Benefit of Implementing eTRVs in Schools

Project Acronym: SMART BUILD

Project Title: Implementing smart ICT concepts for energy efficiency in public buildings

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Extract of SmartBuild study with focus on Micropelt eTRVs

At the School Centre Velenje (SCV) in the town of Velenje, Slovenia, the heating energy demand of five "pairs" of rooms was compared in the period from October 2014 to February 2015 (and ongoing) in the framework of the project SmartBuild[1]. The rooms were equipped and operated by SCV and the data of the Slovenian pilot buildings were evaluated jointly by WIP (Project coordinator - Germany) and Generplus (Italy). All pairs of rooms comprise a scientific monitoring system since 2013. This system includes, among others, room indoor temperature sensors, occupancy sensors, window handles & sensors to detect the window and door opening status[2] and CO_2 monitoring devices. The "reference rooms" were additionally equipped with eTRVs[3], as per below table and HRVs[4].

If windows are opened the eTRV is switched off after 10 minutes. Initially shorter reaction times were programmed but this led to an excessive use of battery/ capacitor power[5] of the eTRVs.

Results of the monitoring action are shown in **Table 1** below. For the room equipped with Micropelt eTRVs results are further specified in **Table 2**, **Table 3** and **Figure 1**.

Table 1. Energy savings identified for typical room categories at the School Centre Velenje, SCV (period 10/2014 to 02/2015).

#	School room category	Annual Energy Savings [%]	eTRV type installed	Heat demand measurement
1	Building A; Class room - Gymnasium	35	Thermokon SAB005*	Calorimeter
2	Building B; Class room - Higher secondary school	31	Thermokon SAB005*	Brunata**
3	Building C; Class room - Higher secondary school	33	Micropelt	Brunata**
4	Building D; Office - "continuous" use	55	Thermokon SAB005*	Brunata**
5	Sports hall	16	Thermokon SAB005*	Calorimeter

* Until 03/2014 the model SAB002 was in use and in part not fully operational.
** Wireless electronic heat dividers.

In the case of the rooms with integrated HRV it is not possible to isolate the effect of the HRV on the energy savings. Teachers and pupils regularly opened the windows in both rooms and more often in the standard rooms but in general high CO_2 concentrations were accepted in the standard rooms. With an available HRV system in the reference rooms, room ventilation was "forced", thus leading to a higher ventilation rate and to a better room comfort.

[1] EC funded project SmartBuild, see: www.SmartBuild.eu
[2] Except for sport the halls. Retrofitting of small windows with sensors would have been expensive and not very effective.
[3] electronic Thermostatic Radiator Valve (eTRV)
[4] Heat Recovery Ventilation systems (HRV)
[5] Micropelt eTRV use energy harvesting technology to power the actuator. No battery exchange is required.

In all pilot rooms at the School Centre Velenje the window opening status can be determined with state-of-the-art sensor technology to evaluate the effect of the HRV on the window utilization. Handles were installed that provide a different status signals for closed, tilted and opened windows. It was found that especially in rooms without heat recovery ventilation - in example room C002 - windows are often tilted/opened and then intermediately closed without moving the window handle. Manual data analysis was required to determine the actual opening/closing status. This analysis considered gradients in indoor temperature and room occupancy signals.

Table 2. Energy savings identified for the two rooms in Building C equipped with Micropelt eTRVs.

	Standard room	Reference room
	C002	C003
Area (m²)	84	84
	Impulses	Impulses
2014 Oct	188	144
2014 Nov	589	462
2014 Dec	657	440
2015 Jan	1.151	692
2015 Feb	891	608
Σ	3.476	2.346
		-33%

NEW

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2015 Jan	1.151	692
2015 Feb	891	608
2015 Mar	894	698
Σ	4.370	3.044
		-30%

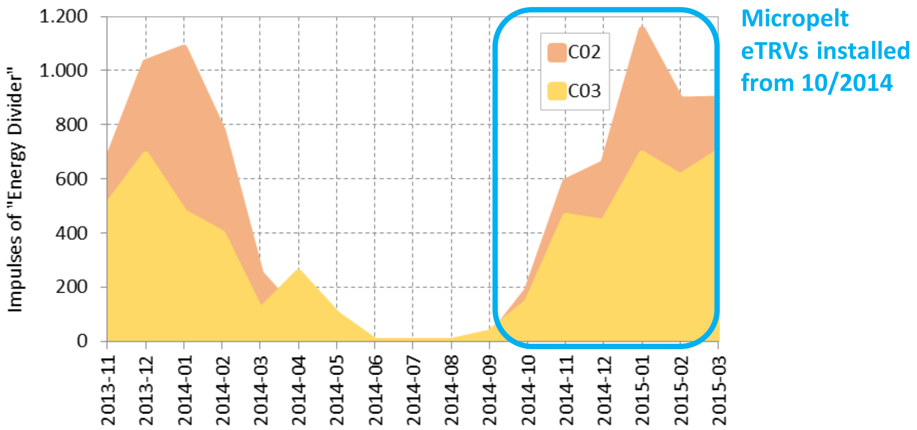

Figure 1. Energy demand for room heating measured via Brunata wireless electronic heat dividers in the two monitored rooms in Building C (standard room in orange; reference room with Micropelt eTRV in yellow). HRV operational from 04/2014. Micropelt eTRV implemented from 10/2014. Initially, Thermokon eTRVs of the type SAB002 were used but they were not fully operational.

Results for the rooms C002 and C003 in March 2015 are depicted in **Table 3**. During room occupancy periods windows are opened during 16% of the time for rooms with HRV and for 45% of the time for rooms without HRV. Relative window opening periods, including outside the occupancy periods, are even higher for the standard room: here the windows are opened during 15% of the time and during 3% of the time for the reference room, respectively.

Note that HRV operation and room heating is stopped in the reference room outside room occupancy periods. Room heating would be activated only if the room temperature falls below the minimum set point.

Table 3. Opening of minimum one of ten windows in the two rooms during March 2015.

		C002 standard room	C003 reference room with HRV & eTRVs
Average room utilisation per school day	**[h]**	**6,0**	**5,0**
Total time window(s) open - incl. Sat & Sun	[h]	3,6	0,8
Total time window(s) open - incl. Sat & Sun	**[%]**	**15**	**3**
Total time room occupied & window(s) open	[h]	2,7	0,8
Total time room occupied & window(s) open	**[%]**	**45**	**16**

In the room category "office" in **Table 1** no HRV system was installed. Here savings are higher (55%). In this building the primary flow temperatures cannot be reduced in the late afternoon, but only in the night. It can also not be generally reduced on weekends or during school holiday periods. This is why the heating control on room level, based on actual room occupancy is more effective. In the class room category "Gymnasium" the HRV was not often used because the teachers did not like the (low) noise. Periodically it was switched off (manual override).

Figure 2. Temperature profiles of two classrooms in comparison (Gymnasium). Blue line: room with ICT controlled heating on room level. During occupancy periods indoor room temperatures are kept at a defined level. During non-occupancy temperatures are regulated down; Orange line: room with manual control based on standard thermostats (normally thermostats are turned on maximum by pupils). Indoor temperatures do sometimes reach high uncomfortable levels. In a consequence windows are opened.

Savings obtained for the sport hall are lower: 16%. The background is understood when having a closer look to the monitoring data: the air exchange in sport halls is high during occupancy periods. Thus, even with a good control, the energy demand for heating remains high. On the other side average room temperatures are lower than in classrooms and the resulting benefit from a shut-down of the heating system via eTRVs during periods with no sport hall operation is lower.

In general automatic control allows for occupancy and schedule based heating control at defined (comfortable) indoor room temperatures. Standard thermostat based control generally reacts slower and room level scheduling is not possible.

The ventilation system in Building C (higher secondary school, #3), reference room C003, is of the same type as the system installed in Building A (gymnasium). **Figure 3** depicts its impact on the CO_2 level in the reference room. Reported values are the daily average (24 hours) of the CO_2 concentration.

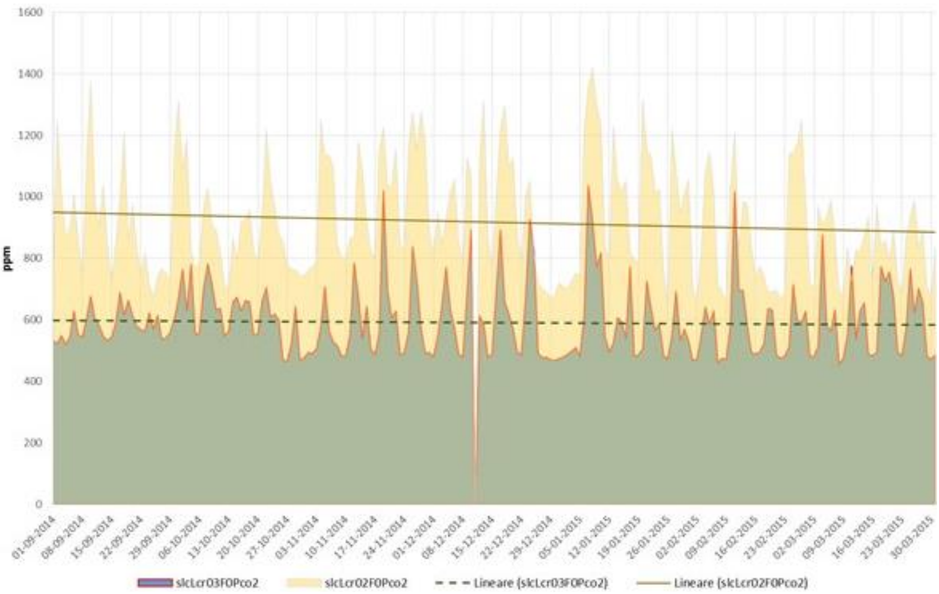

Figure 3. CO_2 level comparison (Building C, reference classroom C003/ green and standard classroom C002/yellow).

Table 4 presents the average overall effect in CO_2 reduction. The benefit of this system in the reference room C003 is high. The comfort is increased significantly. Relating the average CO_2 level to room occupancy periods reveals an even higher effect on the comfort.

Table 4. CO_2 level comparison in Building C.

	Standard room C002 CO2 [ppm]	Reference room C003 CO2 [ppm]	Δ%
2014/09 - 2015/03	591	918	-36
2015/01 (occupancy > 0)	597	972	-39

Figure 4 shows how window opening may impact the indoor room temperature. In the standard classroom of Building C, room C002, a window was left open for two days during a weekend.

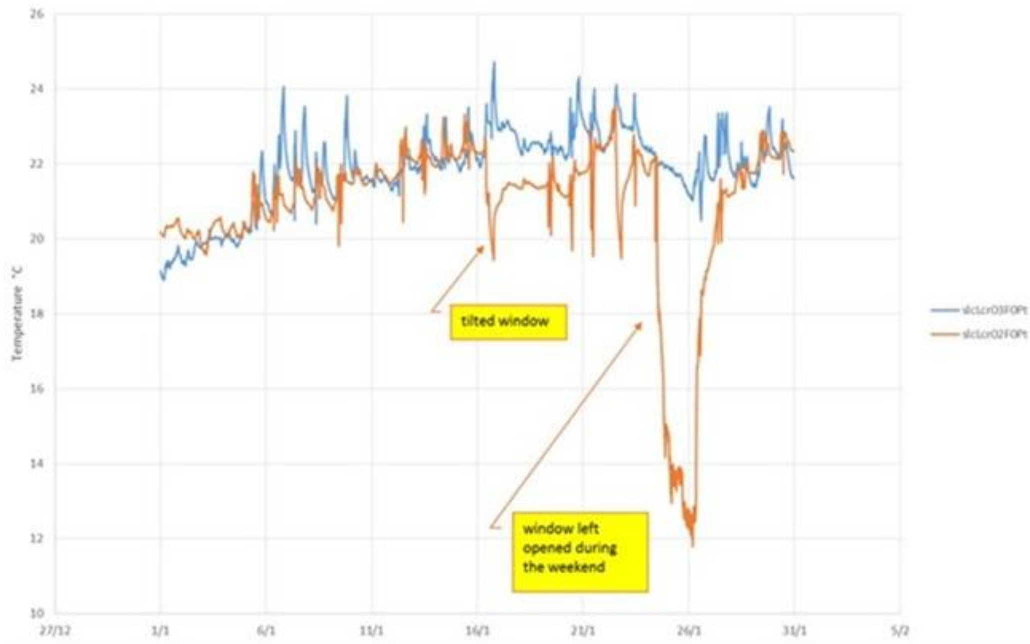

Figure 4. Impact of window opening on indoor classroom temperature in Building C, classroom C002.

Window and door opening has a significant impact on the indoor temperatures and the energy demand. It is beneficial to consider the window opening status for the heat system control (and in future also to alarm the buildings facility manager if windows are left open).

The SmartBuild consortium will continue evaluating the performance of the ICT system. During the winter period 2014/2015 it is planned to periodically switch off the HRV in the reference rooms to verify savings related exclusively to the eTRVs.

M. Grottke, WIP, 23.07.2015