

Towards a zero-energy building stock: monitoring the impact of energy efficient refurbishment projects

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Objectives of WP 5

- to develop a cost efficient methodology to follow up that technical and non-technical KPI are reached on district level with a smart systemic integration as top priority.
- to develop and evaluate detailed online and ex-post impact assessment analyses by different measurement campaigns in the renovated buildings following the rules of the EU energy efficiency of buildings directive, the heating network and the smart grid activities.
- to identify the most effective socio-economic measures in SINFONIA with largest impact in stimulating (changed attitudes and behaviour and acceptance)
- to perform technical assessment of the measures of innovative heating/cooling network and supply
- to perform technical assessment of the measures of innovative solutions for the electricity smart grid.
- to close the gap between calculated and real energy performance in buildings

Measurement Concept General (15 Minutes)

Per apartment:








- Electricity (total)
- Electricity for warm water (or heat meter)
- Electricity for Heating (or heat meter or gas)
- Electricity for Ventilation (if it is decentralized)
- Electricity photovoltaic
- Temperature/relative Humidity
- CO₂

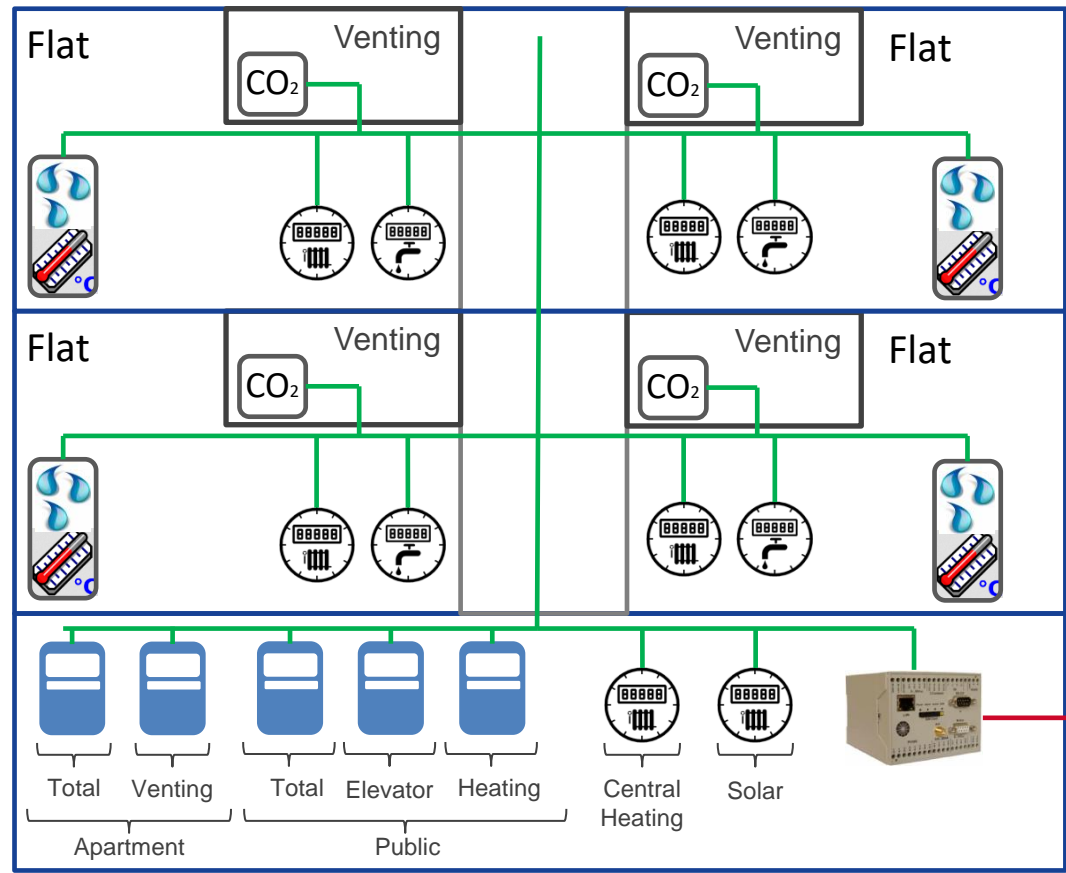
Per Building:

- Electricity (total)
- Electricity for domestic warm water
- Electricity for space heating
- Electricity for Ventilation (if centralized)
- Electricity photovoltaic
- Electricity for Elevator

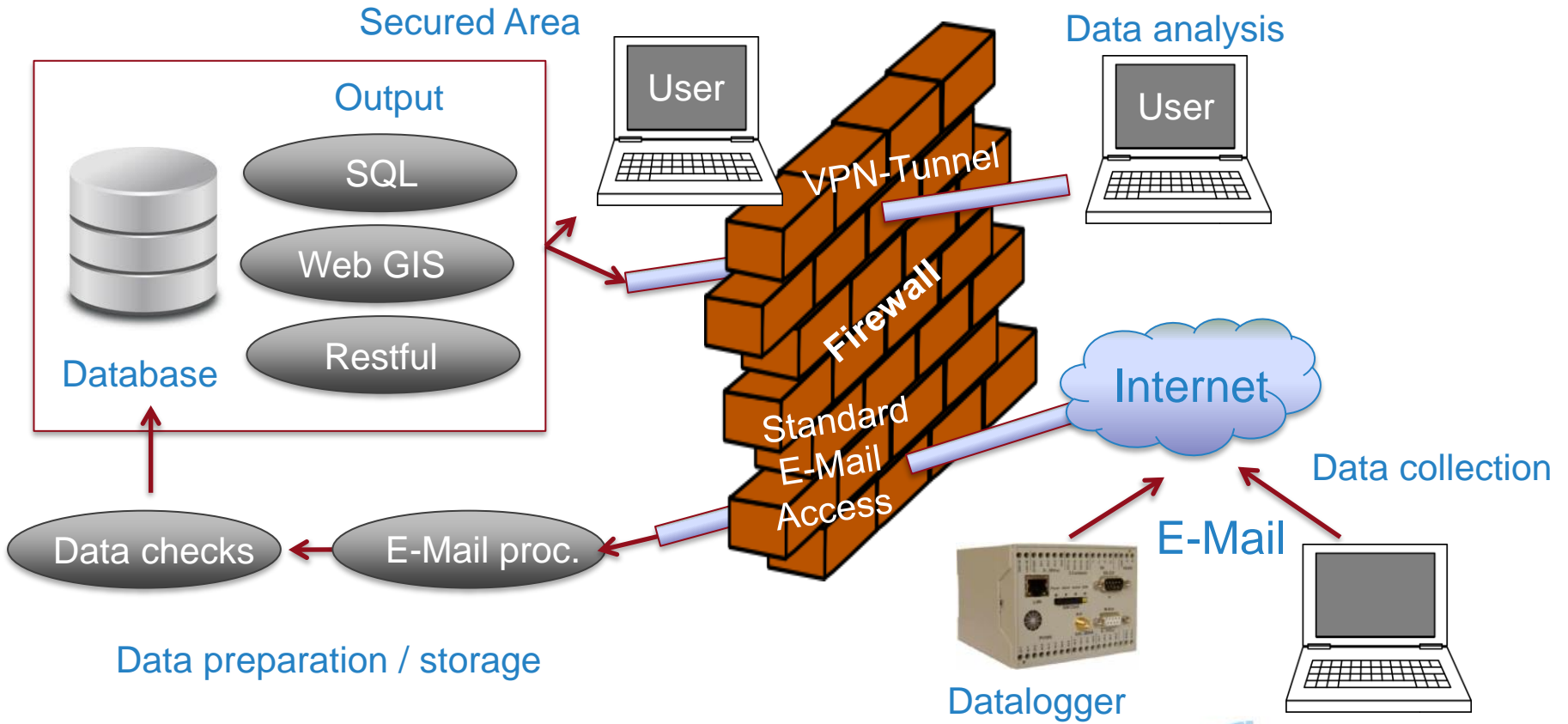
Results Innsbruck

Measurement procedure Innsbruck

-  Electricity Meter
-  Relative Humidity
-  Temperature
-  CO₂ Carbondioxide
-  Heat Meter
-  Water Meter
-  M-Bus



Data Security Concept Innsbruck



Measurement Status Buildings Innsbruck

End of refurbishment (building company)	Tenants agreements (building company)	Technical checklist (building company/UIBK)	Order list (UIBK)	Purchasing order (IKB)	Calibration (UIBK)	Installation (building company)	Completion message (building company)	Starting monitoring (UIBK/building company)	Testrun - system (UIBK/building company)	Testrun - technical (building company/UIBK)	Beginning monitoring period (end all 30.4.20) (UIBK/building company)	Duration / final disc. (UIBK/building company)
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TO DO

Building ID	Category	Address	End of refurbishment	Tenants agreements	Technical checklist	Order list	Purchasing order	Calibration	Installation	Completion message	Starting monitoring	Testrun - system	Testrun - technical	Beginning monitoring period	Duration / final disc.	Notes
BEST03(34) 13	IIG	Sebastian-Scheel-Str., 18, 18a, 18b (Sillblock)	nov16											1.5.19	12	caretaker reading
BEST04(40) 15		Schubertstr. 6-12	dec19											1.1.20	6	caretaker reading
BEST05(20) 5		Mozartstr. 5-7	dec19											1.1.20	6	caretaker reading
BEST16(14) 14		Elementary school Rotadlerstr. 10	nov18											1.5.19	12	
BEST17(18) 18		Elementary school Siegmairstr. 1	jan16											1.5.19	12	
BEST17(7) 7		Elementary school Siegmairstr.1/BT 2	nov18											1.5.19	12	
BEST18(13) 16		Elementary school Angergasse 18	nov16											1.11.17	12	

Building ID	Category	Address	End of refurbishment	Tenants agreements	Technical checklist	Order list	Purchasing order	Calibration	Installation	Completion message	Starting monitoring	Testrun - system	Testrun - technical	Beginning monitoring period	Duration / final disc.	Notes
BEST07(49) 7	NHT	IN 40 Reichenauerstr. 62, 64, 66	nov17											1.8.19	11	caretaker reading
BEST08(92) 16		IN 13 Brucknerstr.2-10, H.-W.-Str.2-4, V.D.Str.11	jul18											1.3.20	4	caretaker reading
BEST11(84) 17		IN 28 Fennerstr. 4-14, Osw.-Redlichstr.7-11	sept16											1.5.19	12	caretaker reading
BEST12(70/14) 68		IN 22/23 Domanigw. 2-8, L.str.20-28, M.g.17,19,36	may19											1.8.19	11	caretaker reading
BEST13(60) 12		IN 43 Reichenauerstr. 94, 94a, 94b, 94c, 94d	nov17											1.8.19	11	caretaker reading
BEST19(269) 27		IN 3 Gumpstr.	oct 18											1.6.20	1	caretaker reading

Total apartments/classes

235 out of 330 acc. DoW

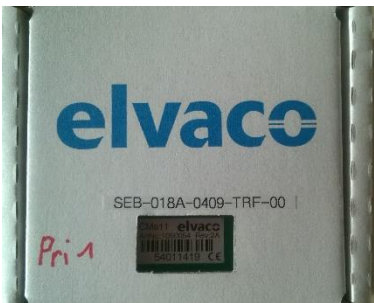
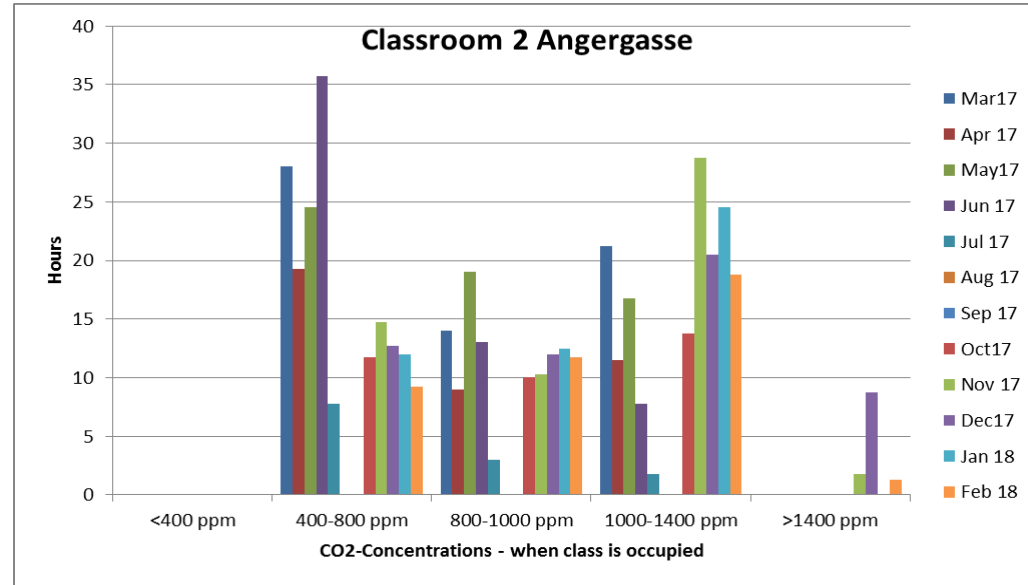
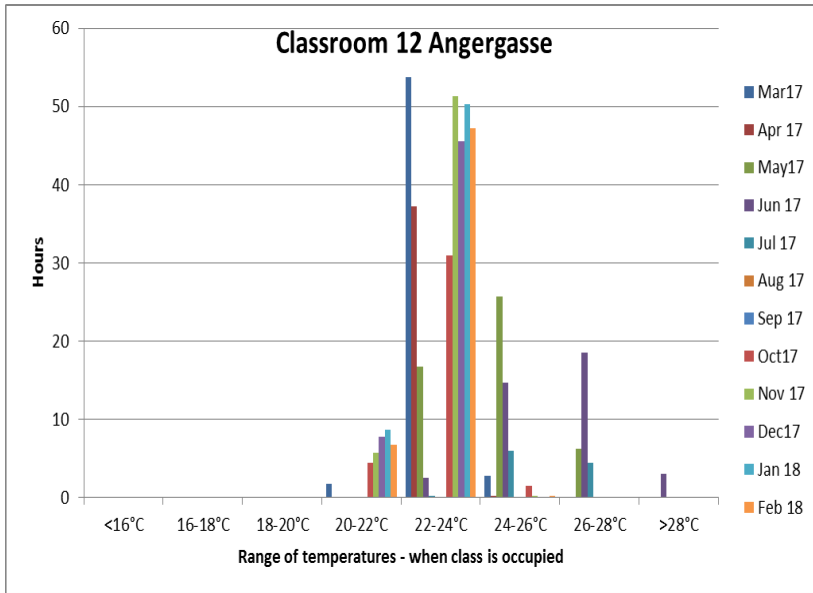
in time

possible delays

timeout (delay in following phases)



Results Innsbruck Schools

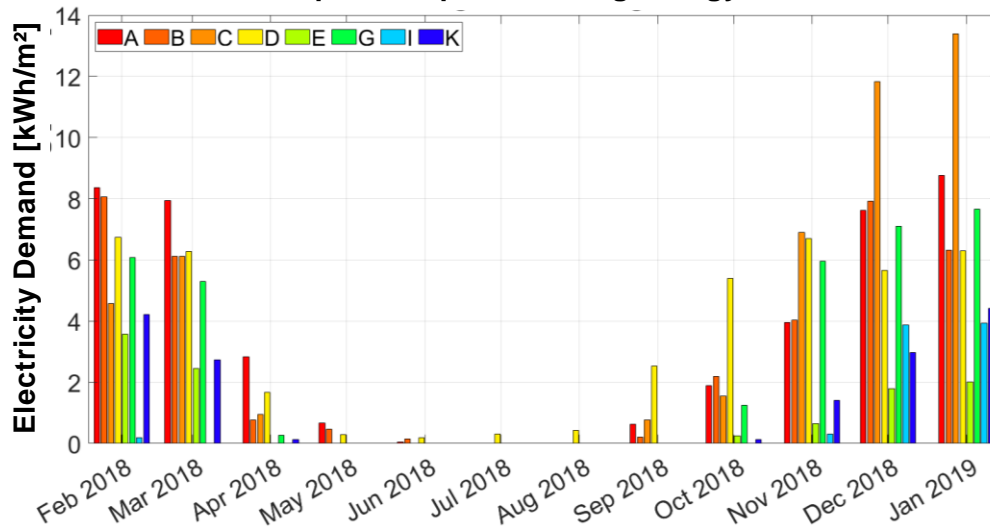


Energy consumptions, separated by purpose, of both schools compared

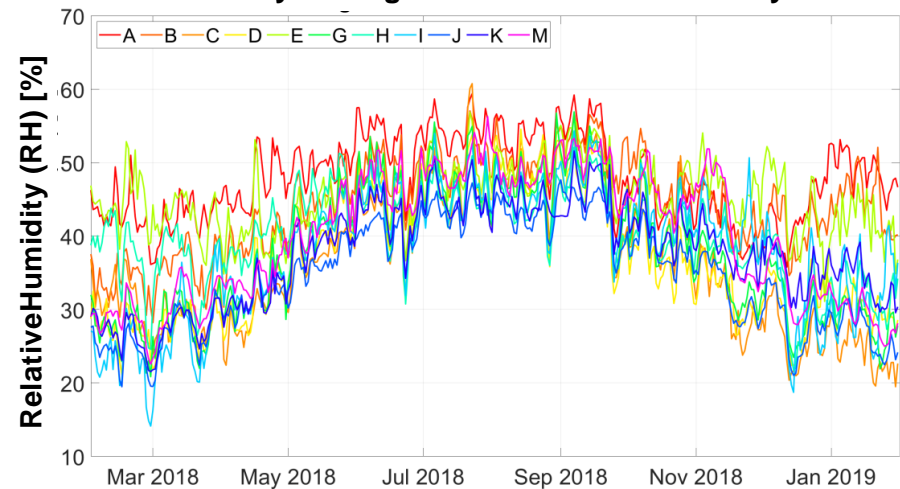
SIEGMAIR	[kWh/m ² a]	ANGER-GASSE
154.4	BEST: existing building (calculated)	156.5
81.5	BEST: suggested specification (calculated)	30.3
118.57	Measured existing building	75.53
35.65	Measured heating final energy consumption	22.58
3.25	Ventilation	1.63
1.48	Lights	5.22
2.21	Domestic hot water	2.73
10.76	Total electricity consumption	8.53

Results Innsbruck Buildings (Sillblock)

Specific Space Heating Energy Demand

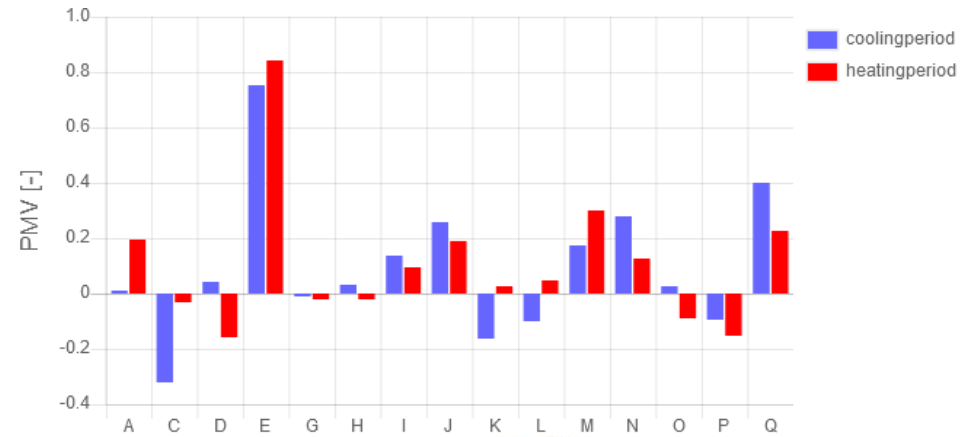
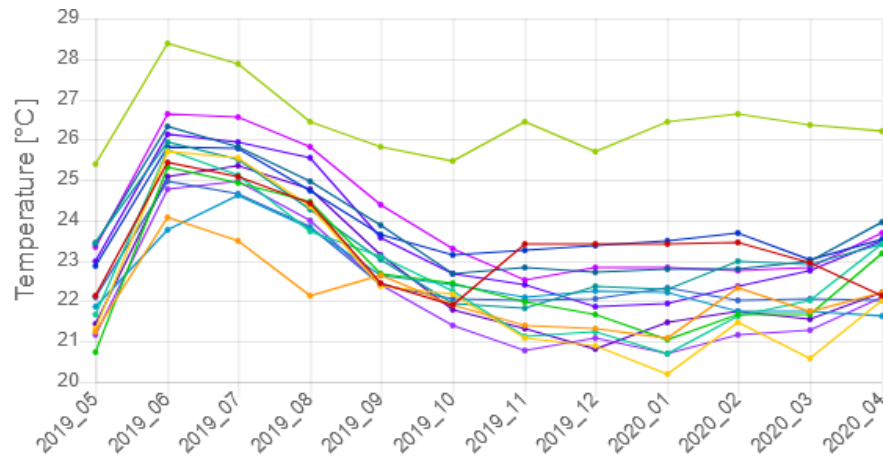
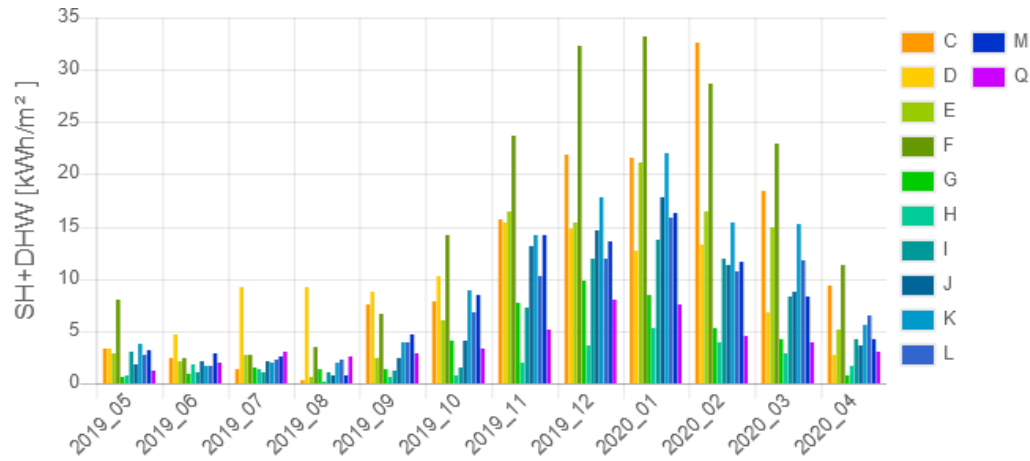


Daily Average Indoor Relative Humidity

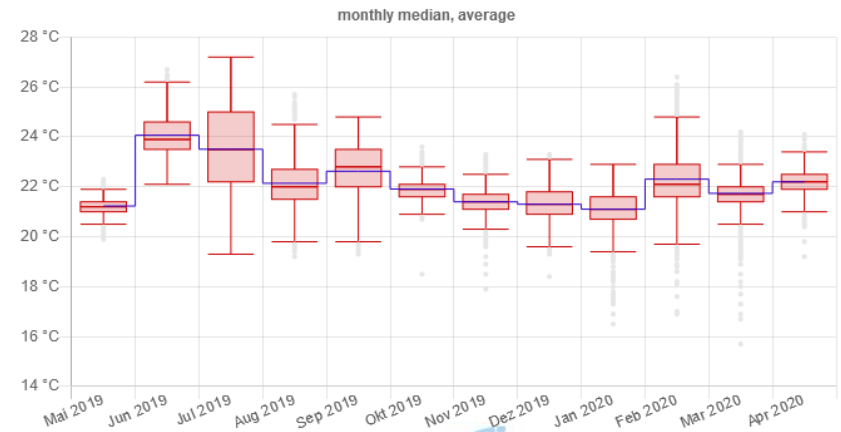
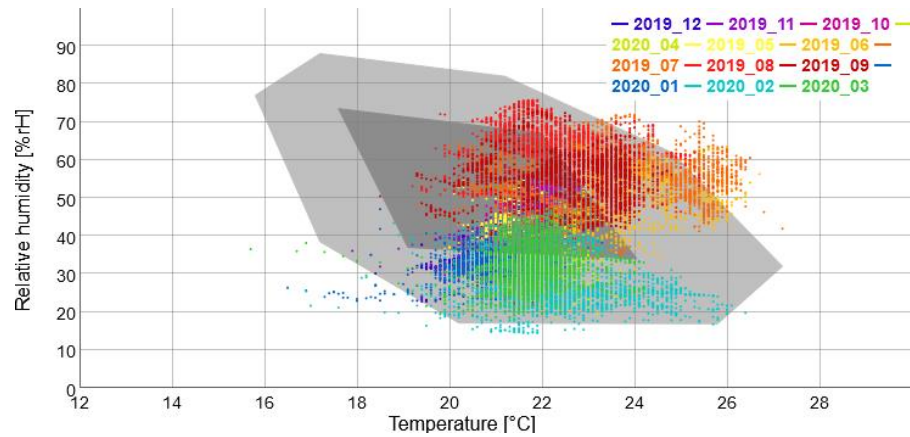
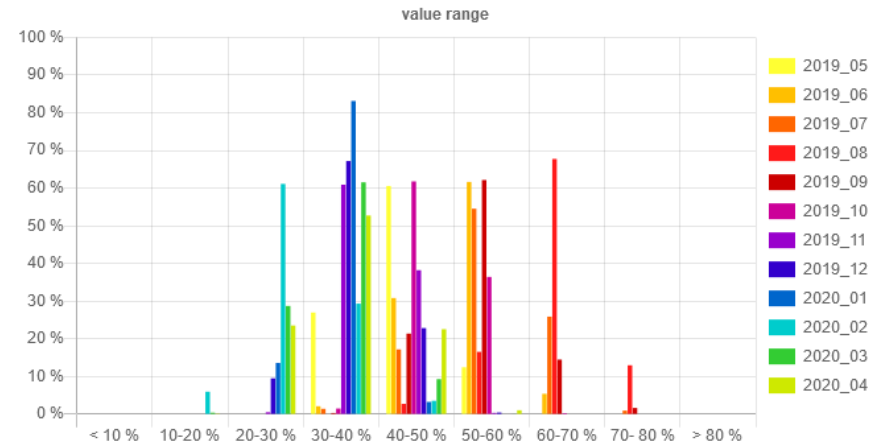
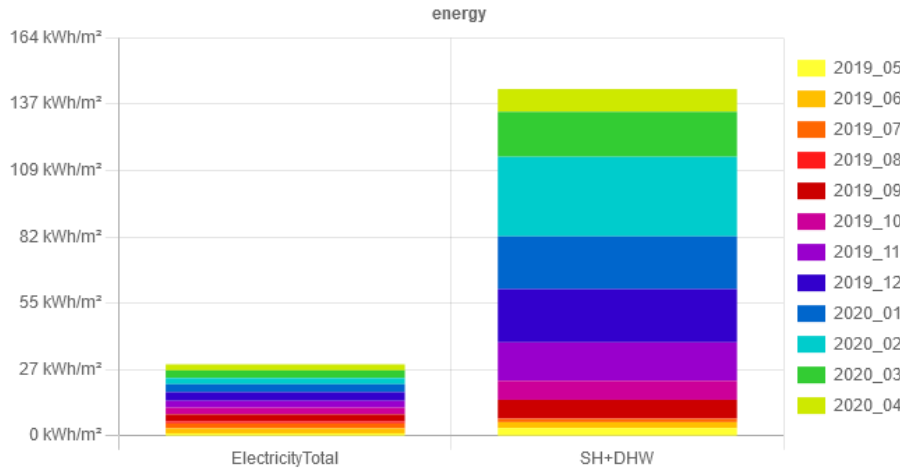


Specific Space Heating Energy Demand	
EnerPhit-Standard:	25,00 kWh/m ² a
BEST-Sheet:	23,20 kWh/m ² a
Energy Certificate:	19,71 kWh/m ² a
PHPP with Standard climate:	21,14 kWh/m ² a
PHPP with Climate 2018:	17,05 kWh/m ² a
Monitoring:	20,65 kWh/m ² a

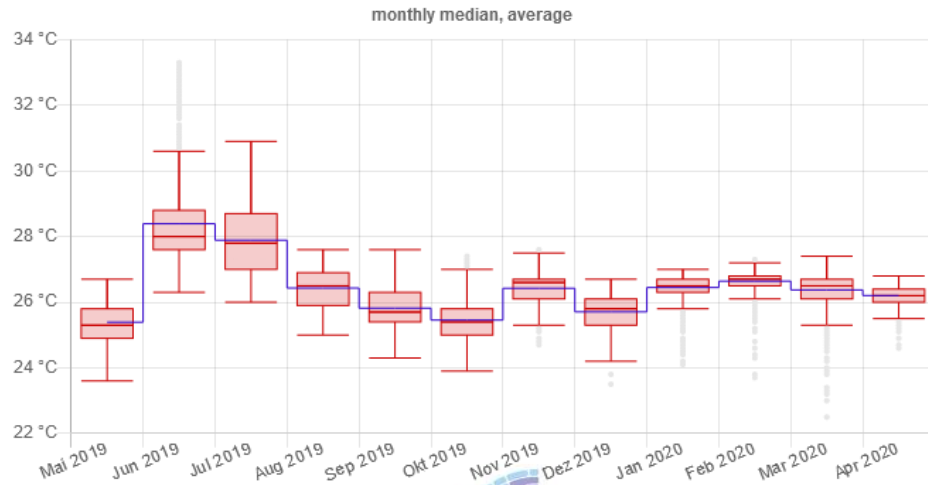
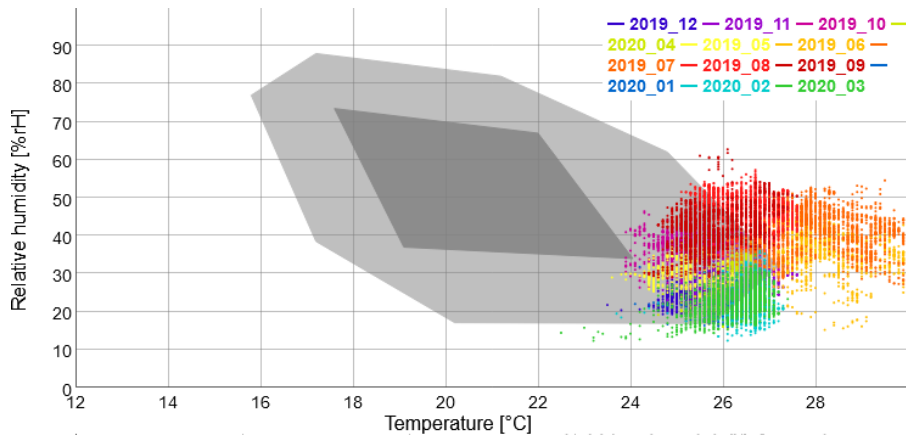
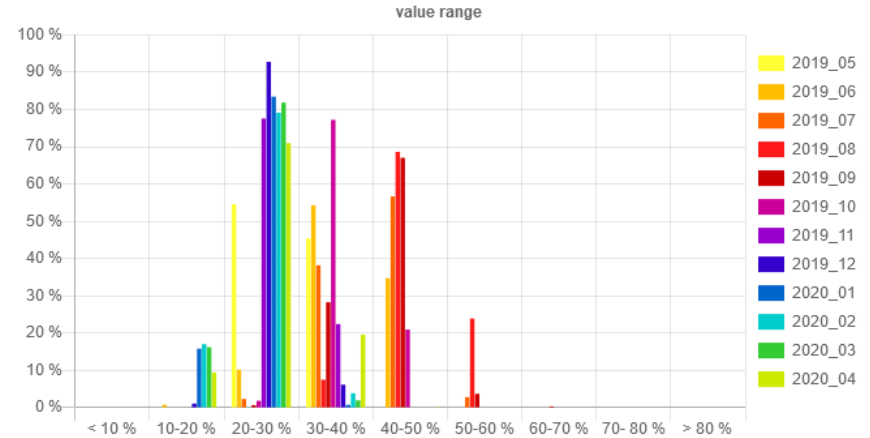
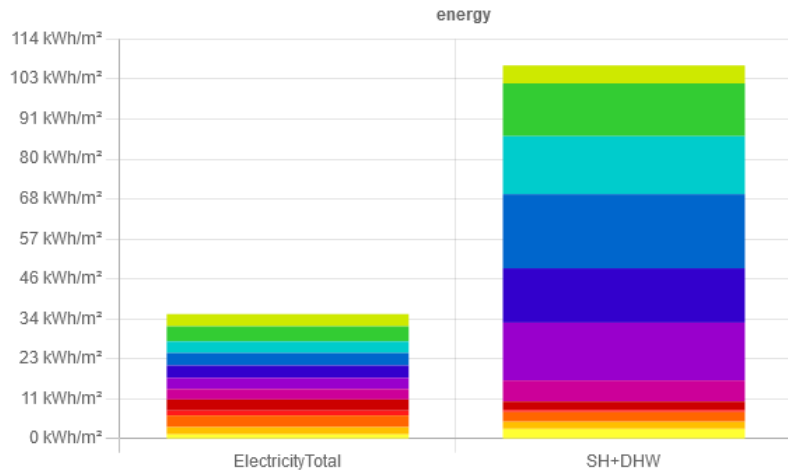
Results Innsbruck Buildings (IN28)



Results Innsbruck Buildings (Apartment C)



Results Innsbruck Buildings (Apartment E)



Results Innsbruck Buildings

PHOTOVOLTAIK INSTALLATIONS AT REFURBISHED BUILDINGS

Building	Best sheet	Building space [m ²]	Capacity [kW _p]	Annual production [MWh/a]	Specific PV capacity [kW _p /m ² *a]
Sillblock 18, 18a, 18b	3	500	17.4	17	0.035
Schubertstr. 6, 8, 10, 12	4	650	26.9	24	0.041
Mozartstr. 5, 7	5	330	14.3	12	0.043
VS Neuarzl 2	16	1,100	76.0	72	0.069
VS Pradl-Ost Part 12+22	17	1,850	-	-	-
VS Angergasse 1	18	1,000	58.0	50	0.058
IN 28	11	1,681	41.1	44	0.024
IN 13	8	1,400	50.0	50	0.036
IN 43	13	910	21.0	22	0.023
IN 22/23	12	1,908	18.0	14	0.009
IN 3	19	9,337	33.3	44	0.004
IN 40	7	850	35.9	38	0.042
Total		21,516	391.9	388	0.018

Results Innsbruck District

OVERVIEW OF SINFONIA MEASURES IMPLEMENTED FROM IKB

Sinfonia sites	Total installed capacity		Additional energy from RES	
	[kW _{el}]	[kW _{th}]	[MWh _{el} /a]	[MWh _{th} /a]
Power house Rossau				
Biomass gasification plant	261	393	1,797	3,690
Biogas CHP (sewer gas)	1,702	1,866	5,164	5,324
Biogas hot water boiler (sewer gas)	n.a.	1,800	n.a.	9,488
Heat recovery sewage sludge dryer	n.a.	385	n.a.	3,160
PV facade biomass gasification plant	15	n.a.	12	n.a.
PV roof biomass gasification plant	34	n.a.	33	n.a.
Dried sewage sludge (4.000 t/a)	n.a.	n.a.	n.a.	13,000
Heat extraction to district heating grid	n.a.	n.a.	n.a.	2,681
IKB Smart City Lab				
Biogas CHP	260	370	128	258
Heat pumps	n.a.	180	n.a.	380
PV installations	330	n.a.	353	n.a.
Power-to-Heat	200	n.a.	n.a.	n.a.
Waste heat transformer station Salurner Str.				
Heat pumps	n.a.	87	n.a.	300
Public swimming pool O-Dorf				
PV installation	41	n.a.	41	n.a.
Richard-Berger-Str. 2				
PV installation	398	n.a.	429	n.a.
Smart Flowers				
PV installation	4	n.a.	6	n.a.
An-der-Lan Str.				
PV installation	32	n.a.	25	n.a.
Public swimming pool Amras				
Power-to-Heat	n.a.	1,000	n.a.	n.a.
Total	3,277	6,081	7,989	38,281
Of which dedicated Sinfonia measures	3,098	6,081	7,804	38,281
Of which dedicated Sinfonia measures excl. PV	2,423	6,081	7,089	38,281

Source: SINFONIA reports D 7.3 (Innovative Hybrid Grid and Grid Automation) and D 7.4 (Implementations of new and retrofit DH energy supply)

Results Innsbruck District

SCALING OF SINFONIA MEASURES TO OVERALL CITY

	Reference case			SINFONIA case		
	residential	non-residential	total	residential	non-residential	total
	[GWh/a]	[GWh/a]	[GWh/a]	[GWh/a]	[GWh/a]	[GWh/a]
Total final energy	865	910	1,775	405	657	1,061
Space heating and DHW	712	548	1,260	252	294	546
Electricity	153	362	515	153	362	515
Total final energy from RES	108	118	226	n. a.	n. a.	348
RES heating*	81	53	134	30	30	61
RES electricity from grid**	27	65	92	27	65	92
RES PV generation	n. a.			140		140
SINFONIA measures RES electricity IKB				0	7	7
SINFONIA measures RES heat IKB				0	38	38
SINFONIA measures RES heat TIGAS				0	10	10
Total primary energy	1,337	1,641	2,978	744	1,351	2,095
Space heating and DHW	936	692	1,628	343	402	745
Electricity	401	949	1,350	401	949	1,350

* incl. share of RES in district heating system; ** RES share of Austrian electricity mix

Reduction of Primary Energy SH and DHW: 54%
Increase of Renewables 54 %



Results Bolzano

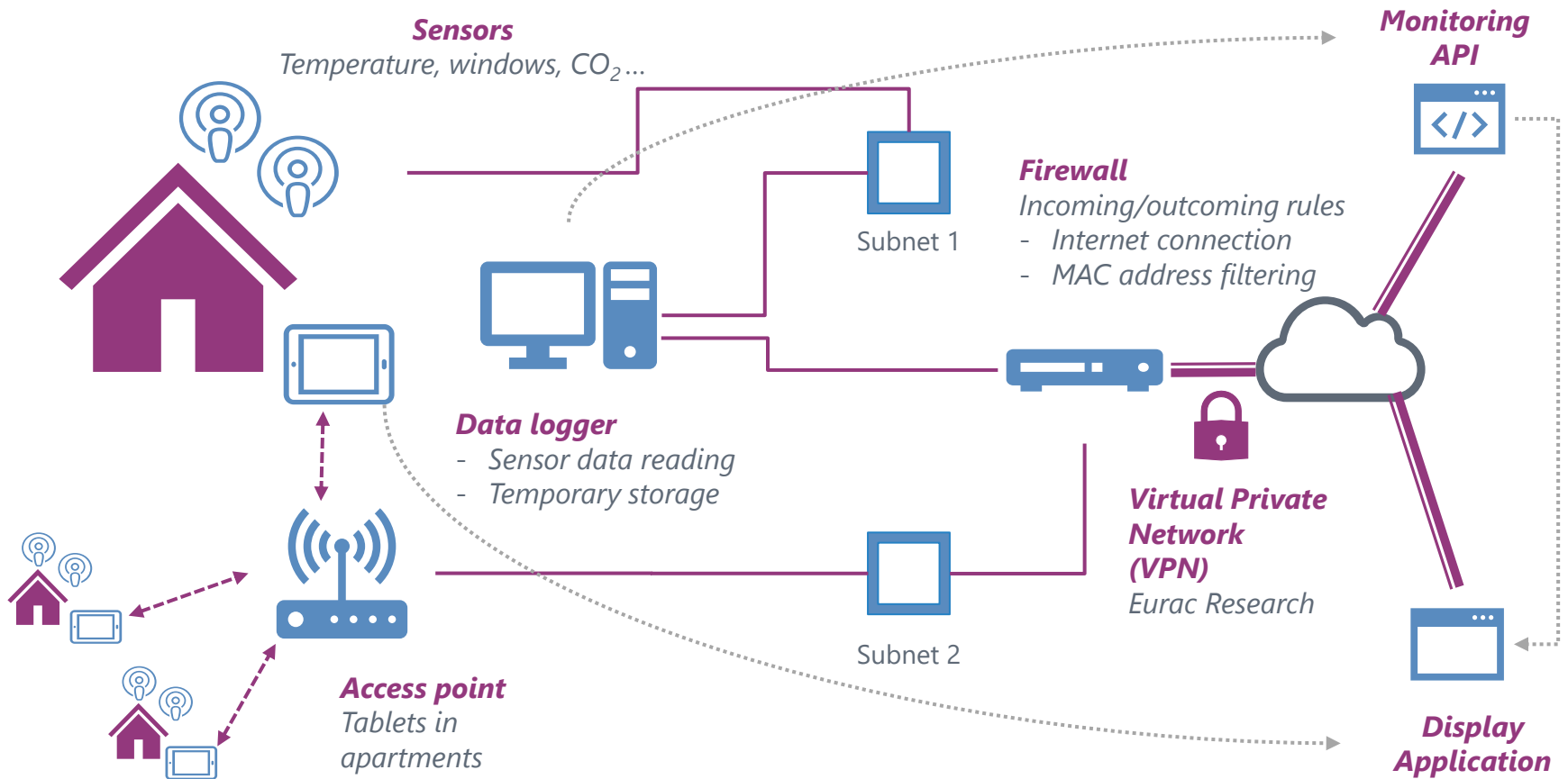
Monitoring and Feedback to users system in Bolzano

EURAC Working team:

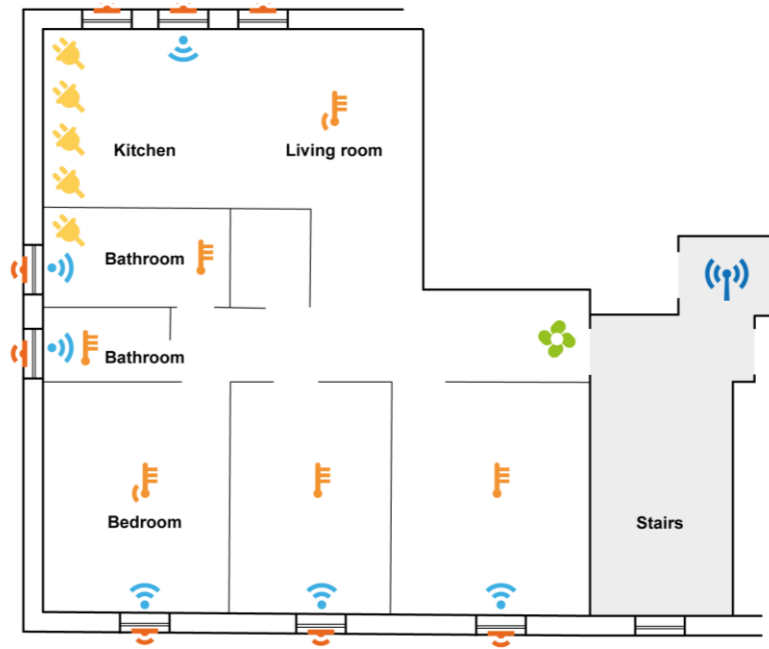
- Pietro Zambelli (overall integration, API, Database, installation of displays, data analysis, GDPR)
- Aaron Estrada (API, Database, coding, backend and frontend, installation of displays, data analysis)
- Marco Castagna (displays concept, data analysis)
- Hanna Pfattner (DPO, GDPR)
- Daniele Vettorato (general coordination and link to other tasks/partners of the project)

Monitoring system building architecture

Bolzano



Monitoring system building architecture Bolzano

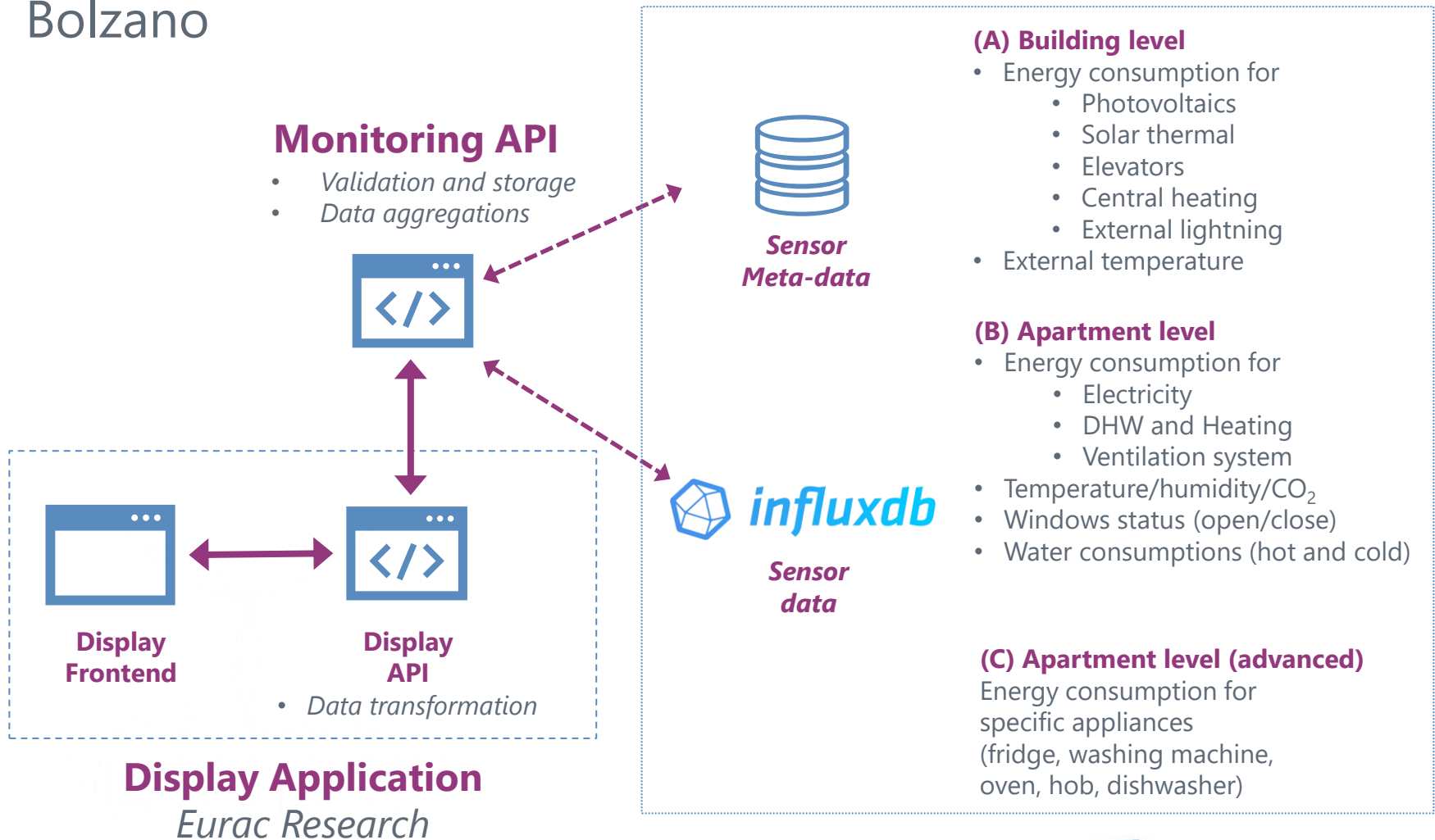


Apartment Type 1
Advanced Monitoring

-  Plug Electric Meter (Large Appliances)
-  Temperature and Humidity Sensor
-  Mechanical Ventilation state Sensor
-  Temperature, Humidity and CO2 Sensor
-  Windows open/closed state Sensor
-  WMBus repeater
-  Thermal energy allocator

Monitoring system architecture

Bolzano



Monitoring system data acquisition

Bolzano



Monitored apartments



Sensors

Via Brescia - Cagliari

41

out of 106

5 buildings

1.967

233M values

Via Similaun

26

out of 59

3 buildings

1.406

58M values

Via Passeggiata dei Castani

25

out of 72

8 buildings

1.200

80M values

Via Aslago

20

out of 80

6 buildings

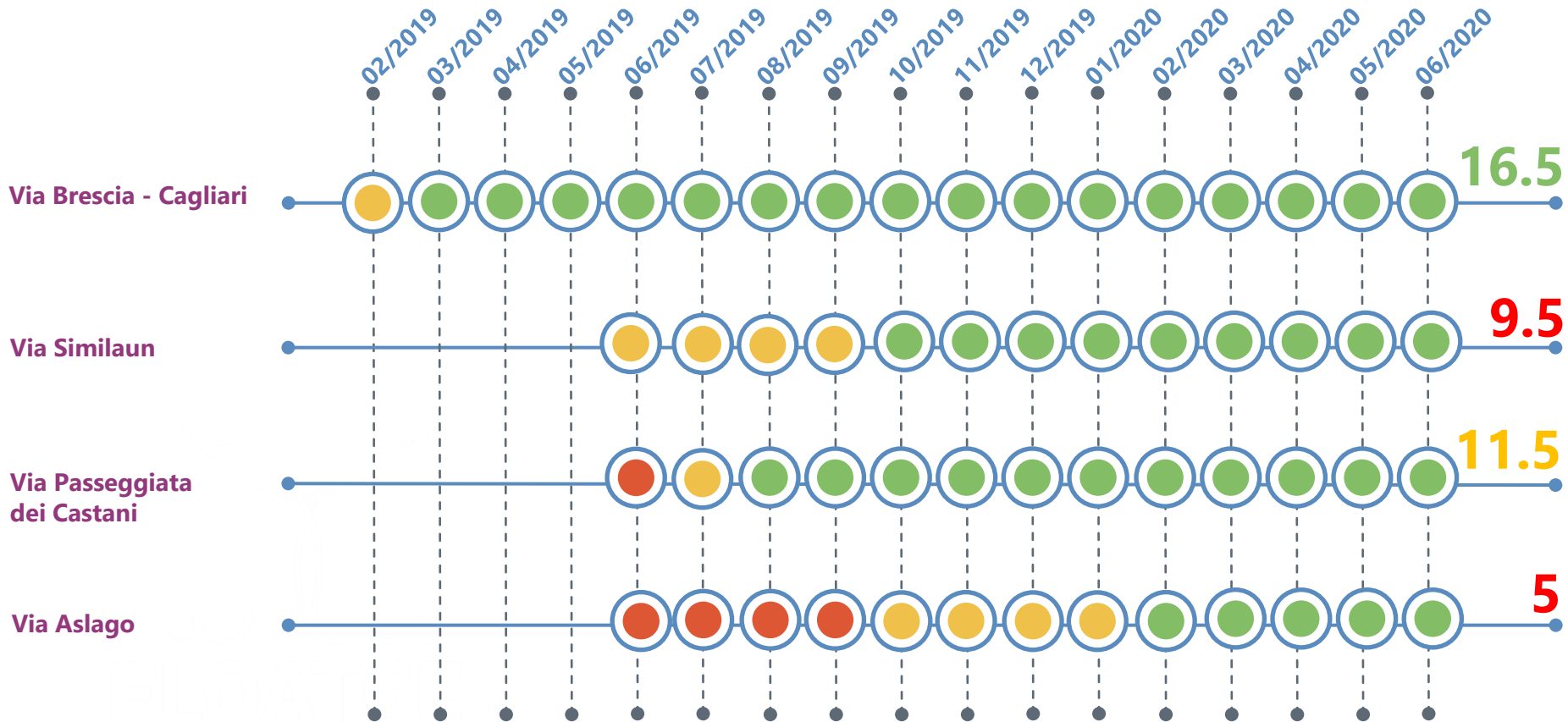
1.178

33M values



Monitoring system months acquired

Bolzano



Feedback to tenants

Bolzano







Feedback to tenants energy indicators

Bolzano



Electrical power [kW]

A speedometer diagram shows the real-time power value.

Yesterday's consumption [kWh]

A bar chart shows the amount of energy consumed in the past day.

Historical consumption

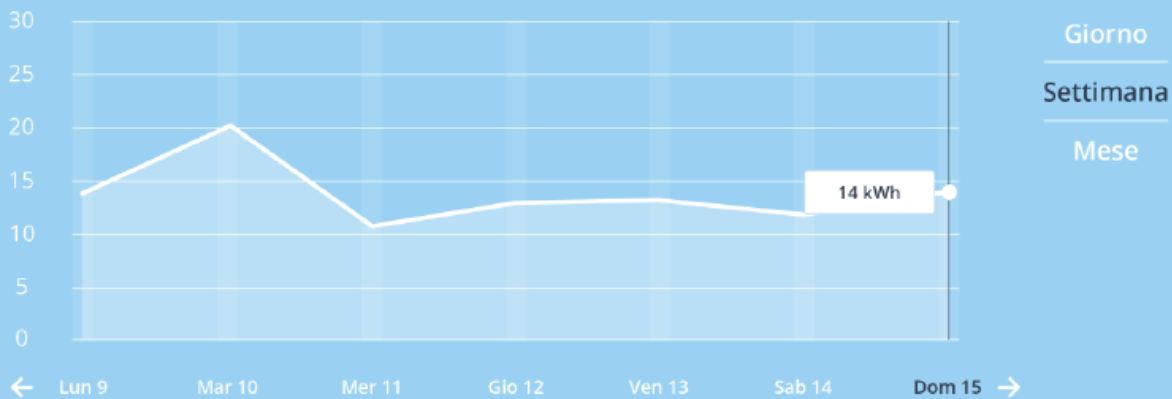
It allows to check for consumption of the last days, weeks and months. It is possible to visualise the trend for both electrical and thermal energy.



← INDIETRO

ENERGIA
ELETTRICA

Storico Consumi - 09/07/2018 - 15/07/2018



Consumo medio nell'ultima settimana: 14 kWh



DEUTSCH

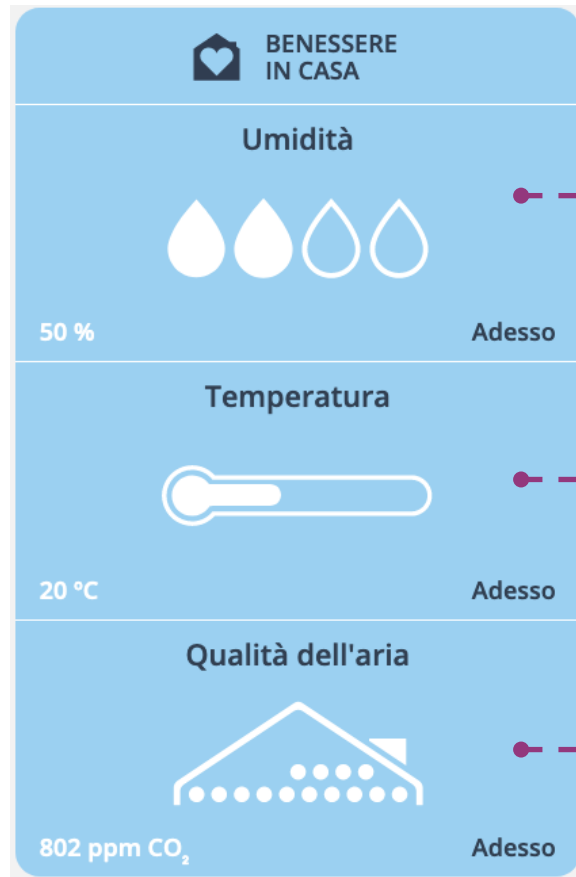


CONTATTACI

Feedback to tenants

indoor environment quality indicators

Bolzano



Relative humidity [%]

The outline of 4 drops is filled up depending on the measured humidity level in real-time. The range goes from 0 to 100%

Indoor temperature [°C]

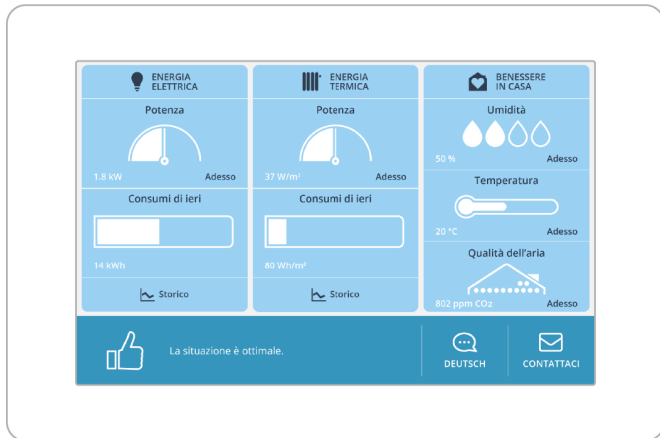
The outline of a thermometer rises up or down, depending on the measured indoor temperature in real-time basis.

Air quality [ppm CO₂]

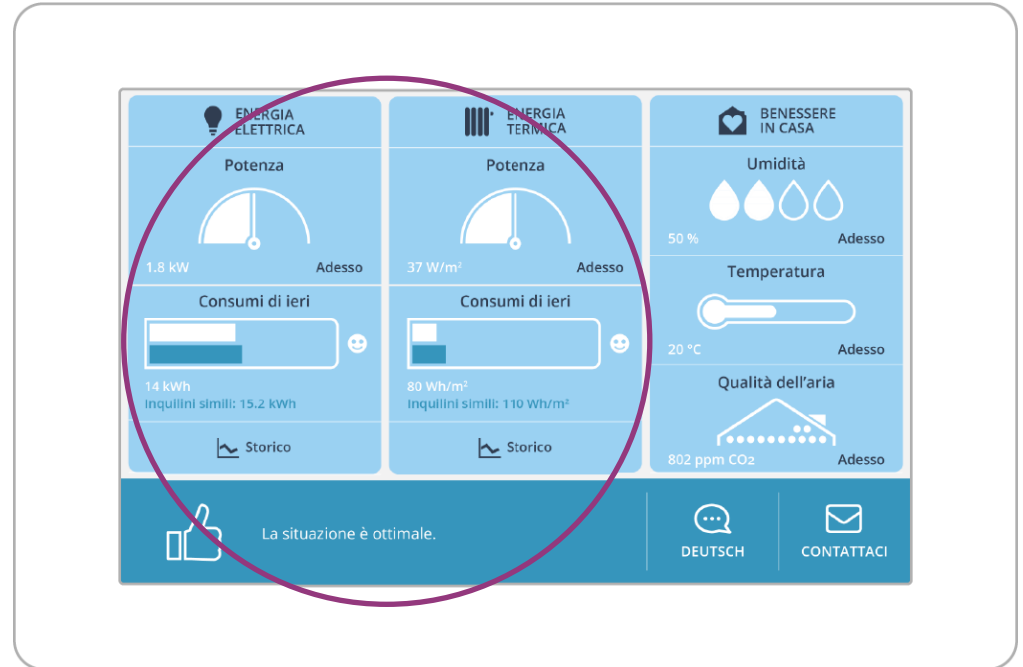
The outline of a house is gradually filled by small dots, that represent the measured value of carbon dioxide in real-time, inside the apartment.

Feedback to tenants social comparison tips

Bolzano



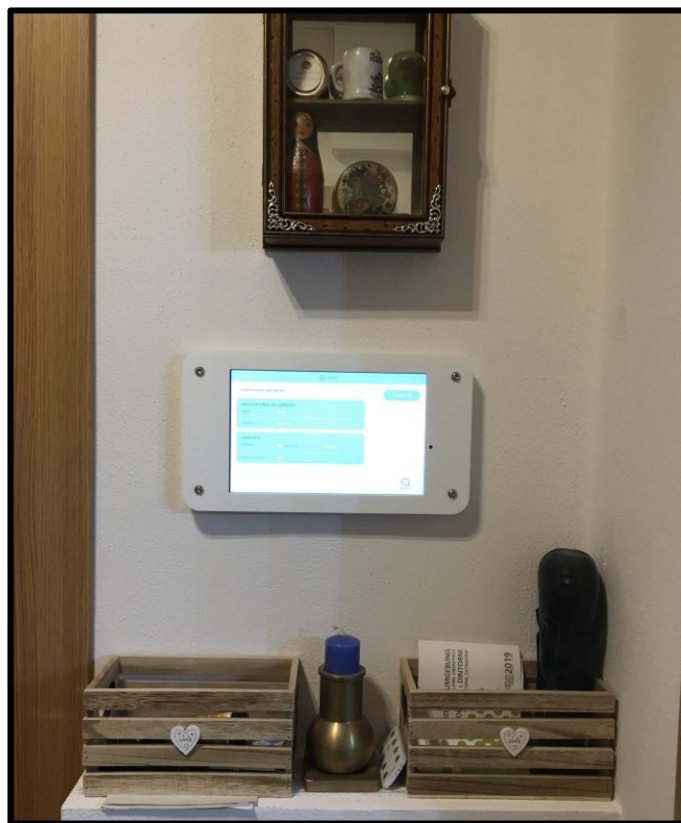
Display 1: Control group



Display 2: Treatment group

Feedback to tenants installed displays

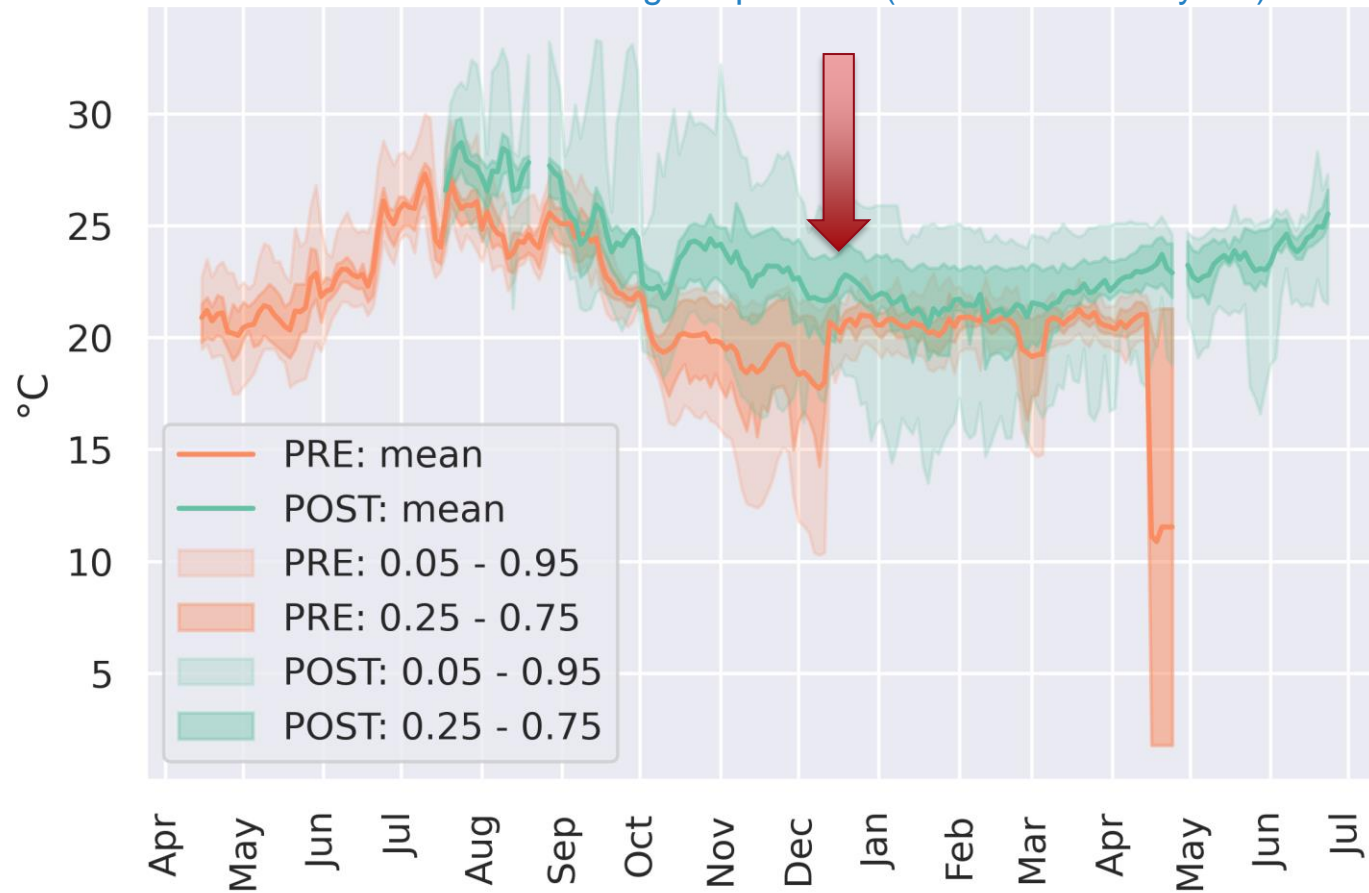
Bolzano



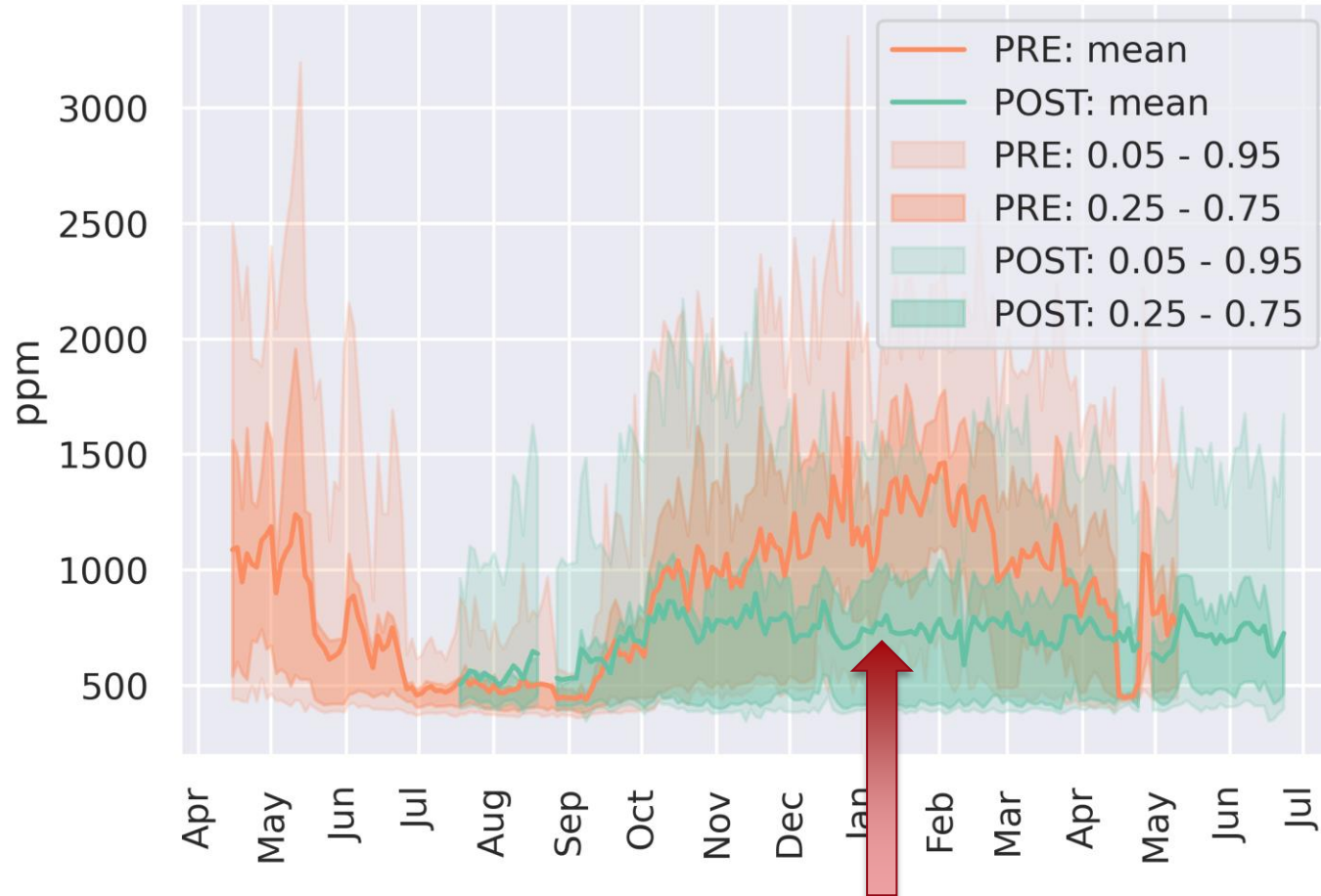
Results internal temperature PRE vs POST

Bolzano

Installation of the displays: Reduction of the heating temperature (to be further analysed)

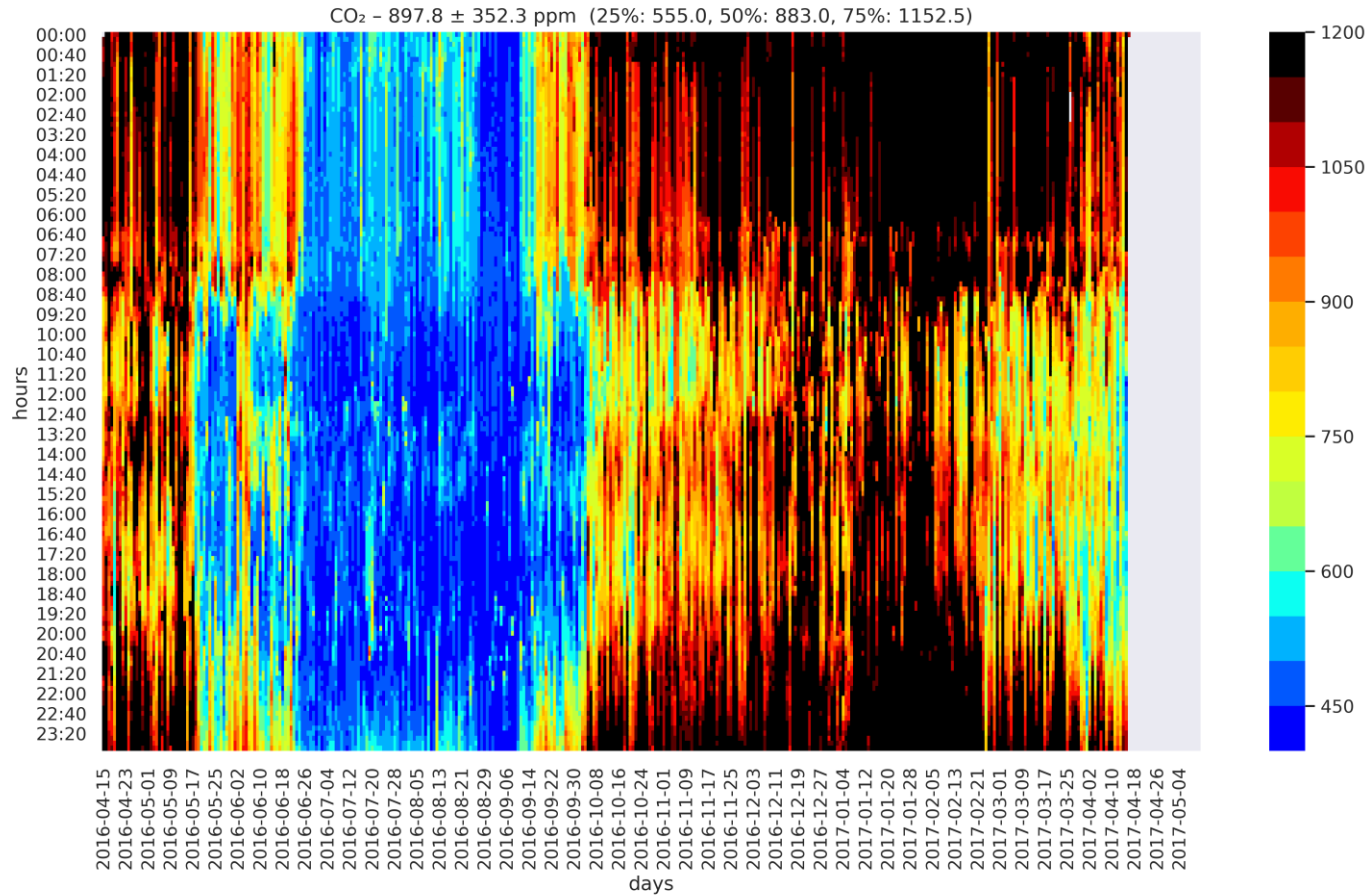


Results internal CO₂ PRE vs POST Bolzano

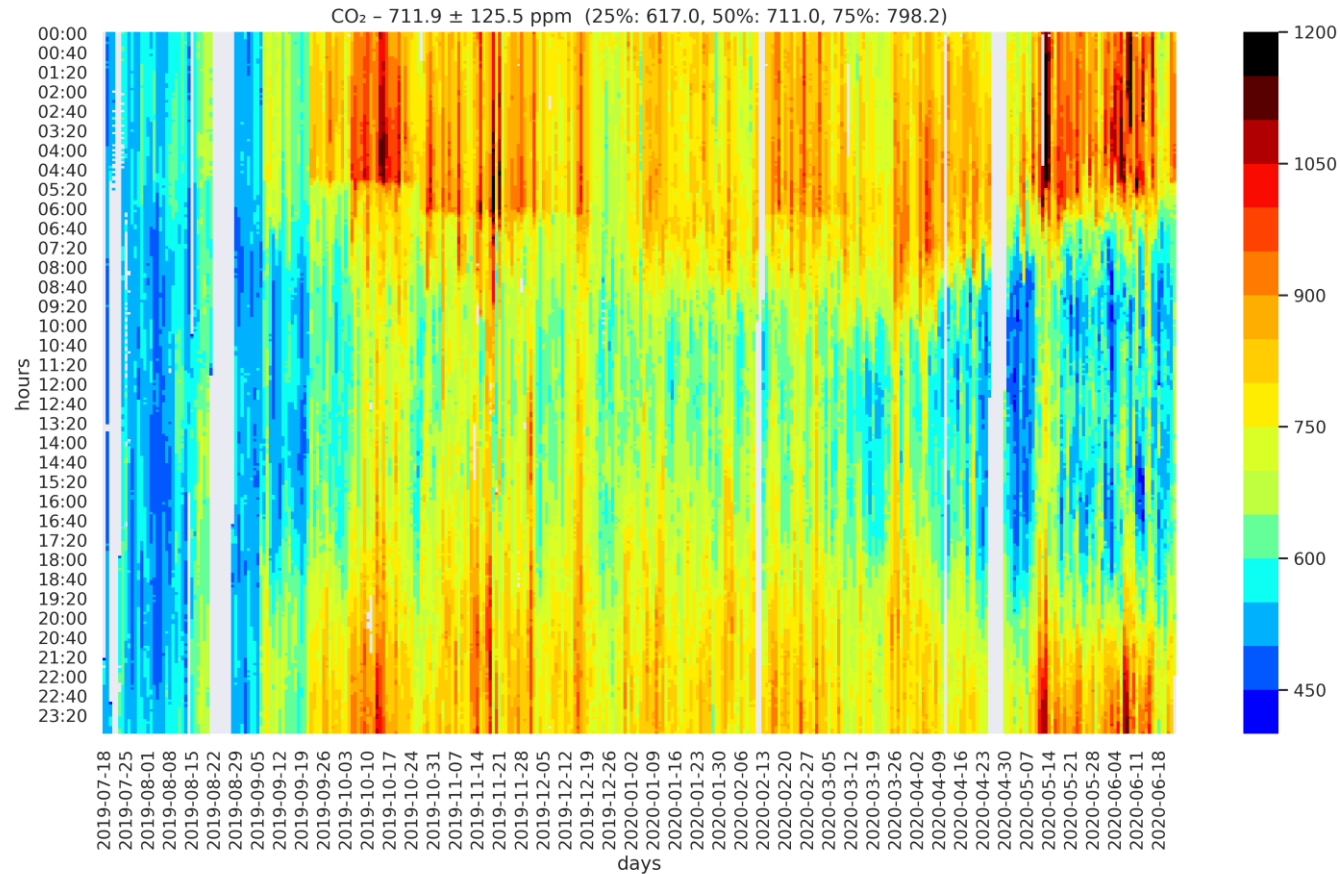


Mechanical ventilation grants lower levels of CO₂
in winter: improved indoor comfort

Results PRE internal CO₂ (5 apartments) Bolzano

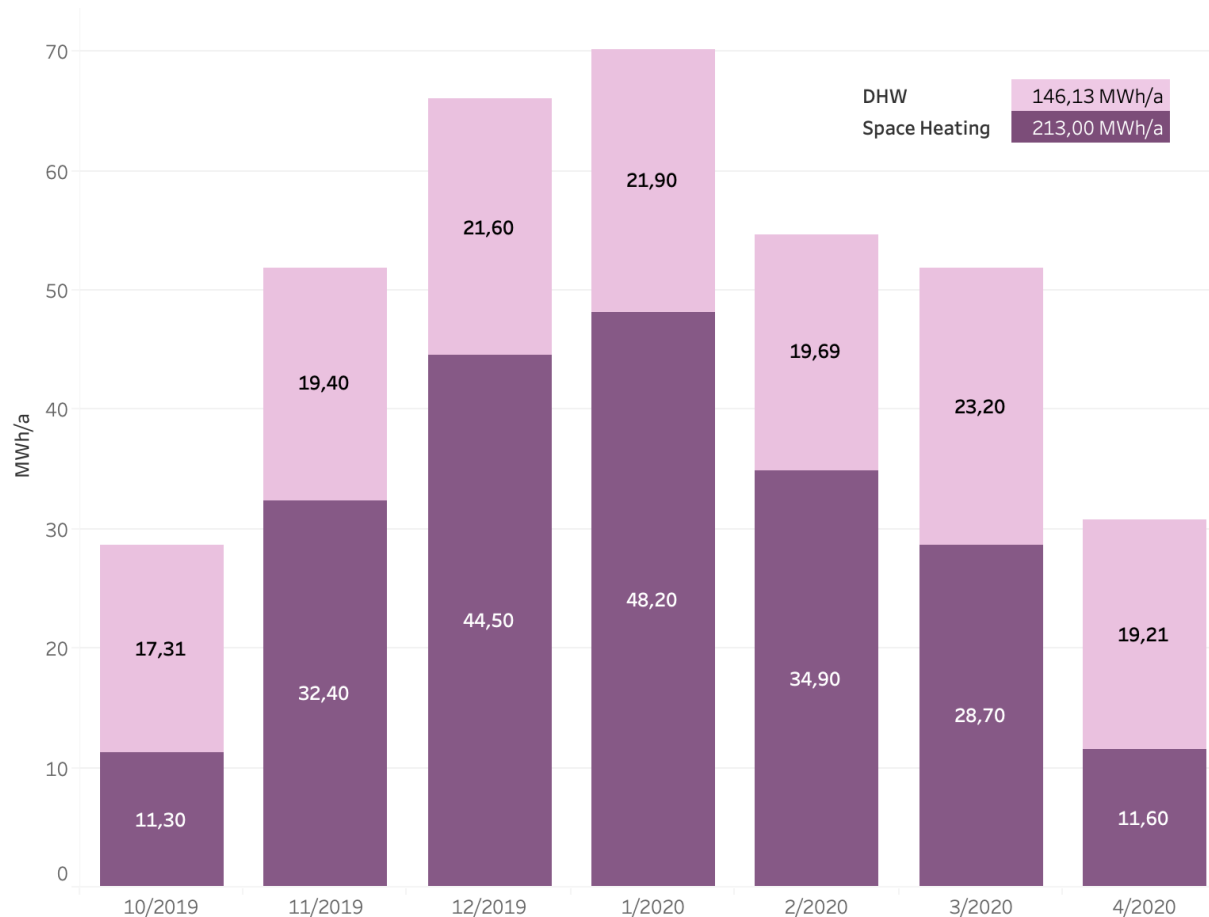


Results POST internal CO₂ (26 apartments) Bolzano



Results Space Heating and DHW energy consumption

Bolzano: Via Passeggiata dei Castani



Final and primary Energy demand for space heating and DHW as well as final energy from renewables before and after refurbishment

Building	Best sheet	Final energy demand* [MWh/a]		Primary energy demand* [MWh/a]		Final energy from RES* [MWh/a]	
		Before refurbishm.	After refurbishm.	Before refurbishm.	After refurbishm.	Before refurbishm.	After refurbishm.
IPES via Brescia/Cagliari	1	1940	424	1552	339	0	166
IPES via Similaun	2	961	170	1009	136	57	69
COMUNE via Passeggiata dei Castani	7	1633	207	1715	197	0	206
COMUNE via Aslago	8	1380	232	1449	232	0	33
IPES via Palermo	9						
Total							

Photovoltaic installations at refurbished buildings

Building	Best sheet	Gross floor area [m ²]	Capacity [kW _p]	Annual production [MWh/a]	Specific PV capacity [kW _p /m ²]
IPES via Brescia/Cagliari	1	9403	19	21	0,0020
IPES via Similaun	2	4864	10	10	0,0021
COMUNE via Passeggiata dei Castani	7	7365	74	84	0,0100
COMUNE via Aslago	8	5524	33	33	0,0060
IPES via Palermo	9	3995			
Total					

Scaling Sinfonia results to Bolzano city

Scenario: max energy performance

Original consumption class [kWh / m ²]	Energy savings [GWh – final]	Consumption [GWh – final]	Percentage of saving per class [%]	Percentage of saving [%]	Heated surf. Per class [m ²]	Percentage of heated surface [%]	Consumption post refurbishment [kWh / m ²]
below 50	0.082	0.082	100.00%	0.00%	1,651	0.0%	0.00
50-70	10.257	10.257	100.00%	0.00%	166,768	4.4%	0.00
70-90	13.549	36.212	37.42%	2.90%	453,259	11.8%	50.00
90 – 110	34.588	69.018	50.11%	7.40%	688,603	18.0%	50.00
110-130	74.737	129.198	57.85%	15.99%	1,089,216	28.4%	50.00
130-150	56.367	88.047	64.02%	12.06%	633,601	16.5%	50.00
above 150	94.654	134.539	70.35%	20.25%	797,714	20.8%	50.00
	284.233	467.352		60.82%	3,830,813		

Scaling Sinfonia results to Bolzano city

Scenario: cost-optimality

Original consumption class [kWh / m ²]	Energy savings [GWh – final]	Consumption [GWh – final]	Percentage of saving per class [%]	Percentage of saving [%]	Heated surf. Per class [m ²]	Percentage of heated surface [%]	Consumption post refurbishment [kWh / m ²]
below 50	0.082	0.082	100.00%	0.00%	1,651	0.0%	0.00
50-70	10.257	10.257	100.00%	0.00%	166,768	4.4%	0.00
70-90	13.549	36.212	37.42%	2.90%	453,259	11.8%	50.00
90 – 110	20.816	69.018	30.16%	4.45%	688,603	18.0%	70.00
110-130	52.953	129.198	40.99%	11.33%	1,089,216	28.4%	70.00
130-150	31.023	88.047	35.23%	6.64%	633,601	16.5%	90.00
above 150	62.745	134.539	46.64%	13.43%	797,714	20.8%	90.00
	191.424	467.352		40.96%	3,830,813		

Status of general WP5 Conclusions

- The delay of the refurbishment delayed the monitoring
- With the extension of the project to End of July 2020 only 9 of 13 buildings in Innsbruck and 2 out of 4 (originally 5) buildings in Bolzano will have 12 months of monitoring
- Therefore the monitoring will be extended to the end of 2020 and revised reports will be delivered
- 235 apartments/school classes are monitored in Innsbruck, 112 apartments in Bolzano
- In Innsbruck the measured energy demand matches the predicted after refurbishment (3 buildings so far)
- The smart city measures reach the predicted values
- Upscaling calculations to the district show that the sinfonia goals can be reached in both cities

