total Area [m2]
Type of space	Entree	Hobbykamer/kantoor	Slaapkamer 1	Slaapkamer 2	Badkamer 1	[illegible]	[illegible]			
Height - surface	2.59	2.34	2.34	2.34	2.25	2.58	2.57			
Length - surface	3.7	3.05	3.14	3.58	2.14	3.08	7.04			
Width - surface	2.14	2.5	3.23	3.19	1.66	1.77	3.57			
Area - surface	7.92	7.63	10.14	11.42	3.55	5.45	25.13		**71.24**	**96**
Has outer wall a window?	Ja	Ja	Ja	Ja	Ja	Ja	Ja			
Type of space	Verkeersruimte	Leefruimte (bv. woonkamer, kantoor)	Slaapruimte	Slaapruimte	Sanitaire ruimte	Leefruimte (bv. woonkamer, kantoor)	Leefruimte (bv. woonkamer, kantoor)	Second window in living room	Total Glazing Area [m2]	
Width - window	0.98	1.6	2.74	3.2	1.04	1.79	3.25	1.89		
Length - window	2.14	1.57	1.54	1.62	1.65	2.58	1.9	1.97		
Area - window	2.10	2.51	4.22	5.18	1.72	4.62	6.18	3.72	**30.25**	

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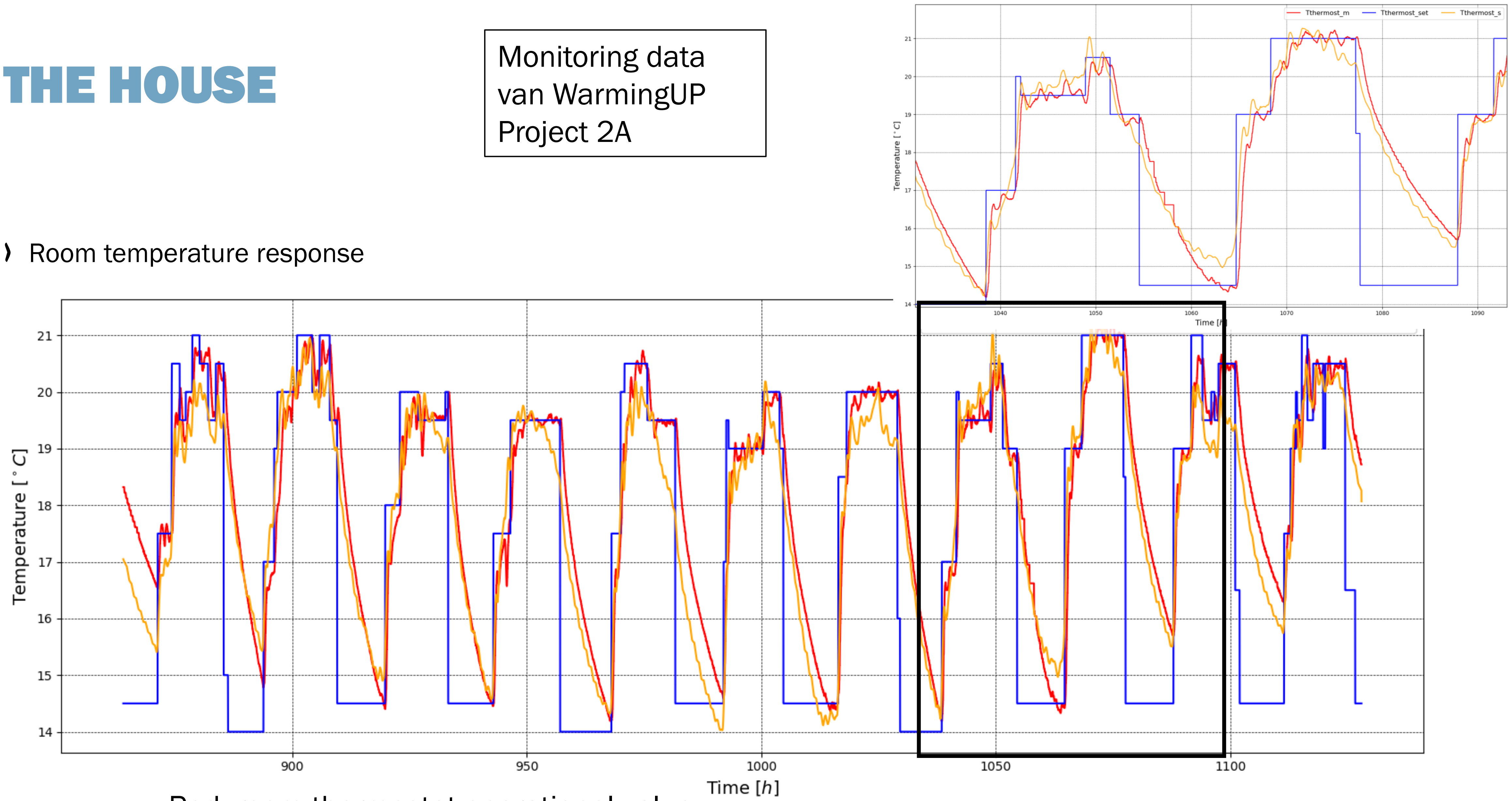
THE HOUSE

Monitoring data
van WarmingUP
Project 2A

- Room temperature response

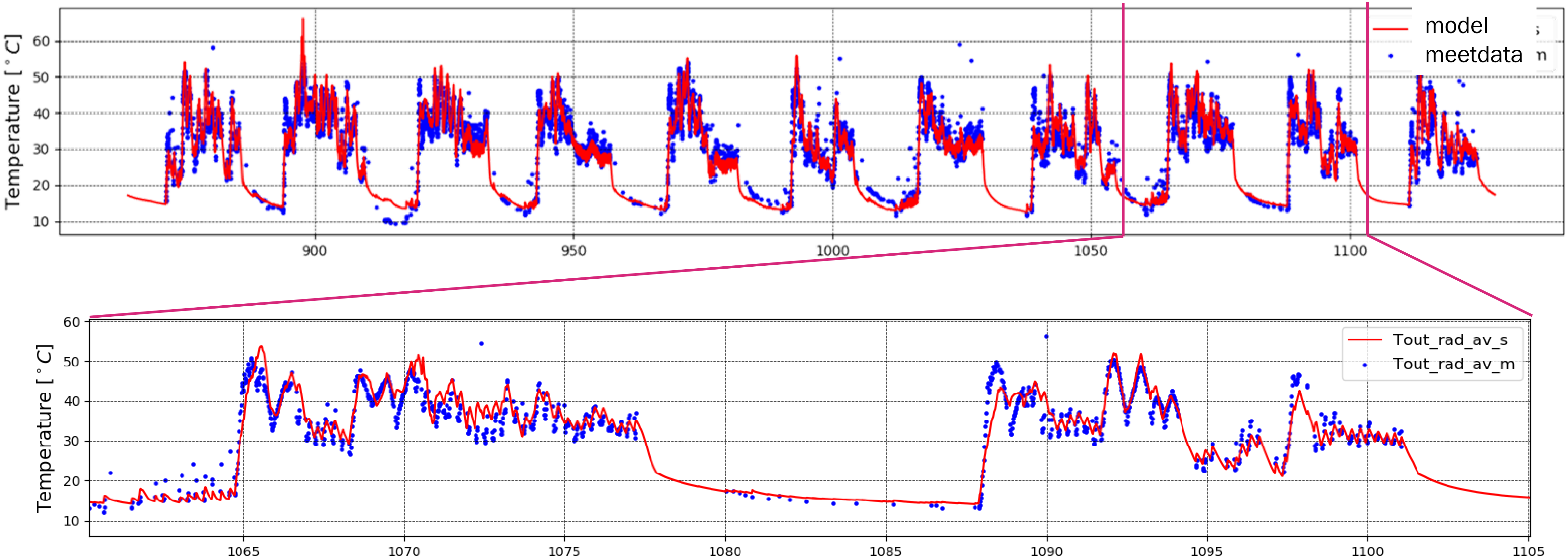


Red: room thermostat operational value
Blue: room thermostat set value
Yellow: Model

THE HOUSE

Monitoring data van WarmingUP Project 2A

- Radiator water temperature



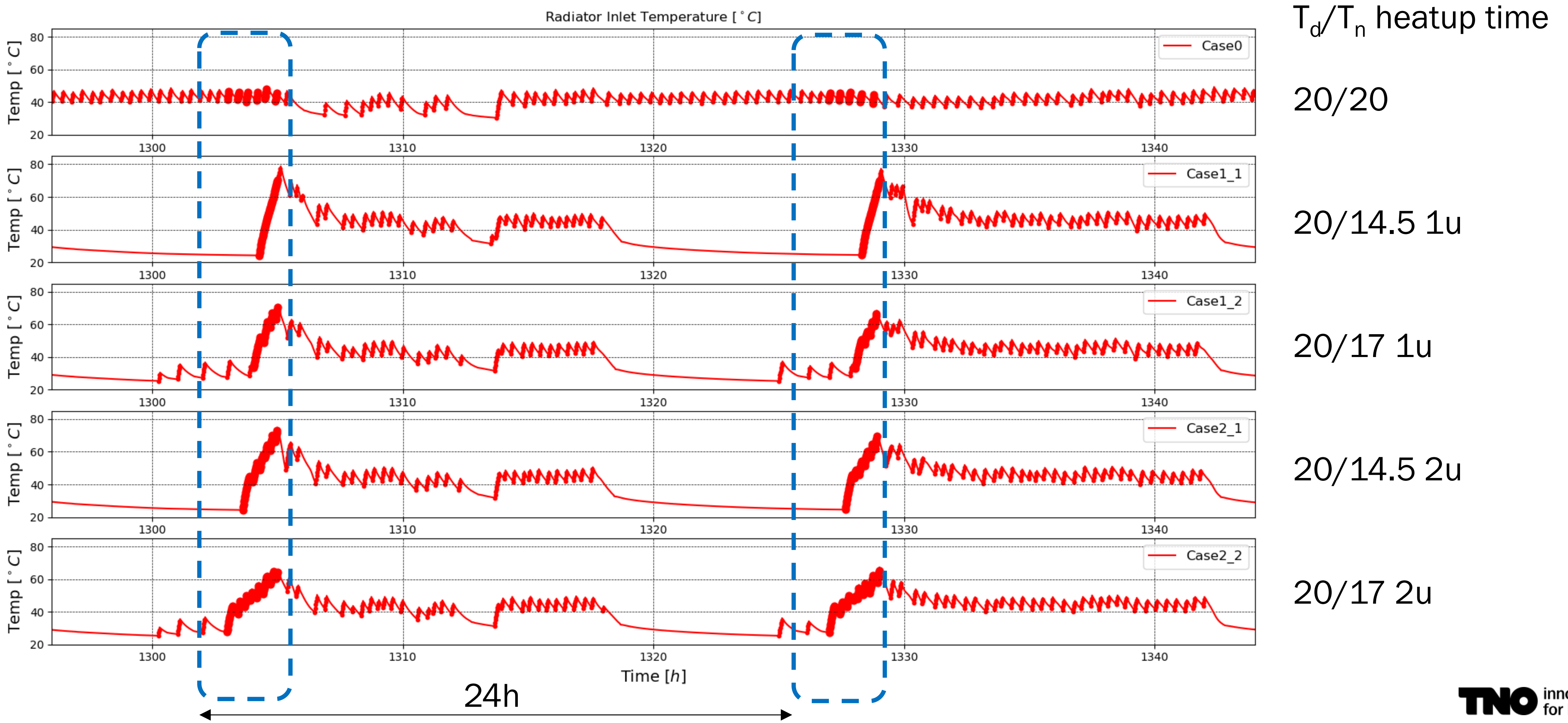
THE STUDY

- With the model established, 5 scenarios are used to calculate the effect of night setback.
- Two aspects of night setback are considered: amount of temperature setback and reheat period.

	Day temperature [°C]	Night temperature [°C]	Reheat time span [hours]
Case0	20 (always)	20 (always)	-
Case1.1	20 (9:00 – 22:00)	14.5 (22:00 – 8:00)	1
Case1.2	20 (9:00 – 22:00)	17 (22:00 – 8:00)	1
Case2.1	20 (9:00 – 22:00)	14.5 (22:00 – 7:00)	2
Case2.2	20 (9:00 – 22:00)	17 (22:00 – 7:00)	2

RESULTS 1: REQUIRED HEATING WATER TEMPERATURE

- Big difference in heating water temperature with the utilization and depth of night setback.



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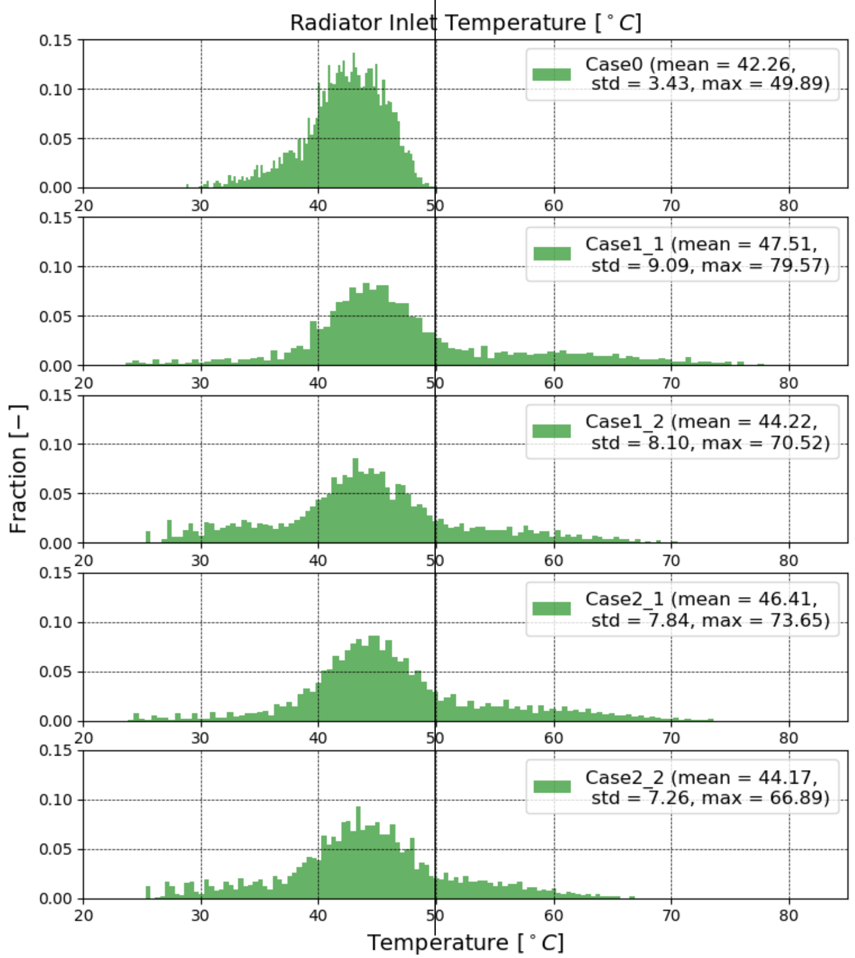
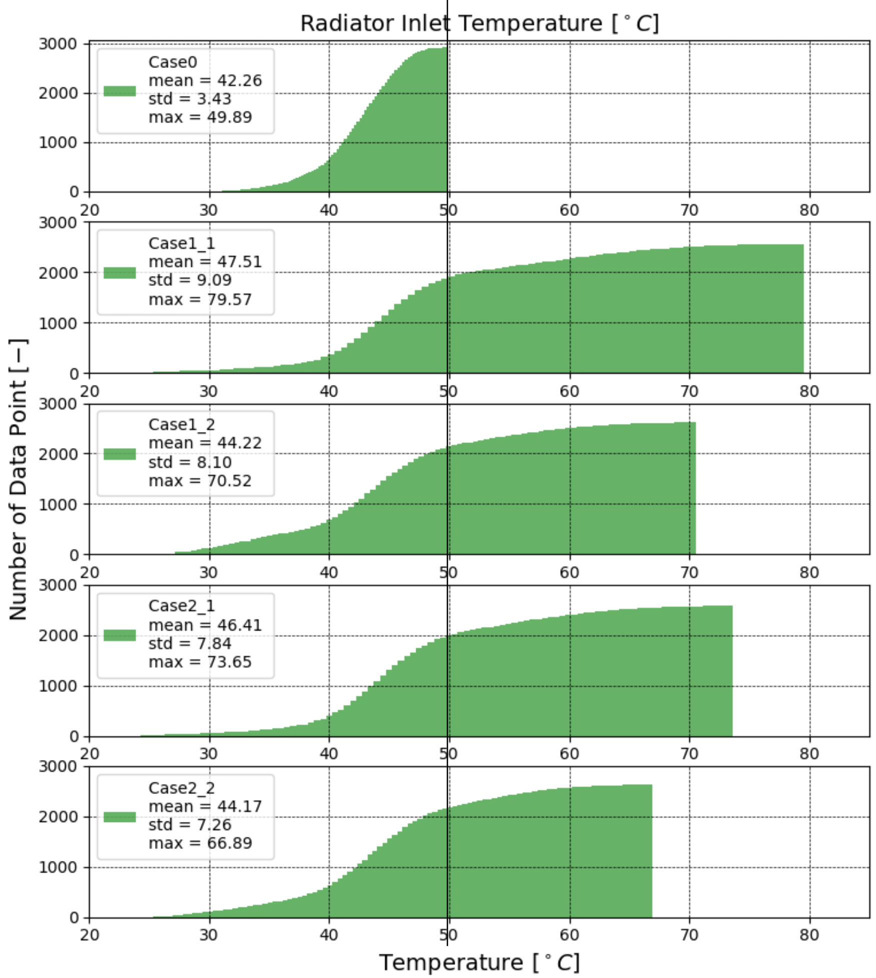




Max 50C

Max 79C

Max 71C

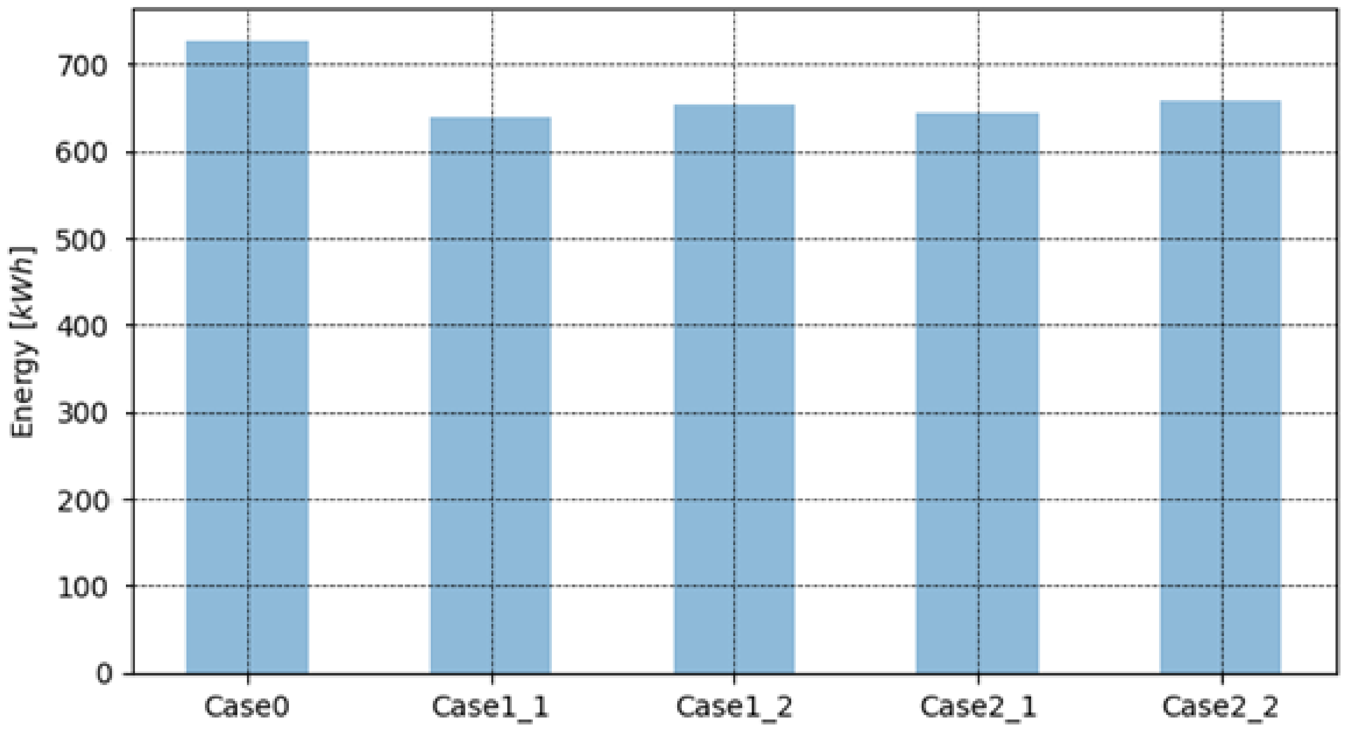
Max 73C

Max 67C

RESULTS 2: HEAT CONSUMPTION

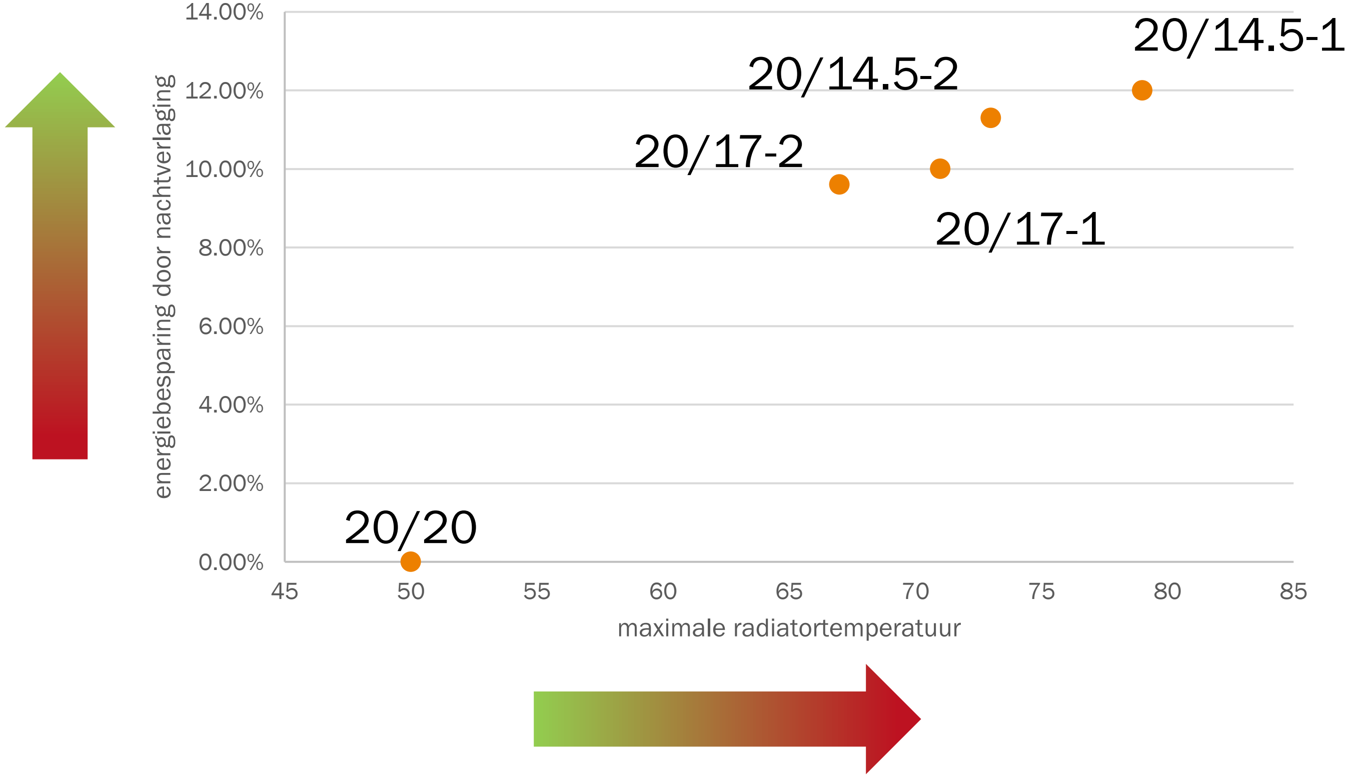
- Energiegebruik van 2 weken
- Besparing in energie:

	Energy Saving [%] (compared to case0)
Case1.1	12.0
Case1.2	10.0
Case2.1	11.3
Case2.2	9.6



EFFECT OF NIGHT SETBACK: TRADEOFF BETWEEN ENERGY SAVING AND INCREASED EFFICIENCY

- Increasing the depth and decrease the reheat time of a night setback increases the amount of energy saving compared to the base case.
- This comes at a cost of an increase in required water temperature due to the increase in heat consumption.



CONCLUSION

- By changing night-setback there seems to be a direct trade-off between heating water temperature and energy (heat) consumption.
- Note that this work is looking at a single dwelling. It is understood for houses which cool down less during a night setback have a reduced energy saving.
- Not taken into account is the effect of the capacity peak on the heat network. If that is of interest, then the simultaneity over various dwellings should be addressed as well.

THANK YOU FOR
YOUR TIME

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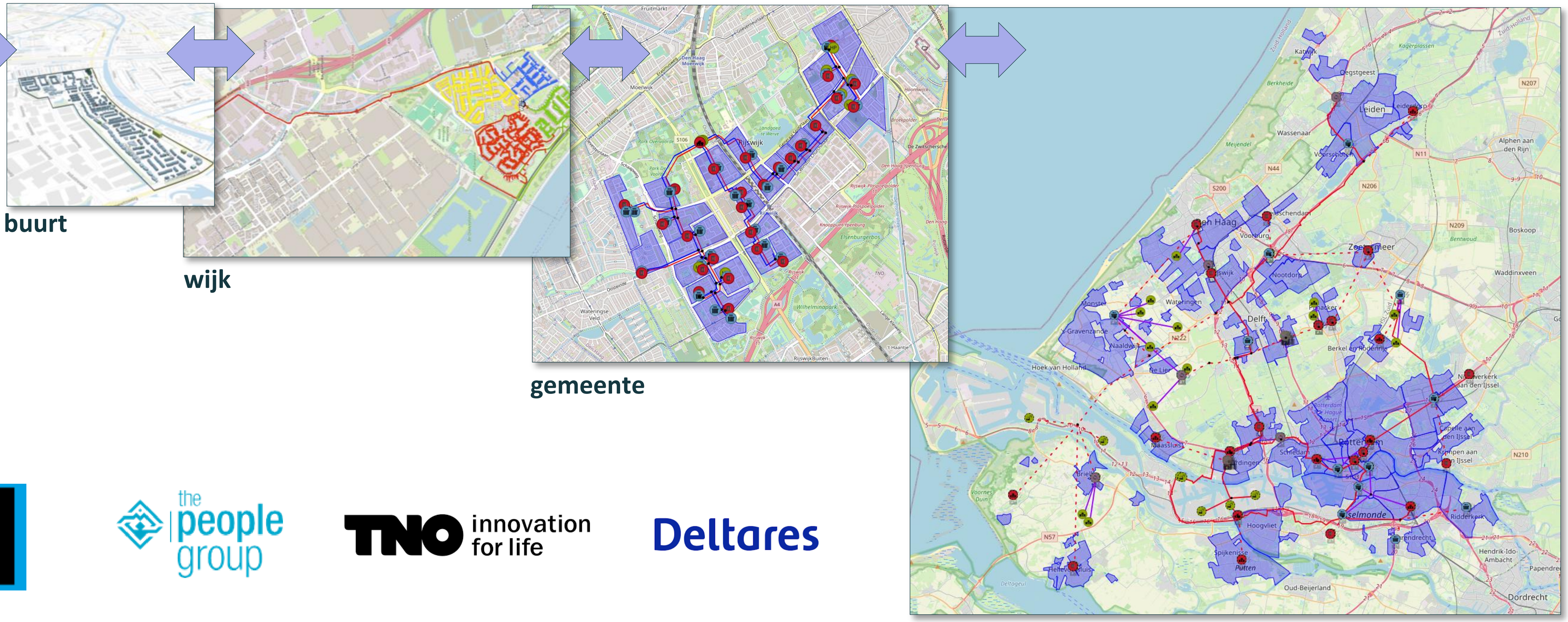

the early birds

the people group

TNO innovation for life

Deltares

Integral design for future-proof heating networks

Design Toolkit together with tools that take the residents and their house as the starting point

martijn.clarijs@tno.nl

nieuwe warmte nu

Heating networks: lack of clarity, delays, high end user costs and many, many aligment issues and many many reports…

- Currently little alignment between different spatial levels (district, municipality, region)
- No alignment between development of different system/infra parts

- => Contracting heat demand and development of supply: catch-22

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What can be improved with an integral approach?

- Start with the resident and house! What are the motives, when does the resident opt for a heating network?
- Aim to minimize the national costs by aligning the integral “chain” from resident/house up to the sources, and all-in between
- Use an Open Werkplatform: no reports, but digital collaboration between local stakeholders involved in planning and design of collective heating solution, bringing in data, expertse and desires/conditions

How: couple already existing tools!

residents ↔ district net ↔ energy system

V V

the early birds — **BuurtWarmteWijzer**

the people group — **GeoSmartDesign**

TNO innovation for life, Deltares — **Design Toolkit**

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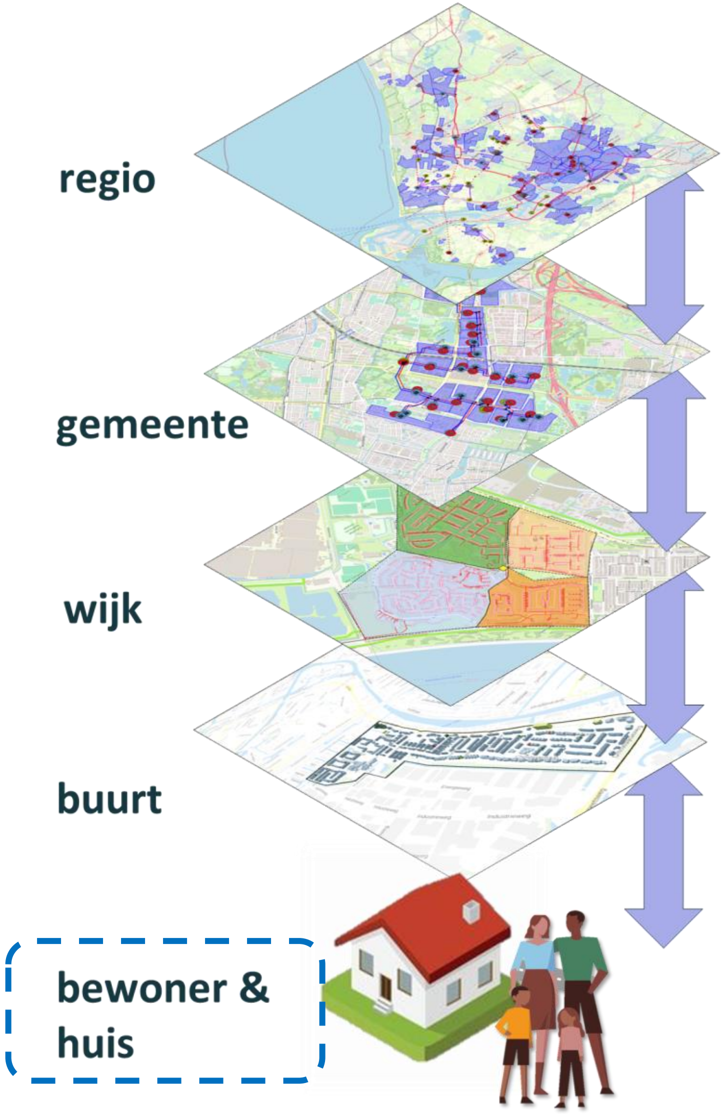
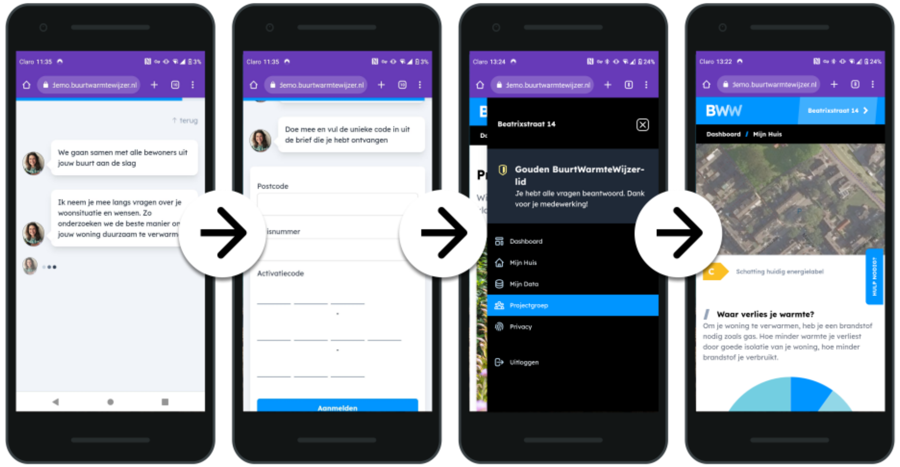
Working together on future-proof heating networks



Resident: my neighbourhood, my home, my choice

TheEarlybirds – Buurtwarmtewijzer

- What measures have residents taken in their house and what is their energy consumption?
- What drives residents in their choices? Comfort, lowest costs, CO2 emissions, etc.
- Which preferences do residents have for heating solutions in their house?



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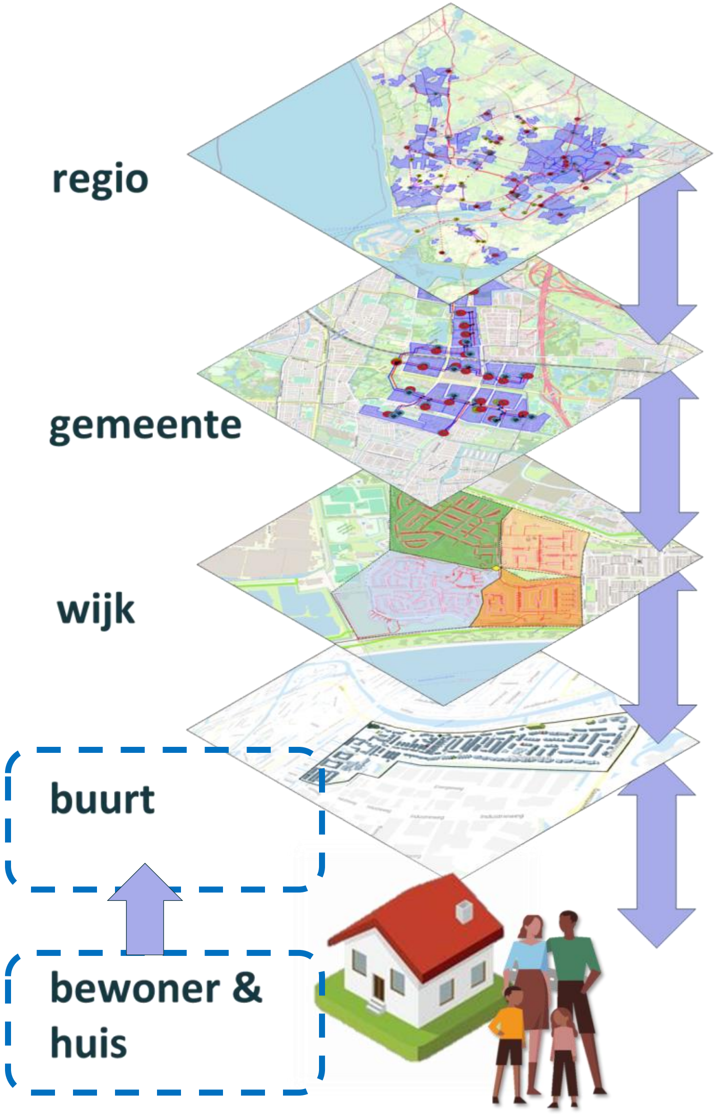
Working together on future-proof heating networks



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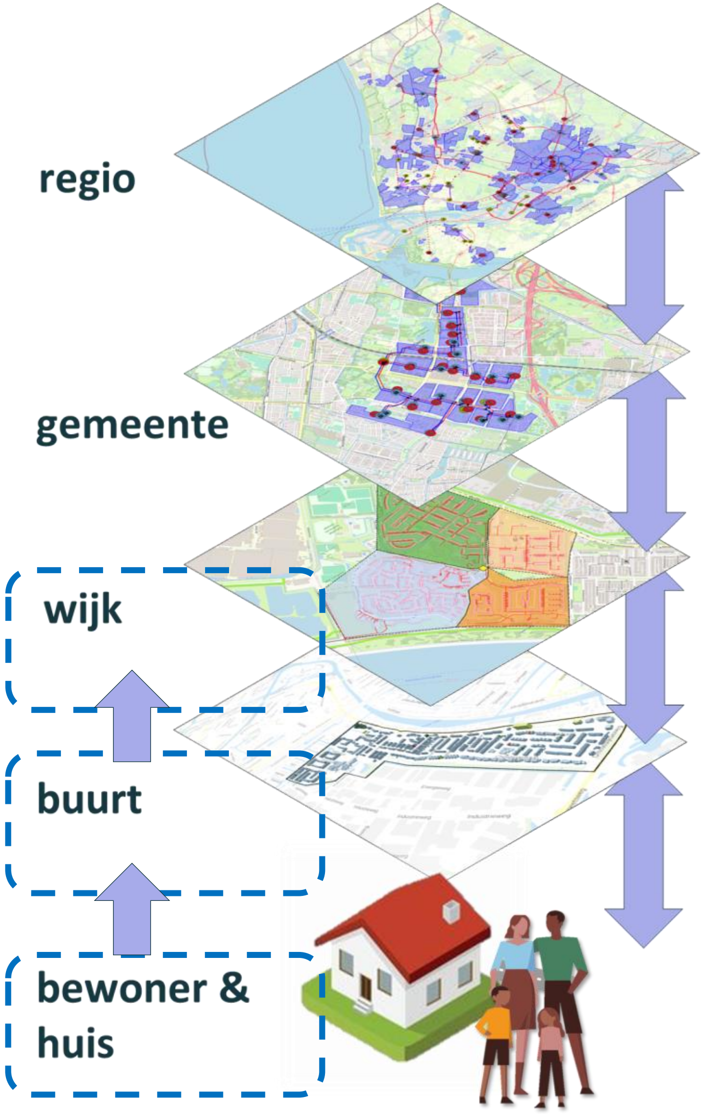
Resident: my neighbourhood, my home, my choice

TheEarlybirds – Buurtwarmtewijzer

- At which price of heat do residents opt for a heating network?
- How many houses in the neighbourhood would then be willing to connect?
- What are the costs of insulation measures and how does that translate to lower heating costs?
- What is the collective heating demand in the neighbourhood, now and in the future?

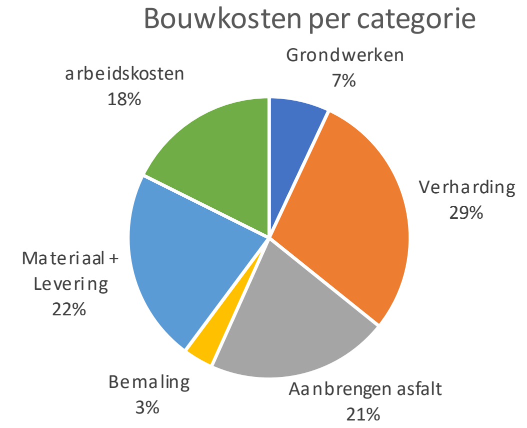
Working together on future-proof heating networks

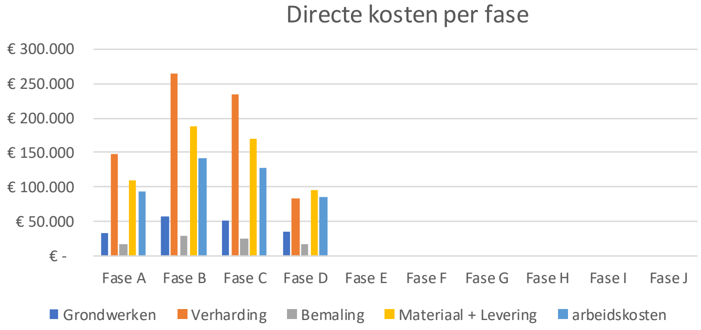


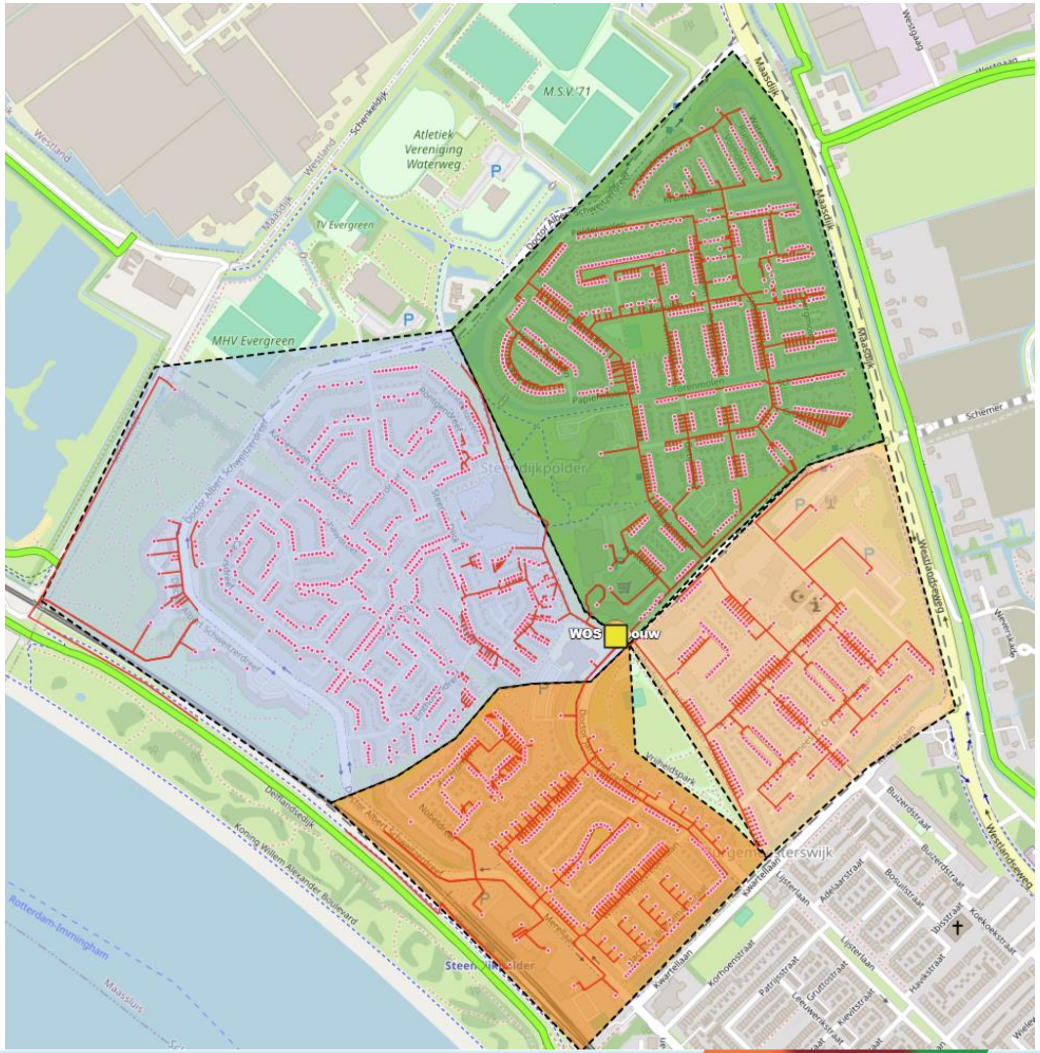
District level: a realistic heating grid that meets demand

The People Group – GeoSmartDesign Heat

- How is the routing and the sizing of the piping grid in the secondary grid?
- A realistic* and cost-optimized design of the local heating grid, spatially feasible and in line with all practical constraints
- *co-development with Heijmans, cost figures compiled with Witteveen + Bos







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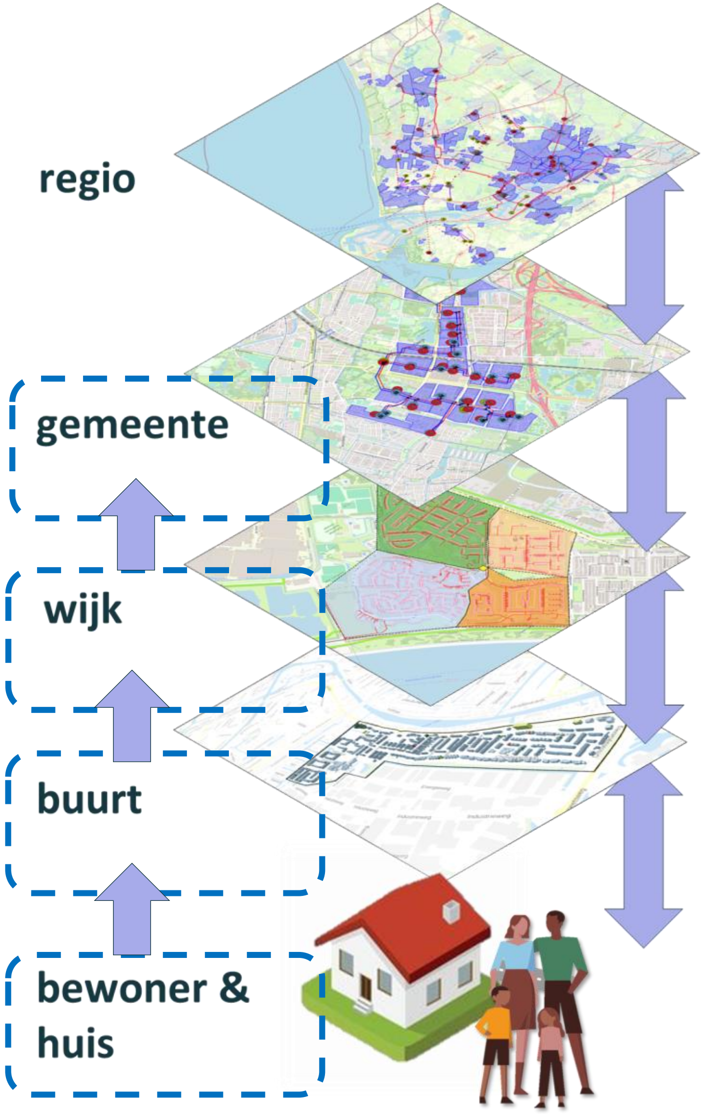
Working together on future-proof heating networks



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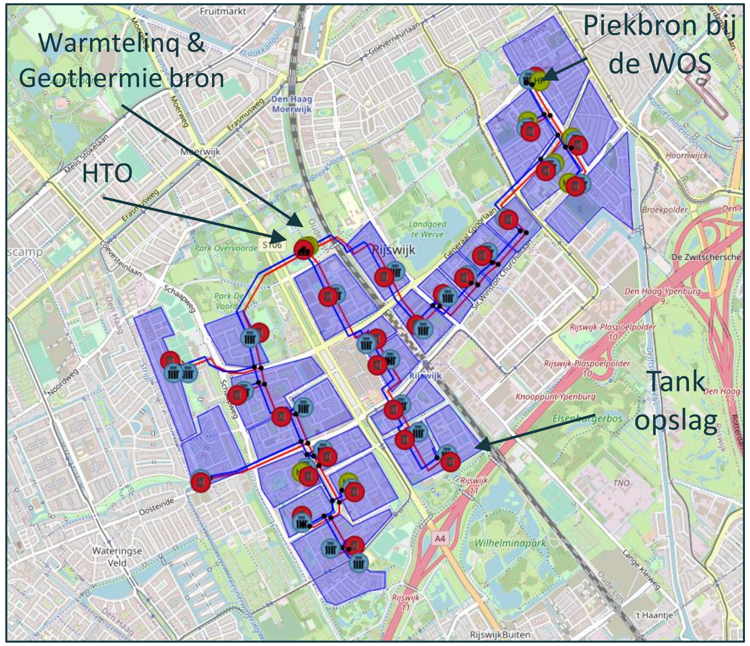
Municipality: a sketch heat network as a concrete step after the TVW's

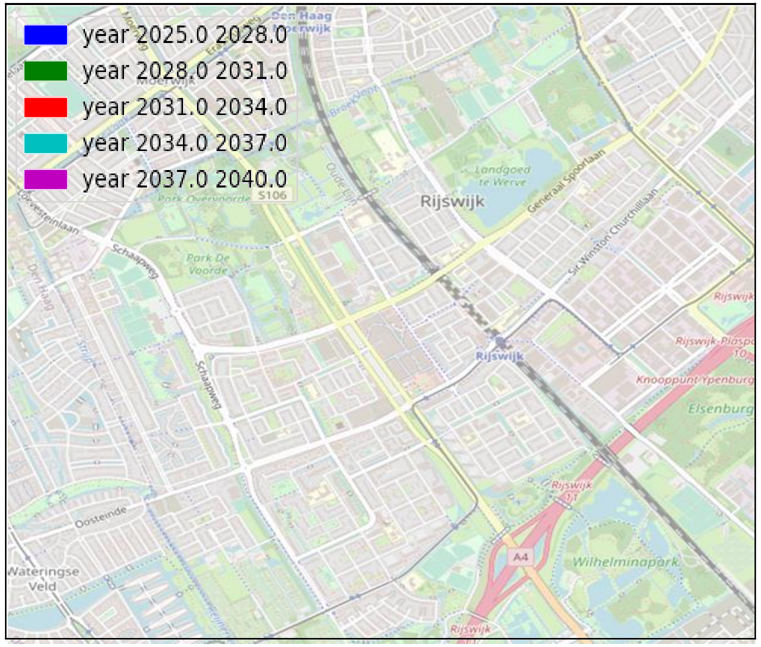
TNO en Deltares – NWN Design Toolkit

- Which sources bring heat to which districts? How is that roll-out over time?
- If there are different sources, how do you determine the ideal mix?
- How do you align connecting the districts with development of the sources, towards 2050? How can storage help?
- How can we reach lowest national costs, from source up to resident, my maximum alignment of the integral chain?

Where is a heating grid foreseen?



And when? (roll-out)



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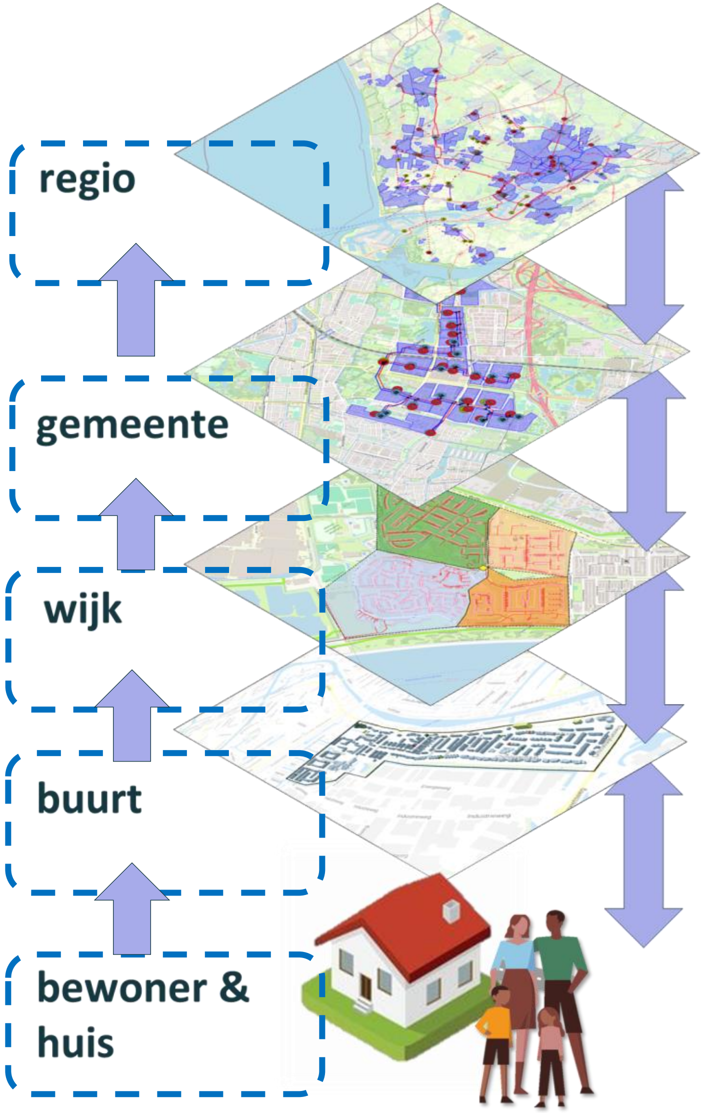
Working together on future-proof heating networks



Let's look how it all comes together in Design Toolkit…

Preparing Dutch Homes for Energy Transition

A Decision Support Framework for Renovating Existing Dutch Dwellings for Lower Temperature District Heating

Prateek Wahi

PhD Candidate
Faculty of Architecture and the Built Environment, TU Delft

Cover: Image generated using Dall.E

Climate Agreement Goals : 2030

Decarbonising the built environment by transition towards sustainable source of heating

Making
1.5 million
homes gas free

Transformation rate of
200,000
homes / year

District heating with lower temperature supply

Energy Renovations for integrating lower temperature supply

IEBB

Integrated Approaches for the Energy Transition in the Existing Buildings.

Project 1.5 : Collective Warmte

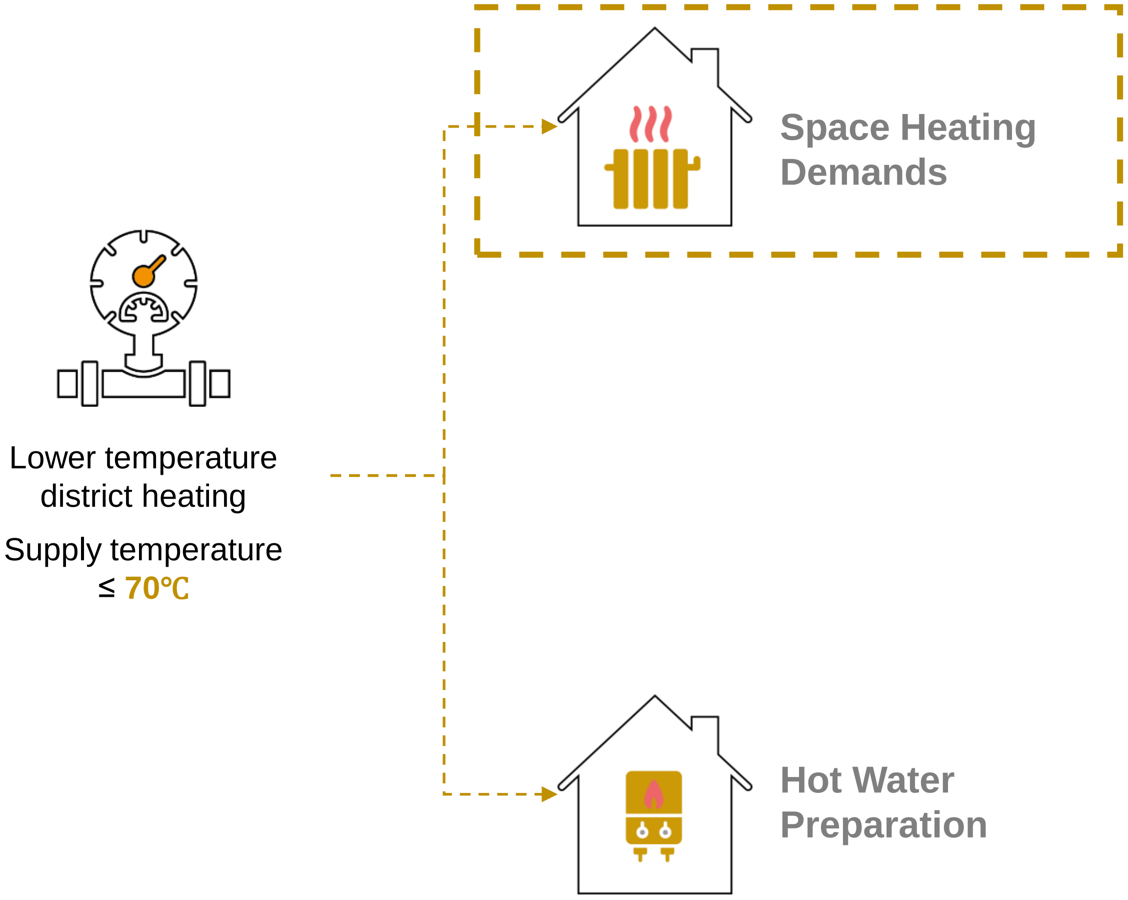
Develop methods to connect homes to medium-temperature heat networks cost-effectively.

Partners

TNO innovation for life
Eneco
VATTENFALL
ennatuurlijk
Stadsverwarming Purmerend
hvc. energie en hergebruik
ARCADIS
Gemeente Almere

Source: CBS, 2022; Dutch Ministry of Economic Affairs and Climate, 2019; EUKN Secretariat, 2018,2019; IEA,2020

Energy renovations are needed for a comfortably heated home

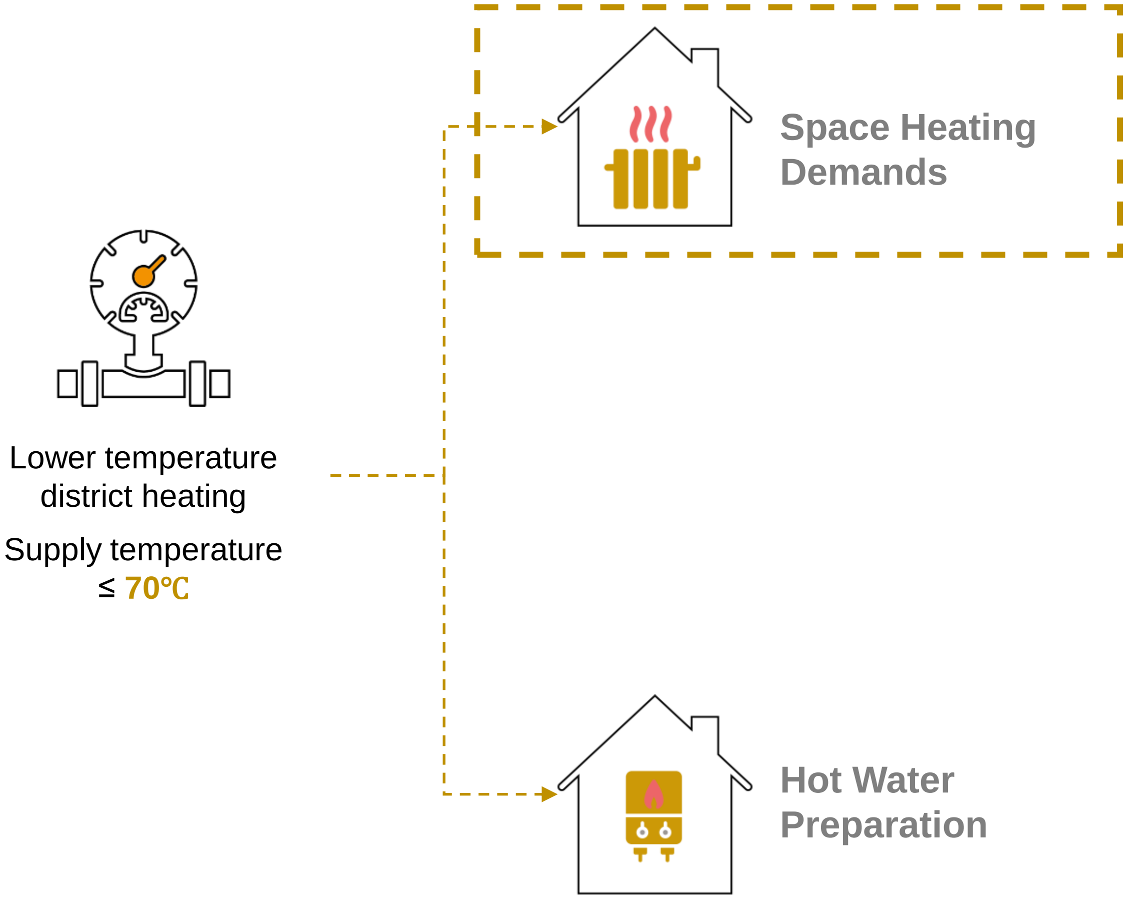


- Lowering the supply temperature reduces the heating capacity.
- Existing radiators might be oversized, but if not, occupants would have thermal discomfort.

- These houses would then need a higher temperature supply to maintain comfort.
- Bottleneck to reduce supply temperature or shifting towards sustainable heat sources.

- Limits to reduce supply temperature are also restricted by regulations to prevent Legionella.
- Often solved by instantaneous or local water boiler.

How do you select appropriate strategies for preparing a home for LTH?



Challenge 1 :
Lack of lower temperature ready definition.

Challenge 2:
Various renovation options: Decision paralysis

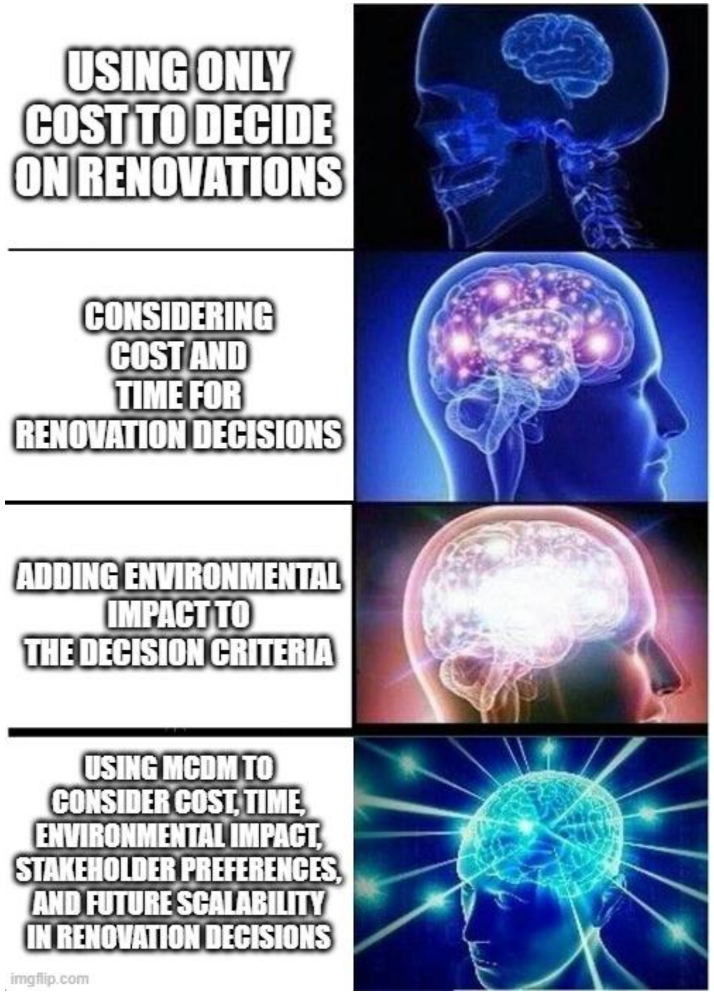
Challenge 3:
Diverse dwelling require tailor-made solutions

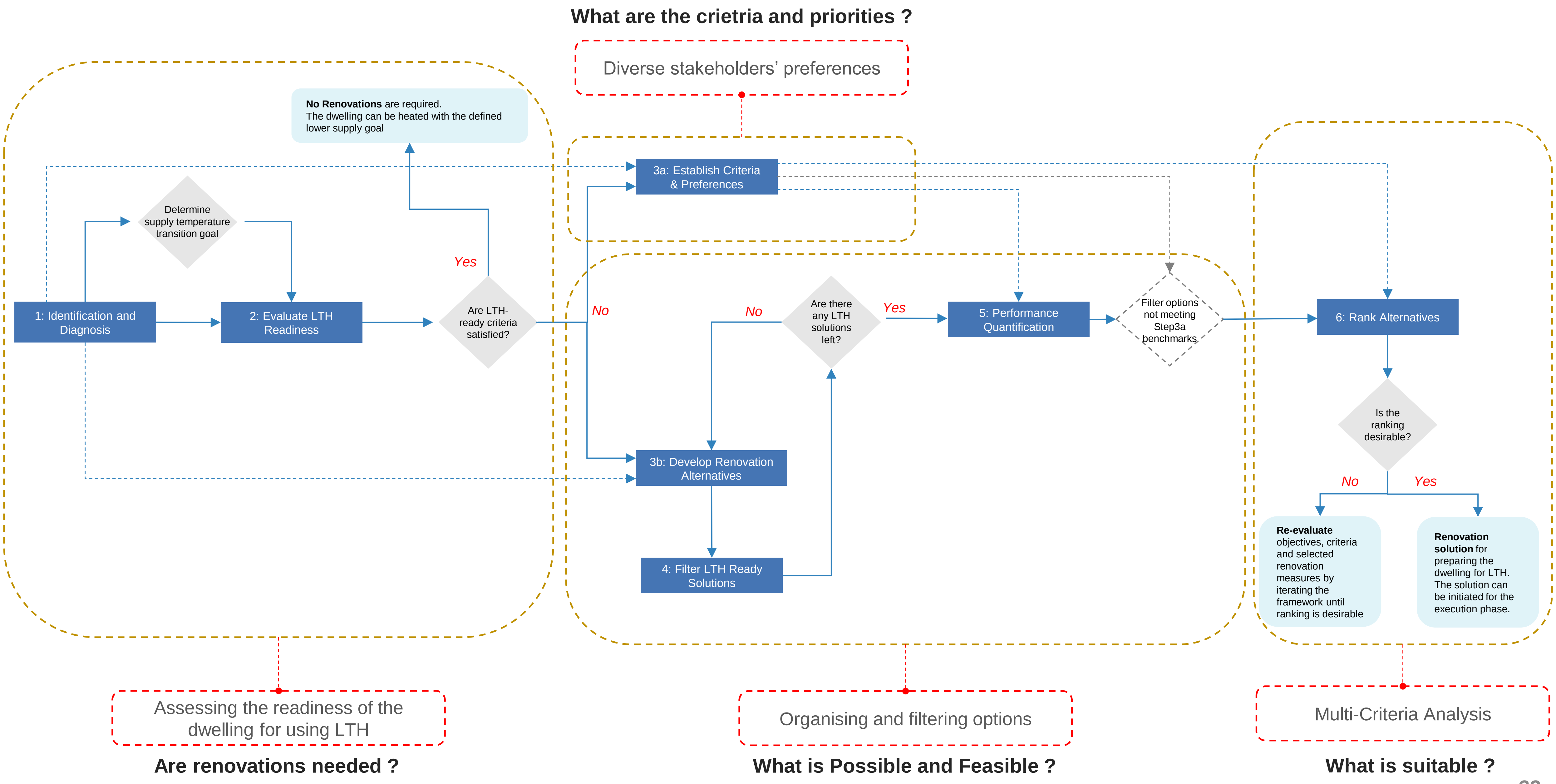
Challenge 4:
Informational barrier due to lack of decision-support insights in the context of LTH

Wahi, P., Konstantinou, T., Tenpierik, M. J., & Visscher, H.. (2023). Lower temperature heating integration in the residential building stock: A review of decision-making parameters for lower-temperature-ready energy renovations. Journal of Building Engineering. https://doi.org/10.1016/j.jobe.2022.105811

MCDM Multi-Criteria Decision Making

A Systematic Approach to renovation Decision-making




What are the crietria and priorities ?
Diverse stakeholders' preferences
No Renovations are required.
The dwelling can be heated with the defined lower supply goal
3a: Establish Criteria & Preferences
Determine supply temperature transition goal
Yes
1: Identification and Diagnosis
2: Evaluate LTH Readiness
Are LTH-ready criteria satisfied?
No
No
Are there any LTH solutions left?
Yes
5: Performance Quantification
Filter options not meeting Step3a benchmarks
6: Rank Alternatives
Is the ranking desirable?
No
Yes
3b: Develop Renovation Alternatives
4: Filter LTH Ready Solutions
Re-evaluate objectives, criteria and selected renovation measures by iterating the framework until ranking is desirable
Renovation solution for preparing the dwelling for LTH. The solution can be initiated for the execution phase.
Assessing the readiness of the dwelling for using LTH
Organising and filtering options
Multi-Criteria Analysis
Are renovations needed ?
What is Possible and Feasible ?
What is suitable ?

LTH readiness | Criteria and preferences | Renovation solutions | Multi-crietria Assessment

Project	Senior Housing complex
Location	Bloemendaal
Type	Gallerij + portiek
Number of units	180
Renovation objective	Sustainability and energy transition
Old supply temp	High (90/70) from block heating
New Supply	Low (55/40) with air-water heat pump Gas boiler for peak demand
Renovation strategies	Building envelop Change heat generation No changes to hot water production PV panels

Analysed as built conditions in 1980s.

Determine supply transition goal

Low Temperature Supply: 55/35 ℃

Are the apartments LT ready ?

Lower-temperature-ready criteria

Maintaining the energy efficiency and thermal comfort of the dwelling compared to its existing condition with a high-temperature supply

Supply Temperature	Annual space heating energy [kWh/m2]	Occupied underheated hours
HT supply (90/70)	215	330/5840
LT supply (55/35)	**165**	**1397/5840**

- Reduction in supply temperature can have an impact on the radiator heating capacity
- 24% of the occupied hours are underheated in LT supply.

The apartments need renovations before being connected to an LT supply system.

Define and prioritize decision-making criteria

Define crietria

1. Translate the renovation goals into objectives
2. Establish hard criteria for deciding renovations
3. Determine KPIs and benchmarks for each criterion

Space heating demand and **thermal comfort** are two non-negotiable criteria for assessing LTH readiness

Goals	Objectives	Criteria
Environmental	To reduce operational and primary energy consumption	Annual Space heating demand
		Annual net energy consumption
		Total primary energy consumption
		Renewable energy generation
		Energy savings
	To reduce direct and indirect embodied emissions	Global wamring potential
		Estimation of emboided energy
		Estimation of carbon emissions
Economic	To imporve affordability	Total investment costs
		Available local and national subsidies
	To optimise cost-benefits	Rent increment
		Payback period
		Life cycle costs
Social	To imporve indoor comfort	Thermal comfort
		Visual comffort/daylight
		Accoustical comfort
		Indoor air qualtiy
	To imporve social acceptability	Aesthetics
		Renoavtion duration
		Energy costs

LTH readiness | **Criteria and preferences** | Renovation solutions | Multi-cirietria Assessment

Define and prioritize decision-making criteria

Prioritization of crietria

- **Pairwise comparison method**
- Assess the relative importance of each criterion against all criteria as well as with the stakeholders
- Calculated criteria weights as relative importance

Environmental

		Extremly important	Very strong to extreme importance	Very strong importance	Strong to very strong importance	Strong importance	Moderate to strong importance	Moderate importance	Equal to moderate importance	Equal importance	Equal to moderate importance	Moderate importance	Moderate to strong importance	Strong importance	Strong to very strong importance	Very strong importance	Very strong to extreme importance	Extremly important		Score	
Space heating demand	C1	9	8	7	6	5	4	3	2	1	1/2	1/3	1/4	1/5	1/6	1/7	1/8	1/9	C2	7	Energy Label
Space heating demand	C1	9	8	7	6	5	4	3	2	1	1/2	1/3	1/4	1/5	1/6	1/7	1/8	1/9	C3	6	Energy-Index
Space heating demand	C1	9	8	7	6	5	4	3	2	1	1/2	1/3	1/4	1/5	1/6	1/7	1/8	1/9	C4		Share of renewable energy generation
Space heating demand	C1	9	8	7	6	5	4	3	2	1	1/2	1/3	1/4	1/5	1/6	1/7	1/8	1/9	C5		Energy Savings (gas)
Energy Label	C2	9	8	7	6	5	4	3	2	1	1/2	1/3	1/4	1/5	1/6	1/7	1/8	1/9	C3		Energy-Index
Energy Label	C2	9	8	7	6	5	4	3	2	1	1/2	1/3	1/4	1/5	1/6	1/7	1/8	1/9	C4	1/9	Share of renewable energy generation
Energy Label	C2	9	8	7	6	5	4	3	2	1	1/2	1/3	1/4	1/5	1/6	1/7	1/8	1/9	C5		Energy Savings (gas)
Energy Label	C3	9	8	7	6	5	4	3	2	1	1/2	1/3	1/4	1/5	1/6	1/7	1/8	1/9	C4		Share of renewable energy generation
Energy Label	C3	9	8	7	6	5	4	3	2	1	1/2	1/3	1/4	1/5	1/6	1/7	1/8	1/9	C5		Energy Savings (gas)
Share of renewable energy generation	C4	9	8	7	6	5	4	3	2	1	1/2	1/3	1/4	1/5	1/6	1/7	1/8	1/9	C5		Energy Savings (gas)

- The main objective of the project was to enhance the energy performance of the apartments with the lowest investment costs.
- Aggregated from four participants who were involved in the decision-making process.

Criteria		Weights [%]
C12	Energy cost savings	14.3
C8	Life cycle costs	12.9
C1	Space heating demand	12.8
C10	Thermal comfort	11.7
C6	Investment costs	10.9
C5	Energy savings (gas)	10.7
C9	Payback period	5.9
C4	Share of renewable energy	4.9
C13	Rent increment	4.1
C7	Investment per label step per unit	3.8
C11	Renovation nuisance	3.2
C2	Energy label	2.9
C3	Energy index	2

Goals	Objectives		Criteria		KPI	Benchmark	Optimal
Environmental	O1	To upgrade the apartment complex to energy label B	C1	Space heating demand	Average kWh/m2 per year	Lower than the existing HT supply	Minimum
			C2	Energy Label	A++ to G	Label B or higher	Minimum
			C3	Energy index	[-]	<= 1.4	Minimum
	O2	To reduce environmental impact	C4	Share of renewable energy generation	%	>0	Maximum
			C5	Energy savings (gas)	Average m3 per year	>0	Maximum
Economic	O3	To reduce investment costs	C6	Invstment costs	€	-	Minimum
			C7	Investment per label step per unit	€	<€7000	Minimum
	O4	To optimise cost benefits	C8	Life cycle costs (30 years)	€	-	Minimum
			C9	Payback period	Years	<20 years	Minimum
Social	O5	To improve indoor comfort	C10	Thermal comfort	Average occupied cold hours	Lower than the existing HT supply	Minimum
	O6	To minimise inconvenience for tenants	C11	Renovation nuisance	Subjective rating 1 (minimum) to 5 (maximum)	-	Minimum
	O7	To optimsing living costs for tenants	C12	Energy cost savings	Average €/month	-	Maximum
			C13	Rent increment	€/month	< 26.50	Minimum

LTH readiness | Criteria and preferences | **Renovation solutions** | Multi-crietria Assessment

Generating and organising solutons

Scenario-based sub-framework

The relative importance of building-level strategies that affect the readiness of dwellings for MT or LT supply.

This feature importance is used for diagnosing a dwelling and developing targeted strategies.

Renovation scenario

Possible alternative situations for testing renovation objectives

Basic

No changes to the building envelope

Moderate

Targeted improvements to the building envelope, with optional changes to HVAC system or controls

Deep

Holistic changes to the building envelope, system and controls

Renovation strategies

Building-level approaches to address renovation scenario

Terraced Intermediate		Apartments	
MT (70/50°C)	LT (55/35°C)	MT (70/50°C)	LT (55/35°C)
Heating setpoint	Heating setpoint	Infiltration	Heating setpoint
Ventilation system	Ventilation system	Heating setpoint	Infiltration
Roof insulation	Roof insulation	External wall insulation	Roof insulation
Glazing insulation	Infiltration	Glazing insulation	Ventilation system
Infiltration	Glazing insulation	Roof insulation	Glazing insulation
External wall insulation	External wall insulation	Ground insulation	External wall insulation
Ground insulation	External door insulation	External door insulation	Ground insulation
External door insulation	Ground insulation	Ventilation system	External door insulation

and
Radiator oversizing

Renovation measures

Product-level alternatives for applying renovation strategy

- Basic measure 1
- Basic measure n^{th}
- Moderate measure 1
- Moderate measure n^{th}
- Deep measure 1
- Deep measure n^{th}

LTH readiness | Criteria and preferences | **Renovation solutions** | Multi-crietria Assessment

Generating and organising solutons

Basic scenarios were rejected,
- A high setpoint is needed for the elderly
- changing the radiator alone does not contribute towards the objective.

Moderate level of intervention:
- A1-A4 proposed in the project
- With target improvements at vent system, wall, window, radiators

Deep level of interventions:
- Holistic changes to the building

New solutions: 14
Initially proposed: 4

18 solutions were analysed

Scenario		**Building envelope**						**System**			
		Roof	**Wall**	**Floor**	**Infilteration**	**Glazing**	**Door**	**Vent. system**	**Heat generation**	**Heat distribution**	**Other**
		R-value	R-value	R-value	dm3/s.m2	U-value	U-value				
Existing		**2.5**	**0.69**	**0.15**	**1.95**	**1.8**	**3.4**	**Mechanical**	**HR107**	**Existing**	**FL-light**
Moderate	A1	-	1.69	-	1.5	-	-	-	-	-	LED
	A2	5.84	1.69	-	1.2	-	-	-	-	-	PV, LED
	A3	5.84	1.69	-	1.2	-	-	-	HP, PV	-	PV, LED
	A4	5.84	1.69	-	1.2	-	-	-	HP, PVT	-	PV, LED
	A5, A5R	-	6.3	-	1.2	-	-	-	HP, PVT	EX, LTR	PV, LED
	A6, A6R	-	6.3	-	1.2	-	-	Balanced, MVHR	HP, PVT	EX, LTR	PV, LED
	A7, A7R	-	6.3	-	1	1	-	-	HP, PVT	EX, LTR	PV, LED
	A8, A8R	-	6.3	-	1	1	-	Balanced MVHR	HP, PVT	EX, LTR	PV, LED
Deep	A9	5.84	1.69	-	0.7	1	-	-	HP, PVT	LTR	PV, LED
	A10	5.84	1.69	-	0.7	1	-	Balanced MVHR	HP, PVT	LTR	PV, LED
	A11	5.84	1.69	2.6	0.4	1	-	-	HP, PVT	LTR	PV, LED
	A12	5.84	1.69	2.6	0.4	1	-	Balanced MVHR	HP, PVT	LTR	PV, LED
	A13	5.84	1.69	2.6	0.4	1	1.4	-	HP, PVT	LTR	PV, LED
	A14	5.84	1.69	2.6	0.4	1	1.4	Balanced MVHR	HP, PVT	LTR	PV, LED

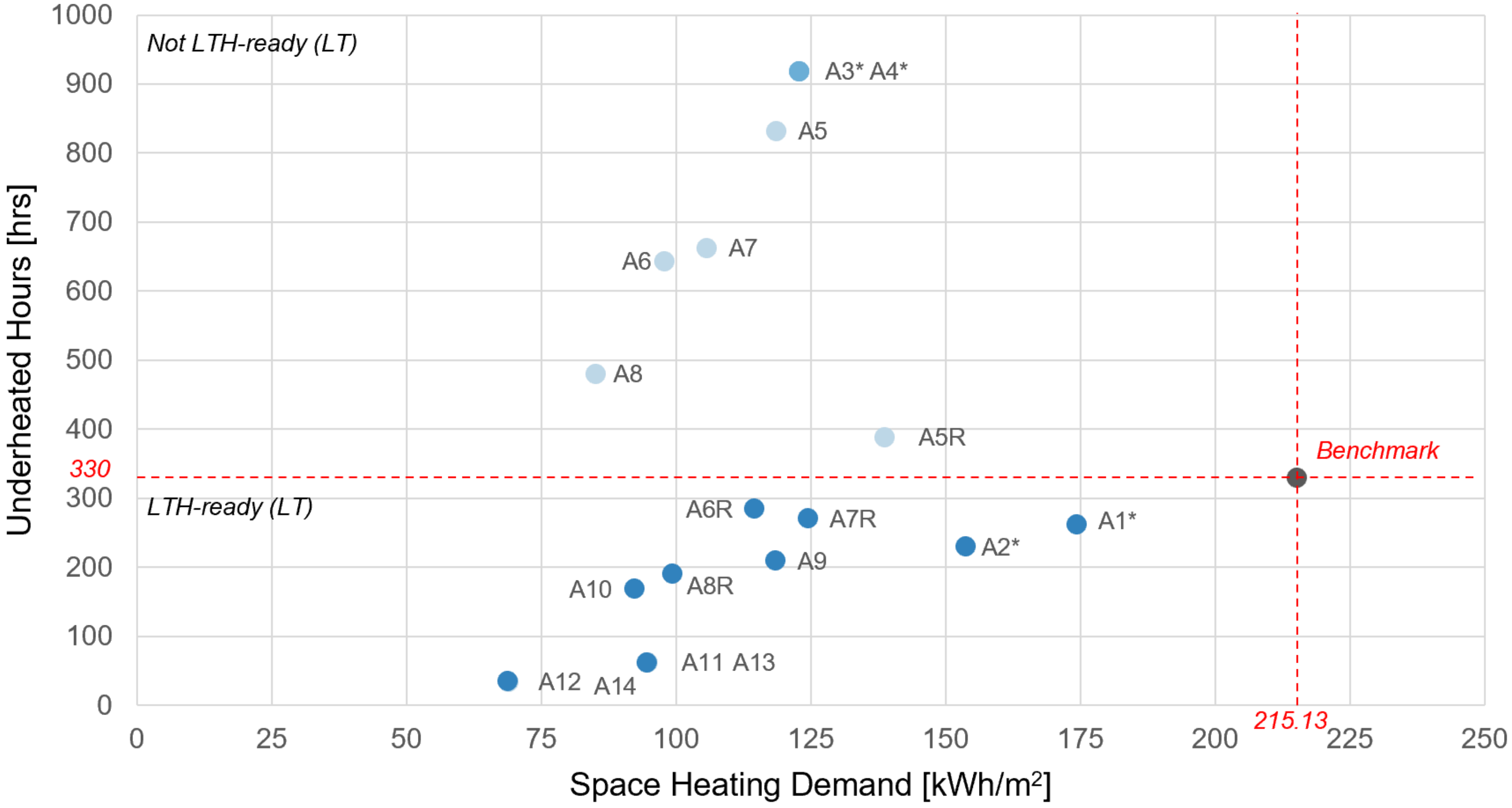
Filter non feasible solutions

Filter 1 : Solutions that cannot prepare the apartments LTH-ready

Filter 2: Filtered solutions that do not meet criteria KPIs

Project proposed solutions :
- A1-A2 uses HT supply
- A3-A4 LT supply reduces space heating but high underheated hours

Not LT-ready solutions



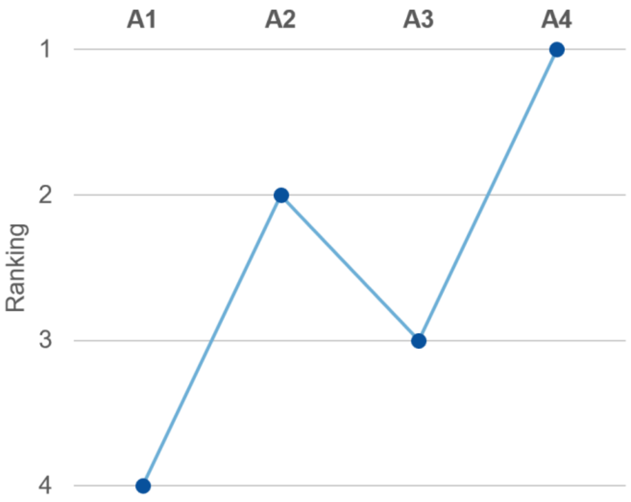
A total of five alternatives were left for final ranking.
- A7R
- A9
- A10
- A11
- A12

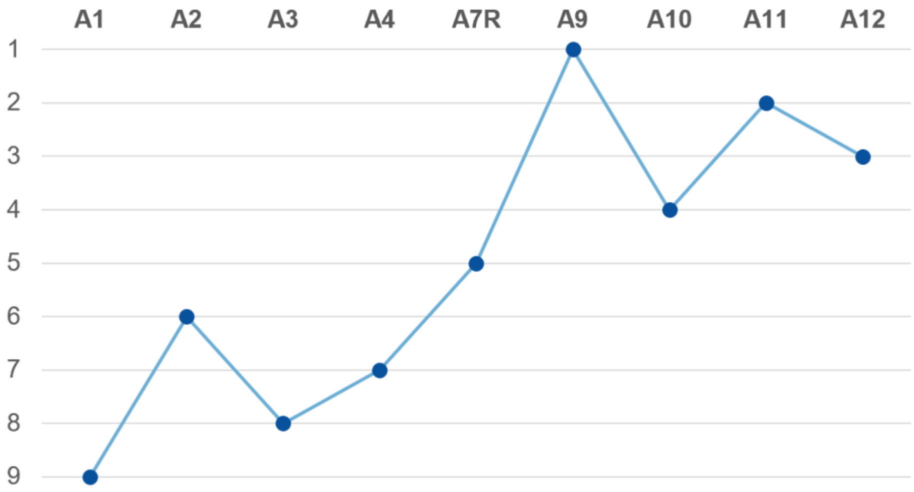
The **Technique for Order of Preference by Similarity to the Ideal Solution (TOPSIS)** method is used to compute rankings.

Comparison :

- Ranking between project proposed and new solutions
- Effect of ranking on both based on performance-based and preference-based.

Performance-based Ranking : Equal criteria weighting





Indicating the framework's applicability and potential in representing real-world context.

- A4 is suggested as the optimal, original selection for the project.
- But it is not an LT-ready solution.

- A9 is the most optimal and is an LT-ready solution.
- Initial investment costs are 15% higher than A4
- LCC over 30 years is only 1% higher than A4
- Take an extra year to have payback compared to A4
- Additional investment pays in the long term

The **Technique for Order of Preference by Similarity to the Ideal Solution (TOPSIS)** method is used to compute rankings.

Comparison :
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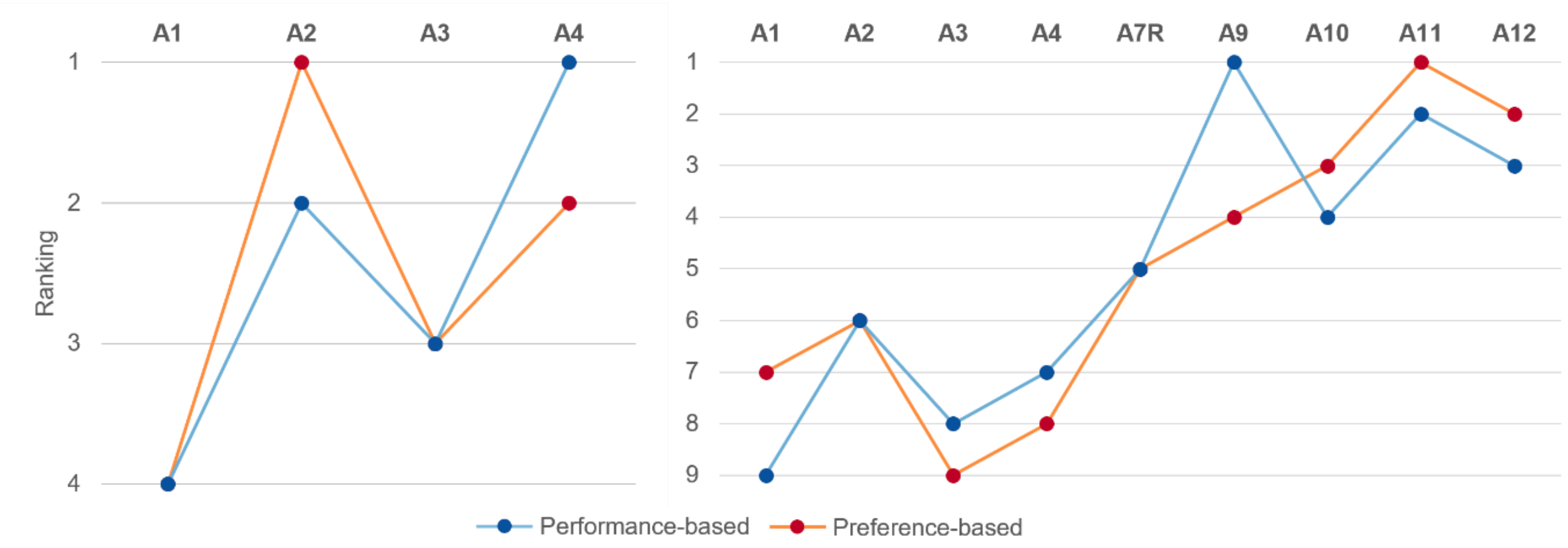
Preference-based Ranking : Criteria weighting



Stakeholders' preference often has a huge impact on selection compared to only performance-based comparison.

- Preferences ranked A2 as optimal than A4.

- A11 emerges as the most optimal

Framework Validation

- Framework accurately represented their decision-making process, described it as **clear, concise and structured.**
- **Pairwise comparison method** (preferences) is an interesting tool for **dialogue among different actors** and **comparing policy.**
- It provides an **analytical basis** to their current intuition-based process.

Limitations and suggestion

- **Incorporate** a more in-depth analysis of **social factors**, **practical considerations** of the solutions, and **the local context.**
- **Logical models** may not always be enough to capture the complexity of social factors, so **human-based insights** may also be necessary.
- **Risk analysis** must be incorporated into another layer of **filtering.**
- Framework must be **validated** further with other cases with **LT supply from DH systems.**

- The decision-support framework provides a **systematic approach** for assessing **LTH readiness and renovation needs.**
- It aids in
  - identifying possible solutions,
  - filtering out non-feasible options, and
  - evaluating multiple criteria to select the most suitable solutions for LTH.
- By **addressing key decision-making challenges**, the framework provides **valuable insights** for making **informed choices.**

Prateek Wahi

P.wahi@tudelft.nl

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