NZEB-like Educational Buildings

Pilot projects from 13 countries

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Introduction

Throughout the Energy Performance of Buildings Directive (EPBD) it is requested that "*the public sector in each Member State should lead the way in the field of energy performance of buildings*" and "*buildings occupied by public authorities and buildings frequently visited by the public should set an example*". New buildings occupied and owned by public authorities shall be Nearly Zero-Energy Buildings (NZEB) two years earlier than all other types of new buildings. Among the most promising public building types to act as lighthouse projects are educational buildings including school buildings. They are visited by different age groups like pupils, teachers and parents. Furthermore, educational buildings are often used for providing lectures on energy efficiency and environmental awareness, showcasing actual improvements of the buildings' envelope and the buildings' own technical services systems, as well as on how to support energy savings by responsible user behaviour.

A collection of pilot projects within CA EPBD

Database

Between November 2015 and May 2016, the Concerted Action EPBD has collected and discussed detailed information on good practice examples of NZEB(-like) educational buildings in the different Member States (MSs). In total, 17 examples of educational buildings have been collected and compared, three of which are kindergartens, eight are schools (mostly primary schools), two are combined kindergartens and schools, and four are university buildings. Figure 1 gives a graphical overview of the pilot projects.

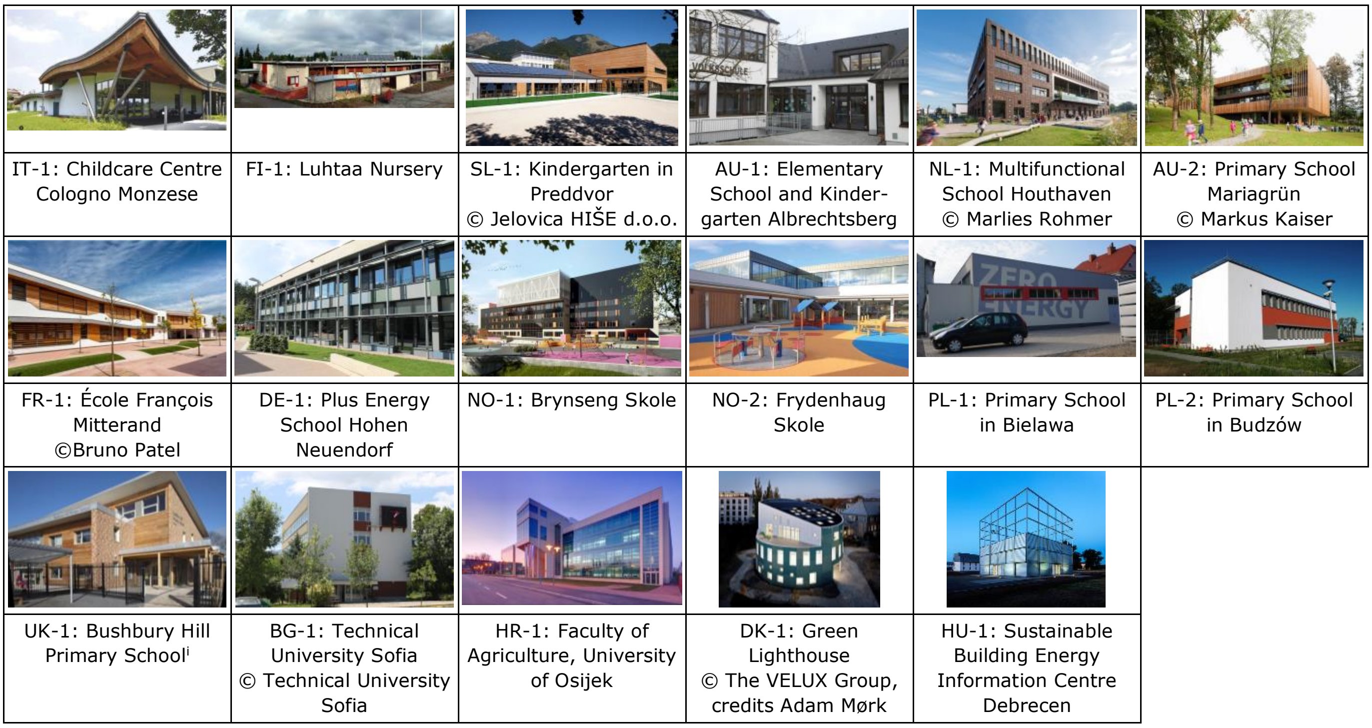

Figure 1. Photos of the 17 different NZEB-like educational buildings collected within the CA EPBD.

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Cross comparison of the used building and technical systems technologies

Case study			IT-1	FI-1	SL-1	AU-1	NL-1	AU-2	FR-1	DE-1	NO-1	NO-2	PL-1	PL-2	UK-1	BG-1	HU-1	DK-1	HU-1
Type			Kindergarten			Kinderg.+School		School (mostly primary schools)								University buildings			
Floor area [m²]			580	1,603	1,347	1,278	6,500	2,500	3,558	6,563	10,737	5,085	681	821	1,900	1,630	18,717	950	300
U-value [W/m²K]	Walls		0.19	0.09	0.10	0.15	0.20	Ø 0.16	Ø 0.15	0.14	Ø 0.16	0.12	0.11	0.09	0.13	0.35	0.40	0.095	0.16
	Windows		1.17	0.66	0.88	Ø 0.81	1.10	Ø 0.65	1.76	0.80	Ø 0.73	0.80	Ø 0.78	Ø 0.78	0.90	1.70	1.1	0.72	1.10
	Roof		0.17	0.06	0.09	0.11	0.20	Ø 0.11	0.08	0.11	Ø 0.12	0.09	0.10	0.07	0.10	0.26	0.30	0.084	0.15
	Basement		0.20	0.07	0.12	0.54	0.20	Ø 0.11	Ø 0.17	0.10	0.10	0.08	0.17	0.08	0.06	0.56	Ø 0.38	0.085	0.22
Building service systems	Space heating (H)		Ground water heat pump	District heating	District heating	Biomass boiler	District heating	Local DH: gas boiler in next building	Gas cond. boilers	Biomass CHP	Geo-thermal HP	Geo-thermal HP, solar thermal	Geo-thermal heat pump	Geo-thermal heat pump	Gas con-densing boiler	Ambient air heat pump	Water/ water heat pump	DH: heat dri-ven HP	DH, air/ water HP
	DHW								Decen-tral/gas		HP + el.					Decen-tral/el.		DH + solar th.	Solar th. +DH+HP
	Cooling (C)		Free cooling	-	Via vent. s.	Night ventil.	DC (lake water)	-	-	-	Free c.: bore h.	Free c.: wells			-	VRF system	Adiab. c.: wells	HP, night vent.	Air/ water HP
	Ventila-tion (V)	Mechan.	HR	75% HR	HR	70% HR	HR	80% HR	w/o HR	Decen-tral	Pres./CO_2 control	70% HR	82% HR	80% HR	Winter: 80% HR	HP + 75% HR	85% HR	Winter	HR, CO_2/ temp. c.
		Other	-	-	-	-	-	-	windows	Autom. windows	-	-	-	-	Summer: windows	-	-	Summer: natural	-
	Lighting (L)		Energy saving lamps	LED pres. detect.	CFL manual	Un-known	Pres. detect.	Un-known	T5, pres. detect.	T5/LED, pres./dl. detect.	LED/T5, pres./dl. detect.	LED/T5 DALI control	LED manual	LED manual	CFL pres. detect.	Energy saving lamps	Energy saving lamps	LED/ daylight depend.	Pres./dl. detect.
Renew-able energy	Thermal		Geo-thermal	Biomass + waste in DH	Biomass in DH	Biomass	Waste in DH; DC	-	-	Biomass CHP	Geo-thermal, free c.	Geo-thermal, solar th.	Geo-thermal	Geo-thermal	-	Ambient	Water wells	Geo-thermal, solar th.	Ambient + solar thermal
	Elec-trical	PV	110 m²	150 m²	98 kWp	213 m²	X	-	406 m²	400 m²	1,100 m²	-	75 m²	-	-	-	-	60 m²	-
		Others	-	In grid 56%	-	-	-	-	-	Biomass CHP	-	-	-	-	-	-	-	-	-
Final energy	Inclu-ded	H DHW C	H DHW -	H DHW C	H DHW C	H DHW C	H DHW C	H DHW C	H DHW C	H DHW C	H DHW C	H DHW C	H DHW C	H DHW C	H DHW -	H DHW C	H DHW C	H DHW C	H DHW C
		V L A	- - -	V L A	V L -	V L -	V L -	V L A	V L A	V L -	V L A	V L A	V L -	V L -	V L A	V L -	V L A	V L A	V L -
	Total [kWh/m².yr]		19.6	116.0	44.5	88.6	10.1	54.3	33.7	33.7	44.1	37.0	51.8	67.9	79.0	16.0	43.0	12.0	28.5
	RES [% of total]		30	50	80 +PV	100	52	0	21	21	36	51	38	25	0	63	Unkn.	90	65
Primary energy [kWh/m²yr]			42.9	76.0	61.5	Unkn.	16.1	86.0	-7.5	-0.5	Not used	Not used	Unkn.	104.0	193.0	47.9	68.8	3.0	28.5
Improvem. on regulation [%]			30	60	100	69	45	Unkn.	> 100	100	40	38	Unkn.	24	80	78	33	97	67
Additional costs	[€/m²]		Unkn.	235	Unkn.	Unkn.	333	Unkn.	Unkn.	Unkn.	135	Unkn.	Unkn.	Unkn.	0	Unkn.	Unkn.	2,600	316
	[% of total]		Unkn.	10	Unkn.	Unkn.	14	Unkn.	Unkn.	Unkn.	3	Unkn.	Unkn.	Unkn.	0	Unkn.	Unkn.	50	27

Table 1. Comparison of the main characteristics of the collected pilot projects.

Abbreviations used in Table 1:

A: Appliances
Adiab. c.: Adiabatic cooling
Autom.: Automatic control
bore h.: bore holes
C: Cooling
CFL: Compact fluorescent lighting
CHP: Combined heat and power unit
DALI: Digital addressable lighting interface
DC: District cooling
DH: District heating
DHW: Domestic hot water
d.l.: daylight
depend.: dependent
el.: electrical
free c.: free cooling
Gas cond. boiler: Gas condensing boiler
H: Space heating
HP: Heat pump
HR: Heat recovery
Improvem.: Improvement
L: Lighting
Kinderg.: Kindergarten
Mechan.: Mechanical ventilation system
Night vent.: Night ventilation
Pres. detect.: Presence detection
PV: photovoltaic
solar th.: solar thermal
temp. c.: temperature control
Unkn.: Unknown
V: Ventilation
Via vent. s.: Via ventilation system
VRF: Variable refrigerant flow
w/o: without

Main results of the comparison

- Concrete/masonry construction was the most commonly used, although several of the buildings are of lightweight construction. The windows are triple-glazed in ten of the buildings, and double-glazed in four of the buildings. U-values were found within the following ranges:
  - Walls: 0.09 – 0.40 W/m²K (average: 0.16 W/m²K)
  - Windows: 0.60 – 1.76 W/m²K (average: 0.97 W/m²K)
  - Roof: 0.06 – 0.30 W/m²K (average: 0.13 W/m²K)
  - Ground/cellar ceiling: 0.06 – 0.56 W/m²K (average: 0.19 W/m²K)
- For space heating, heat pumps are used in nine of 17 examples, gas boilers in two examples, biomass in one example, district heating in six examples and a combined heat and power unit based on wood pellets in one example. Hot water is mostly generated in combination with the space heating but some buildings have additional water heating features like electrical top-up and solar thermal panels. One example uses decentralised electric water heating.
- Twelve of the buildings include cooling systems with five of them using a reversible heat pump, one using a district cooling system, three using free cooling, one using adiabatic cooling, two using night ventilation and one having cooling built into the ventilation system.
- All buildings include elements of demand controlled mechanical ventilation, 14 with heat recovery and three without heat recovery. Controls are based on CO_2 emissions, occupancy, humidity or temperature.
- Lighting controls are based on manual control (four examples) or occupancy control (six examples). Daylighting control is included in five schools. One building uses DALI (Digital Addressable Lighting Interface) controls.
- Four buildings have no Renewable Eenergy Sources (RES) system included. Photovoltaic systems are installed in ten of the buildings. Three buildings have solar thermal panels on the roof. RES (waste heat and/or biomass) are also included in the district heating systems used in three of the buildings, one of which also uses water from a nearby lake for cooling.
- The average final energy use for the buildings is 50.5 kWh/m².year but includes partly differing energy demands. The average primary energy use is 55.3 kWh/m².year.
- The improvement compared to current requirements is on average 68%. The average renewable energy contribution rate is 49%.
- The documented additional costs compared to conventional new educational buildings are on average 603 €/m² floor area (17% of total costs), or 204 €/m² (11% of total costs) if the by far most expensive example is not included.

The variety in the thermal quality of the building envelope and in used service system technologies shows the impact of the different climatic conditions, regional building culture, user expectances, and specific aims of the pilot projects.

Conclusion

The collection of NZEB-like educational buildings demonstrated that many countries are using public pilot projects in order to gain experience with the building standard, and to motivate building owners of private and commercial buildings to develop and realise NZEB in advance of the 2019/2021 deadline. The analysis of the case studies showed however that the additional investment costs, with an average of 11% (or about 200 € per m² floor area), are still substantial.

Further information

The European Commission has co-funded several projects that deal with energy efficient school buildings over the last years, including:

- EU IEE project ZEMedS (http://www.zemeds.eu)
- EU FP7 demonstration project School of the Future (www.school-of-the-future.eu)
- EU CIP project VERYSchool (www.buildup.eu/en/explore/links/veryschool-project-learning-doing)
- EU IEE project RENEW SCHOOL (www.renew-school.eu)

Additionally, national programmes for improving the energy efficiency of schools and other educational buildings are available in:

- Germany: *BMWi* research focus *EnEff:Schule* (www.eneff-schule.de), *BMUB* research initiative *Effizienzhaus Plus* (including schools, http://www.forschungsinitiative.de/effizienzhaus-plus)
- Austria: Klimaschulen, ein Programm des Klima- und Energiefonds [Climate Schools, a programme of the Climate and Energy Fund] (http://klimaschulen.at/).

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i http://www.elementalsolutions.co.uk/passivhaus-schools