Temperature reduction in existing DH substations: issues and case studies

Sweet DeCarbCH lunch talk, 8th February 2022

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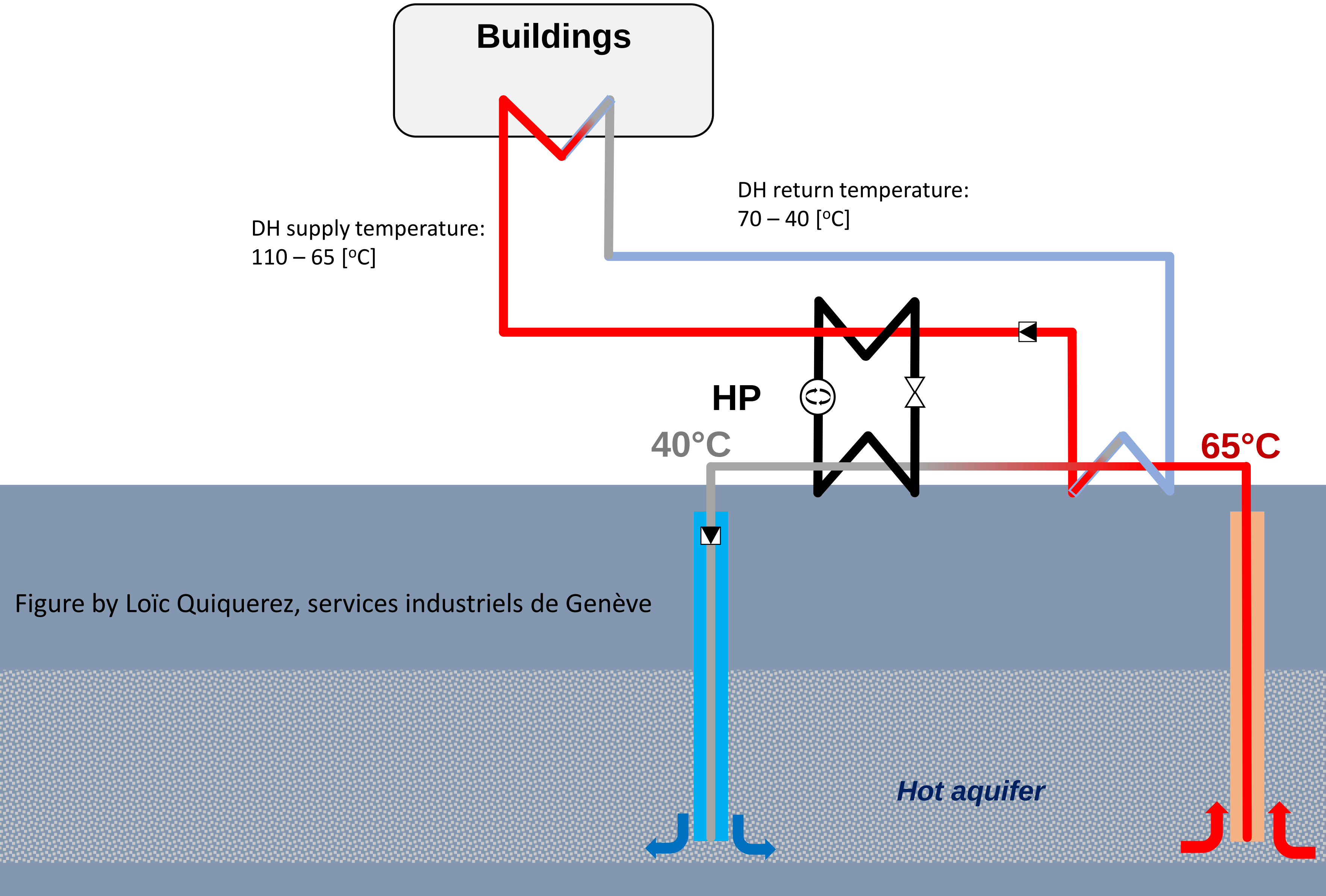
Content

- Benefits of lowering DH temperature in the context of renewable heat
- Benchmark of several DH networks in Switzerland and Denmark
- Possible strategies to lower DH temperatures
- Case study: a low temperature DH network in Geneva
- Conclusions

Benefits of lowering DH temperature in the context of renewable heat

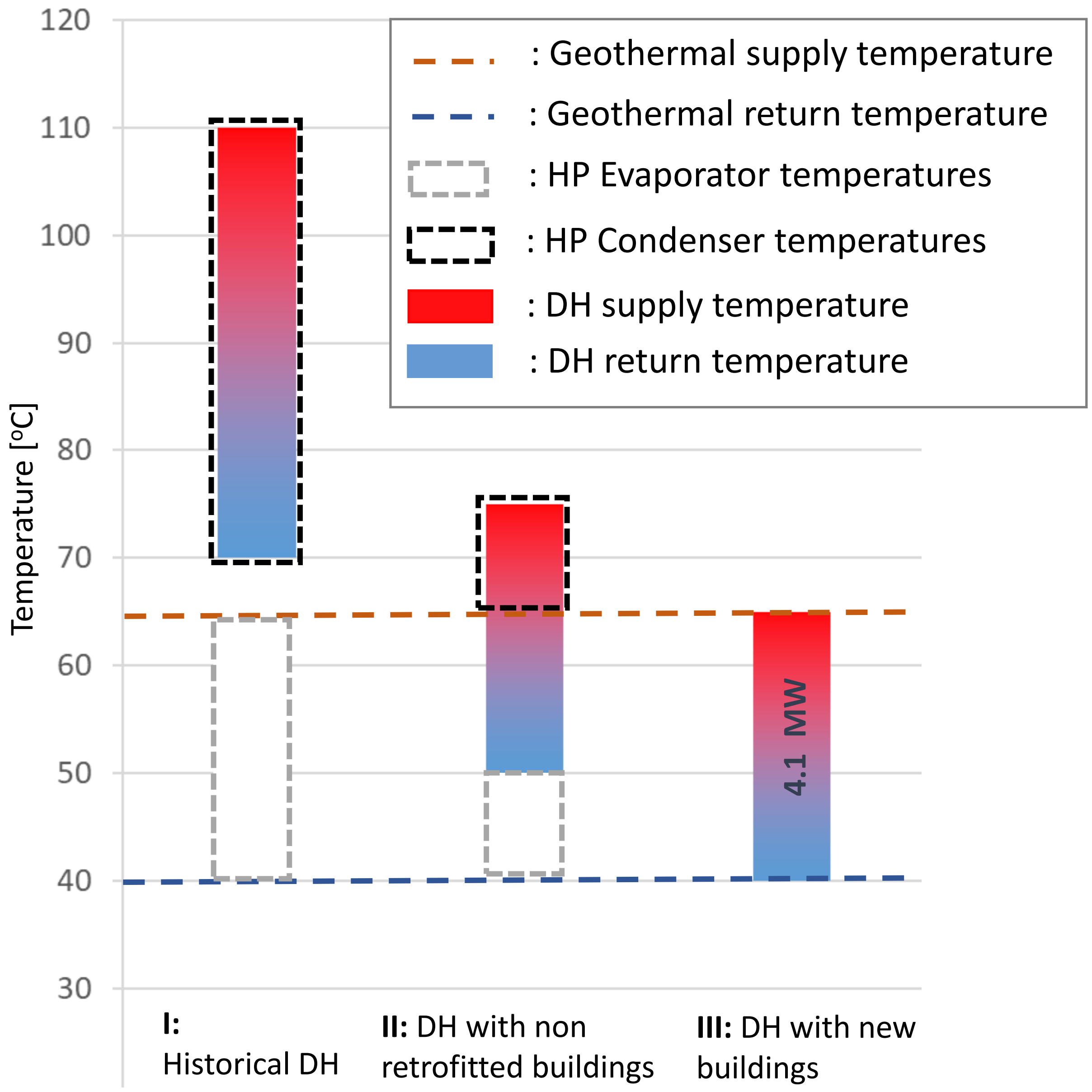
Example 1: using geothermal heat in the context of district heating



- Geothermal supply temperature: 65 [°C]
- Flow 40 [l/s]
- Available power with ΔT = 25 [°C] : 4.1 MW

Figure by Loïc Quiquerez, services industriels de Genève

Benefits of lowering DH temperature in the context or renewable heat

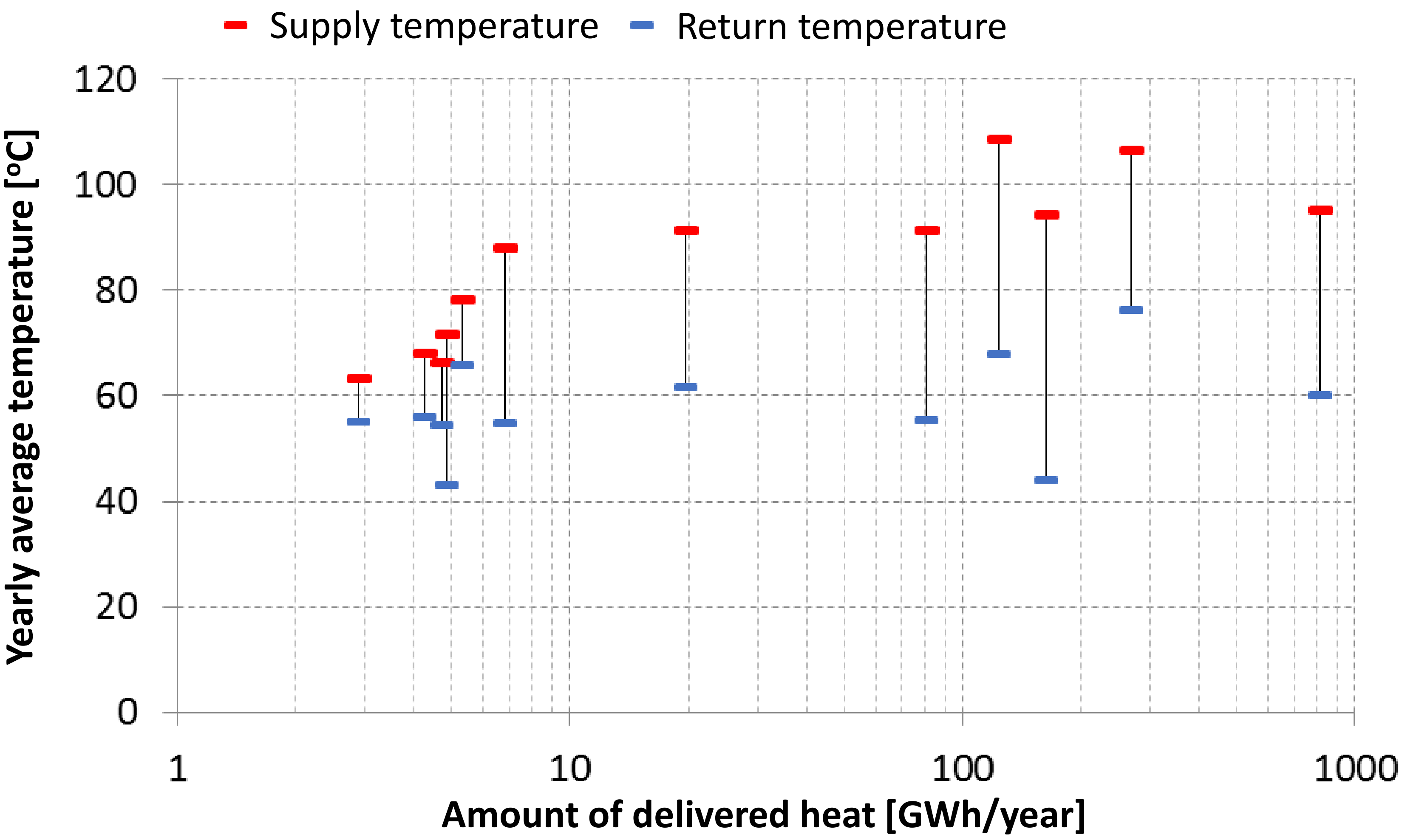


- **Case I**: full heat pump assistance (high electric demand)
- **Case II**: partial heat pump assistance (medium electric demand)
- **Case III**: direct use (low electric demand)

Original figure by Loïc Quiquerez, services industriels de Genève

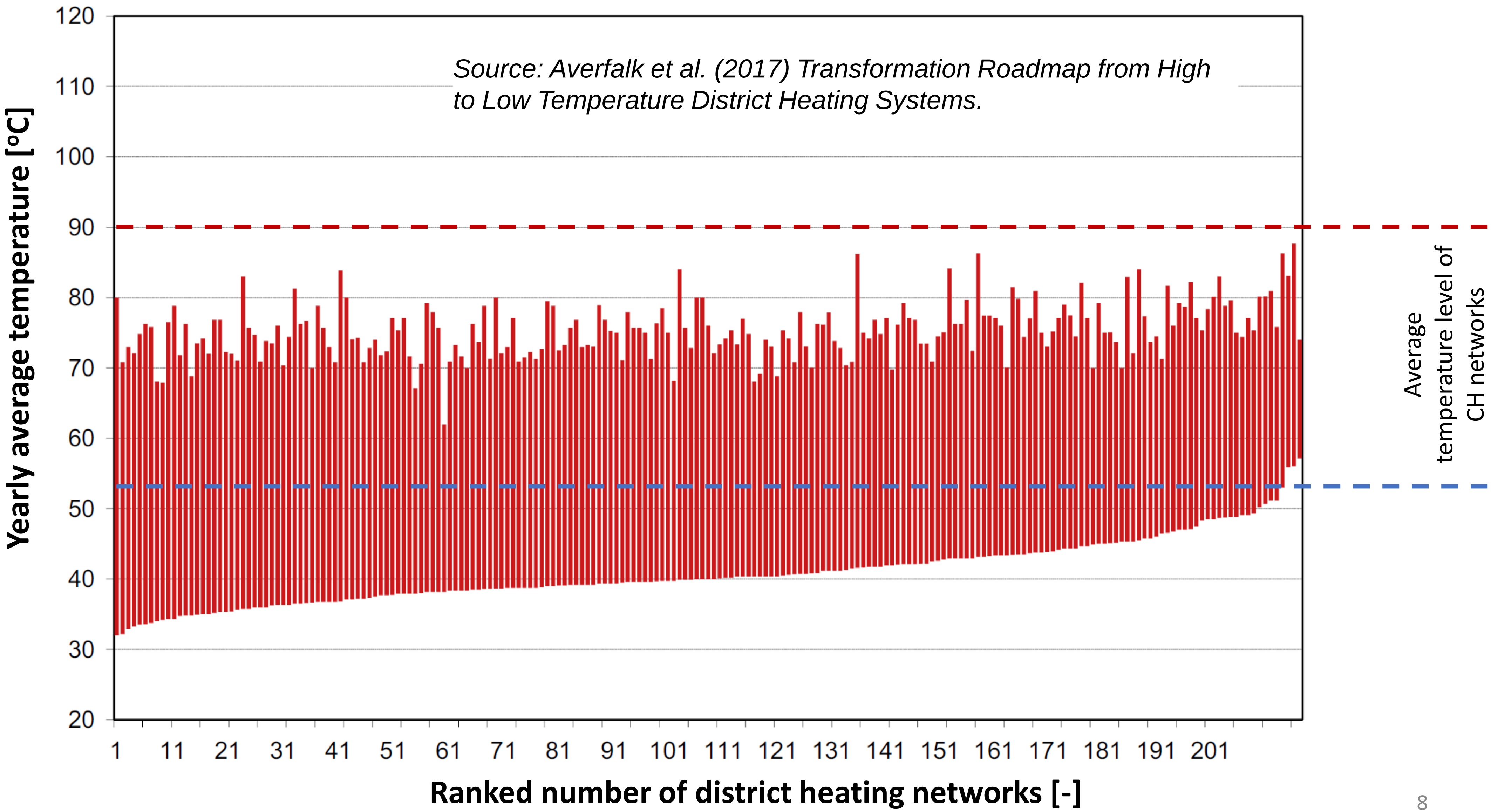
Benchmark of several DH networks in Switzerland and Denmark

A benchmark of DH network temperatures in Switzerland



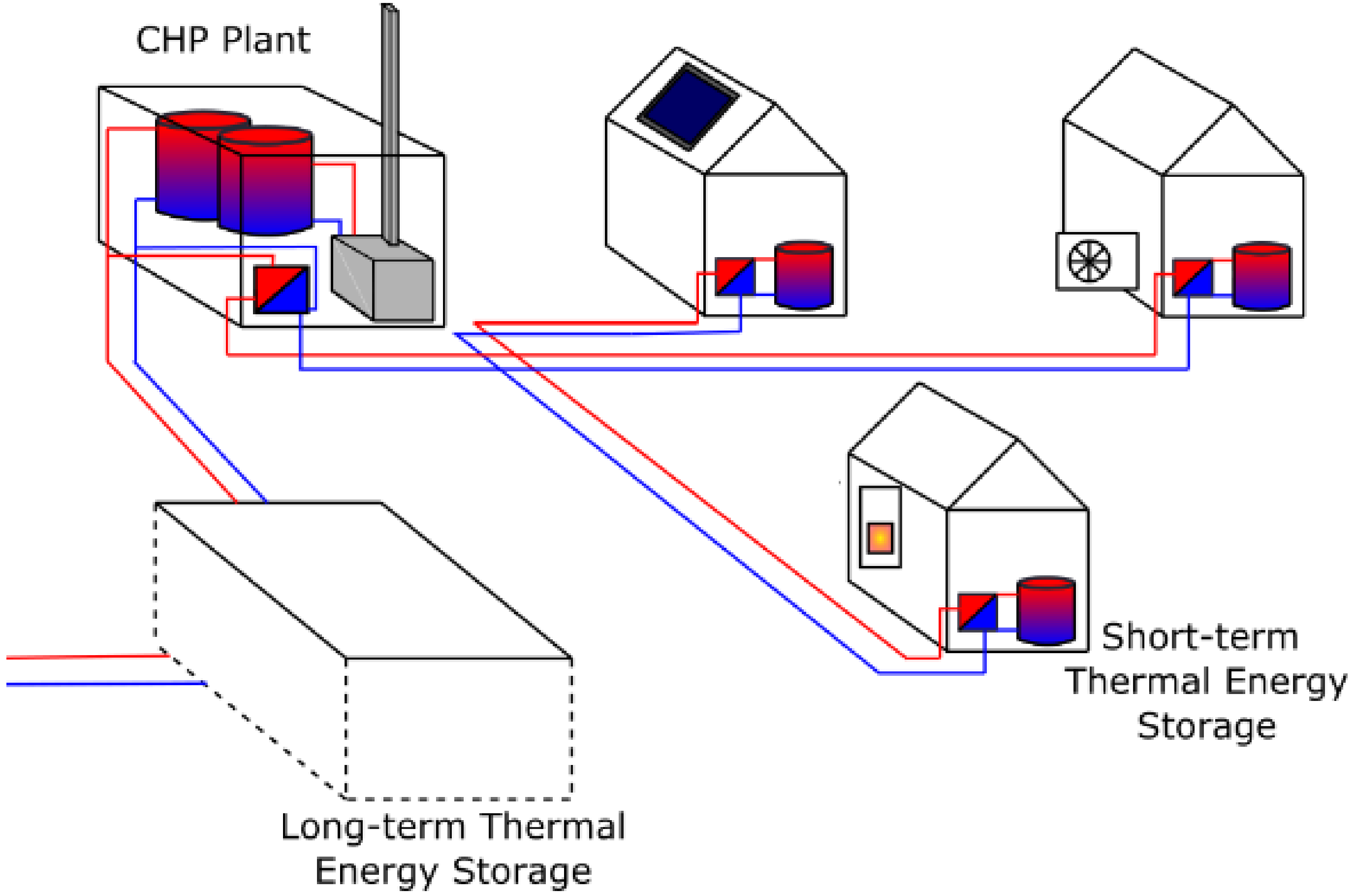
Source: Quiquerez (2017) Décarboner le système énergétique à l'aide des réseaux de chaleur: état des lieux et scénarios prospectifs pour le canton de Genève. Available at: https://archive-ouverte.unige.ch/unige:93380

A benchmark of DH network temperatures in Denmark



Possible strategies to lower DH temperatures

The general principles



What you do control:

supply temperature

- For space heating, 40 to 60 [^{o}C] are required depending on the building type
- For domestic hot water, 65 to 70 [^{o}C] are required (in case of DHW storage)

What you do not control:

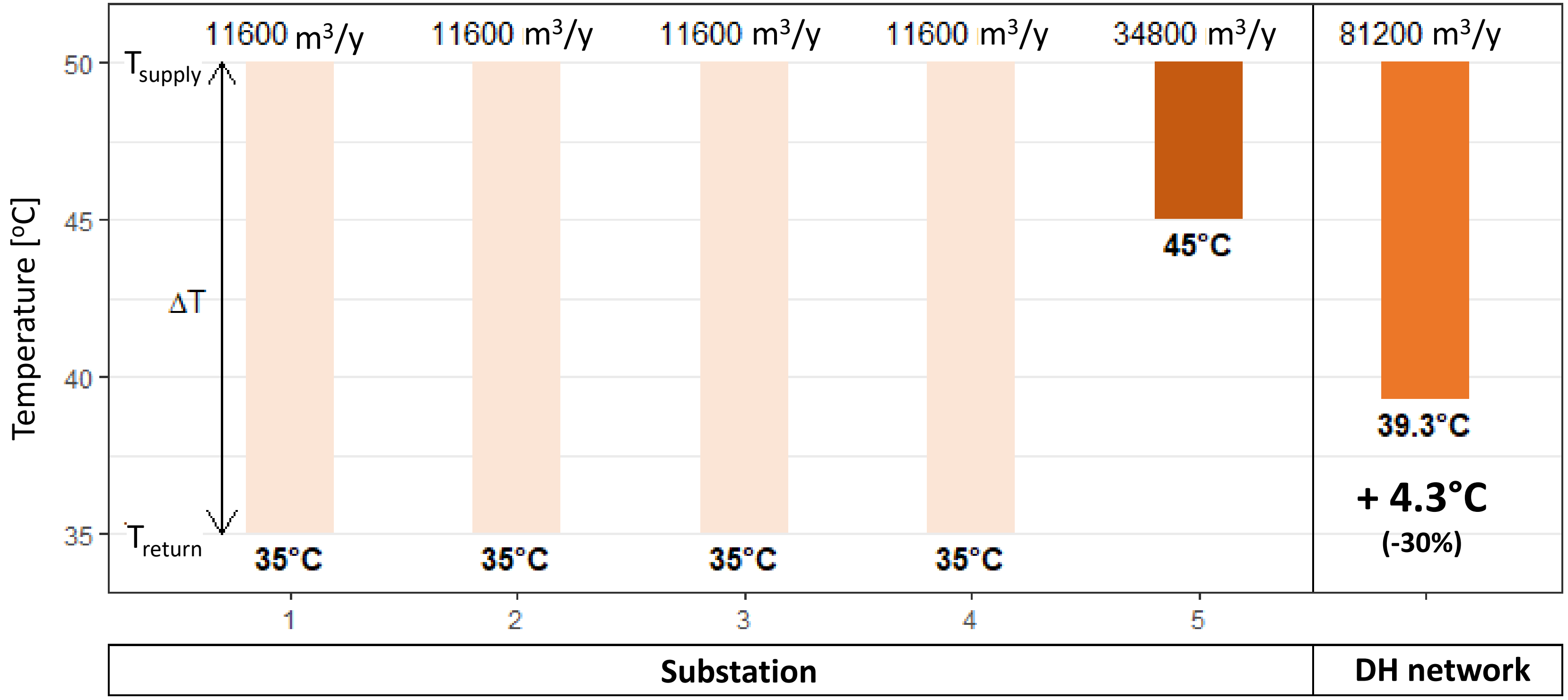
return temperature

- Substation architecture
- Heat exchanger efficiency
- Hydraulic regulation of heat distribution system of the building

Identifying problematic buildings contributing to high return temperatures

Example :

- DH supply temperature = 50°C
- 5 substations : 4 «good» users (ΔT = 15°C) and 1 «bad» user (ΔT = 5°C)
- All buildings have same yearly heat demand: 200 MWh/an



Identifying problematic buildings: a simple Excel tool

- **DH planification guide** (Chapter 10), Office fédéral de l'énergie OFEN, Berne 2018 (www.qmchauffageadistance.ch)
- Goal : analyse and optimise the DH substations

Analyse des consommateurs de chaleur

QM Fernwärme

Droits d'auteur : Verenum, Langmauerstrasse 109, CH-8006 Zürich
Version : 3.3 (Mai 2020)
Décharge de responsabilité : Toute responsabilité concernant l'application et l'exactitude est exclue.

Sprache/Langue/Langı Français

Cellule d'entrée pour la valeur ou la formule
Valeur de calcul
* Le nombre d'heures de fonctionnement à pleine charge est extrapolé vers le haut ... période d'évaluation est courte, plus l'erreur de calcul est importante.
** t se réfère à la période d'observation définie.

Hypothèses et situation initiale

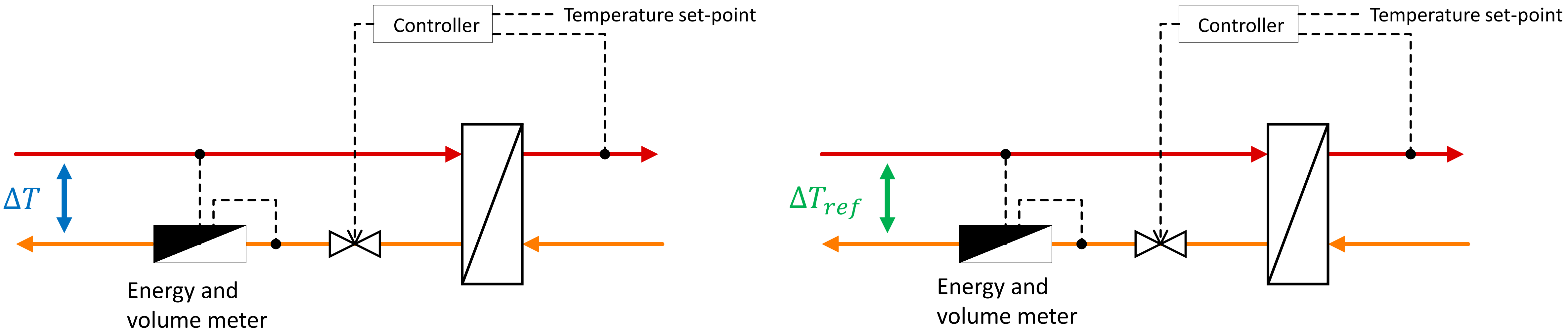
Différence de température de référence	K	30	
Capacité thermique spécifique	kJ/(kg K)	4.185	
Densité de l'eau	kg/m^3	980	
Période d'évaluation			
Début	Date	31.01.2016	
Fin	Date	30.05.2016	
Nombre de jours	d	120	
Nombre d'heures	h	2880	
Demande totale de chaleur / Vente totale de chaleur	kWh/t**	1 848 043	Demande totale de chaleur / Vente totale de chaleur de tous les clients. L'entrée de furmula est possible.
Volume total d'eau	m^3/t**	63 853	Volume d'eau total de tous les clients de chaleur. Possibilité d'introduire des furmula.
Différence de température moyenne	K	25.4	

Numéro de client	Description du client	Capacité thermique contractuelle (puissance connectée)	Quantité de chaleur	Volume d'eau	Heures de fonctionnement à pleine charge*	Consommation d'eau supplémentaire	Différence de température moyenne	Classement	Influence sur la température de retour primaire	Classement	Consommation d'eau supplémentaire pondéré
–	–	kW	kWh/t**	m^3/t**	h/a	m^3/t**	K	–	°C	–	m^3/(t** K)
20	Wärmeabnehmer/Consommateur/Heat custom	375	299 890	12 563	2 432	3 788.51	21.0	1	1.6	3	180.81
19	Wärmeabnehmer/Consommateur/Heat custom	275	157 535	7 863	1 742	3 253.68	17.6	2	1.4	2	185.01
30	Wärmeabnehmer/Consommateur/Heat custom	18	15 412	2 547	2 604	2 096.06	5.3	3	0.9	1	394.63
43	Wärmeabnehmer/Consommateur/Heat custom	65	60 787	2 398	2 845	618.93	22.3	4	0.2	4	27.81
29	Wärmeabnehmer/Consommateur/Heat custom	75	81 245	2 774	3 295	397.15	25.7	5	0.2	5	15.45
33	Wärmeabnehmer/Consommateur/Heat custom	31	27 976	1 144	2 745	325.35	21.5	6	0.1	6	15.16
38	Wärmeabnehmer/Consommateur/Heat custom	141	127 429	4 015	2 749	286.85	27.9	7	0.1	8	10.30
27	Wärmeabnehmer/Consommateur/Heat custom	30	33 210	1 256	3 367	284.41	23.2	8	0.1	7	12.26
39	Wärmeabnehmer/Consommateur/Heat custom	61	63 688	2 074	3 176	210.55	27.0	9	0.1	10	7.81
15	Wärmeabnehmer/Consommateur/Heat custom	30	23 597	892	2 392	201.58	23.2	10	0.1	9	8.68
9	Wärmeabnehmer/Consommateur/Heat custom	51	41 122	1 394	2 453	190.71	25.9	11	0.1	11	7.36

Identifying problematic buildings: a simple Excel tool

- Required data to make the analysis:
  - ✓ For each substation: **heat demand** (Q in kWh) et **total DH flow volume** (V en m^3)
  - ✓ A target optimized value for difference between supply and return temperatures (ΔT_{ref} en °C)
- Method : compare the real (V) et optimized (V_{ref}) volume and temperature differences

$$Q = V \cdot \rho \cdot C_p \cdot \Delta T = V_{ref} \cdot \rho \cdot C_p \cdot \Delta T_{ref}$$



Identifying problematic buildings: a simple Excel tool

Annahmen und Ausgangslage

Referenz-Temperaturspreizung	K	15
spez. Wärmekapazität	kJ/(kg K)	4.185
Dichte Wasser	kg/m^3	980
Beurteilungsperiode		
Start	Datum	01.01.2021
Ende	Datum	31.12.2021
Anzahl Tage	d	364
Anzahl Stunden	h	8736
Gesamte Wärmemenge	kWh/t**	1'000'000
Gesamte Wassermenge	m^3/t**	81'800
mittlere Temperaturspreizung	K	10.7

Input

ΔT_{ref}

Q V

$$\Delta V = V - V_{ref} \quad with \quad V_{ref} = \frac{Q}{\Delta T_{ref} \cdot \rho \cdot C_p}$$

$$\Delta T = \frac{Q}{V \cdot \rho \cdot C_p}$$

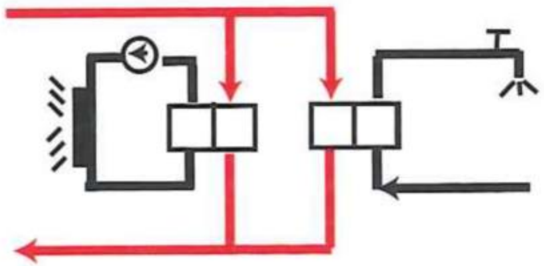
Influence on DH return temperature

Output

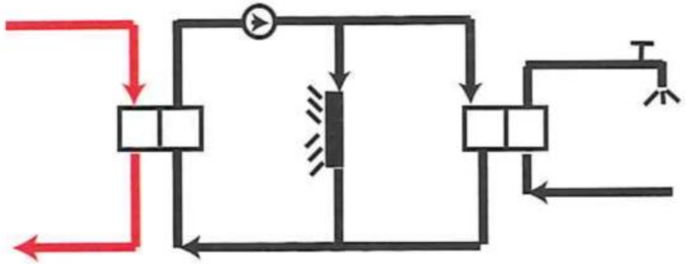
Kunden Nummer	Kunde Beschreibung	abonnierte Leistung (Anschlussleistung)	Wärmemenge	Wassermenge	Vollbetriebsstundenzahl*	Mehrverbrauch	Mittlere Temperaturspreizung	Klassierung	Einfluss auf primäre Rücklauftemperatur
–	–	kW	kWh/t**	m^3/t**	h/a	m^3/t**	K	–	°C
1	Optim SST 1	80	200'000	11'700	2'507	50.76	15.0	2	0.0
2	Optim SST 2	80	200'000	11'700	2'507	50.76	15.0	2	0.0
3	Optim SST 3	80	200'000	11'700	2'507	50.76	15.0	2	0.0
4	Optim SST 4	80	200'000	11'700	2'507	50.76	15.0	2	0.0
5	Prob SST SST 5	80	200'000	35'000	2'507	23'350.76	5.0	1	4.3

Rank 1: primary target for action

Identifying causes for high return temperatures: SST architecture



D: Indirect space heating & closed hot water supply

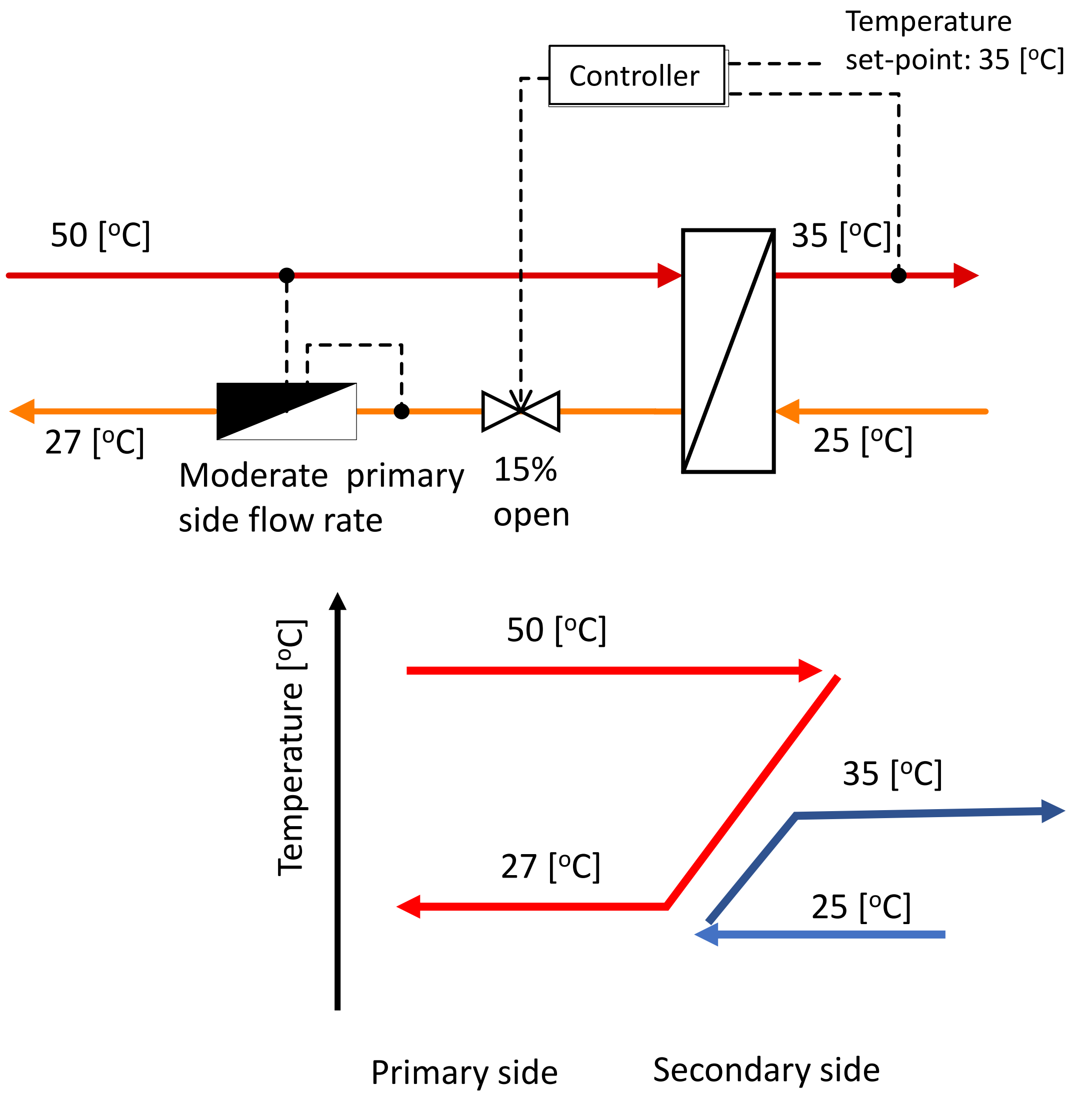


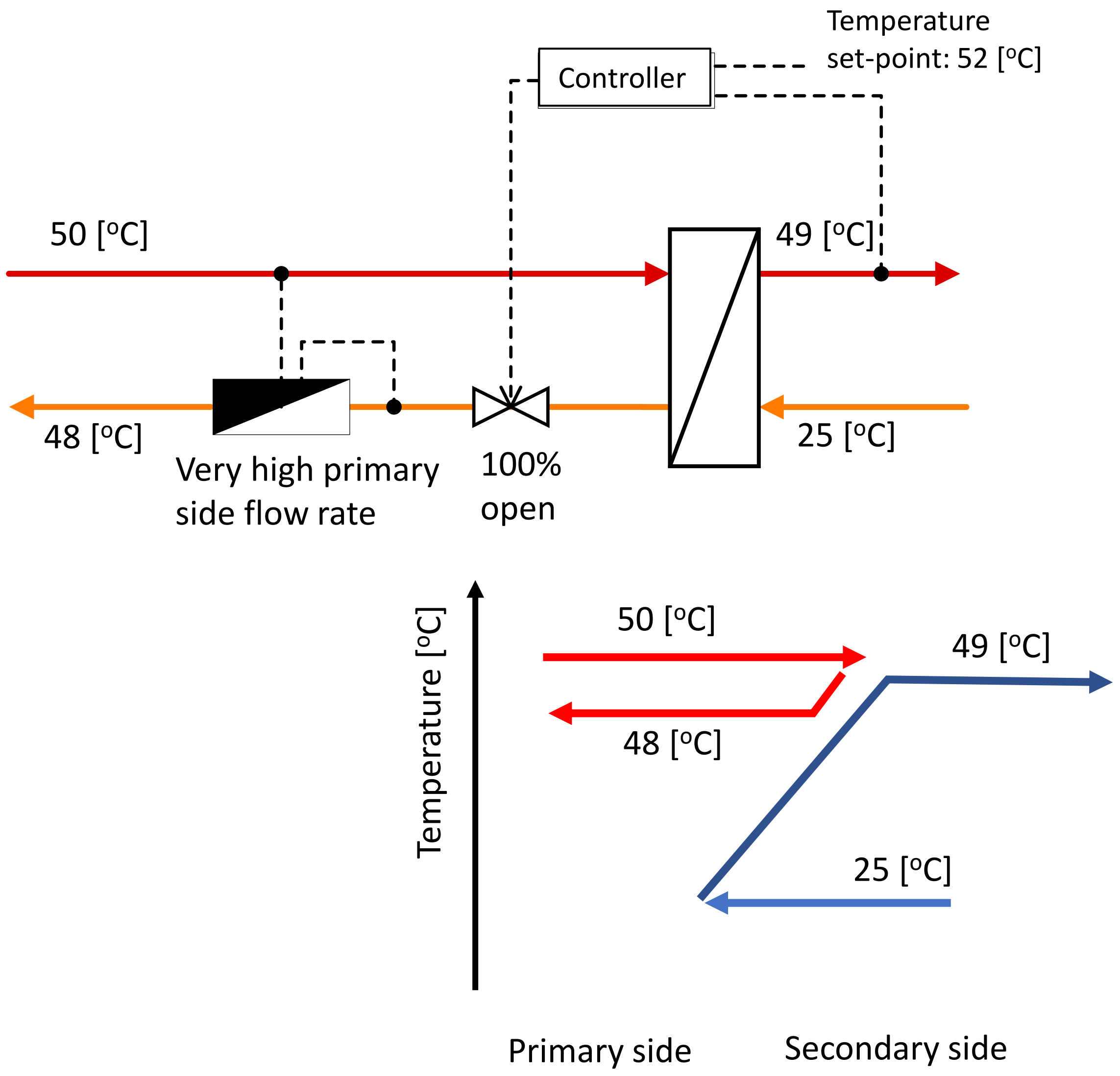
E: Intermediate space heating circuit

- D: Parallel design for space heating and domestic hot water
- E: Two heat exchangers in series for highest temperature level (domestic hot water). May be problematic concerning temperature levels

Illustrations from: S. Frederiksen, S. Werner, District heating and cooling

Identifying causes for high return temperatures: SST regulation issues





Identifying causes for high return temperatures: SST issue summary

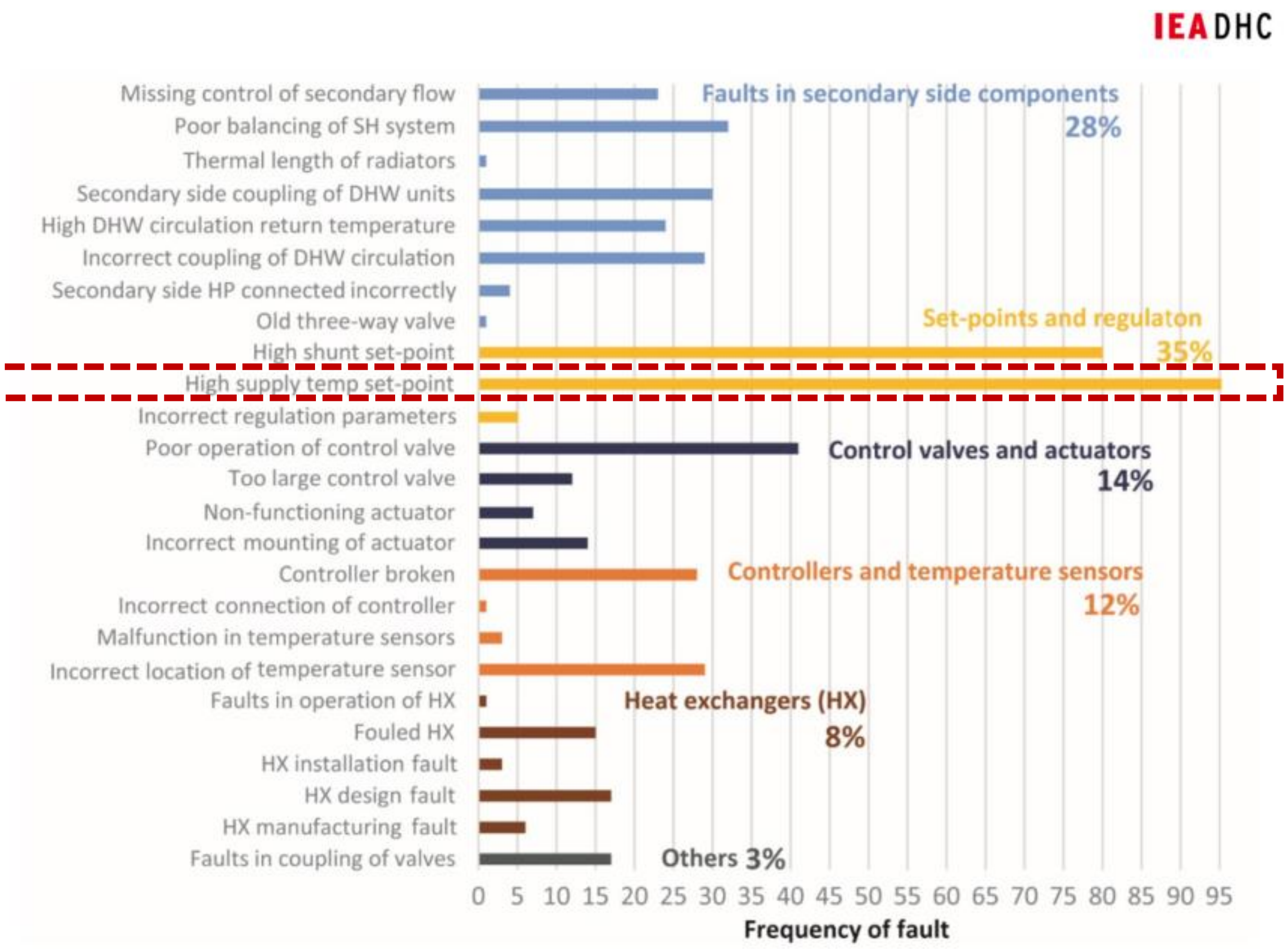


Figure 26. Categorization of 520 faults identified in 246 Swedish substations with high return temperatures. The figure is based on Figure 10.21 in Frederiksen & Werner, 2013, which has been updated based on personal communication.

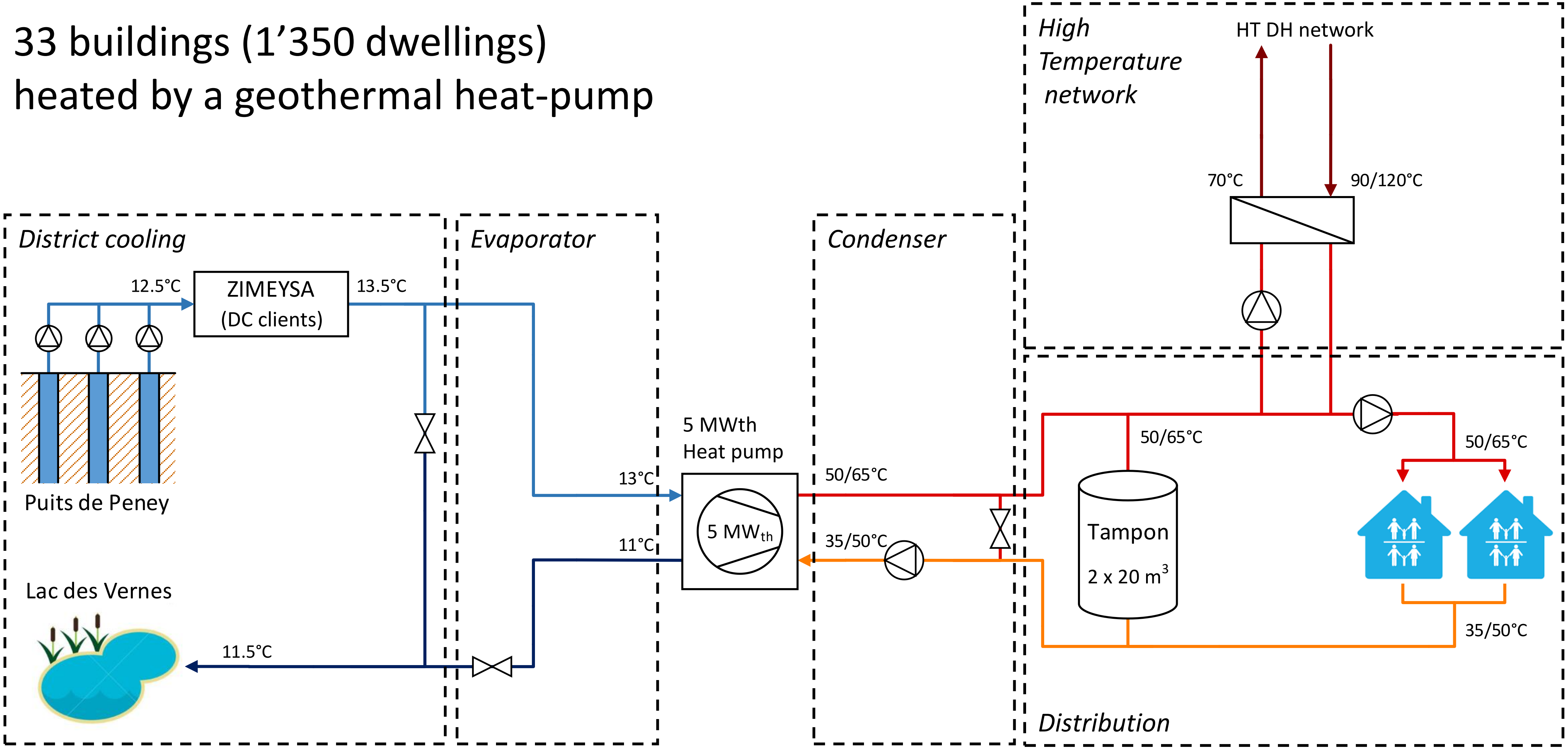
Summary of possible faults responsible for high return temperatures

IEA DHC
Annex TS2 Implementation of Low-Temperature District Heating Systems. Final report

Case study: a low temperature DH network in Geneva

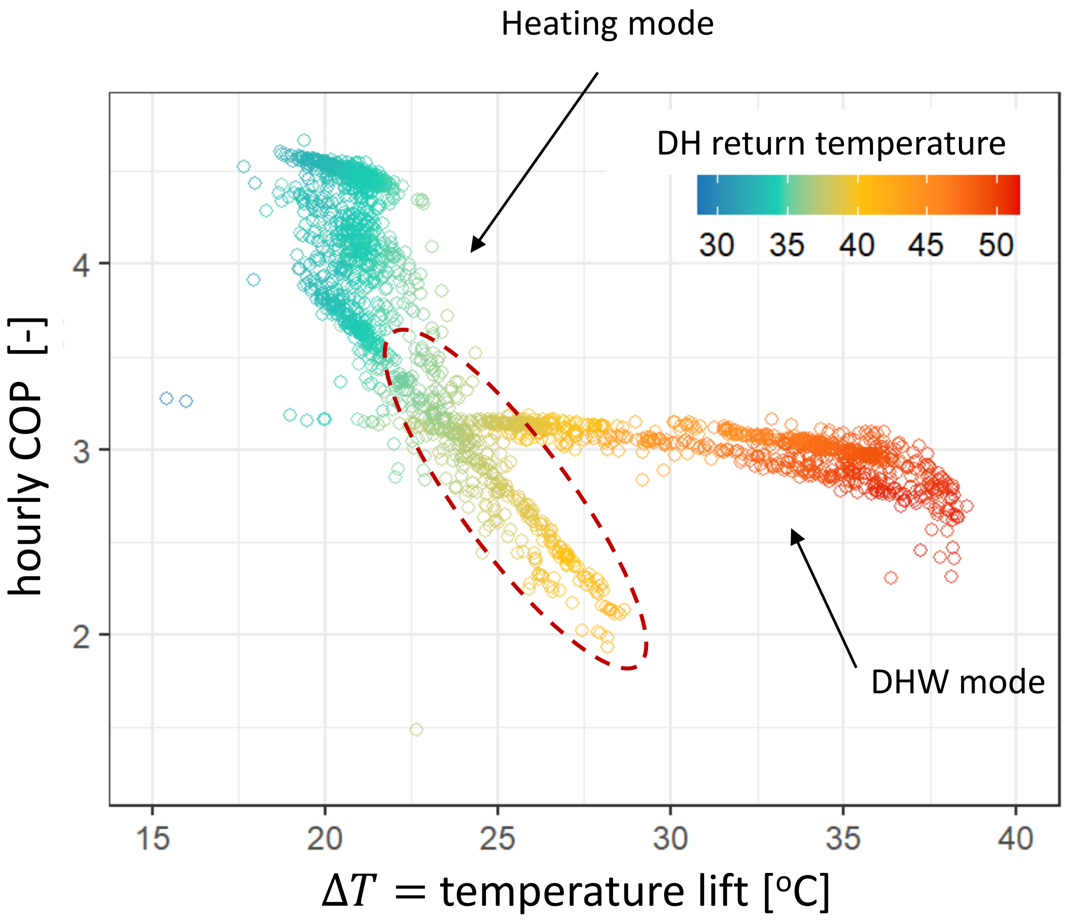
Case study: district heating “Les Vergers” in Geneva

33 buildings (1’350 dwellings) heated by a geothermal heat-pump



Report: S. Schneider, P. Brischoux, D. Santandrea, P. Hollmuller, Retour d’expérience énergétique sur le quartier des Vergers à Meyrin (Genève) - Rapport intermédiaire, Genève, 2020. https://archive-ouverte.unige.ch/unige:147702.

Example 2: optimizing the COP of a shallow geothermal heat pump



- High return temperatures in heating mode lead to a drop of the heat pump COP
- May also the cause of forced shut down to protect the heat pump

Ref: rapp intermédière

Case study: district heating "Les Vergers" in Geneva

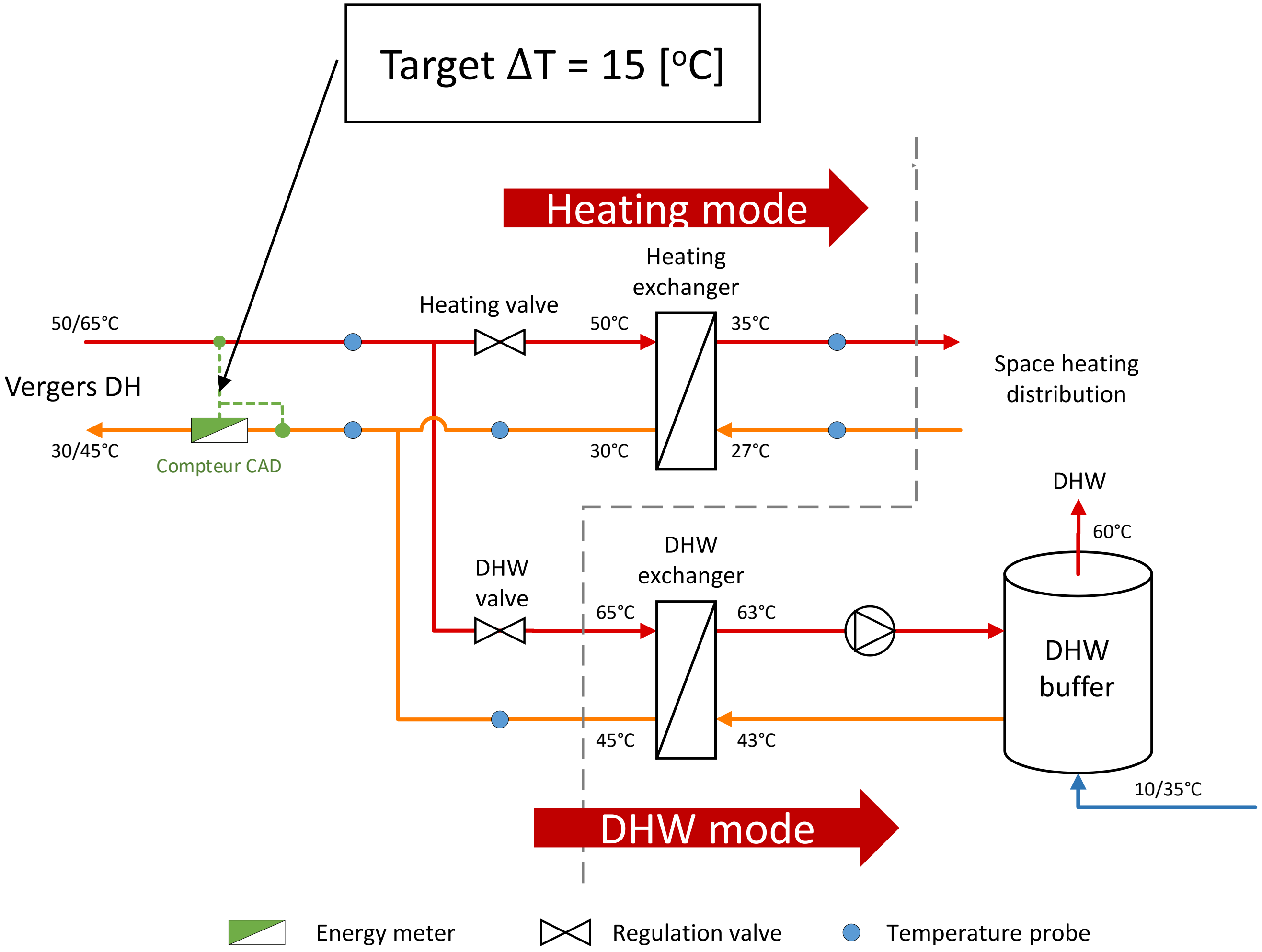
Method :

- Compute **average return temperatures [°C]** (weighted by the flow rate) on primary side of each SST
- Compute **heat demand (kWh)**

Hypotheses :

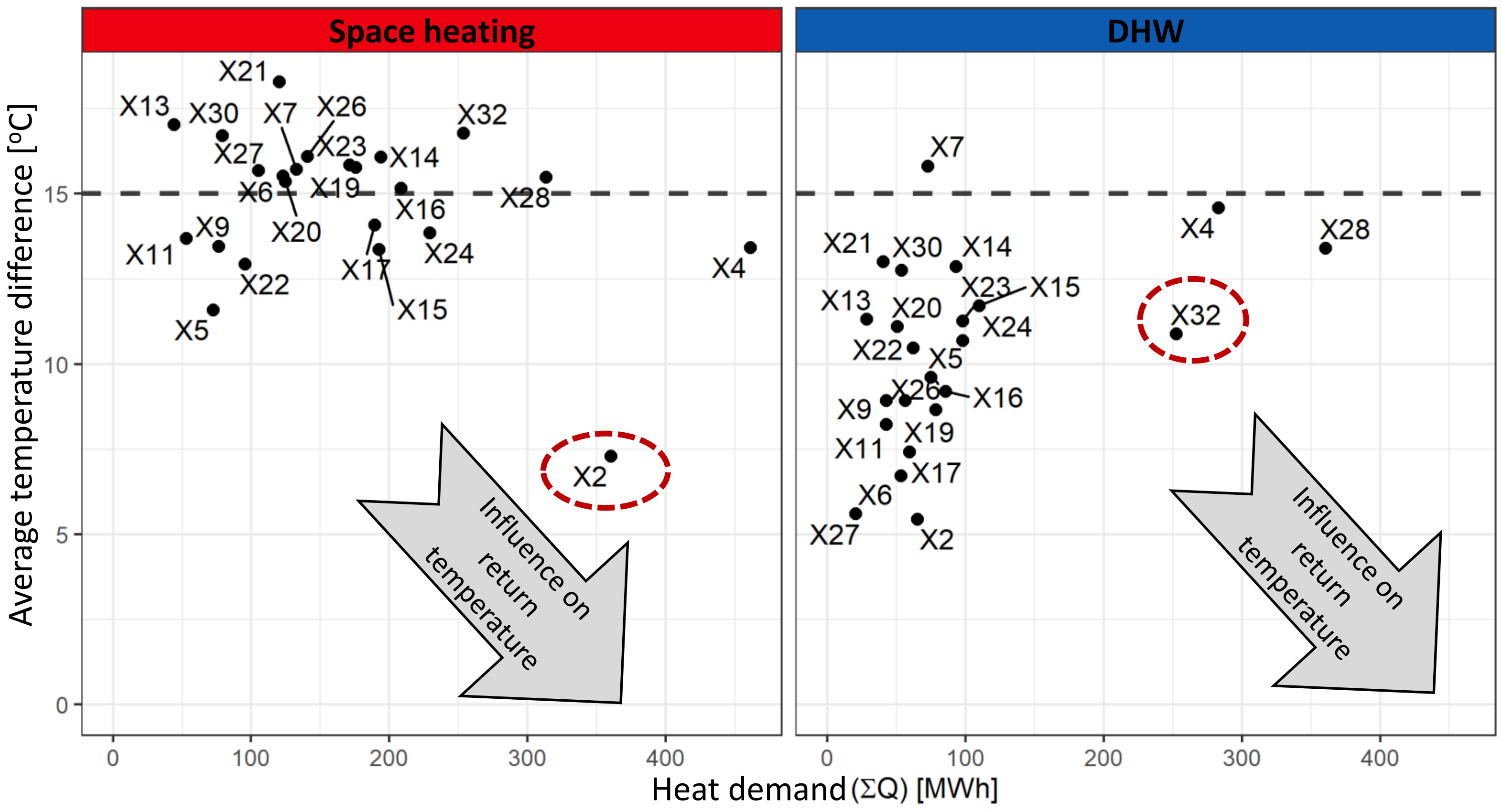
- Target temperature differences between supply and return of **15°C** (i.e. 50/35 [°C] for space heating and 65/50 [°C] for DHW)
- Time of DHW batches : 5h00 to 7h10 (AM and PM)

Period of analysis : from 1er October 2020 to 1er October 2021



Case study: Average temperature difference and delivered heat

Temperature difference and annual heat demand by operation mode (space heating and DHW batch)
Period : 2020-10-01 to 2021-10-01

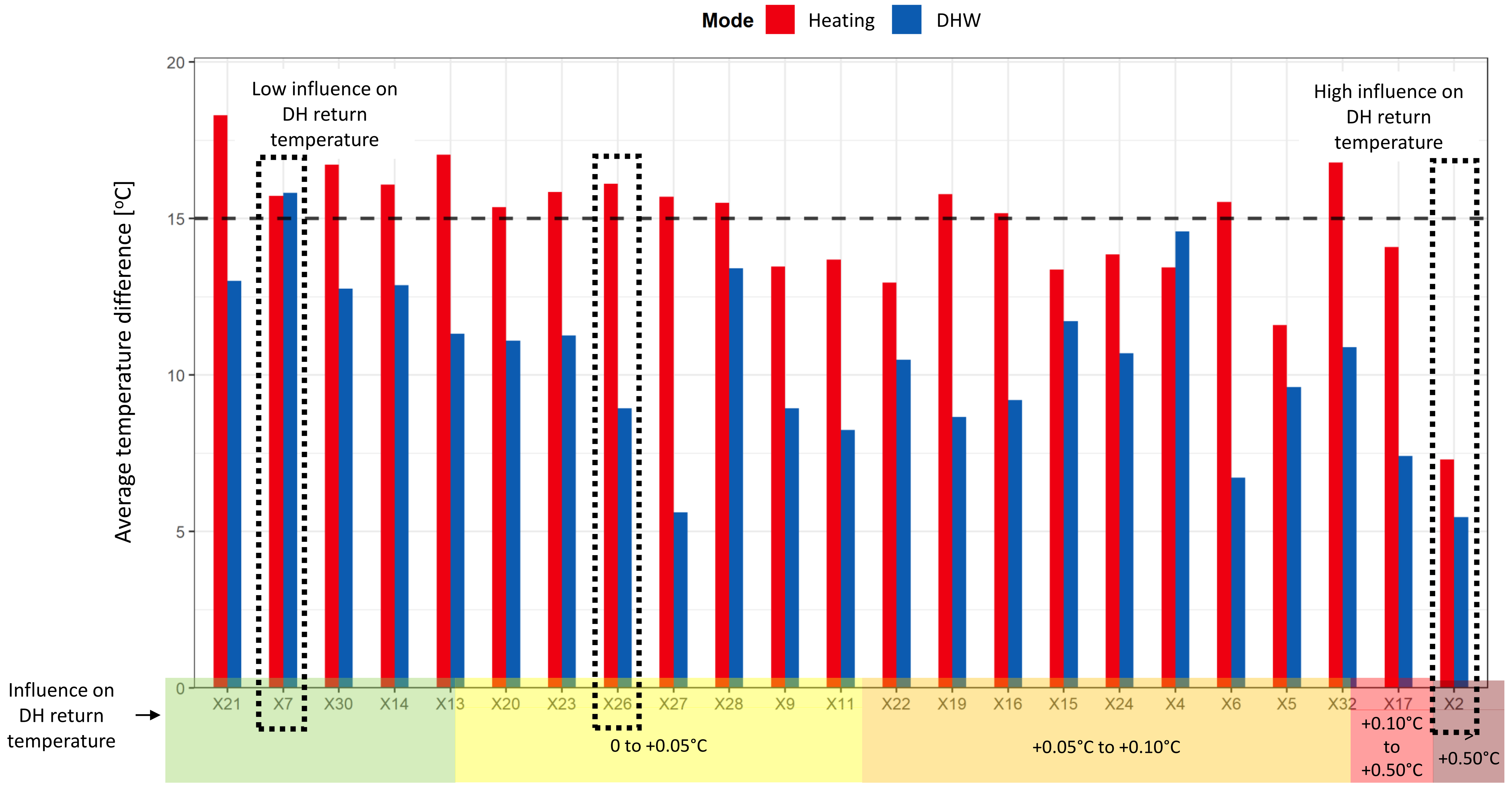


- Mostly all SST do not reach target in DHW mode
- Highest influence on return temperature :

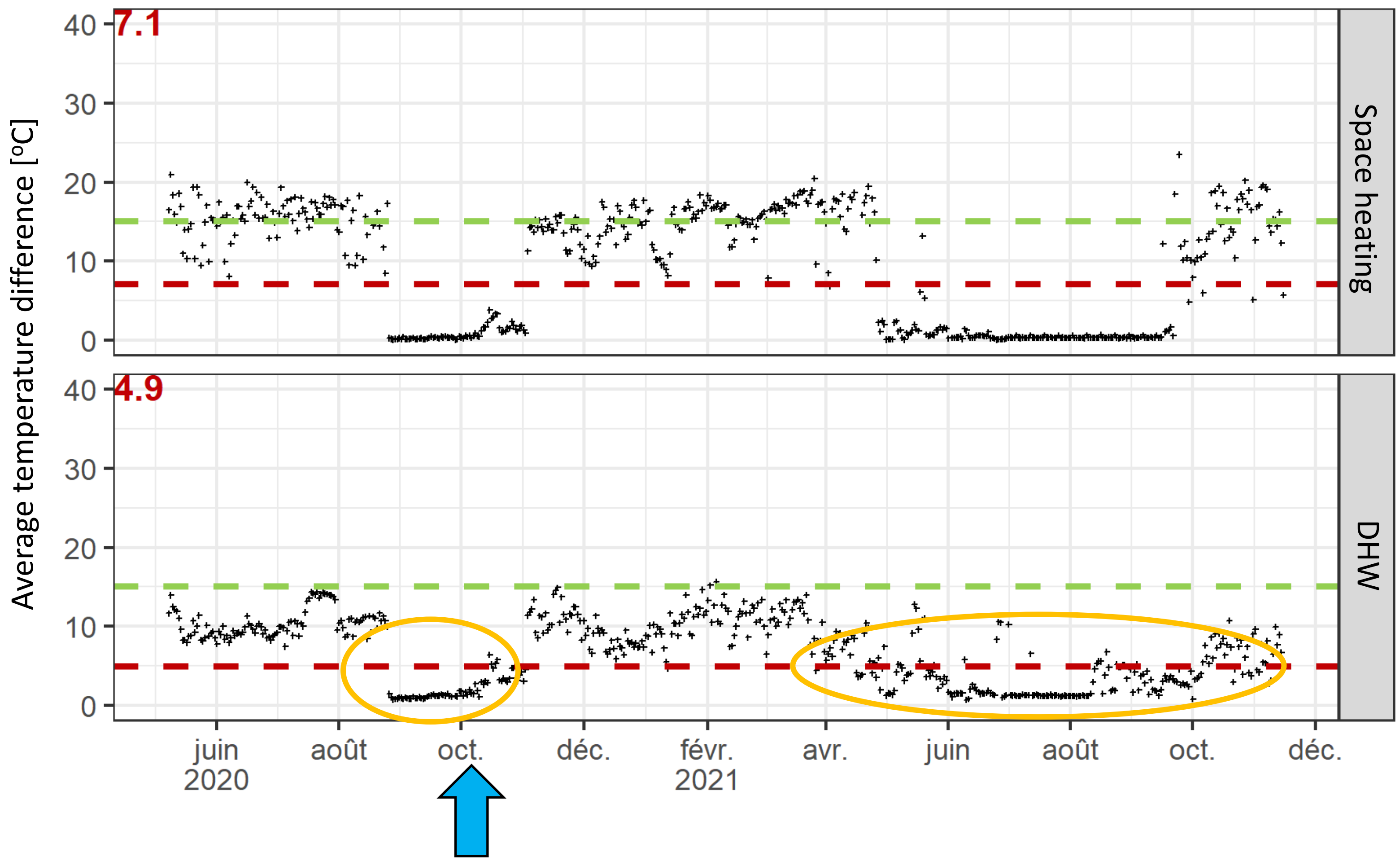
  Heating: X2

  DHW: X32

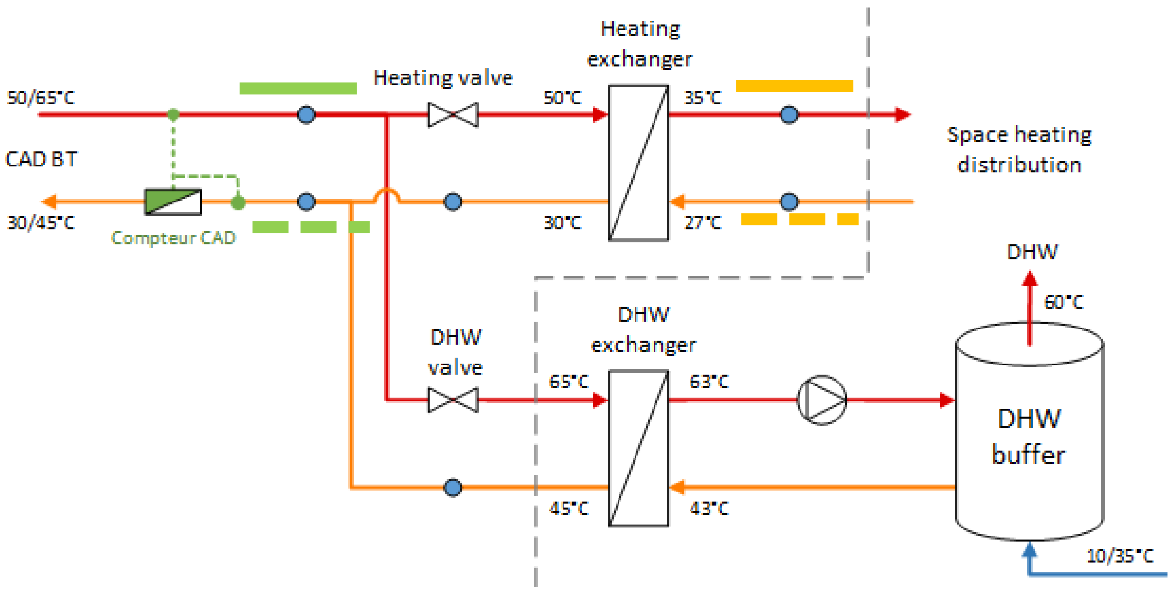
Case study: influence on return temperature, ranking with excel tool

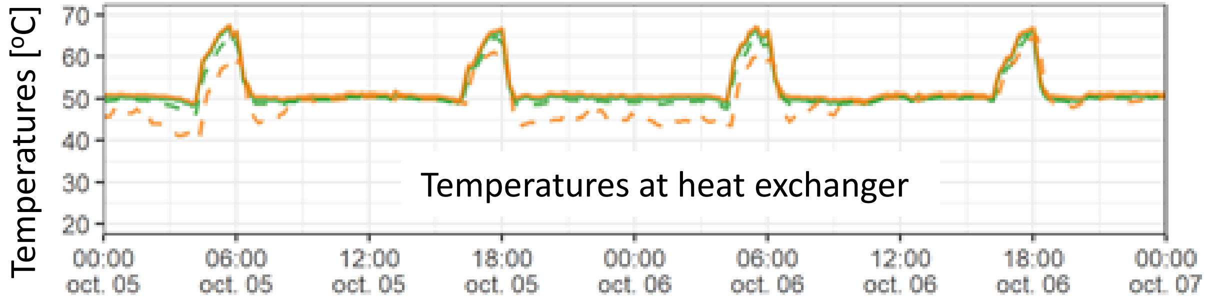


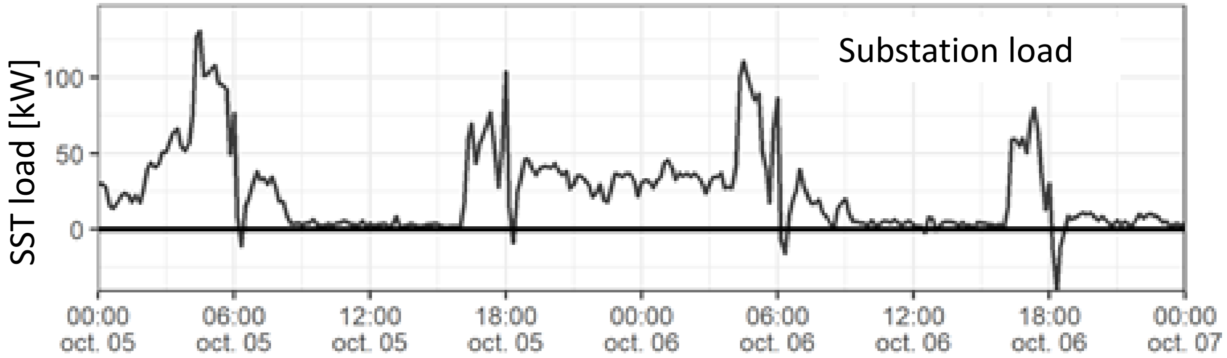
Case study, building X2: identifying problems

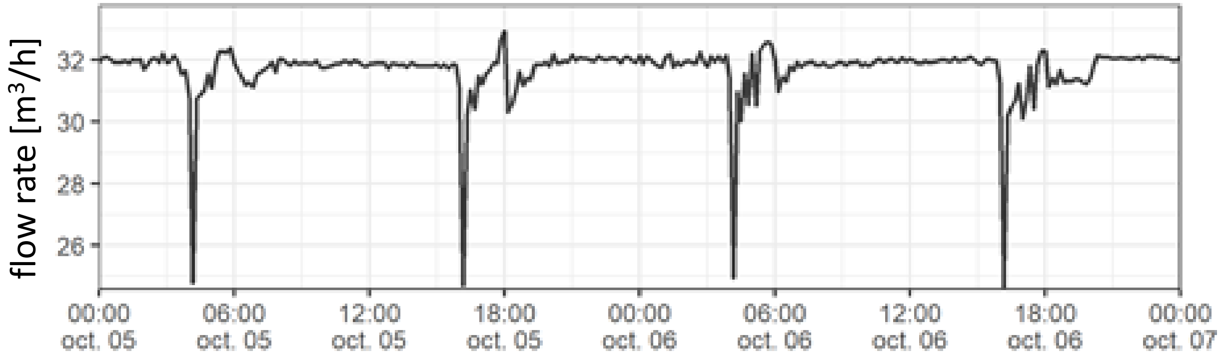


Case study, building X2: identifying problems







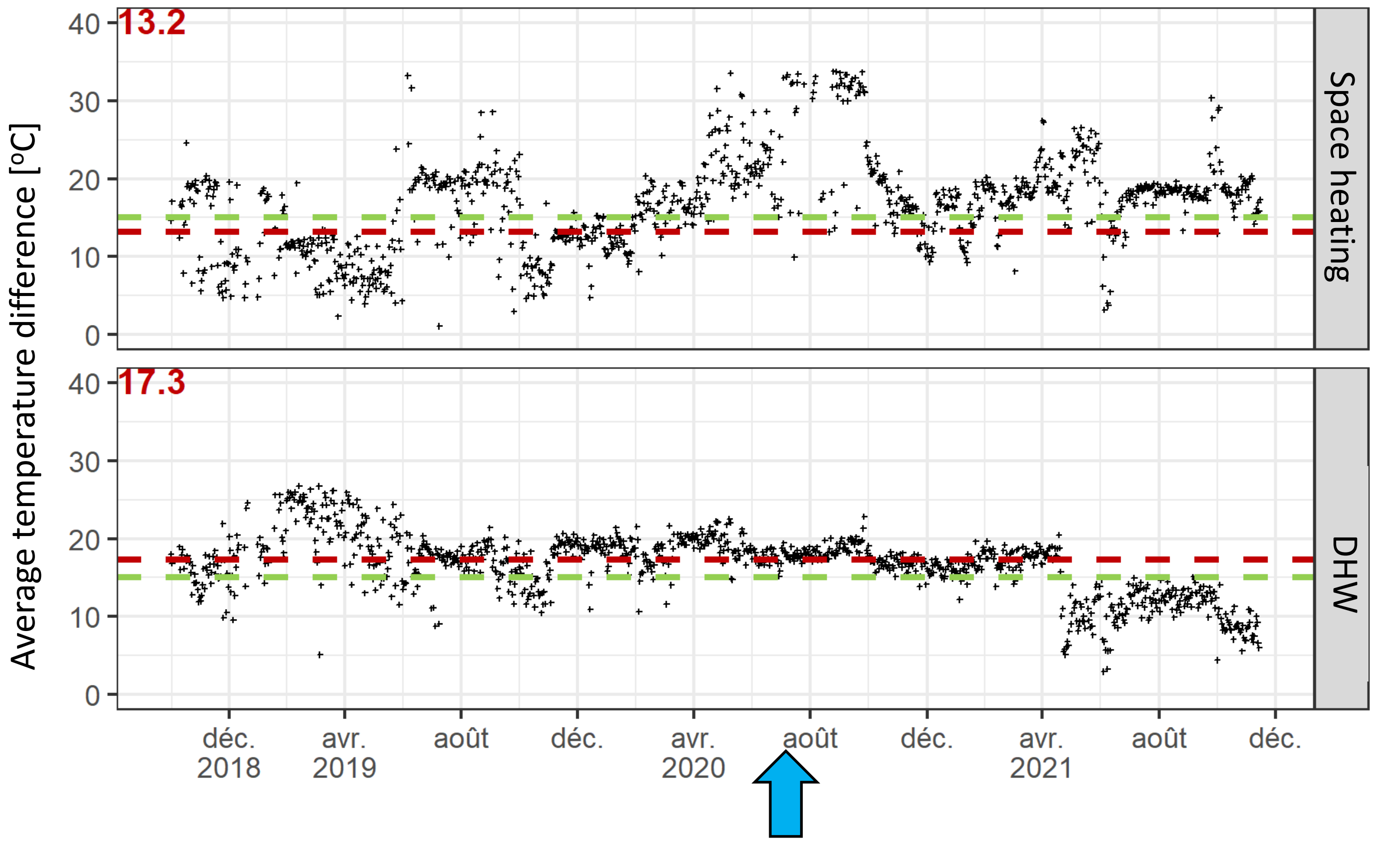


Substation volumetric flow

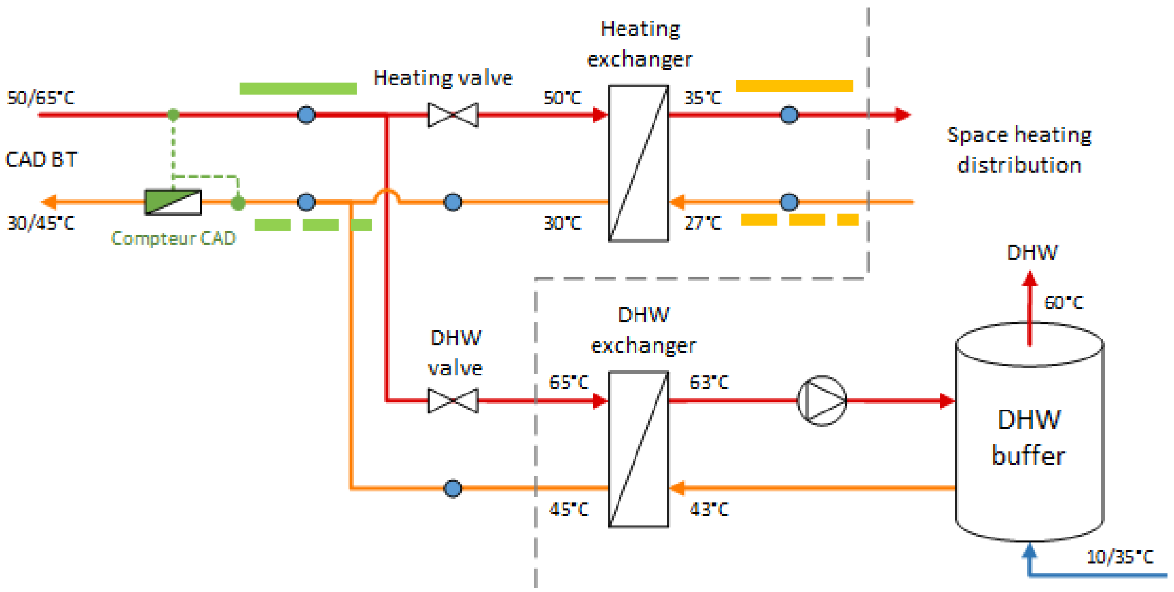
- Incorrect behaviour of heating valve remaining open even when there is no heat demand

- Space heating set-point temperature much to high (50 [°C] instead of 35 [°C])

Case study, building X7: DHW normal behaviour

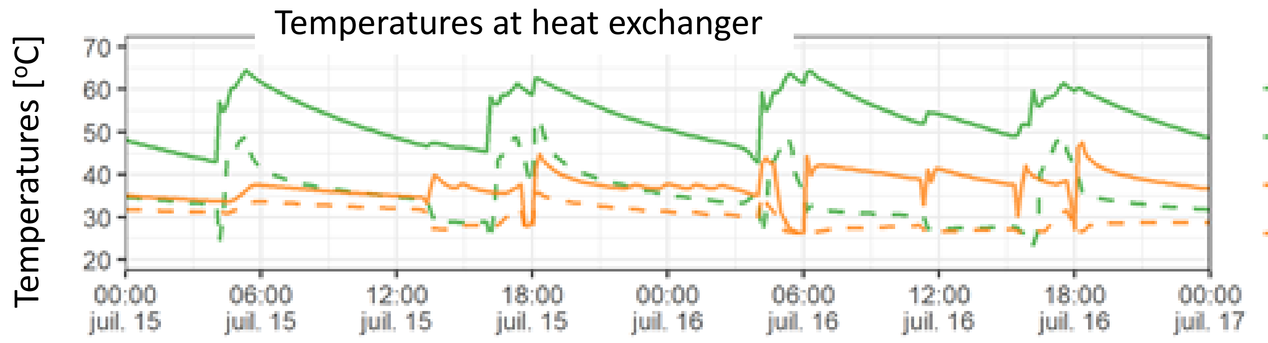


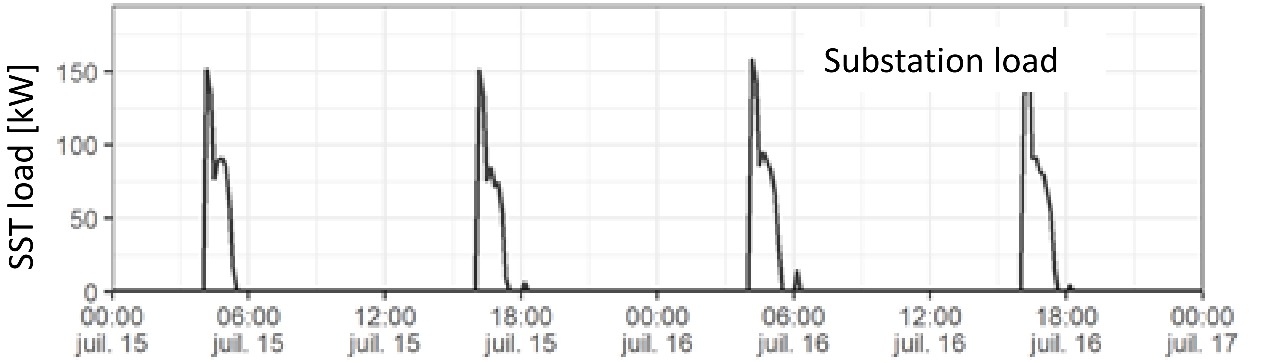
Case study, building X7: DHW normal behaviour

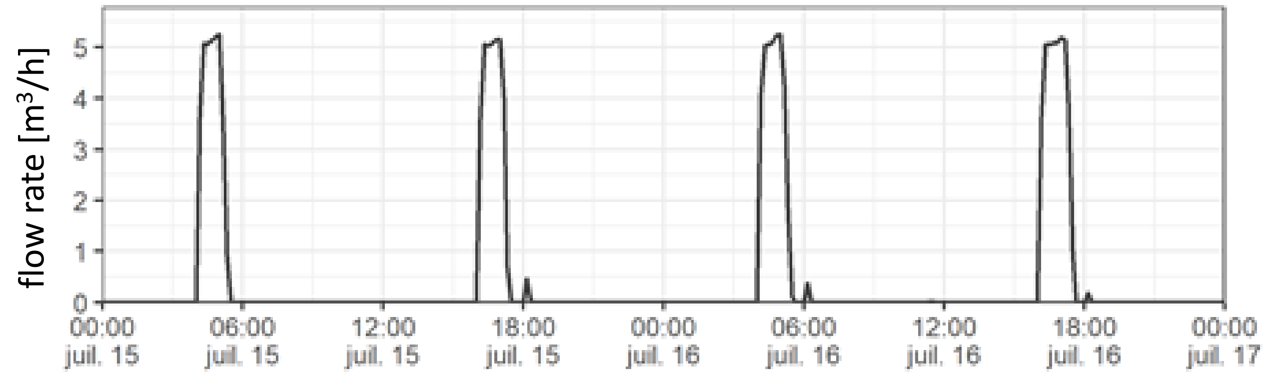


- No flow between DHW batches

- Return temperature never exceeds 50 [°C] at the end of DHW batch

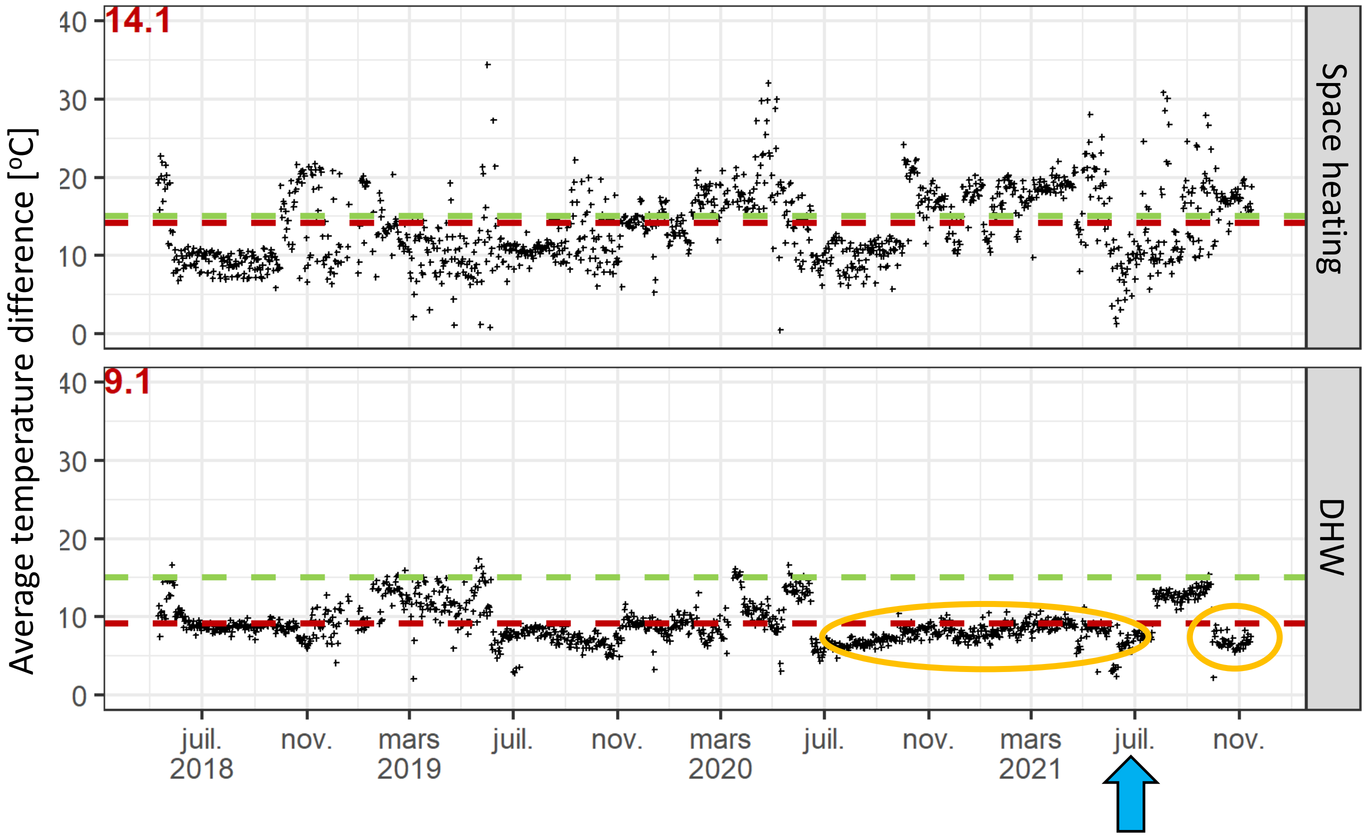




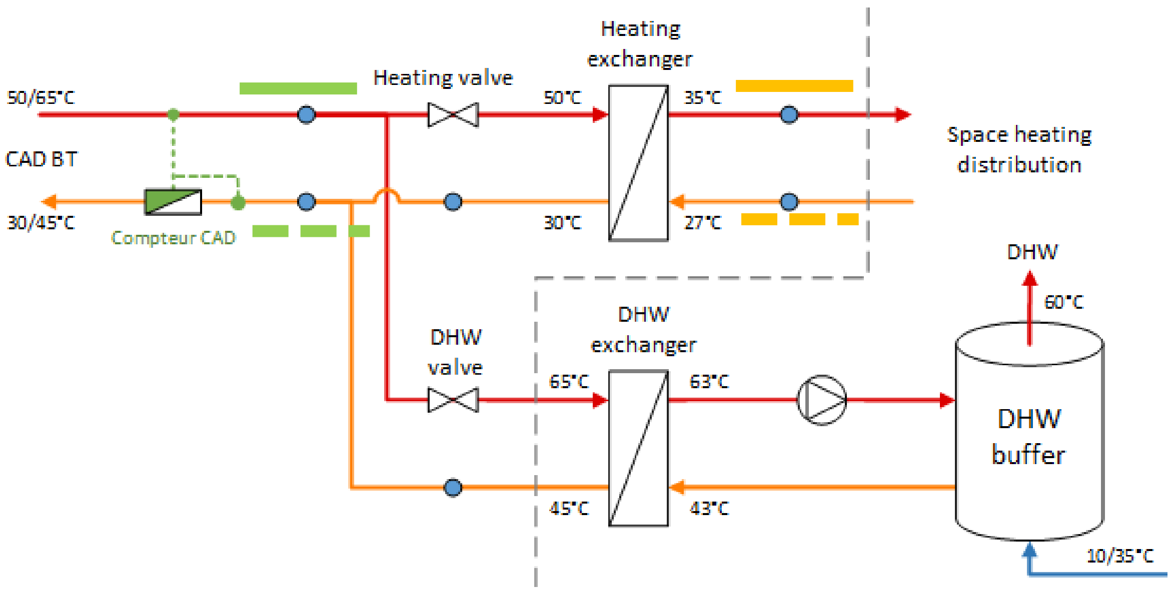


Substation volumetric flow

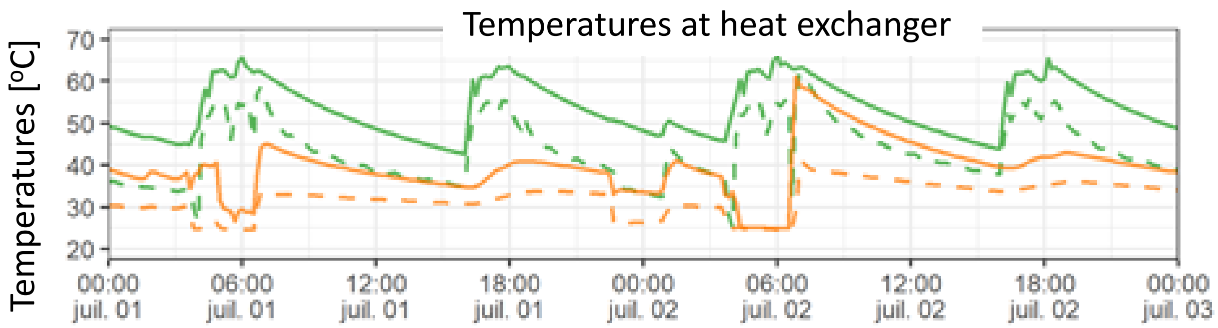
Case study, building X26: DHW less optimal

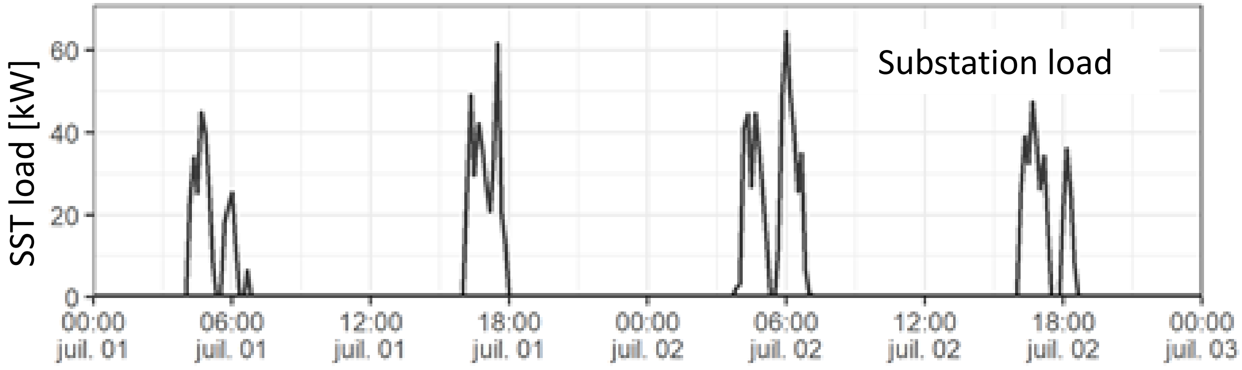


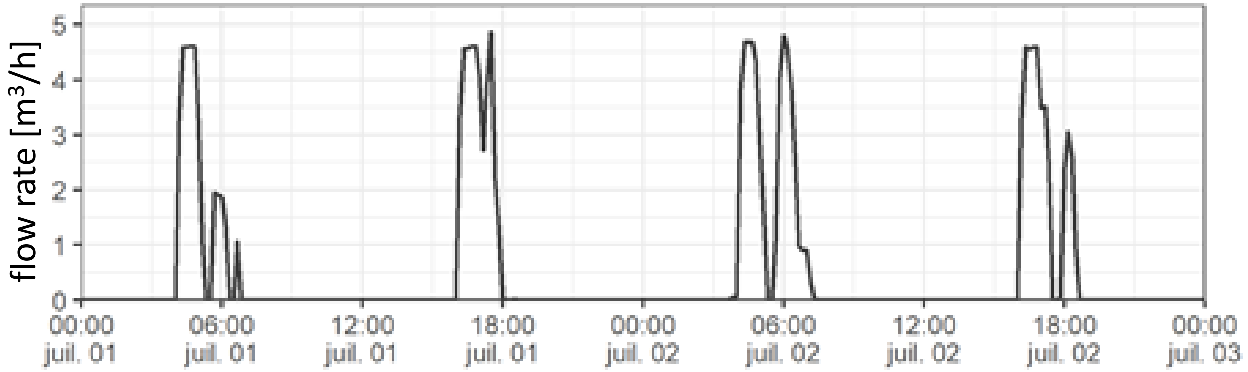
Case study, building X26: DHW less optimal



- No flow between DHW batches
- Return temperature reaches 60 [°C] at the end of DHW
- Poor stratification of DHW buffer or buffer size ?







Substation volumetric flow

Conclusions

Conclusions

- There is room for temperature level optimization on Swiss DH networks, but it is a difficult process
- The DH operator does not control substation (SST) return temperature
- Step 1: identify substations that should be optimized in priority. Requires only annual readings
- Step 2: Identify the cause(s) of high return temperature:
  - “Hardware” issues: SST architecture, size of heat exchanger,…
  - Regulation issue(s) on primary side (control valves, temperature set-point, …)
  - Issue(s) on secondary side
  - Permanent or temporary problem(s)
  - Requires detailed data
- Even if detailed data is available (as in case study), no automatic disfunction control is done
- Billing only consumed energy does not give a price signal to solve issues (bill consumed volume, bonus/malus based on return temperature)

References

L. Quiquerez, *Décarboner le système énergétique à l'aide des réseaux de chaleur: état des lieux et scénarios prospectifs pour le canton de Genève, 2017. Available at:* https://archive-ouverte.unige.ch/unige:93380

H. Averfalk, S. Werner, F. Clemens, R. Karin, R. Wiltshire, S. Svendsen, J. Faessler, F. Mermoud, L. Quiquerez, *Transformation Roadmap from High to Low Temperature District Heating Systems, EIA, 2017.*

Excel tool to calculate influence on DH return temperature:
[http://www.verenum.ch/Dokumente/Mehrverbrauch_V3.3_de.xlsx downloaded the 10/01/2022](http://www.verenum.ch/Dokumente/Mehrverbrauch_V3.3_de.xlsx)

S. Frederiksen, S. Werner, *District heating and cooling, Studentliteratur, Lund, 2013.*

H. Averfalk et al, *Low-Temperature District Heating Implementation Guidebook*
Final Report of IEA DHC Annex TS2: Implementation of Low-Temperature District Heating Systems, 2021

Case study: S. Schneider, P. Brischoux, D. Santandrea, P. Hollmuller, Retour d'expérience énergétique sur le quartier des Vergers à Meyrin (Genève) - Rapport intermédiaire, Genève, 2020. https://archive-ouverte.unige.ch/unige:147702.

Thank you for your attention!

Happy to continue discussion…

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