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ZEMedS: Case studies





Case study:

Salamanque Group school, Montpellier, France

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August 2015



General data

Salamanque Group school, Montpellier, France

Name of the school

Salamanque Group school



Primary building



Pre-school building

Location

Montpellier, France



Type of school



Pre-school and Primary school (3-12 years old)

Number of pupils



320



Public

Owner

Year of construction



The year of construction is 1965.
Last energy upgrade in 2010.



General data

Salamanque Group school, Montpellier, France



Building typology

2 buildings

Heated area m2

2303 m²

Primary: 3-floor building

Pre-school: 1-floor building with a recent extension.

The buildings are constructed of metal structure (posts and beams).
The slabs are concrete slab and walls made of non-insulated panels.

Climate

Mediterranean. Climate class H3 in French Regulation.

Heating degree days (base 18)*: 1718

Cooling degree days (base 26)*: 65

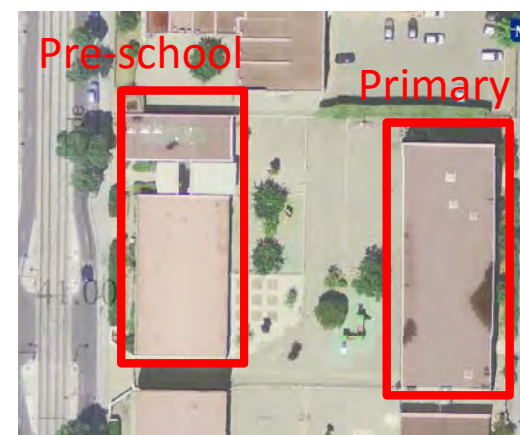
* <http://www.degreedays.net/>



Site

Medium density

Urban





Current situation

Salamanque Group school, Montpellier, France

Renovation needs

Very low comfort in summer season.

Upgrading required for these buildings that are at end of cycle.

High reproducibility: 30 schools of the same type in Montpellier.

Building use

Primary: Weekdays, except Wednesday:

7h45 - 9h: extra school time (20% of pupils)

9h -12h: class

12h – 13h45: cantine (40% pupils)

13h45 – 16h45: class

16h45 – 18h45: recreation activities (15% pupils)

Wednesday: 7h45 - 12h & 13h45 – 18h45: recreation activities (15% pupils) and 12h – 13h45: cantine

Pre-school: Weekdays, except Wednesday: 7h45 - 12h & 13h30 - 18h15.

Wednesday: 7h45 - 12h.

Utilization rate

Standard use of 145 school days a year with 320 pupils attending classes.

Wednesdays and during all summer season, 20% of pupils attending classes.

Building surroundings

Urban and mineral area.

No shadows over the buildings.



Current situation

Salamanque Group school, Montpellier, France

Primary - Walls

Cinderblock walls without insulation, $U = 3.1 \text{ W/m}^2\text{K}$.

Panels walls without insulation, $U = 2.7 \text{ W/m}^2\text{K}$.



Facade east



Facade west

Primary - Groundfloors

Groundfloor without insulation, $U = 2.2 \text{ W/m}^2\text{K}$.

Exterior floor on yard with insulation, $U = 0.24 \text{ W/m}^2\text{K}$.



20 years old windows



5 years old window

Note: values of U don't include possible thermal bridges.

Primary - Roofs

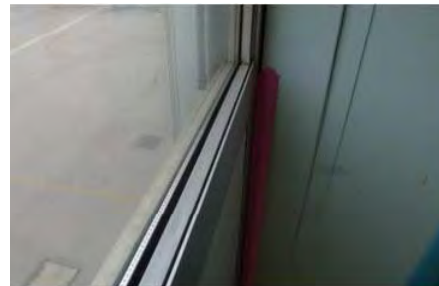
Flat roof with insulation, $U = 0.19 \text{ W/m}^2\text{K}$.



Primary - Windows and exterior doors

20 years old double glazing windows and exterior doors 4/6/4 $U_g = 3.3 \text{ W/m}^2\text{K}$ with aluminium frame with no thermal bridge. Existing exterior roller shutters for solar protection.

5 years old low-e double glazing windows and exterior doors 4/16/4 $U_g = 1.9 \text{ W/m}^2\text{K}$ with aluminium frame with thermal bridge. Existing exterior roller shutters for solar protection.



Windows in non insulated panels



Windows in cinderblock walls



Current situation

Salamanque Group school, Montpellier, France

Pre-school - Walls

Panels walls without insulation, $U = 2.7 \text{ W/m}^2\text{K}$.

Cinderblock walls with internal insulation, $U = 0.23 \text{ W/m}^2\text{K}$.



Facade west (panel walls)



Facade west (cinderblock walls)

Pre-school - Groundfloors

Groundfloor without insulation, $U = 2.2 \text{ W/m}^2\text{K}$.



Façade east

Pre-school - Roofs

Flat roof without insulation, $U = 3.2 \text{ W/m}^2\text{K}$.

Pre-school - Windows and exterior doors

20 years old double glazing windows and exterior doors 4/6/4 $U_g = 3.3 \text{ W/m}^2\text{K}$ with aluminium frame with no thermal bridge. Existing exterior roller shutters for solar protection.

5 years old low-e double glazing windows and exterior doors 4/16/4 $U_g = 1.9 \text{ W/m}^2\text{K}$ with aluminium frame with thermal bridge. Existing exterior roller shutters for solar protection.

Note: values of U don't include possible thermal bridges.



Current situation

Salamanque Group school, Montpellier, France



East facades of primary school



East facades of pre-school



West facades of primary school



*East facades of pre-school
(new building)*



Library in primary school



Classroom in pre-school



Current situation

Salamanque Group school, Montpellier, France

Airtightness:

No measurements in any of the buildings (poor performance)

Heating and cooling:

2 natural gas boilers (230 kW each) situated in the primary school feeds pre-school. Mon - Thu - Thu - Fri : start heating 4am and 6pm total shutdown. Not maintaining the temperature at night. Wed : start heating at 4 am and 3pm total shutdown. Same program for all heating network.



The new radiators are equipped with thermostatic valves.

Electric fans are installed in some spaces.



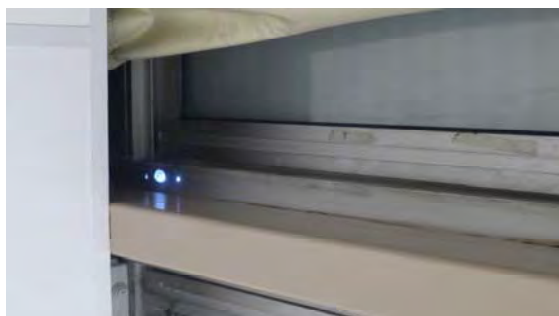


Current situation

Salamanque Group school, Montpellier, France

Ventilation: No mechanical ventilation systems, except on toilets and kitchen.

Lighting: **Primary school:** T8 fluorescents 18Wx4 and T8 fluorescents 36Wx2 in classrooms. T5 fluorescents 14Wx3 in offices. T8 fluorescents 36Wx2 in corridors, staircases and toilets.
Pre-school: T8 fluorescents 18Wx4 in classrooms and corridors. LBC 15Wx1, LBC 15Wx2 in offices and toilets.



High infiltration in façade



T8 Fluorescents 18Wx4 in classroom in pre-schol



T8 fluorescents 36Wx2 in corridor in primary building



Current situation

Salamanque Group school, Montpellier, France

Appliances:

Primary: 2 printers/copiers, 27 computers (1 computer/classroom)

Pre-school: 1 printers/copiers, 9 computers (1 computer/classroom)

DHW:

Primary: 2 electric heaters of 75L (teacher room) and 300L (kitchen)

Pre-school: 1 electric heater of 200L

No data of energy consumption for DHW.

Cooking/kitchen:

Primary: Just catering. 1 electric oven of 6kW, 1 refrigerator of 150W, 1 dishwasher of 10kW.

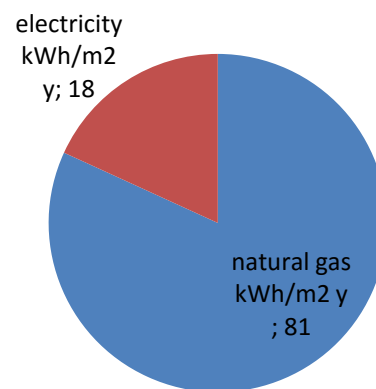
Pre-school: no cooking service



Current situation

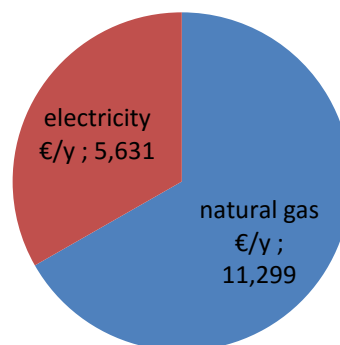
Salamanque Group school, Montpellier, France

Current final energy consumption
kWh/m² conditioned area:



Total energy consumption (bill 2012): 227,091 kWh/year, 99 kWh/year m² conditioned area

Running cost:



Energy (bill 2012): 11,299 €/year (natural gas), 5,631 €/year (electricity). VAT included.

Water: no data

Maintenance: no data



Current situation

Salamanque Group school, Montpellier, France

Health and comfort:

Winter and summer comfort:

Winter comfort is right unless when it is very cold and windy due to air infiltration and cold effect. No mechanical ventilation in classrooms. Ventilation is by opening windows at the discretion of users. The building is not sealed so no major health problem but thermal discomfort.

Discomfort problems in summer due to overheating, so the shutters are often closed all day requiring artificial lighting.

Interior air quality:

No studies carried out of indoor quality. High air infiltration through envelope.

Visual comfort:

Glare problems observed as classrooms are oriented east and west.



nZEB renovation

Salamanque Group school, Montpellier, France

Design approach:

Deep renovation towards ZEMedS nZEB Schools requirements.

ZEMedS Goals:

- Requirement 1: $C_{PE} - \text{Prod}_{RES} \leq 0$

Primary energy consumption yearly (heating, cooling, ventilation, DHW and lighting) is produced by local renewable energies.

- Requirement 2: $C_{FE} \leq 25 \text{ kWh/m}^2 \text{ y}$

FE consumption yearly (heating, cooling, ventilation and lighting) per conditioned area

- Requirement 3: Indoor air quality guaranteed ($\text{CO}_2 \leq 1000 \text{ ppm}$) and temperature above $28^\circ\text{C} \leq 40$ hours yearly during occupancy

National factors for conversion in energy and CO_2 have been taken into account (data 2014).

Methodology in energy simulations:

Steps considered:

- First step: 3 proposals (variant A, B and C) in envelope renovation: from less insulated to more insulated
- Second step: 1 proposals in lighting replacement in pre-school (no saving observed in primary school)
- Third step: mechanical ventilation installation and PV system installation to cover lighting, ventilation and DHW



nZEB renovation

Salamanque Group school, Montpellier, France

➤ **First step:** 3 proposals (variant A, B and C) in envelope renovation: from less insulated to more insulated. Current regulation relative to the thermal characteristics and energy performance of the existent buildings is referred by variant A.

		 Variant A	 Variant B	 Variant C	
Step 1	Uwindows and exterior doors	1.8	1.5	1.4	Decreasing % window area on classrooms in primary school and pre-school <u>Replacement of existing 20 years old windows and exterior doors for:</u> Variant A: low-e double glazing, 16mm(air) and aluminum frame (with thermal break) . Ug=1.6 Uf= 2.2 Variant B: low-e double glazing, 16mm(argon) and aluminum frame (with thermal break) . Ug=1.3 Uf= 2.2 Variant C: low-e double glazing, 16mm(argon) and wooden frame . Ug=1.3 Uf= 1.8
	Solar protection	current			-
	Uroof and Ufloor in contact with exterior air	0.3	0.22	0.15	Ventilated roof with insulation system in pre-school roof Paving concrete slabs in primary roof
	Uwall	0.4	0.3	0.2	Ventilated facade with insulation system (except the north façade in primary school and the renovated façade in pre-school)
	Ugroundfloor	current			-



nZEB renovation

Salamanque Group school, Montpellier, France

➤ **Second step:** replacing lighting in the classrooms of pre-school

➤ **Third step:** installation of mechanical ventilation to improve air quality of spaces and PV systems to cover primary energy consumption of heating, lighting, ventilation and DHW

		Variant A	Variant B	Variant C
Step 2	Lighting	replacing T8 tubes for T5 tubes in classrooms of pre-school with 6.3 W/m ²		There is no saving in electricity consumption when replacing lighting in primary school
Step 3	Mechanical ventilation	mechanical ventilation 6,5l/per sec in classrooms and offices		
	Heating system	current		
	DHW	current		
	Cooling system	no cooling system		
	PV system	42 kWp / 243 m ² PV panels		



nZEB renovation

Salamanque Group school, Montpellier, France

Energy simulations:

Building simulation softwares DesignBuilder v.4 and EnergyPlus

Weather files and main parameters for energy simulations:

Weather data provided of the site of Montpellier in EnergyPlus weather format.

Setpoint temperature for heating: 20°C.

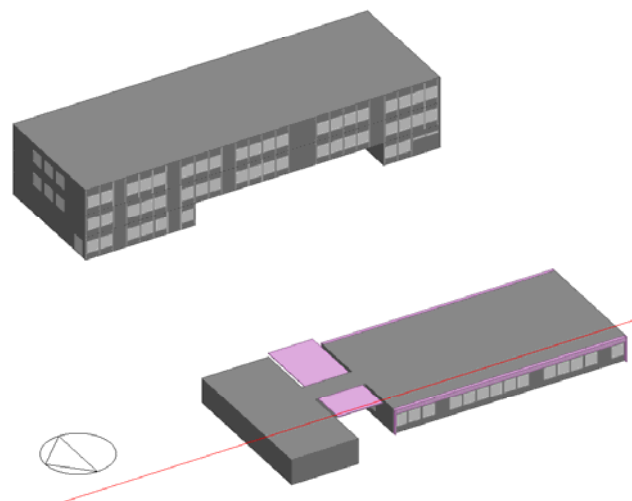
Thermal bridges considered in building envelope.

Main occupancy rates: classrooms (0,44 per/m²), offices (0,21 per/m²), corridors (0 per/m²), wc (0 per/m²), dinning room (1 per/m²).

Infiltration rate of 30 m³/h m² at 50 Pa simulating the existing building and 6 m³/h m² at 50 Pa simulating renovated buildings.

Natural ventilation for opened windows (5 ACH) 15 minutes during break times and half an hour during cleaning tasks.

Considered 2 l/person day for the demand of DHW, including restoration (catering).





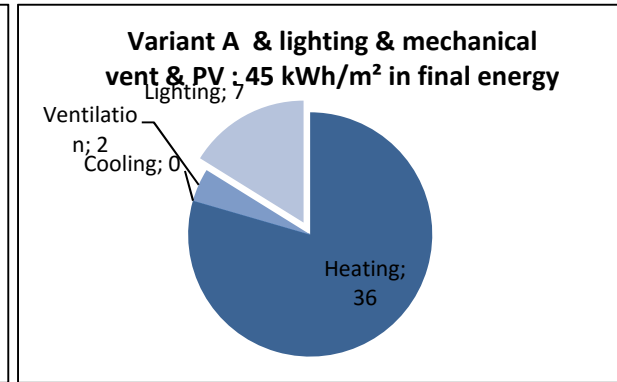
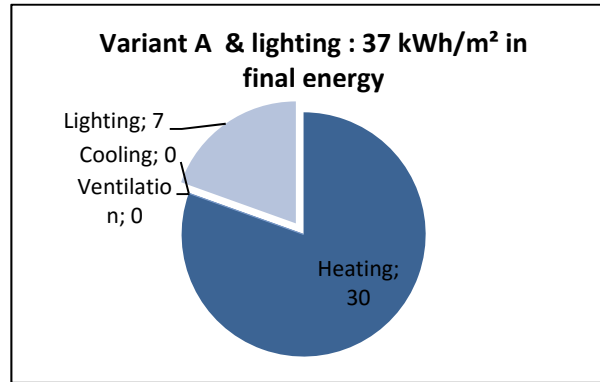
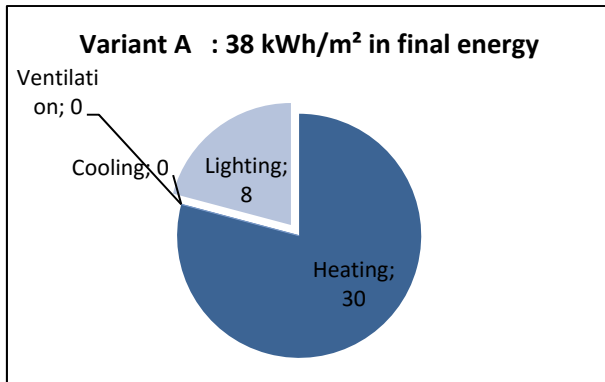
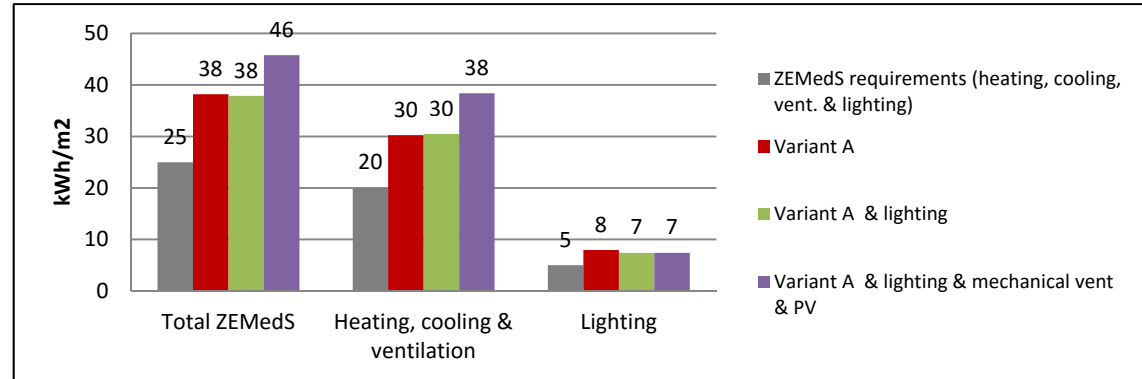
nZEB renovation results

Salamanque Group school, Montpellier, France

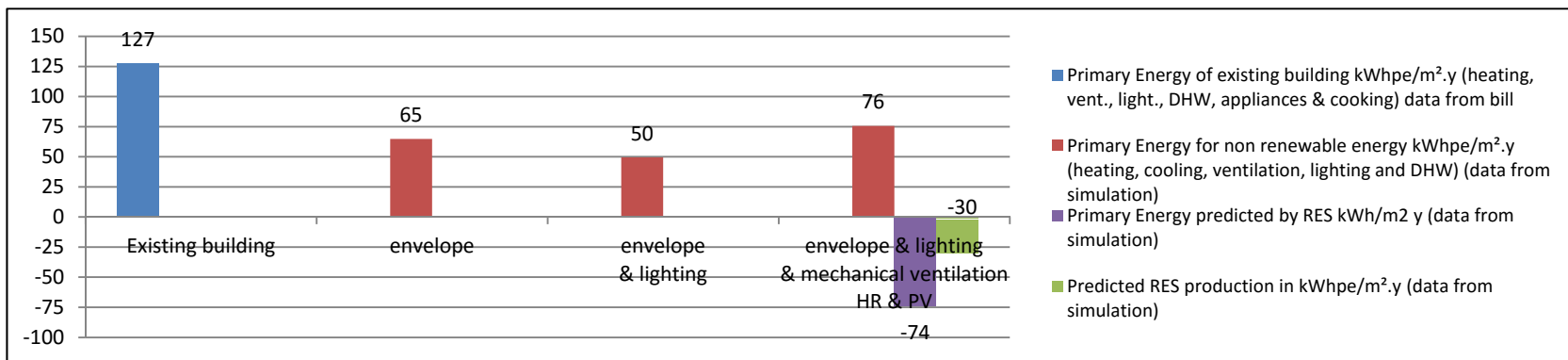


VARIANT A

FINAL ENERGY:



PRIMARY ENERGY:





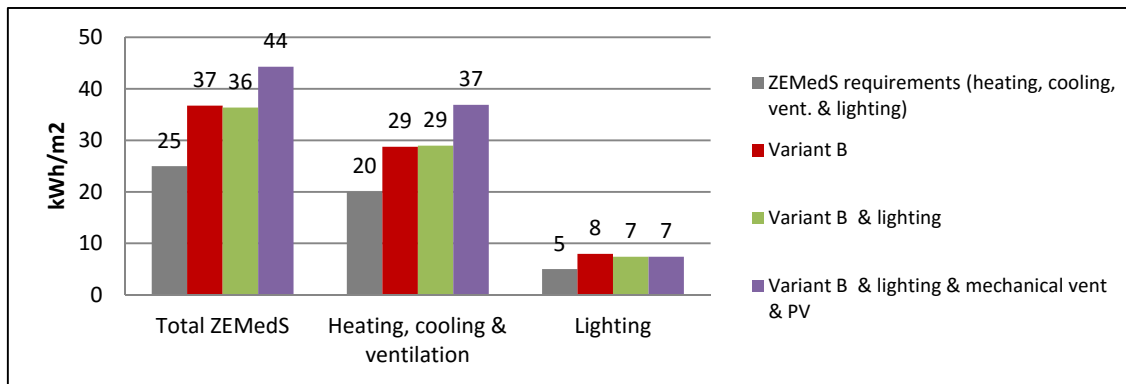
nZEB renovation results

Salamanque Group school, Montpellier, France

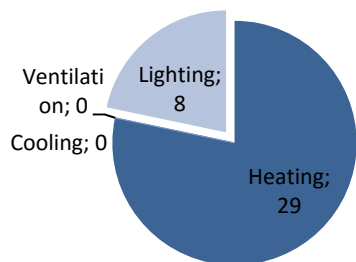


VARIANT B

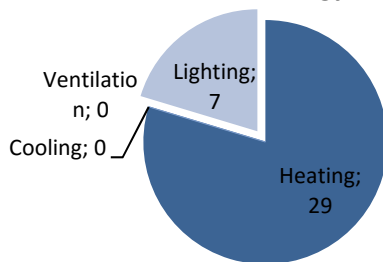
FINAL ENERGY:



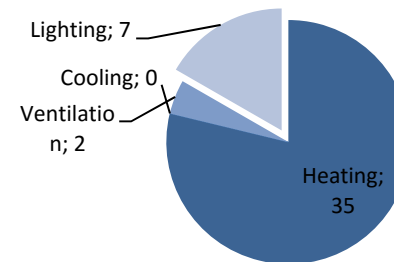
Variant B : 36 kWh/m² in final energy



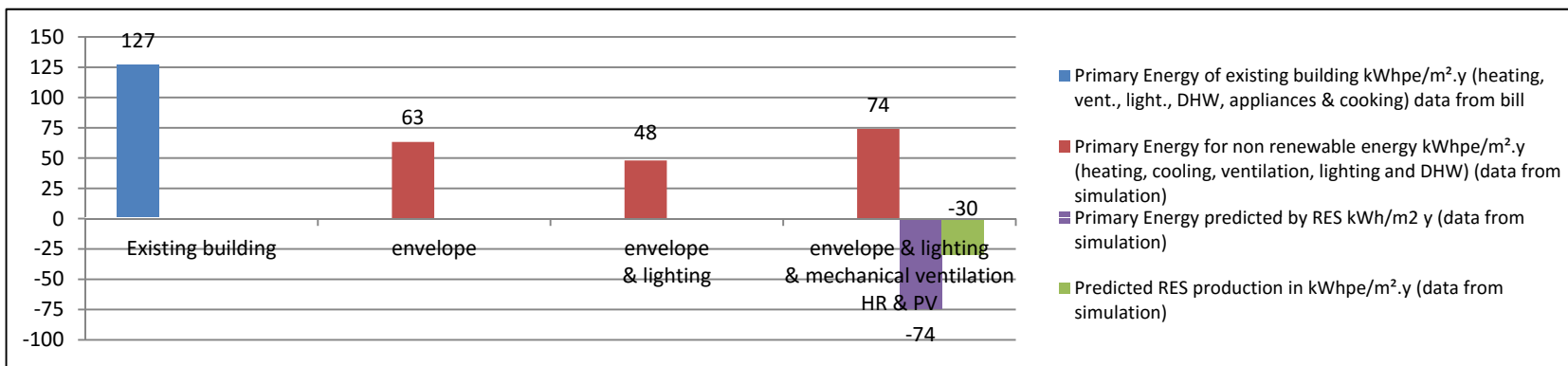
Variant B & lighting : 36 kWh/m² in final energy



Variant B & lighting & mechanical vent & PV : 44 kWh/m² in final energy



PRIMARY ENERGY:





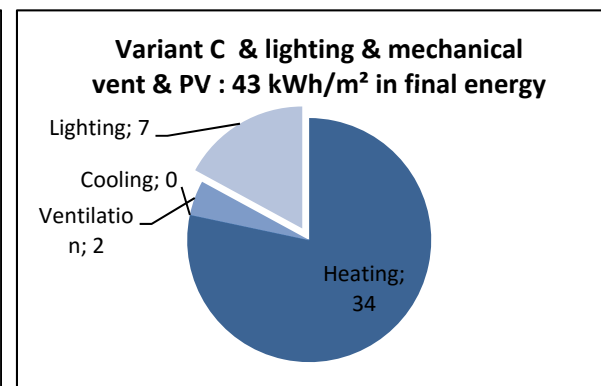
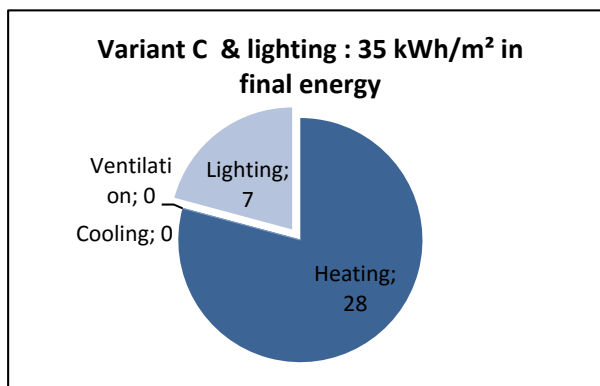
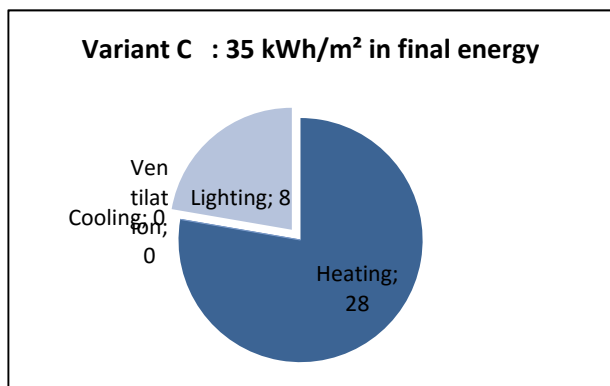
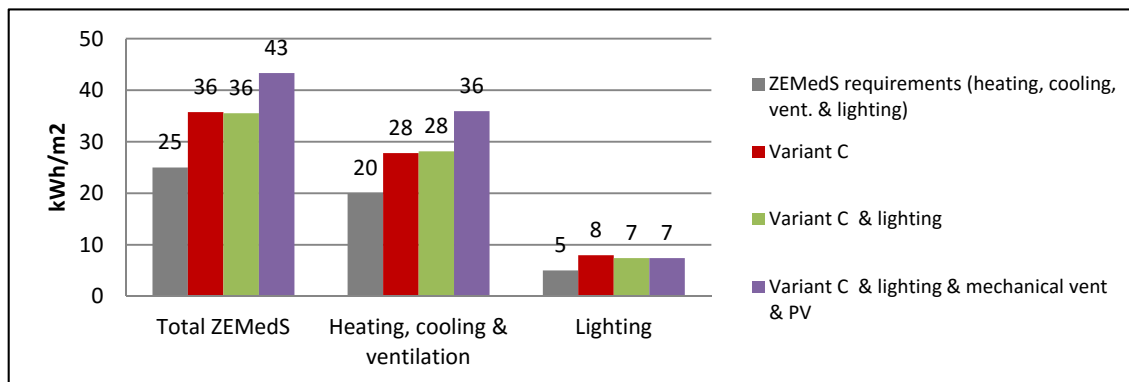
nZEB renovation results

Salamanque Group school, Montpellier, France

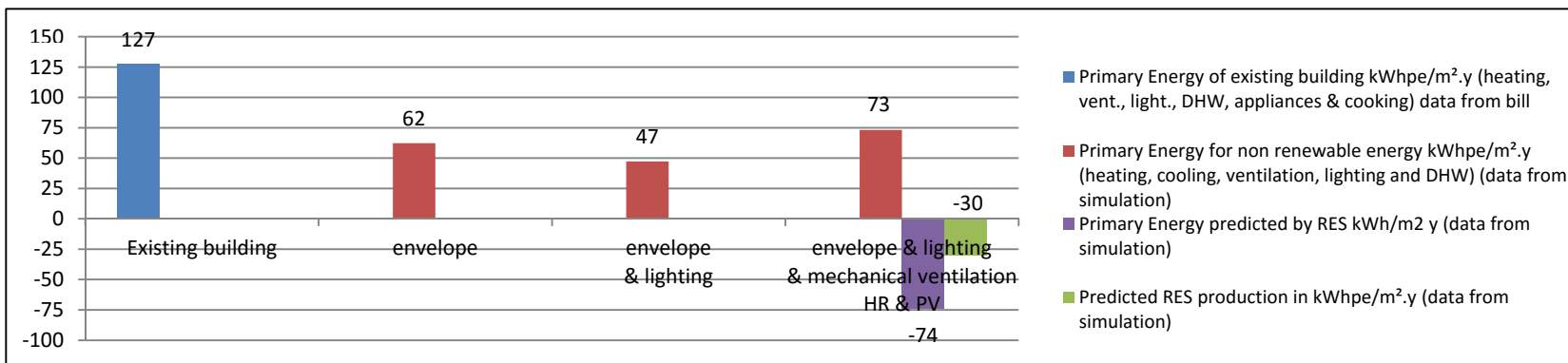


VARIANT C

FINAL ENERGY:



PRIMARY ENERGY:





nZEB renovation

Salamanque Group school, Montpellier, France

Global cost and paybacks for the renovation scenarios:

Global cost and paybacks for the renovation scenarios:

Calculations based on:

- Average yearly increase in gas price*: 6.9 % (data from 2003 to 2014)
- Average yearly increase in electricity price**: 2.9 % (data from 2003 to 2014)

- Overall cost of gas: 11,229 €/year (VAT included)
- Overall cost of electricity: 5,631 €/year (VAT included)
- Considered an overall maintenance cost of the renovation scenarios (yearly percentage of the total cost of the renewals) in 0.5% (envelope measures), 2% (PV)
- Replacement assumed in lighting (15 years lifetime) and inversors of PV system (15 years lifetime)

- Average inflation considered in 1.5% (data from 10 years average)

All construction costs with prices at 2015, VAT included. Assembling, disassembling and daily amortization of scaffold are included in façade renovation costs.

*Source: <http://ec.europa.eu/eurostat/tgm/table.do?tab=table&init=1&language=en&pcode=ten00117&plugin=1>

** Source: <http://ec.europa.eu/eurostat/tgm/table.do?tab=table&init=1&plugin=1&language=en&pcode=ten00118>



nZEB renovation

Salamanque Group school, Montpellier, France

Paybacks for the renovation implemented in steps (every 4 years):

	Expected savings in gas	Expected savings in electricity	Overall cost of gas €/year	Overall cost of electricity €/year	Investment in €	Overall maintenance cost €/year	Cost of replacement in €	Items to be replaced	Payback (years)
var A - envelope	66%	0%	3842	5631	469182	0	0	-	24
var B - envelope	68%	0%	3616	5631	506223			-	25
var C - envelope	69%	0%	3503	5631	562541			-	26
variant A - lighting	-1%	5%	4620	5998	40320	403	42794	lighting T5 tubes (15-20 years lifetime)	>50
variant B - lighting	-1%	5%	4620	5998	40320				>50
variant C - lighting	-1%	5%	4620	5998	40320				>50
variant A - MVHR & PV	-19%	90%	7179	672	143123	1073	8043	inversors PV (15 years lifetime)	>50
variant B - MVHR & PV	-21%	90%	7300	672	143123				>50
variant C - MVHR & PV	-21%	90%	7300	672	143123				>50

Total payback (envelope+ lighting + MVHR &PV) in all variants is > 50 years.



nZEB renovation

Salamanque Group school, Montpellier, France

Paybacks for the renovation implemented in steps (every 4 years):

Values in m2 conditioned area

	Expected savings in gas	Expected savings in electricity	Overall cost of gas €/m2 year	Overall cost of electricity €/m2 year	Investment in €/m2	Overall maintenance cost €/m2 year	Cost of replacement in €/m2	Items to be replaced	Payback (years)
var A - envelope	66%	0%	2	3	217	0.0	0	-	24
var B - envelope	68%	0%	2	3	235			-	25
var C - envelope	69%	0%	2	3	261			-	26
variant A - lighting	-1%	5%	2	3	19	0.2	20	lighting T5 tubes (15-20 years lifetime)	>50
variant B - lighting	-1%	5%	2	3	19				>50
variant C - lighting	-1%	5%	2	3	19				>50
variant A - MVHR & PV	-19%	90%	3	0	66	0.5	4	inversors PV (15 years lifetime)	>50
variant B - MVHR & PV	-21%	90%	3	0	66				>50
variant C - MVHR & PV	-21%	90%	3	0	66				>50

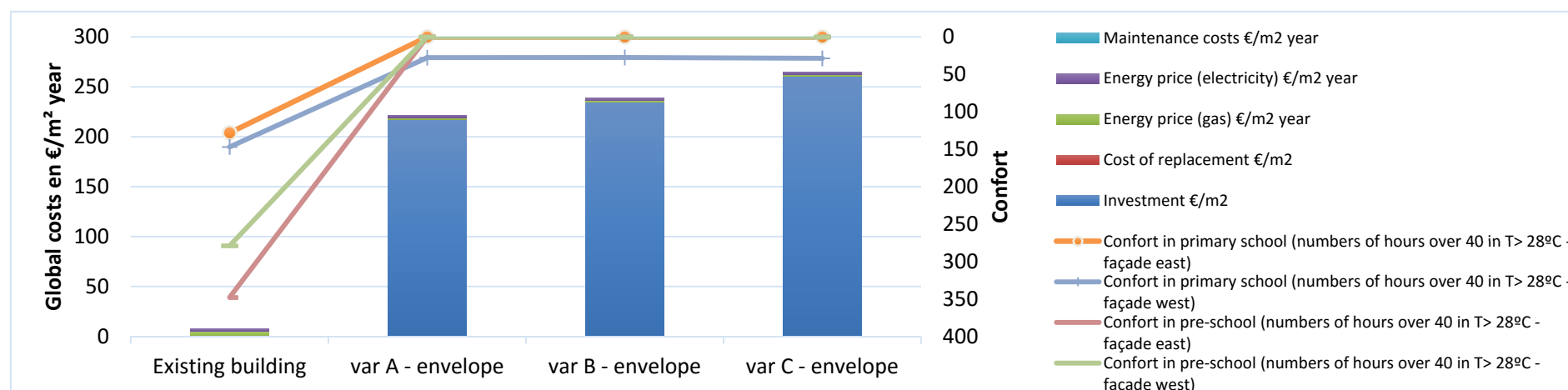
Total payback (envelope+ lighting + MVHR &PV) in all variants is > 50 years.



nZEB renovation

Salamanque Group school, Montpellier, France

In graphics, global cost of step 1 (envelope measures):



As an average, in primary school there are around 30 hours/y with more than 28°C in west orientation after the renovation measures of step 1 as some classroom of primary school under the roof in west orientation can reach around 80 hours/year.

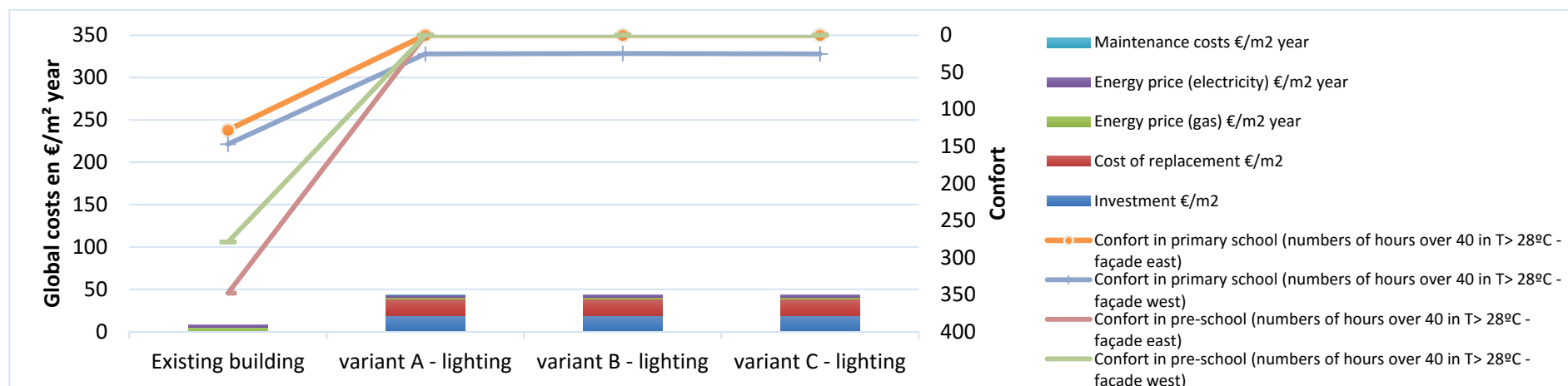
In pre-school building after step 1 is not expected to reach more than 40 hours with 28°C.



nZEB renovation

Salamanque Group school, Montpellier, France

In graphics, global cost of step 2 (renovation in lighting system in pre-school classrooms):



After step 2, the hours decrease to 25 hours/y with more than 28°C.

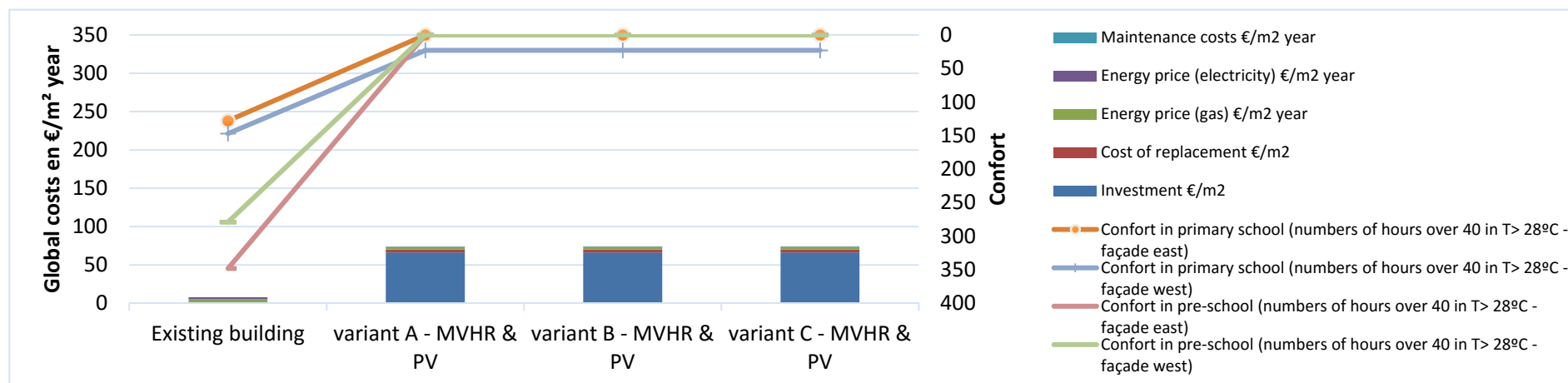
In pre-school building after step 2 is not expected to reach more than 40 hours with 28°C.



nZEB renovation

Salamanque Group school, Montpellier, France

In graphics, global cost of step 3 (installation of mechanical ventilation and PV system):



After step 3, decrease to 23 hours/y with more than 28°C in primary school.

In pre-school building after step 3 is not expected to reach more than 40 hours with 28°C.



nZEB renovation

Salamanque Group school, Montpellier, France

Paybacks for the renovation implemented **all at once (step 1 + step 2 + step 3)** and implemented under current regulation:

	Expected savings in gas	Expected savings in electricity	Overall cost of gas €/year	Overall cost of electricity €/year	Investment in €	Overall maintenance cost €/year	Cost of replacement in €	Items to be replaced	Payback (years)
variant A - envelope & lighting & MVHR & PV	60%	84%	4520	901	652625	1392	47970	lighting T5 tubes (15-20 years lifetime)/inversors PV (15 years lifetime)	28
variant B - envelope & lighting & MVHR & PV	61%	84%	4407	901	689666				29
variant C - envelope & lighting & MVHR & PV	62%	84%	4294	901	745984				29

Total payback in all variants expected to be around 28-29 years.



nZEB renovation

Salamanque Group school, Montpellier, France

Paybacks for the renovation implemented all at once (step 1 + step 2 + step 3) and implemented under current regulation:

Values in m2 conditioned area

	Expected savings in gas	Expected savings in electricity	Overall cost of gas €/m2 year	Overall cost of electricity €/m2 year	Investment in €/m2	Overall maintenance cost €/m2 year	Cost of replacement in €/m2	Items to be replaced	Payback (years)
variant A - envelope & lighting & MVHR & PV	60%	84%	2,1	0,4	302,4	0,6	22	lighting T5 tubes (15-20 years lifetime)/inversors PV (15 years lifetime)	28
variant B - envelope & lighting & MVHR & PV	61%	84%	2,0	0,4	319,6				29
variant C - envelope & lighting & MVHR & PV	62%	84%	2,0	0,4	345,7				29

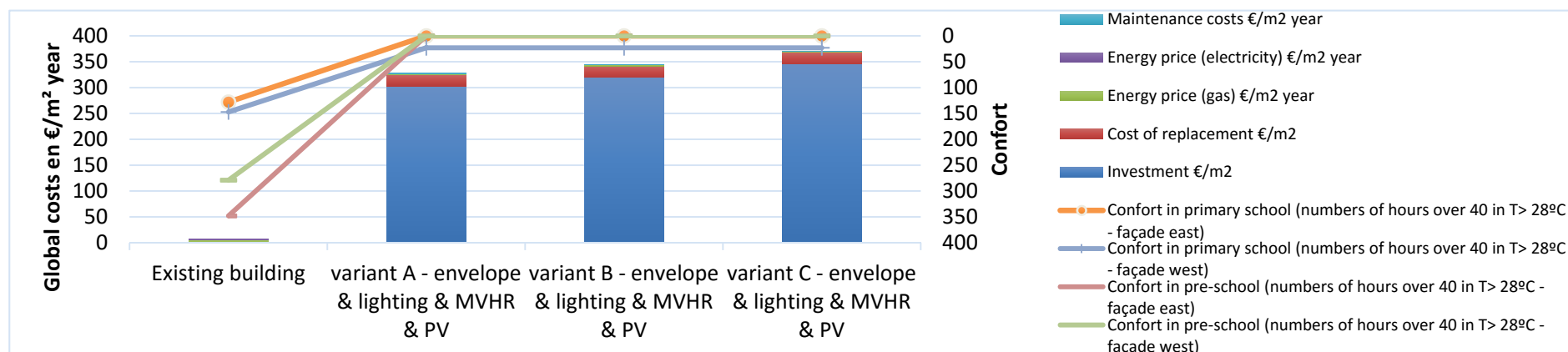
Total payback in all variants expected to be around 28-29 years.



nZEB renovation

Salamanque Group school, Montpellier, France

In graphics, global cost of renovation all at once and global cost of renovation under current regulation:



The number of hours over 28°C is in 35 hours, although classrooms of primary school under the roof in west orientation can reach around 80 hours/year.

In pre-school building after step 3 is not expected to reach more than 40 hours with 28°C.



Summary results

Salamanque Group school, Montpellier, France

Current situation:

	gas		electricity	
	consumption (kWh)	Ratio (kWh/m2)	consumption (kWh)	Ratio (kWh/m2)
Real (invoice information)	185502	81	41589	18
Simulation (Desing Builder)	184207	85	31867	15

Results of nZEB renovation under ZEMedS goals:



		result	
Renovation implemented with energy efficiency measures in		envelope + lighting + mechanical ventilation with heat recovery + PV system covering (heating by natural gas, lighting, ventilation, DHW by electricity)	
Energy balance in PE (kWh/m2 y) (heating, cooling, vent., DHW & lighting) and RES production (kWh and kWh/m2 conditioned area) (ZEMedS requirement 1) (simulations)	Var A	1	64734/30 243 m2 surface PV panels
	Var B	0	64734/30 243 m2 surface PV panels
	Var C	-1	64734/30/243 243 m2 surface PV panels
Energy result in FE (kWh/m2 y) (heating, cooling, vent. & lighting) per conditioned area (ZEMedS requirement 2) (simulations)	Var A	45 (60% gas saving, 84% electricity saving)	
	Var B	44 (61% gas saving, 84% electricity saving)	
	Var C	43 (62% gas saving, 84% electricity saving)	
Goal of (ZEMedS requirement 3)		<ul style="list-style-type: none"> - indoor quality guaranteed by mechanical ventilation - in primary school, the number of hours over 28°C is predicted to be around 35 hours/y as average, as some classroom under the roof in west orientation can reach around 80 hours/year 	
Paybacks (years) step by step implementation		> 50	
Paybacks (years) all at once implementation		28-29	