Joint research project 03ET1234 A bis D

Energie efficiency and hygiene in drinking water installations

im context IEA-DHC Annex TS1 „Low Temperature District Heating for Future Energy Systems“

Supported by:

Federal Ministry for Economic Affairs and Energy

on the basis of a decision by the German Bundestag

Energy efficiency and hygiene in drinking water installations (EE+HYG@TWI)

Focus: Apartment buildings

EnEff:HEAT

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Authors All scientists of the joint research project

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Partners of joint research project – Scientists and Sponsors

Coordinator Technische Universität Dresden

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Overall objectives of the project

Starting point

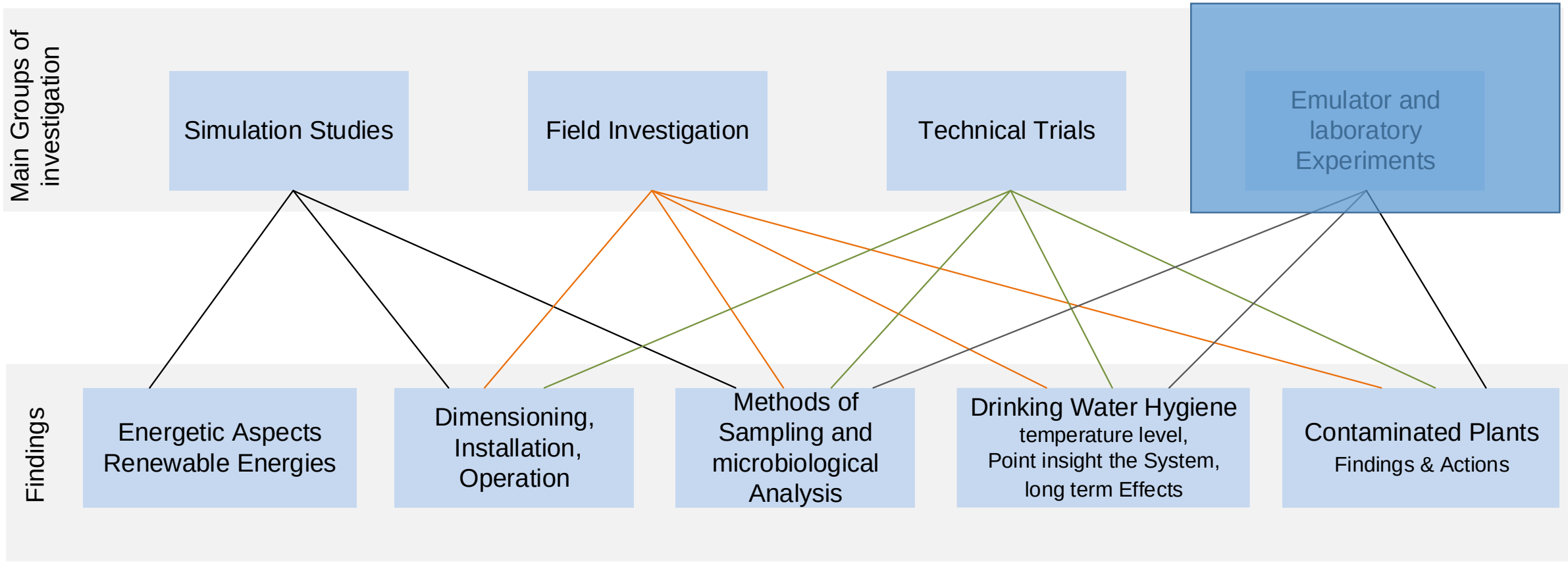
- Decrease of energy demand for space heating
- Share on overall heat demand of buildings for domestic hot water increases
- **Supply line temperature of the whole heating system is dominated by hygienic aspects based on the growth up of *Legionella spp.* at the hot side of drinking water installations**
- Today: $\vartheta_{\mathbf{PWH,\ outlet\ generator}}$ **= 60 °C** because of optimized growth up 30 … 45 °C
  Germany: technical action value > 100 CFU/100 mL *Legionella spp.* (cultivation method)
- High PWH-temperatures have negative influence on several other aspects (scale formation, heavy metal migration, heating up the cold drinking water side also!

Overall Objectives

- Integral and systemic investigation of drinking water installations for future LOW TEMPERATURE-heat supply concepts
- Identification of approaches for use of significant energy saving potential (lowering temperatures domestic water hot) as well as for integration of renewable energies

All together with deep respect for the human health!

Overview interdependencies between main investigation groups and derived findings



Following brief insights in selected methods and results

Field Investigation

Aim

Systematical acquisition of thermo-hydraulic and hygienic-microbiological data of 101 drinking water installation (DWI, means complete hot and cold-water plumbing installation) in existing buildings

Basic-information for tenants and operators

Information material incl. declaration of consent and data privacy statement

Search

Searching for buildings with help of all sponsors and partners insight several housing associations in Germany, Austria and Switzerland

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Vorgehensweise zur Untersuchung von Objekten

im Verbundvorhaben EnEff:Wärme

Energieeffizienz und Hygiene in der Trinkwasser-Installation

im Kontext: DHC Annex TS1 "Low Temperature District Heating for Future Energy Systems"

Sehr geehrte Betreiber einer Trinkwasser-Installation,

zunächst herzlichen Dank, dass Sie sich mit unserer Anfrage beschäftigen wollen und grundsätzlich bereit sind, uns mit Gebäuden zu unterstützen, an denen wir bis Ende 2015 sowohl 4 Wochen thermohydraulische Messungen als auch an einem Tag trinkwasser-hygienische Untersuchungen vornehmen können.

Sicher interessieren Sie über die Kurzfassung unseres Forschungsprojektes hinaus die ganz konkreten Schritte, die wir Forscher an potentiellen Untersuchungsobjekten absolvieren möchten und welche Voraussetzung ein Gebäude benötigt, um im Rahmen dieses Verbundprojektes untersucht zu werden.

Gebäude-Voraussetzung

- Vorzugsweise **Mehrfamilienhäuser** oder Einfamilienhäuser und so genannte typische Nichtwohnhäuser (siehe nachfolgende Checkliste auf Seite 7).
- Im Gebäude sollte aktuell **keine Legionellenproblematik** bekannt sein
- **Pläne der Trinkwasser-Installation** sollten vorhanden bzw. gemeinsam mit unserem Team bei der ersten Begehung leicht erstellbar sein.
- Probenahmeventile im Umfeld des Trinkwasser-Erwärmers (Austritt TWE, Eintritt der Zirkulation in den TWE) sind vorhanden.

Field Investigation – Sampling for hygienic

Categories of contamination following EXNER

[Water and health. presentation, Wasser Berlin 2011]

1. **Contamination at the building entrance point of drinking water**
2. **Central contamination**
3. **Partly-central contamination**

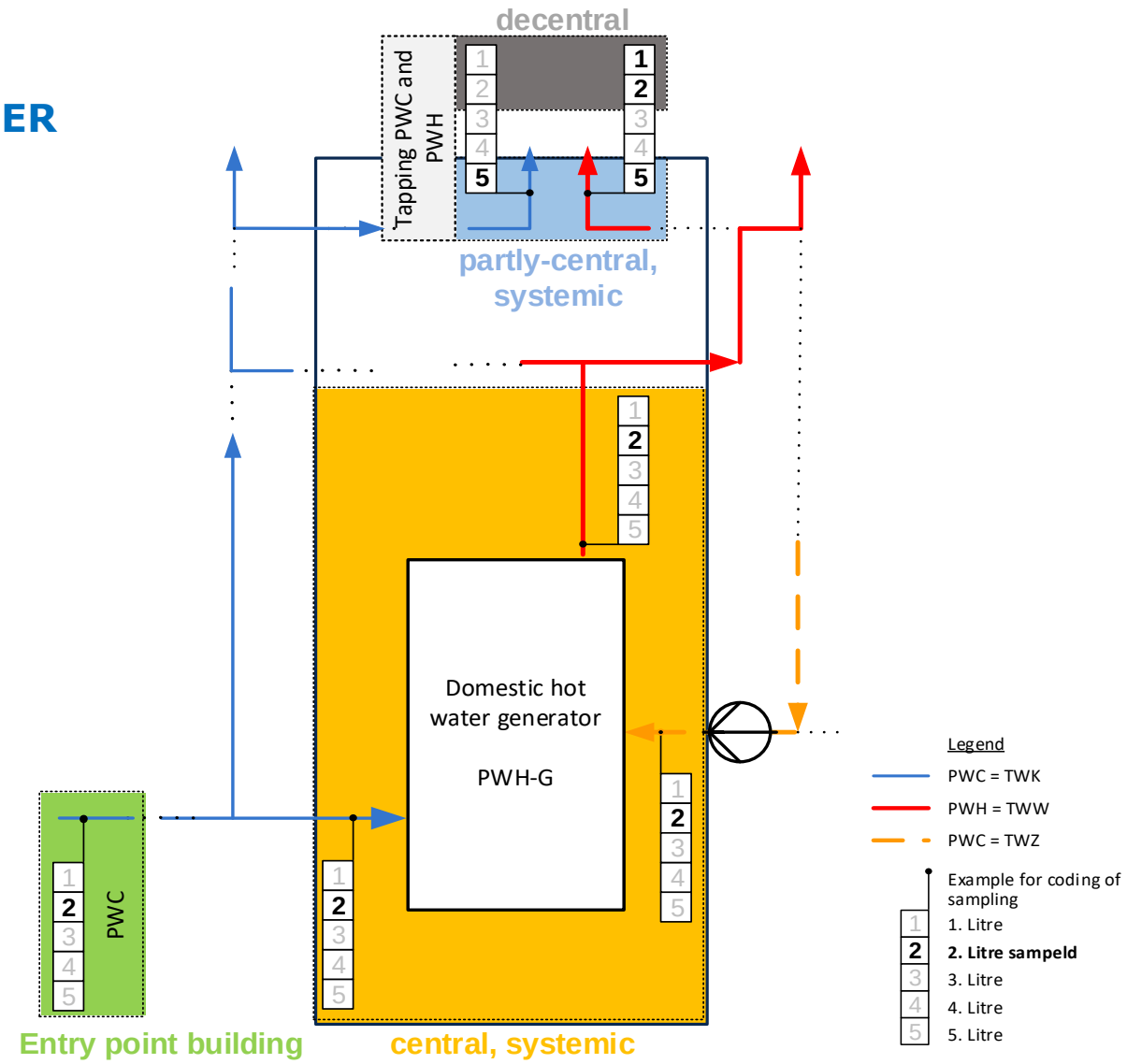
} **Systemic Contamination**

4. **Decentral contamination**

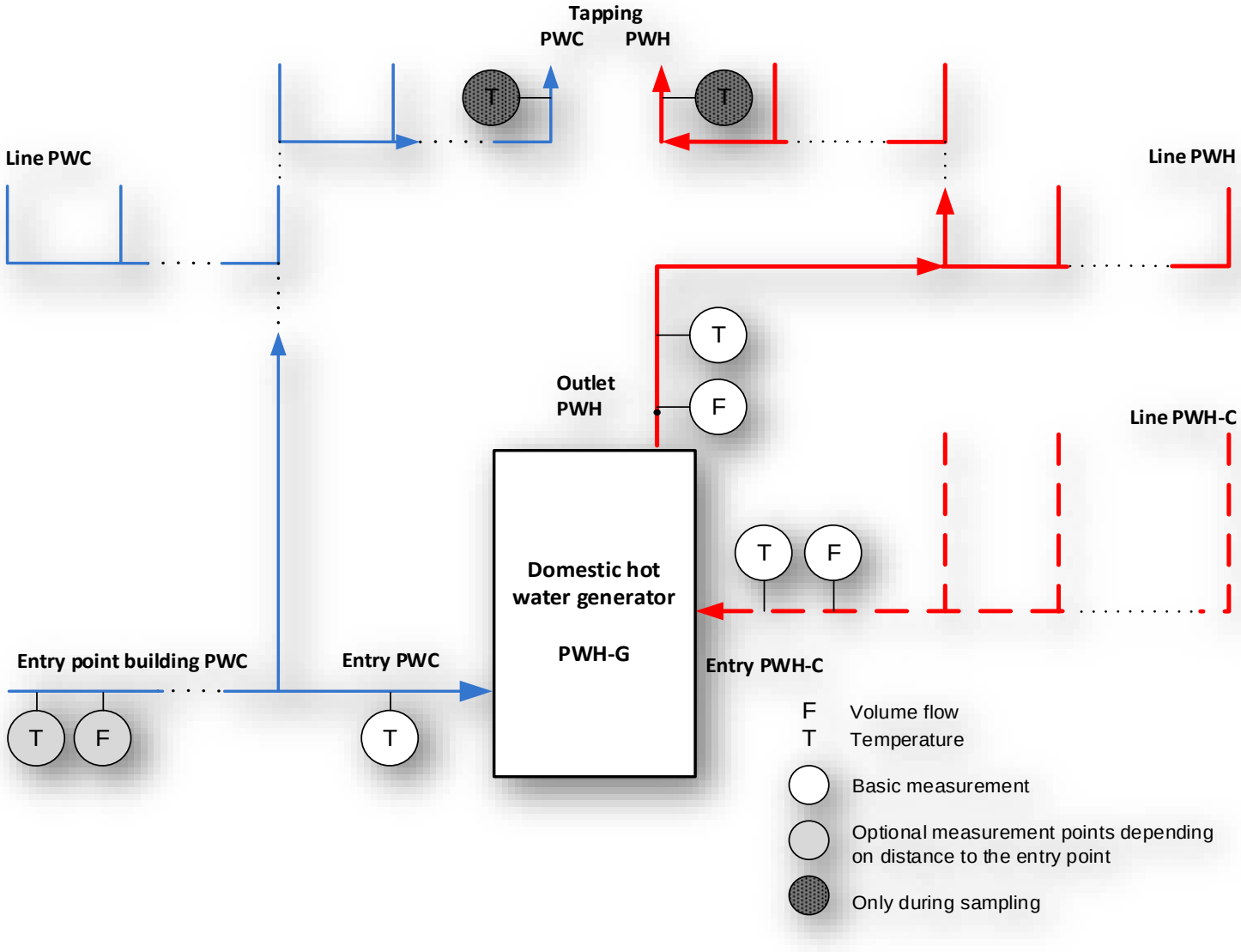
Screening parameters

- Sampling and temperature measurement in the 2nd and decentral 5th Litre
- Temperature also for the 1st und 10th Litre PWH
- Analysis of *Legionella* spp. cultivation, qPCR (*Legionella* spp. + *L. pneumophila*), *Pseudomonas aeruginosa*

qPCR: quantitative polymerase chain reaction – genomic quantification



Field investigation – Thermo-hydraulic measurements THM

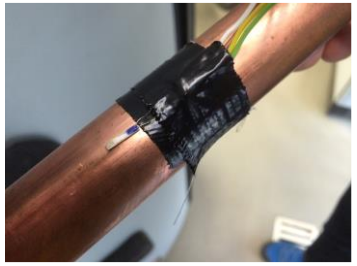


Measurement period

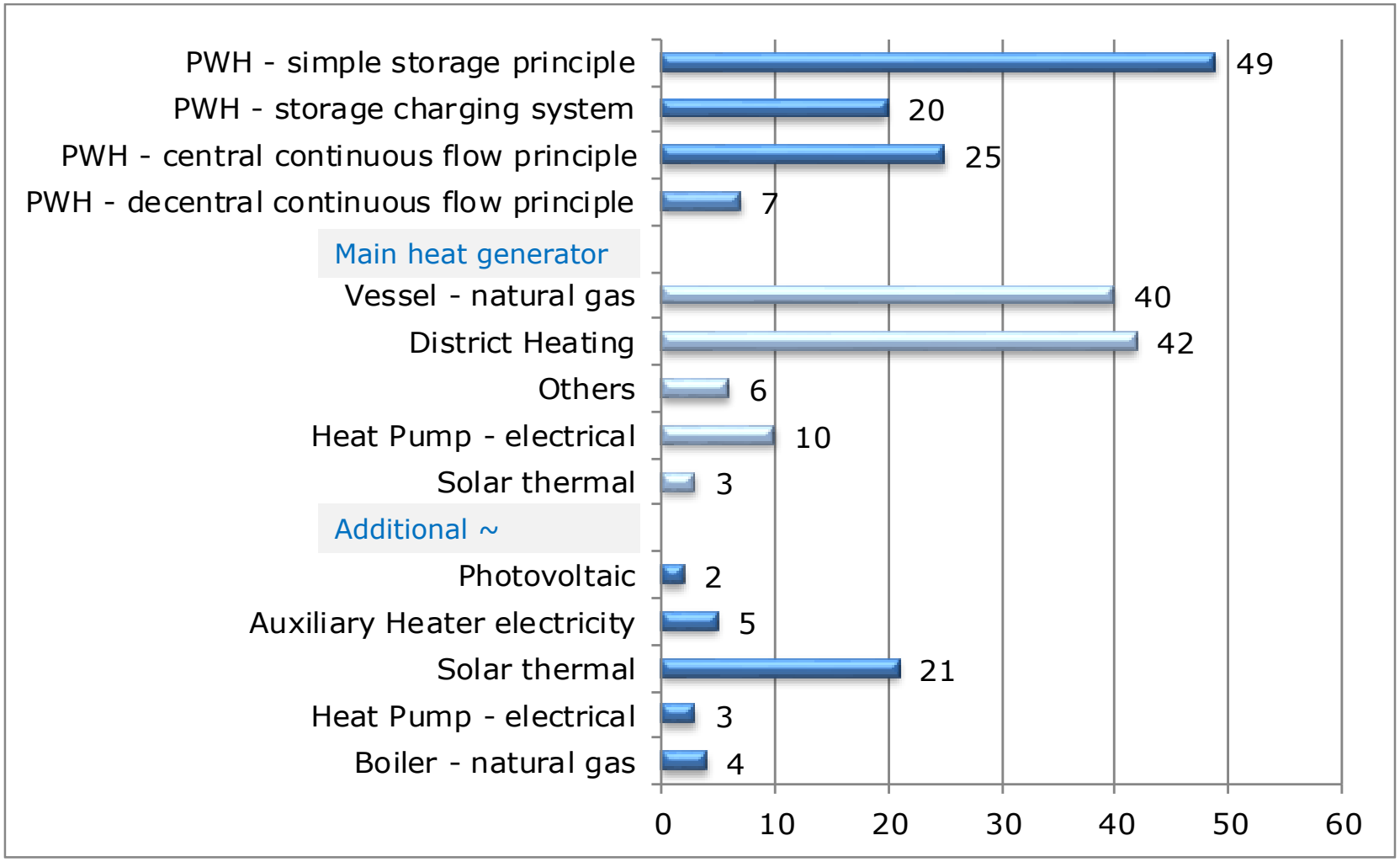
- 14 days in minimum
- Analyzed from Monday 0 a.m. to Sunday 12 p.m.

Measurement equipment

- Volume flow: ultrasonic metering with external Sensors (FLEXIM)
- Temperature: contact sensor PT 100 (insulated)
- Measurement rate: 10 seconds average values



Kind of PWH-generator, heat generator (main and additional), PWH-Temperature
(Basic: Number of objects)



PWH-Temperature at the outlet side of the domestic hot water generator

(average of the 14-day-measurements)

Temp. PWH	No. of objects
> 65 ° C	8
> 60 - 65 °C	32
> 55 - 60 °C	29
> 50 - 55 °C	9
≥ 45 - 50 °C	6
< 45 °C	7

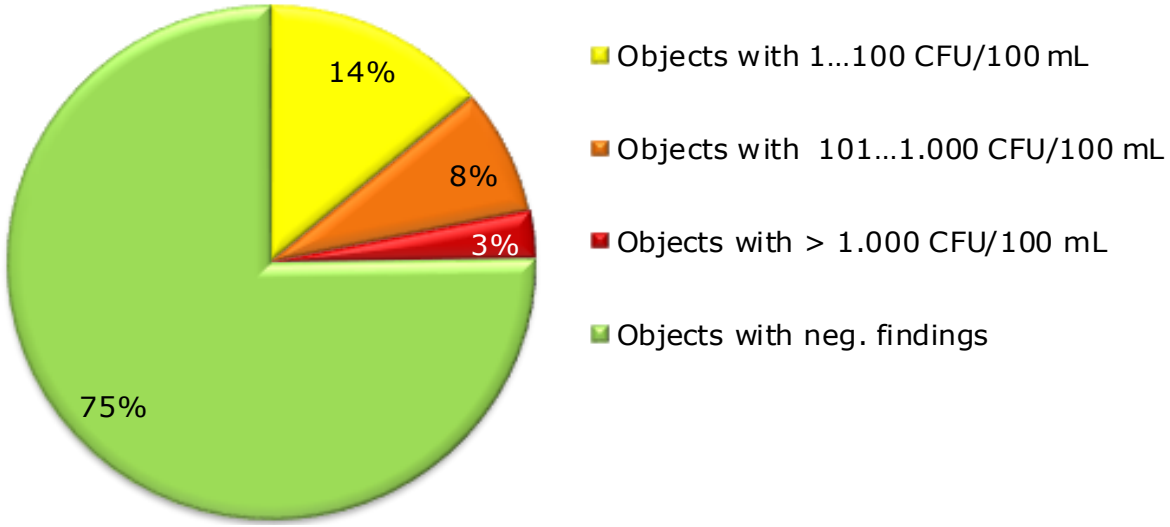
Evaluation hygiene of PWH/PWC – color code depending on microbiological findings

	Analysis results cultivation *Legionella* spp.*	**qPCR *L. pneumophila*****
	negative	≤ lower detection limit (DLimit) Depending on laboratory, labelled with 10 GU/500 mL
	1 … 100 CFU/100 mL	> lower detection limit (Dlimit), but ≤ quantification limit (QLimit) Depending on laboratory, labelled with 200 GU/500 mL
	>100 … 1.000 CFU/100 mL	> quantification limit (QLimit)
	> 1.000 CFU/100 mL	

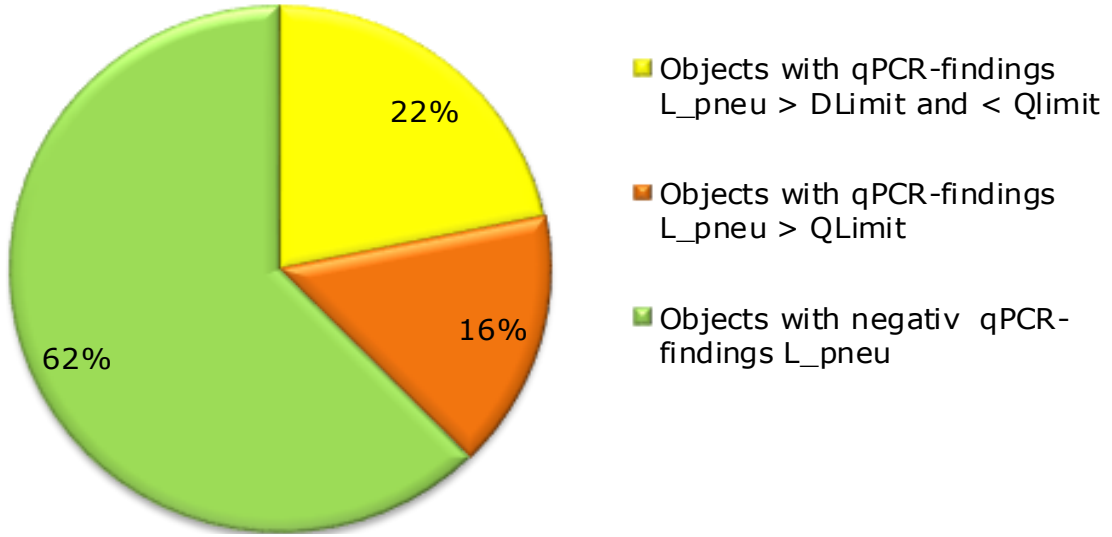
* Positive results cultivation *Legionella pneumophila* in the most cases

** qPCR-analysis results *Legionella* spp. in nearly all investigation objects

Statistic results– color code with highest value of microbiological findings in the objects
(Number of Objects: 101)



Results *Legionella* spp. cultivation



qPCR-results L. pneumophila - Objects

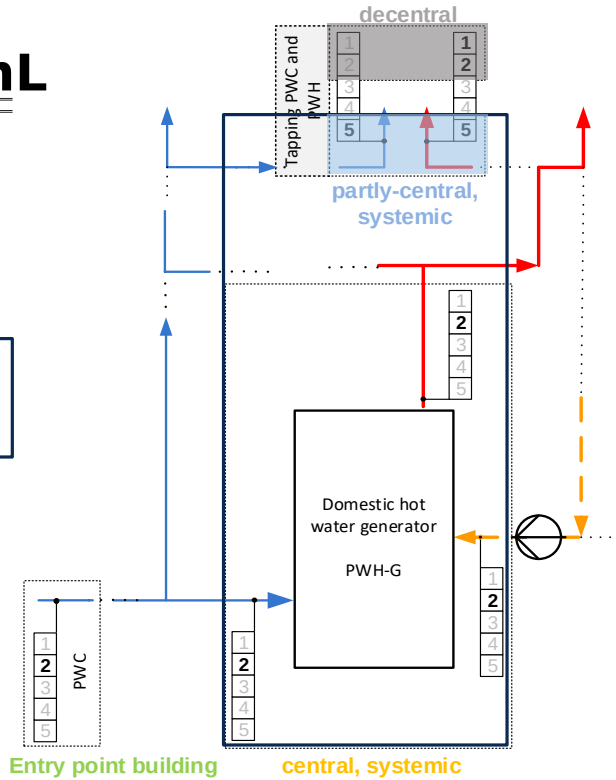
Molecular-biological Analysis without differentiation live/dead

Conclusion:

- 11 % of the objects has microbiological findings above the technical action value of > 100 CFU/ 100 mL
- qPCR *L. pneumophila* delivers positive results more often

Evalation concerning the cathegorie of contamination – cultivation findings ≥ 1 CFU/100 mL, of which > 100 CFU/100 mL

	Description	≥ 1 CFU/100 mL	> 100 CFU/100 mL
	Objects with pos. findings	**25**	**11***
-	**only decentralized** pos. findings = decentralized contamination	3	2
=	**Objects with pos. systemic findings**	**22**	**9**
	Objects, where is a partly-central contamination detected also	**18**	**7**



Conclusion

- Biggest problems partly-central, systemic!

* ▪ 3 Objekts > 1.000 CFU/100 mL decentral
▪ max. findings: 13.000 CFU/100 mL decentral

Technical trials inside the „Centre of Energy Technology“ at Technische Universität Dresden

Without outer wall

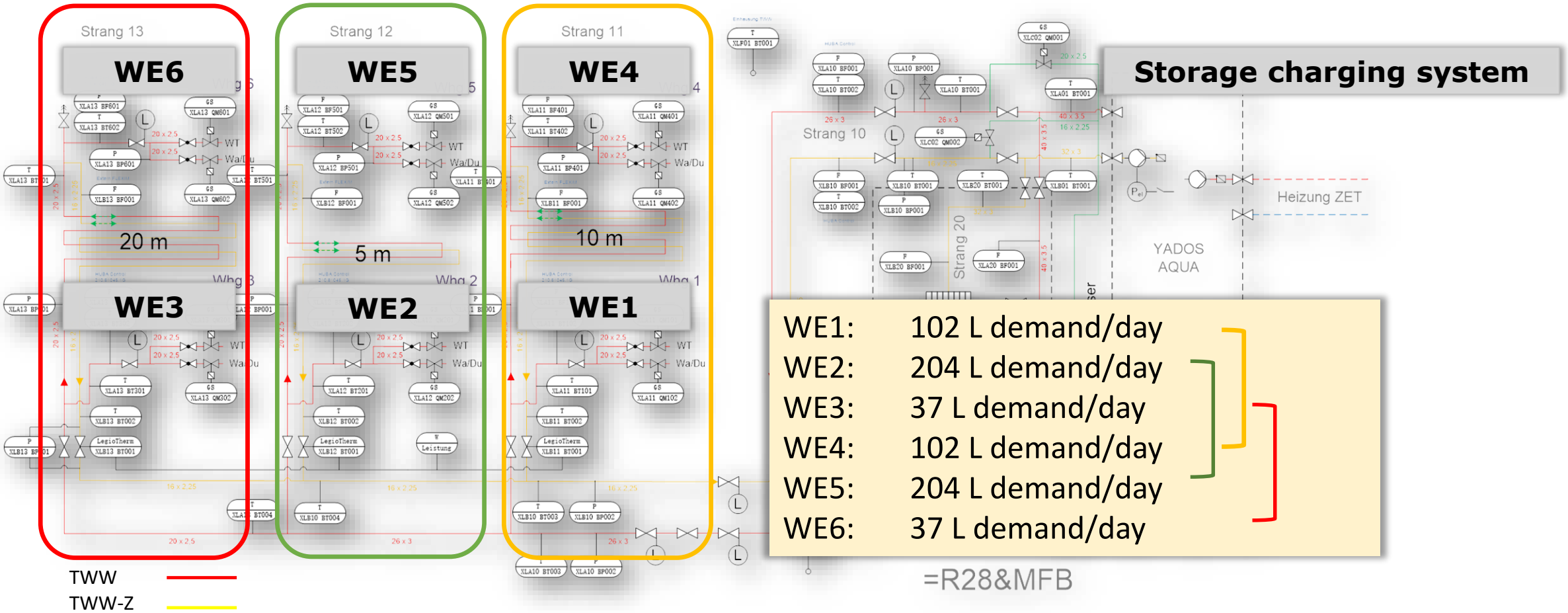
With outer wall

With outer wall and partition wall

Complete hot and cold-water plumbing installation of a six party building

PWH: EU-Reference tapping cycles PWC: DVGW W 510/512-Adaption

WE1 to 6: Apartments 1 to 6 with differences in tube length and tapping cycle



Example: PWH-side of the plant for the technical trials

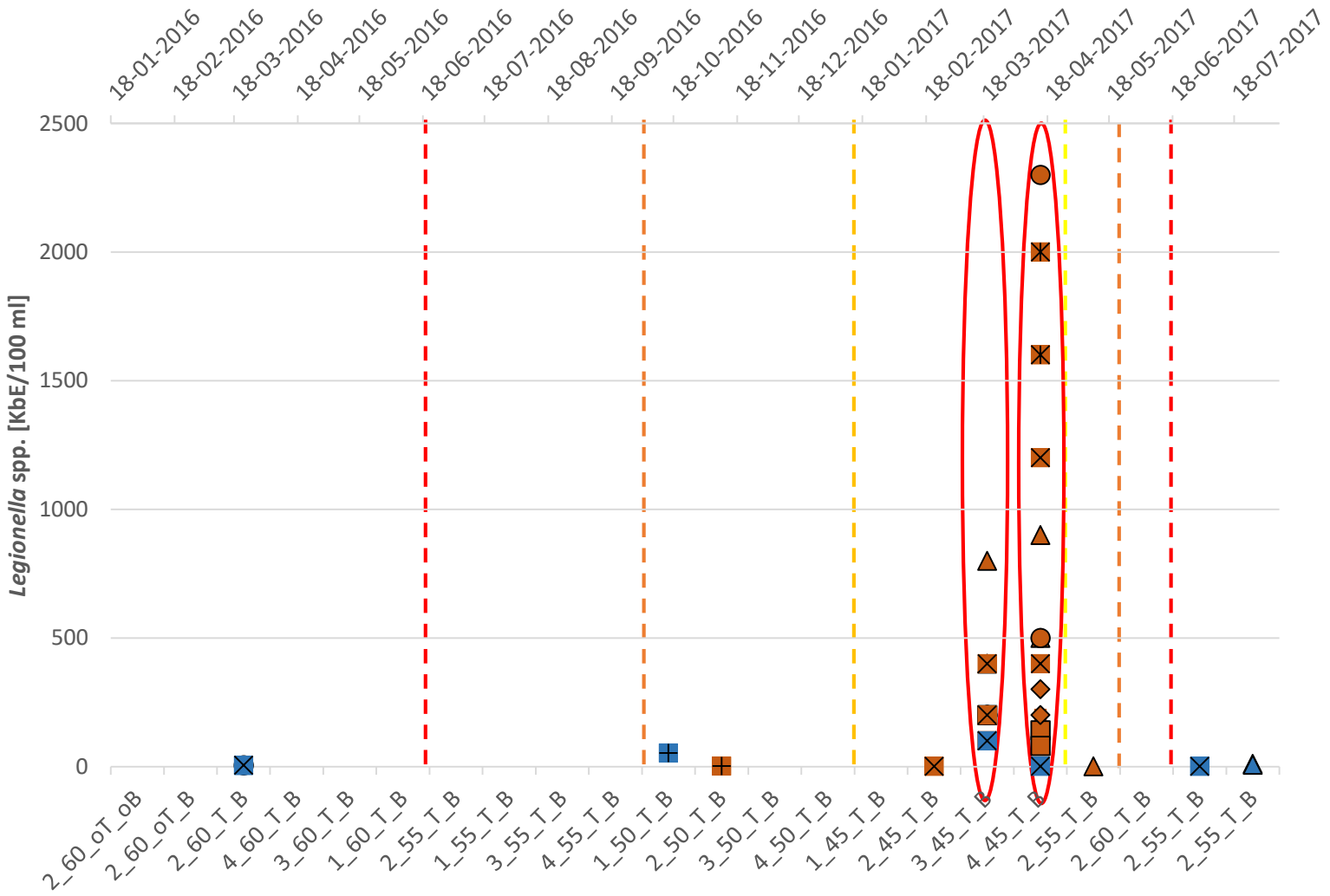
Matrix of the technical trials

- **Which parameters will be changed?**
  - Method thermo-hydraulic balance of the PWH-C (1 – manual, 2 – thermo-electric, 3 – thermo-mechanical) and without circulation but with electrical trace heating (4)
  - Temperature PWH at the outlet PWH-generator:
    started with 60 °C
    lowering in steps of 5 K up to 45 °C
- **Code of the trials:**
  - **A_XY_T_B**
    - With outer wall
    - with partition wall
    - Temperature PWH (60, 55, 50, 45) °C
    - Method of balance (1, 2, 3, 4)

Temp. PWH (outlet generator)	Method thermo-hydraulic balance	Measurement period	Code
60 °C	1	19.05. – 06.06.2016	1_60_T_B
	2	18.03. – 04.04.2016	2_60_T_B
	3	27.04. – 17.05.2016	3_60_T_B
	4	08.04. – 25.04.2016	4_60_T_B
55 °C	1	01.07. – 18.07.2016	1_55_T_B
	2	08.06. – 27.06.2016	2_55_T_B
	3	19.07. – 08.08.2016	3_55_T_B
	4	11.08. – 29.08.2016	4_55_T_B
50 °C	1	30.08. – 15.09.2016	1_50_T_B
	2	19.09. – 10.10.2016	2_50_T_B
	3	11.10. – 01.11.2016	3_50_T_B
	4	02.11. – 21.11.2016	4_50_T_B
45°C	1	22.11. – 14.12.2016	1_45_T_B
	2	09.01. – 30.01.2017	2_45_T_B
	3	15.12. – 09.01.2017	3_45_T_B
	4	31.01. – 20.02.2017	4_45_T_B

Technical trials : Example results *Legionella* spp. – Cultivation findings

Quelle: IMMH



60 °C:

5 CFU/100 mL
L. anisa in WE4-6 **PWC**

50 °C:

L. erythra at Biofilm-Monitor **PWC** WE6 (53 CFU/cm²)

45 °C:

- *L. pneumophila* Sg1 **PWH** (all apartments, storage and circulazion) and **PWC** WE 6
- ***L.pneumophila*** qPCR positive: max. $4x10^4$ GU/500 mL

Increase to 55 °C:

- Legionella < 10 CFU /100 mL
- ***L.pneumophila*** qPCR positiv: 2 x 10^2 GU/500 mL

There is a potential for lowering the PWH-Temp. for well designed (including building side), operated and maintained DWI to 55 °C

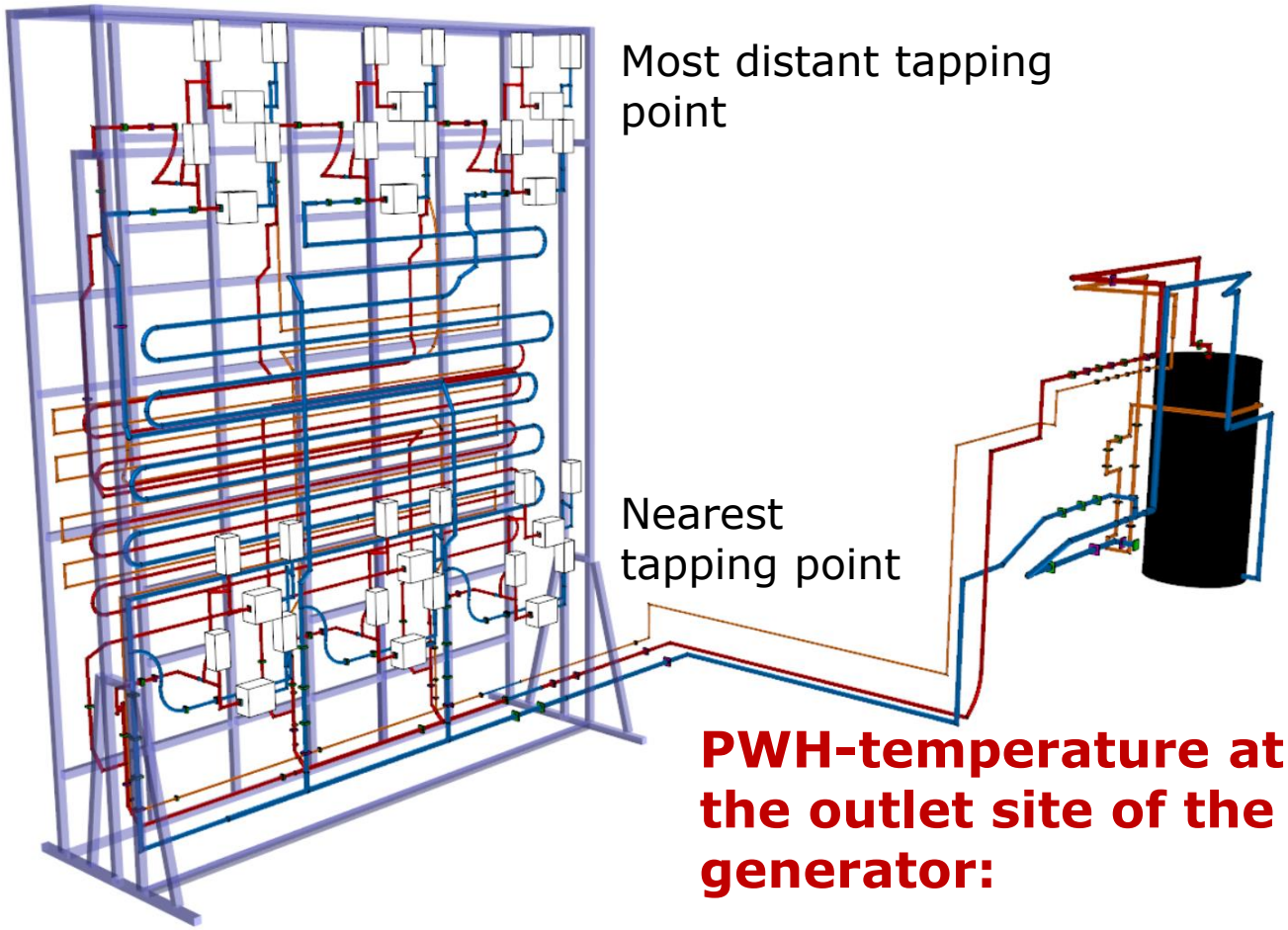
Simulation study – for interactions of PWH and PWC-side with different wall situations

Technical trial CET

- Fully 3D –integration of the whole plumbing and space situation
- Thermo-hydraulic Simulation coupled with canal and space simulation in

TRNSYS-TUD

virtual integration in TRNSYS-TUD

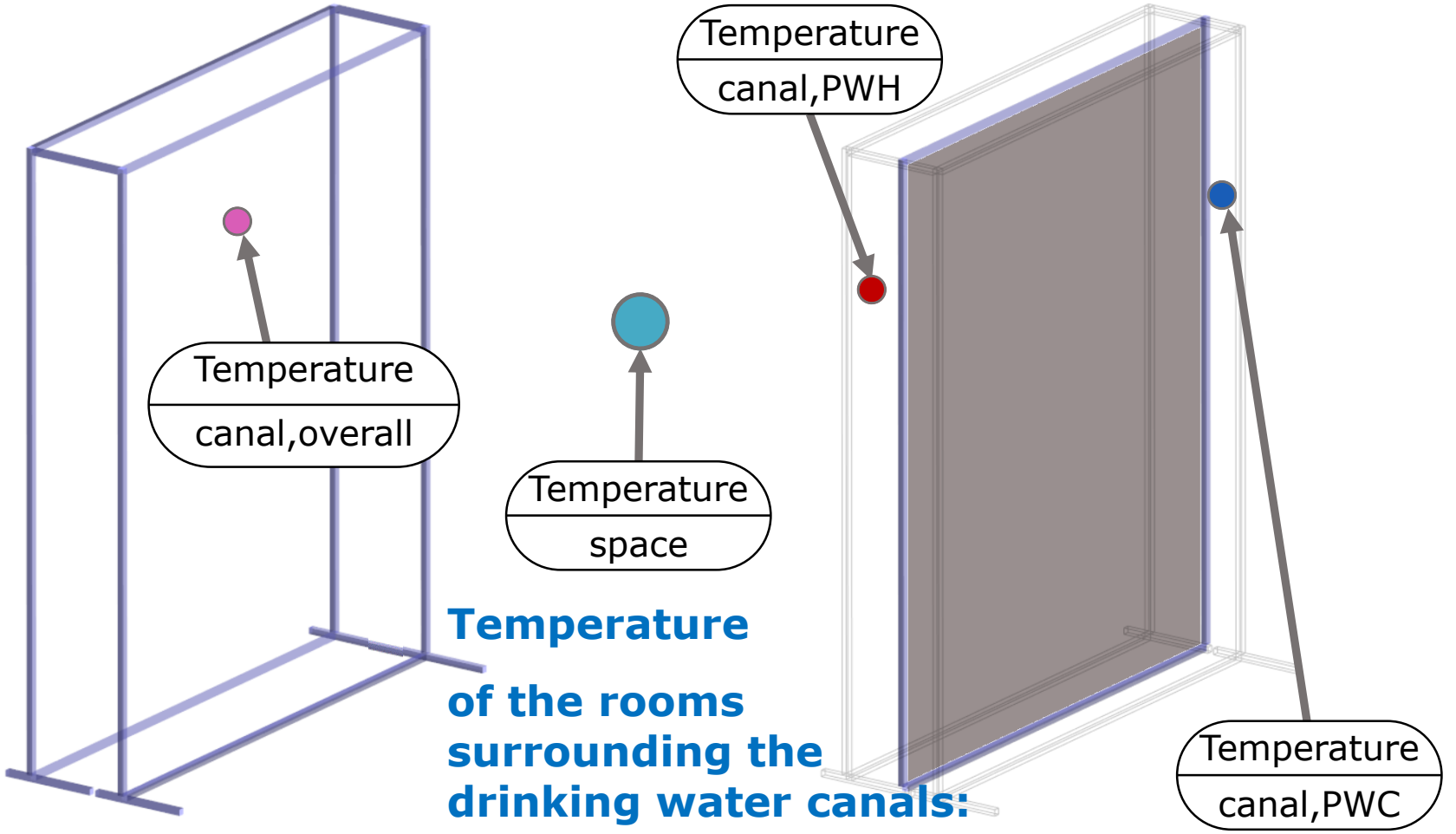


PWH-temperature at the outlet site of the generator:

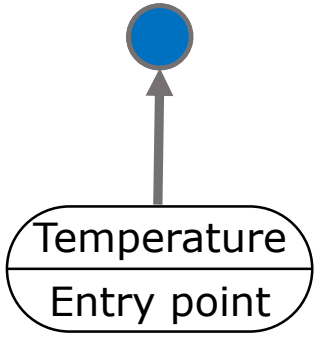
ϑ_{PWH} = 70 … 45 °C

Example Simulation study: Impact of a partition wall on PWC-temperature-distribution

Without versus with partition wall in several situations



Temperature of the rooms surrounding the drinking water canals:
ϑ_{space} = 17, 20, 24 °C



PWC-temperature at the entry point of the Building:

$\vartheta_{PWC,B}$ = 10, 15, 25 °C

Simulation study: Influence of a partition wall on PWC-Temperatures

avarge temperatures (day) without and with partition wall												
temperature			canal			nearest tapping point			most distant tapping point			
-			without	with partition wall		without	with	-	without	with	-	
ϑ_{PWH}	$\vartheta_{PWC,B}$	ϑ_{space}	$\bar{\vartheta}_{canal,overa}$	$\bar{\vartheta}_{canal,PWH}$	$\bar{\vartheta}_{canal,PWC}$	$\bar{\vartheta}_{PWC,WE1}$	$\bar{\vartheta}_{PWC,WE1}$	$\Delta\bar{\vartheta}$	$\bar{\vartheta}_{PWC,WE6}$	$\bar{\vartheta}_{PWC,WE6}$	$\Delta\bar{\vartheta}$	
70	**15**	**20**	28,0	31,2	20,8	19,1	16,9	2,2	23,0	18,6	4,4	
60			26,3	29,0	20,5	18,6	16,8	1,8	22,0	18,5	3,5	
55			25,5	27,8	20,4	18,4	16,8	1,6	21,6	18,4	3,2	
50			24,6	26,7	20,3	18,2	16,8	1,4	21,1	18,3	2,8	
45			23,8	25,6	20,1	18,3	17,0	1,3	21,0	18,5	2,5	
70	**25**	**24**	31,7	34,3	25,5	27,0	25,1	1,9	29,1	25,3	3,8	
60			30,0	32,1	25,2	26,5	25,0	1,5	28,1	25,1	3,0	
55			29,2	30,9	25,0	26,3	25,0	1,3	27,6	25,0	2,6	
50			28,4	29,8	24,9	26,0	24,9	1,1	27,1	24,9	2,2	
45			27,5	28,7	24,7	25,9	24,9	1,0	26,7	24,8	1,9	

Simulation study: Influence of lowering the PWH-temperatures – whole building

construction year-categorie of the building	No. of flats x persons per flat	space heating	heat generator	storage	PHW-generator	PWH-Temp.
< 1978 (WSchVo77)	2 flats x 2 pers. 2 flats x 4 pers. 2 flats x 6 pers.	radiator	Low Temp. boiler natural gas	PWH-storage	storage principle	60 °C 55 °C 50 °C
			District Heating			
1978-1994		radiator	Low Temp. boiler natural gas	PWH-storage	storage principle	60 °C 55 °C 50 °C
			condensing boiler natural gas			
			District Heating			
KfW70		floor heating	condensing boiler natural gas	PWH-storage	storage principle	60 °C 55 °C 50 °C
			heat pump solar thermal	buffer storage (heating side)	central continuous flow principle	
			District Heating	PWH-storage	storage principle	
				-	central continuous flow principle	
			wooden pellets solar thermal	buffer storage (heating side)	central continuous flow principle	

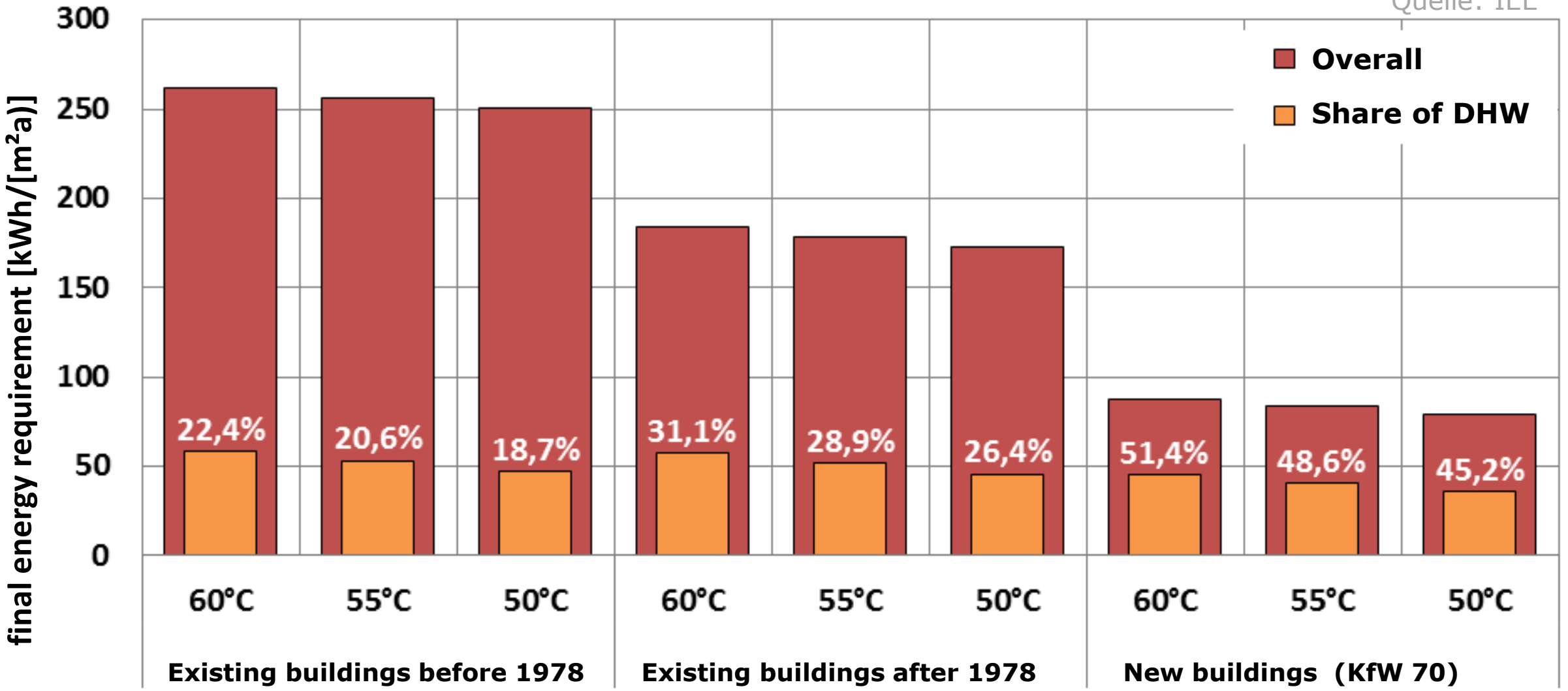
Aim

Quantification of lowering the energy demand and increasing the share of renewable energies

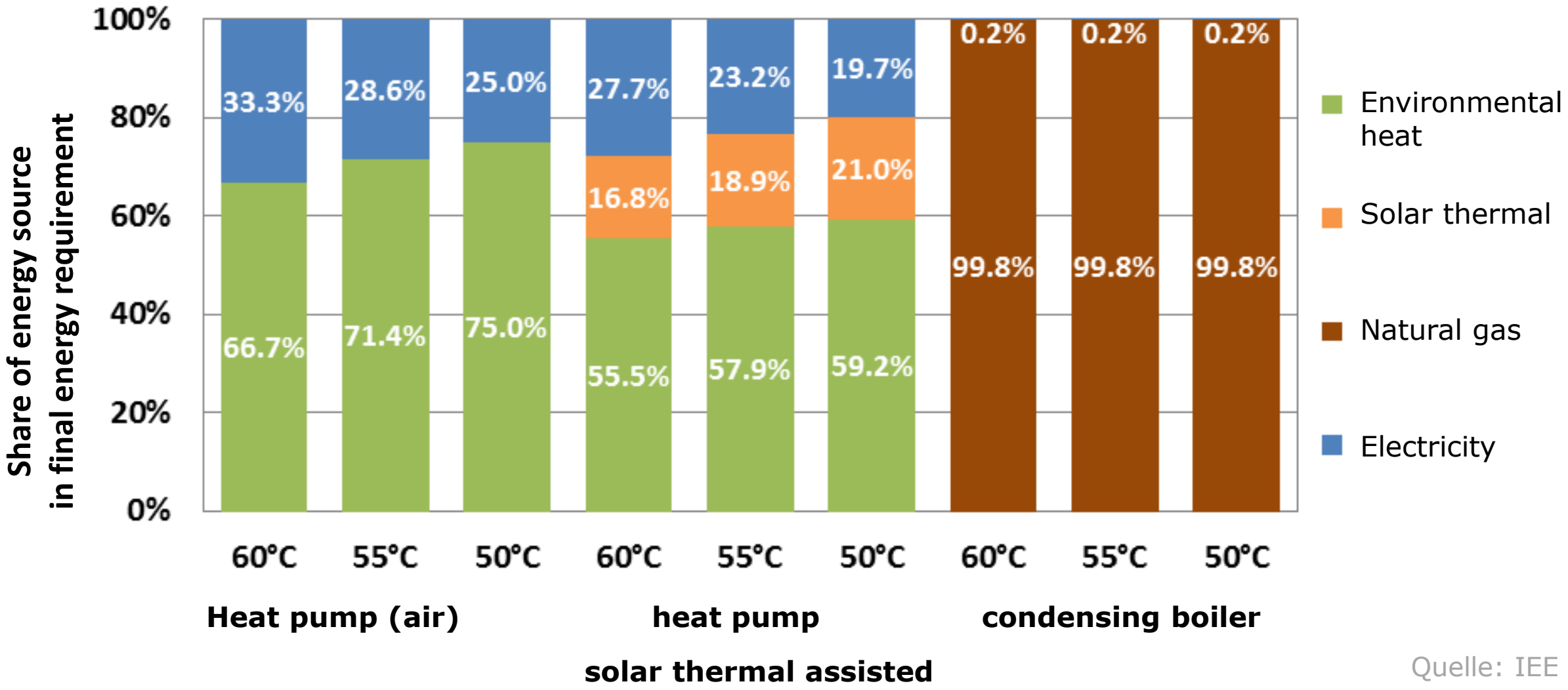
(Reference green colored; $\vartheta_{\text{PWC,building entry point}}$ = 10 °C)

Final energy requirement of a six party building and share of DHW (area related)

Quelle: IEE



Share of renewable energies in the final energy requirement of a six party building



Quelle: IEE

Conclusions are e.g.

- **Decrease of energy demand for space heating with new generations of buildings!**
  (e.g. from ≈ 250 kWh/(m²a) for existing to ≈ 80 kWh/(m²a) for new buildings)
- **But not in the same way for DHW → Share on overall heat demand for buildings for domestic hot water increases!**
  (e.g. from ≈ 22 % for existing to 52 % for new buildings in case of $\vartheta_{PWH,\ outlet\ generator}$ = 60 °C)
- **A well insulated partition wall between the PWH/PWH-C and the PWC-part or separate canals for both are very important to avoid temperatures at the PWC-side above 25 °C**
- **There is a potential for lowering the PWH-Temperature for well designed (including building side), operated and maintained DWI to $\vartheta_{PWH,\ outlet\ generator}$ = 55 °C**
  (Final energy requirement for PWH-generation can reduced from ≈ 50 kWh/(m²a) for 60°C to ≈ 40 kWh/(m²a) for 55 °C; Identification of approaches for integration of renewable energies)
- **In practice the most problems are at the partly-central points of the installation → Missing quality of installation and thermo-hydraulic balance. Control during operation and maintenance is necessary!**

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