WarmingUp 2A: How low can you go?

Online TUDelft Urban Energy Lecture

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Overview

WARMINGUP

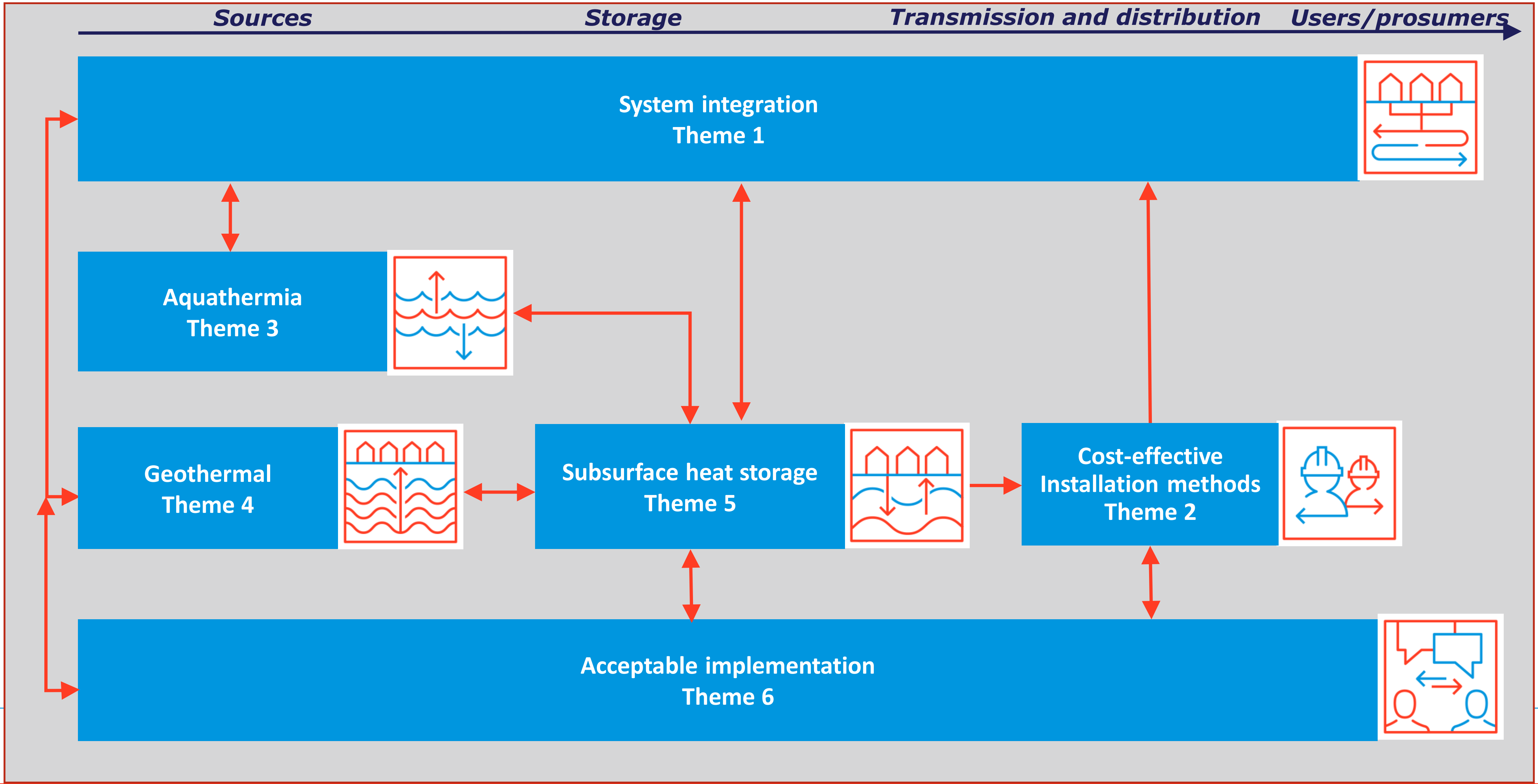
- Intro WarmingUP national R&D programme
- Project 2A How low can you go?

Grand challenge

WARMING UP

- **NL: district heating revolution**
  - from 340.000 to 1.1 million dwellings in 2030
- **Decarbonise district heating** via aquathermia, geothermal energy, waste heat and storage
  - 70% CO_2-reduction in 2030 compared to NG-boiler
- **Acceptable and affordable** system and process innovations in supply chain.
  - 1,5% efficiency gain per year

Coherence


Sources
Storage
Transmission and distribution
Users/prosumers
System integration
Theme 1
Aquathermia
Theme 3
Geothermal
Theme 4
Subsurface heat storage
Theme 5
Cost-effective
Installation methods
Theme 2
Acceptable implementation
Theme 6

Partners and associate partners

Heating/cooling supply

Heating/cooling demand

Erasmus Universiteit Rotterdam
Nijmegen
Gemeente Almere
Deltares
TU Delft
Den Haag
Gemeente Utrecht
Unie van Waterschappen
WN
TNO
Universiteit Utrecht
TU/e
Gemeente Amsterdam
Gemeente Rotterdam
stowa
KWR
Saxion
Rijkswaterstaat
HVC
Vattenfall
Gemeente Breda
provincie Zuid Holland
NAT Netwerk Aqua Thermie
ennatuurlijk
SVP
Firan
Eneco
Net Verder
techniplan adviseurs b
provincie limburg
ebn
bodem energie nl
enpuls
capturam
Tauw
Warm in de Wijk – duurzame warmte in de vruchtenbuurt
Holland Rijnland – waar de Randstad tot bloei komt
Uitvoeringsprogramma Bodem & Ondergrond
Kouwenberg Infra
thermaflex®
rotterdam engineering
Onderzoekcentrum B-ware
The Green Village
engie
Huisman
Platform Geothermie
Feenstra
GreenVis Energy Solutions
CE Delft
if
heijmans
Efteling – Wereld vol wonderen

WarmingUP in numbers

WARMINGUP

39 partners

- DH companies
- Network operators
- Water sector
- Subsurface stakeholders
- Municipalities
- Provinces
- R&D organisations

14 ass. partners

- Network organisations
- Contractors
- Consultants

Innovation plan

- 6 themes, 32 projects, €18,9 M
- 5 PhD’s + 1 PDEng, 100+ experts
- Duration 3 years, start 1-1-2020

Funding

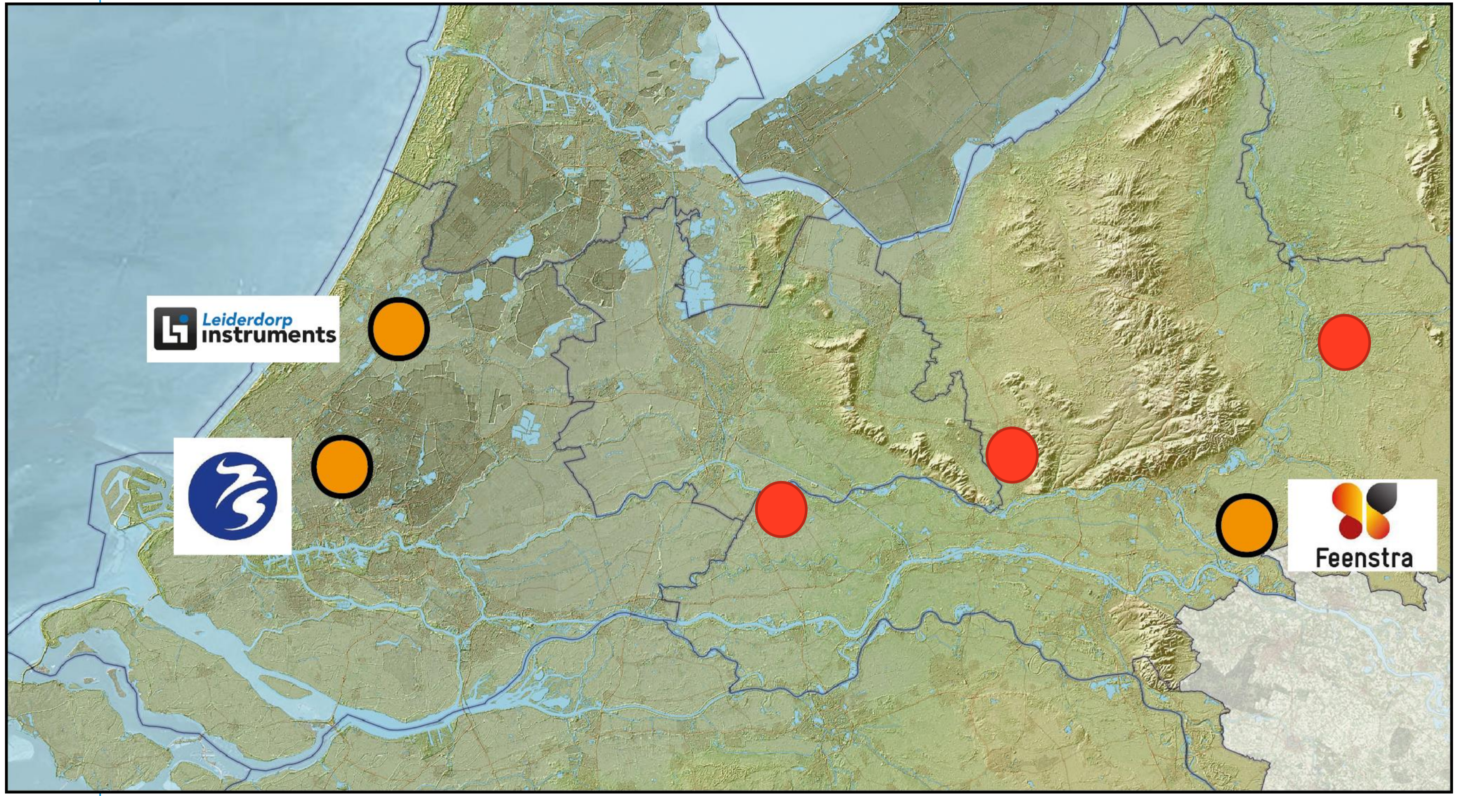
- 25% co-funding private and public organisations
- 25% co-funding from R&D organisations
- 50% subsidy from Min. EZK/BZK, grant TEUE819001

How low can you go?

WARMING^{UP}

- Hypothesis: many existing heating systems are oversized.
- Motivation
  - Renewable sources and heat pumps like low temperatures
  - Large potential saving to decarbonize heat supply
    - 5 mln existing dwellings x 5 – 10 k€ = 25 – 50 bln.€
  - Very little experimental evidence on reduced supply temperature
- Large-scale measurement campaign in 200 dwellings
  - Collaboration with installation company Feenstra
  - No modification to buildings
- Which fraction of existing dwellings is LT-ready? (LT means T_s < 55 °C)
- How low can we go with supply temperature T_s for space heating?

Project plan HLCYG



2020

- Zomer — Define sample of dwellings
- Herfst — Find 220 participants
- Inspect dwelling for feasibility
- Hydraulic balancing + installation

2021

- Winter — Start measurement
- Zomer — Determine reduced supply temperature
- Herfst — Activate reduced supply temperature

2022

- Winter — Measure / monitor
- Lente — Data analysis reduced Supply temperature

Contents

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- Measurement set-up
- Method to determine reduced supply temperature
- Representativity of building sample
- Key results

Measurement set-up (1/2)

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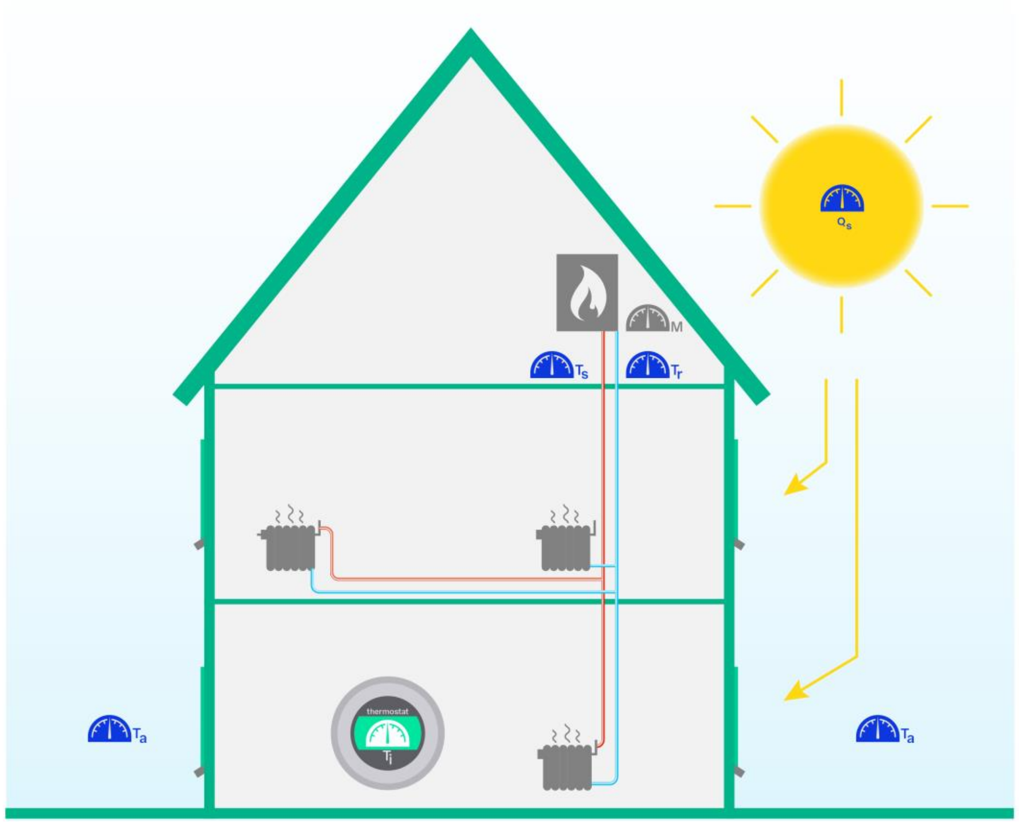
- Gas boiler/Building data
  - Thermostat living room indoor temperature (variable)
  - Indoor temperature setpoint (variable)
  - Gas consumption (day) → specific heat demand
- KNMI-data
  - Ambient Temperature (hour)
  - Solar radiation (hour)
- Additional instrumentation near gas boiler
  - Pulse flow meter (10-min)
  - Supply temperature T_s (10-min)
  - Return temperature T_r (10-min)



T_i = indoor temp
T_s = supply-temperature
T_r = return-temperature
T_a = ambient temperature
M = Mass flow meter (pulse flow meter)
Q_s= solar heat flux

Measurement set-up (2/2)

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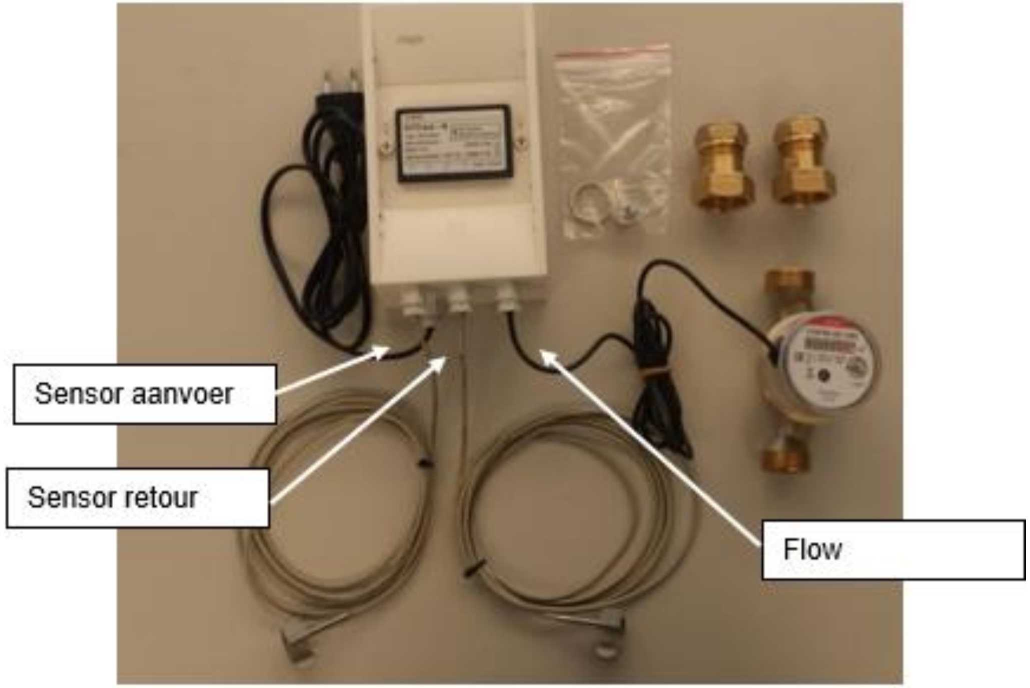
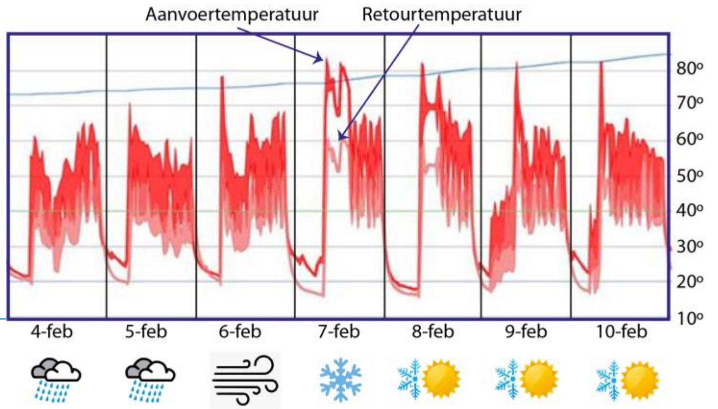
- In dwelling 3 temperature sensors and flow meter
- Temperature difference heating system

$$\Delta T_{sys} = T_s - T_r$$

- Temperature difference radiator – living room
  - Log-mean ΔT drives heat transfer

$$\Delta T_{LMTD} = \frac{T_s - T_r}{ln\left(\frac{T_s - T_i}{T_r - T_i}\right)}$$





Other experimental data

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- Site visit by Feenstra staff
  - Collect 70 parameters on thermal building specs
  - Assess suitability for participation in measurement campaign
- Reasons to reject dwellings
  - Residents hesitant to collaborate (due to COVID)
  - No free plug for instrumentation
  - Additional heat sources present (fireplace)
  - Poorly accessible radiators for balancing
  - Underfloor heating poorly accessible
- Annual questionnaire
- Periodic thermal comfort questionnaire during heating season

Thermal model calibration

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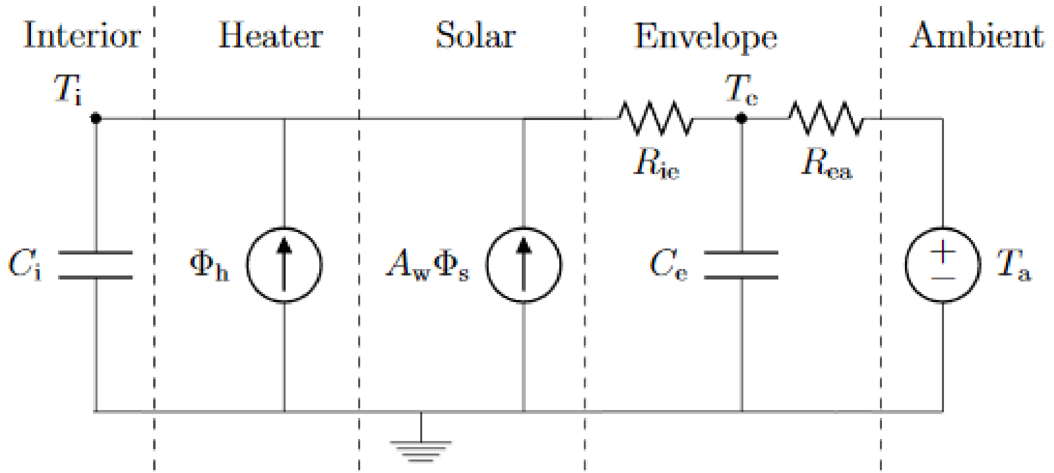
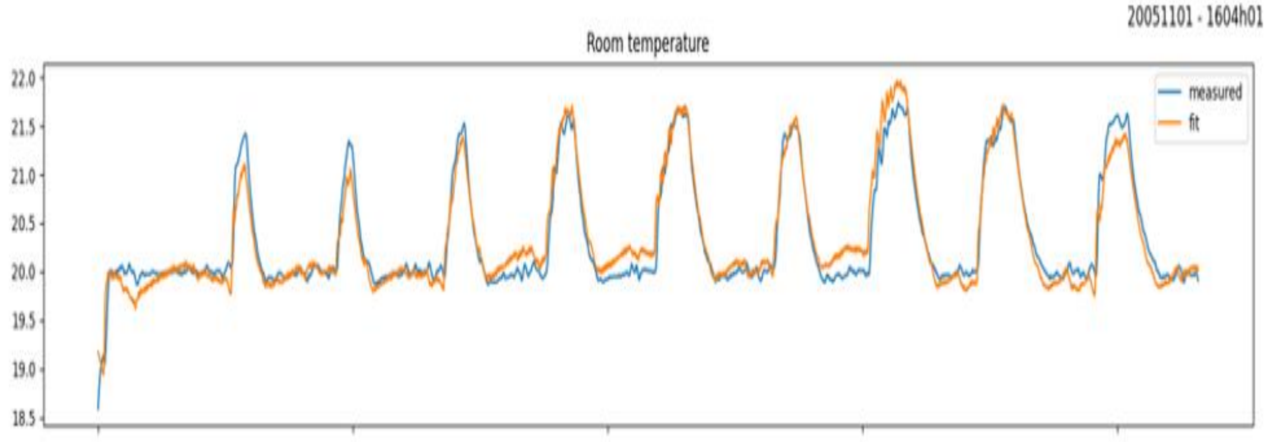
- Lumped model (5 parameters)
  - Heat flow indoor to building envelope (1)
  - Heat flow envelope to outside (2)
  - Solar radiation through windows (3)
  - Total heat supply from radiators
  - Heat capacity living room (4)
  - Heat capacity building envelope (5)
  - Indoor temperature predicted
  - So called 2R-2C model
- Model calibrated to 2 cold 10-day periods and verified on 3rd 10-day period
  - Successful calibration in 187 dwellings
  - Insufficient cold periods this winter



Source: Bacher, Madsen (2011), Identifying suitable models for the heat dynamics of buildings, J. Energy and Buildings 43, 1511-1522



Method for reduced design supply temperature

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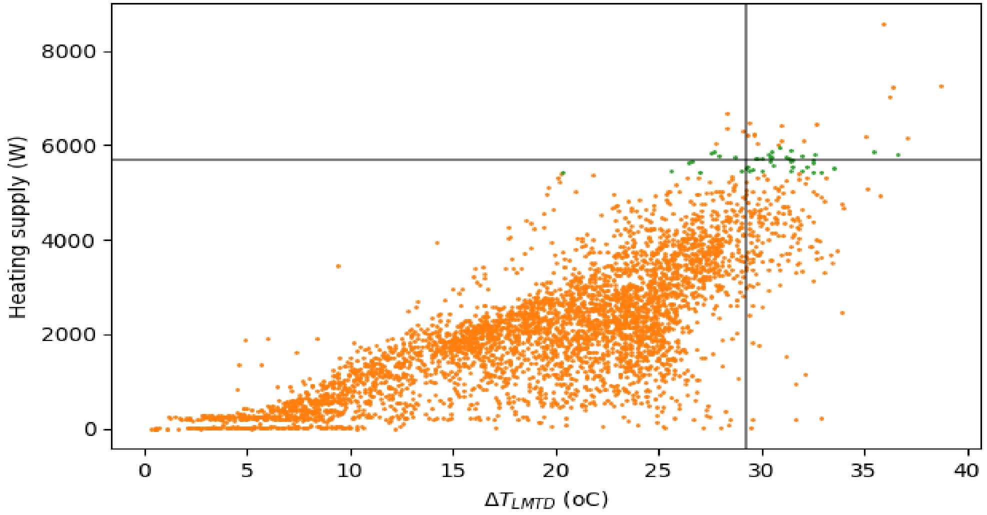
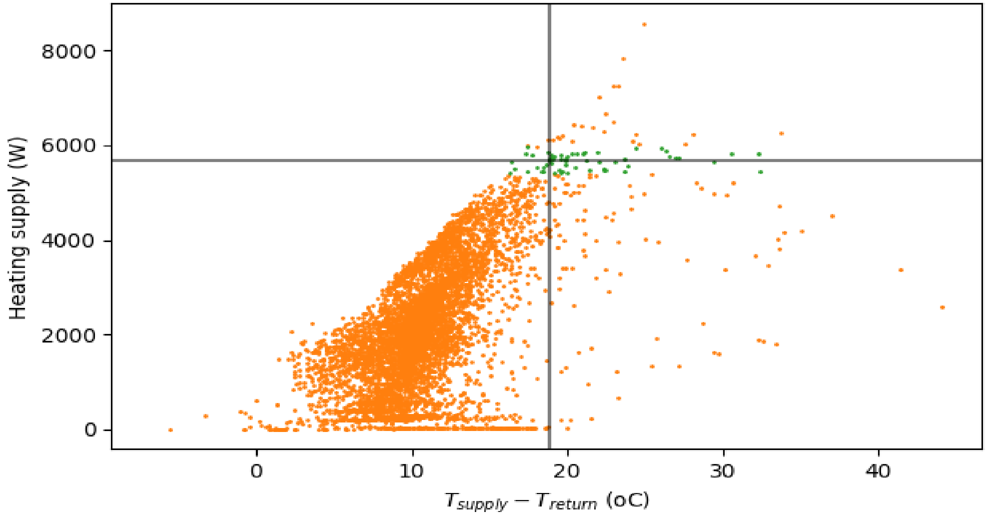
- Design condition: -10 °C ambient, no solar radiation, +20 °C indoor
  - Daily average condition
- Determine design heat demand Q_d (W) from calibrated model
  - Assuming 18 full load hrs on design day
  - See horizontal lines
- Determine ΔT_{LMTD} and ΔT_{sys} to reach Q_d (kW)
  - Select hourly averaged data points around Q_d
  - Determine 25-percentile in radiator ΔT_{LMTD} at Q_d
  - Determine 25-percentile in van system ΔT_{sys} at Q_d
  - No assumptions required, fully data-driven method





Determination of reduced design supply temperature

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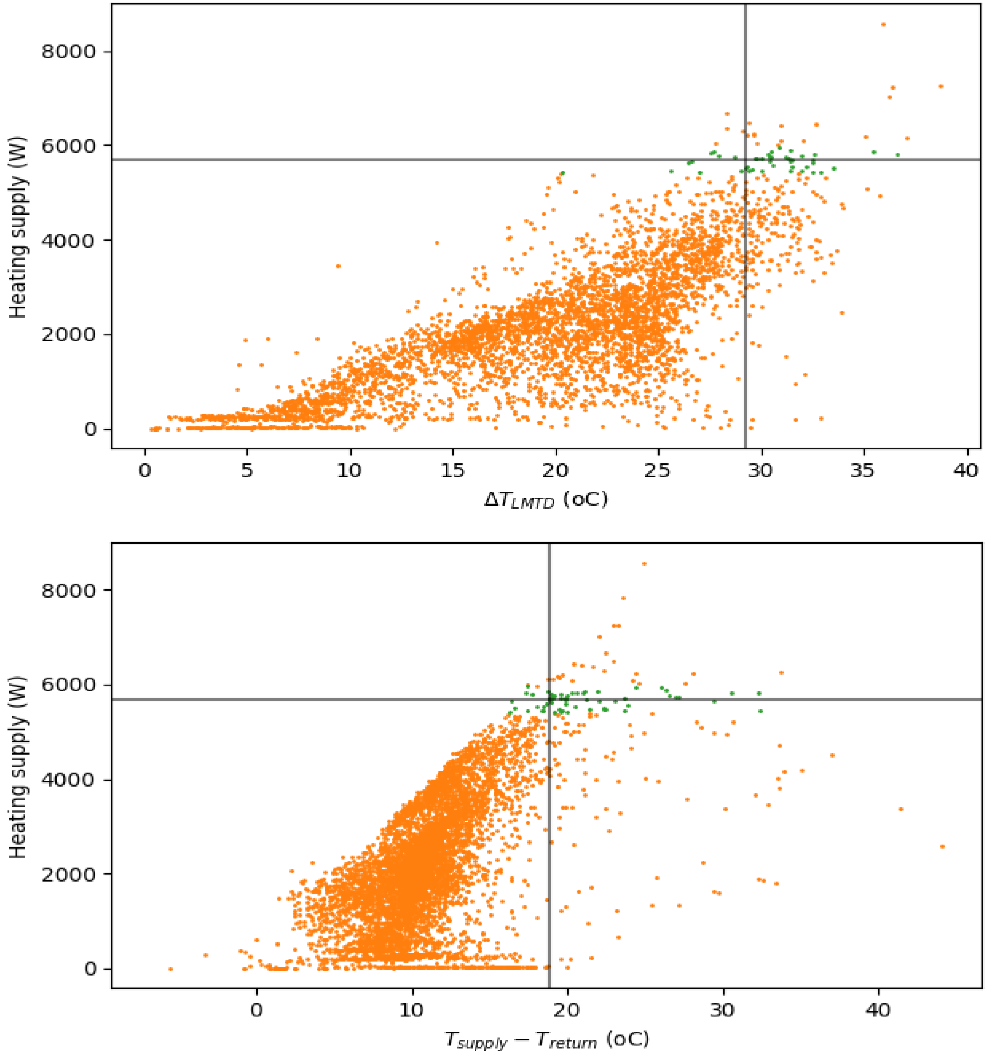
- Given $\Delta T_{LMTD,d}$ *and* $\Delta T_{sys,d}$, reduced design supply temperature

$$T_{s,d} - T_i = \frac{\Delta T_{sys,d}}{1 - e^{-\left(\frac{\Delta T_{sys,d}}{\Delta T_{LMTD,d}}\right)}}$$

$$T_{r,d} = T_{s,d} - \Delta T_{sys,d}$$

- Example dwelling: $T_{s,d}$ =59.7 °C; $T_{r,d}$ =40.8 °C



Is our building sample representative? (1/2)

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Period	Detached	Corner	Terraced	Apartement	Total
After 1991	7/8	11/10	17/16	9/12	**44/46**
1974–1991	6/5	20/13	25/21	14/14	**65/53**
Before 1974	19/16	28/24	32/28	32/53	**111/121**
Total	**32/29**	**59/47**	**74/65**	**55/79**	**220/220**

- Apartements underrepresented
- Distribution over construction periods reasonably close

Specific heat demand representative? (2/2)

Type	Construction Period	Specific heat demand SH. Source: SDE (PNH), CBS (kWh/m²/yr)	Specific heat demand in sample (kWh/m²/yr)
Single family	After 1991	54	105
	1974–1991	75	109
	Before 1974	97	93
Apartement	After 1991	45	92
	1974–1991	70	100
	Before 1974	92	105

- Our sample has larger Spec. Heat demand than average
- Specific heat demand is based on 2021 data
  - KNMI De Bilt 2804 °C*days
  - KNMI Deelen 2976 °C*days
  - +/- 150 °C*days colder than average
- Average construction year is 1998 in category "After 1991"

- Reasonably representative sample

Key results for design condition

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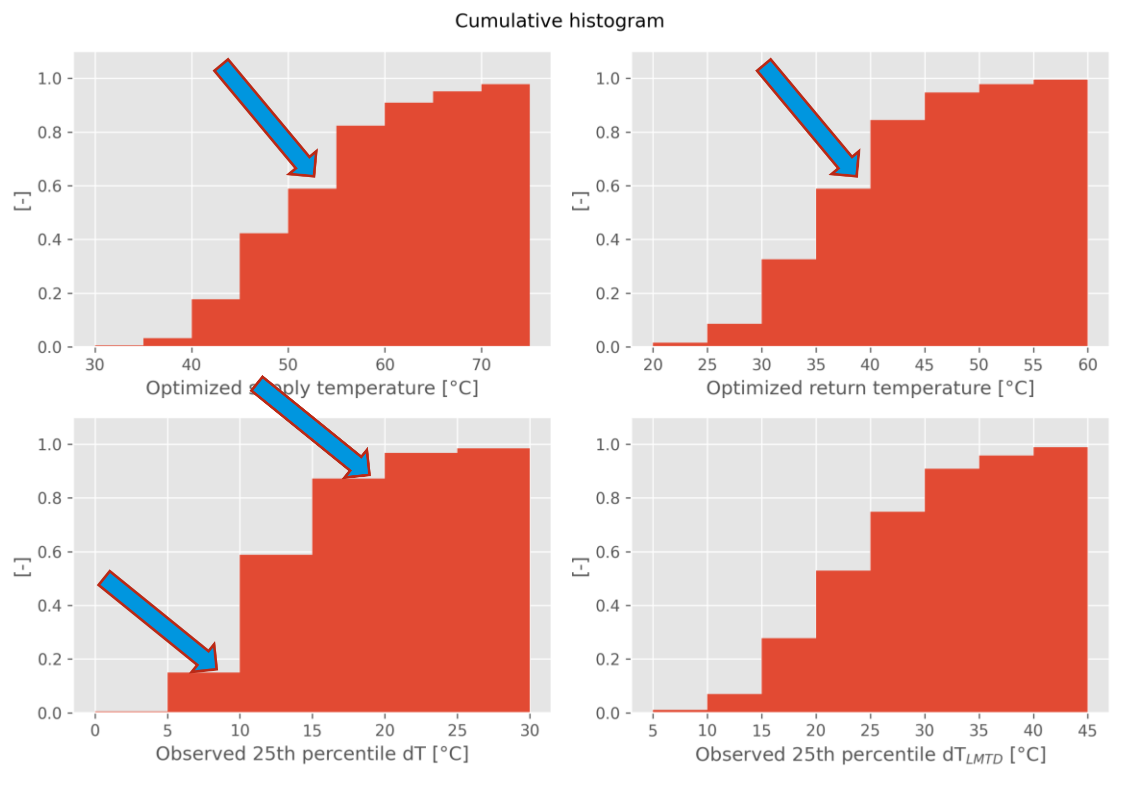
- In 60% buildings T_s < 55 °C (LT-ready)
  - In 80% buildings T_s < 60 °C
  - In 95% buildings T_s < 70 °C
- In 60% woningen: T_r < 40 °C
- In 70% woningen: 10 °C < $T_s - T_r$ < 20 °C
- Only 15% with $T_s - T_r$ > 20 °C



Which 60% of buildings is LT-ready?

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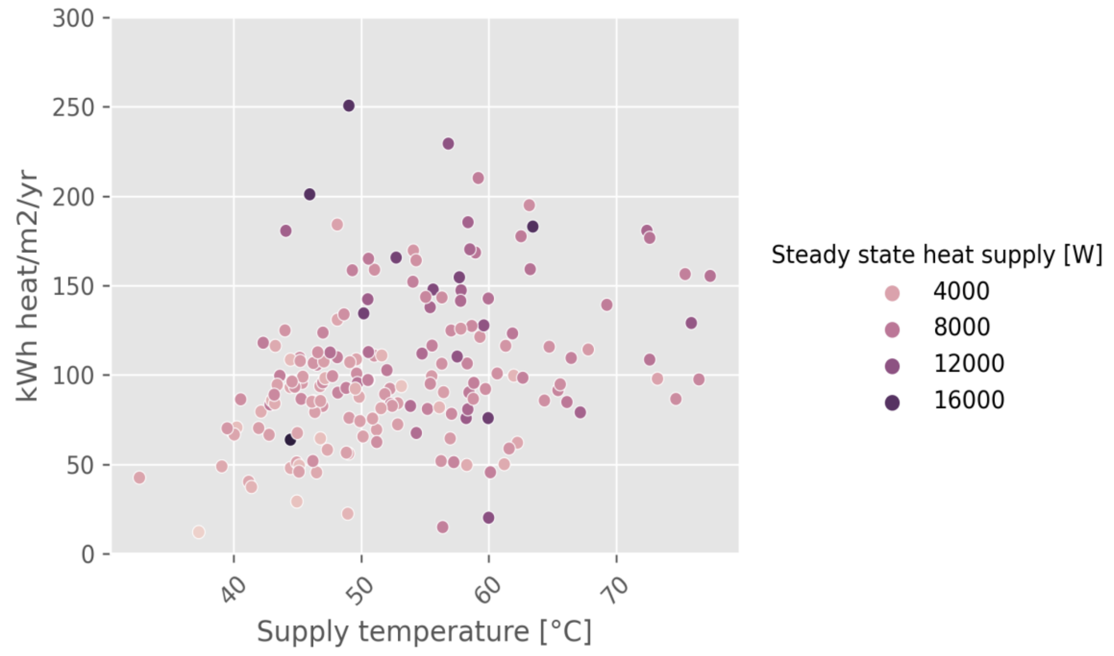
- Correlations show that T_s **NOT** related to:
  - Construction period
  - Building type
  - Specific demand space heating

- To do
  - Correlate dimensionless radiator capacity (Q_d / $Q_{installed}$) or oversizing factor to reduced design supply temperature



Further research

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- Extend monitoring campaign to next winter due to mild winter
  - Assess thermal comfort experience in cold ambient conditions
- Quantify minimum supply and return temperature at part-load conditions
- Direct gas savings due to reduced supply temperature
  - Ongoing project with HvA
- 200 calibrated building models
  - Explore flexibility potential during heating season using available thermal mass

Take-away messages

- “Meten is weten” (measure to understand)
- LT (<55°C)-heating requires peak shaving operation
- 60% building stock NL is LT-ready

- Acknowledgements
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