Cool-roof impacts on a School-building thermal and energy performance in Greece

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CRES

Cooperation between EU and Mediterranean partner Countries in the Energy Sector- International Workshop

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Project overview

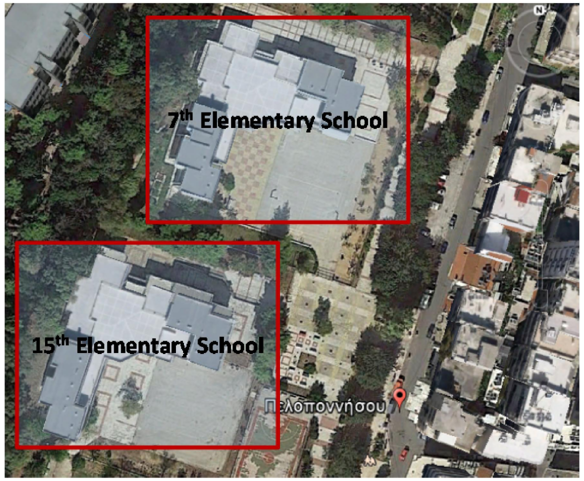
- Scheduling of cool-roof application and of measurement procedure.
- Installation of monitoring equipment.
- Onsite thermal and energy inspection (collection of data and interviews with end-users).
- Development of the building energy simulation model.
- Validation and calibration of the model with comparisons between simulated and measured thermal indicators.
- Estimation of temperature difference between the situations before (ex-ante condition) and after (ex-post condition) the application of cool roof on the pilot building.
- Evaluation of cool-roof impacts on thermal comfort and energy performance through whole-year building energy simulation using the model developed.
- Collation of simulated results for different conditioning scenarios to determine under which conditions the cool-roof contributes to total primary energy savings.

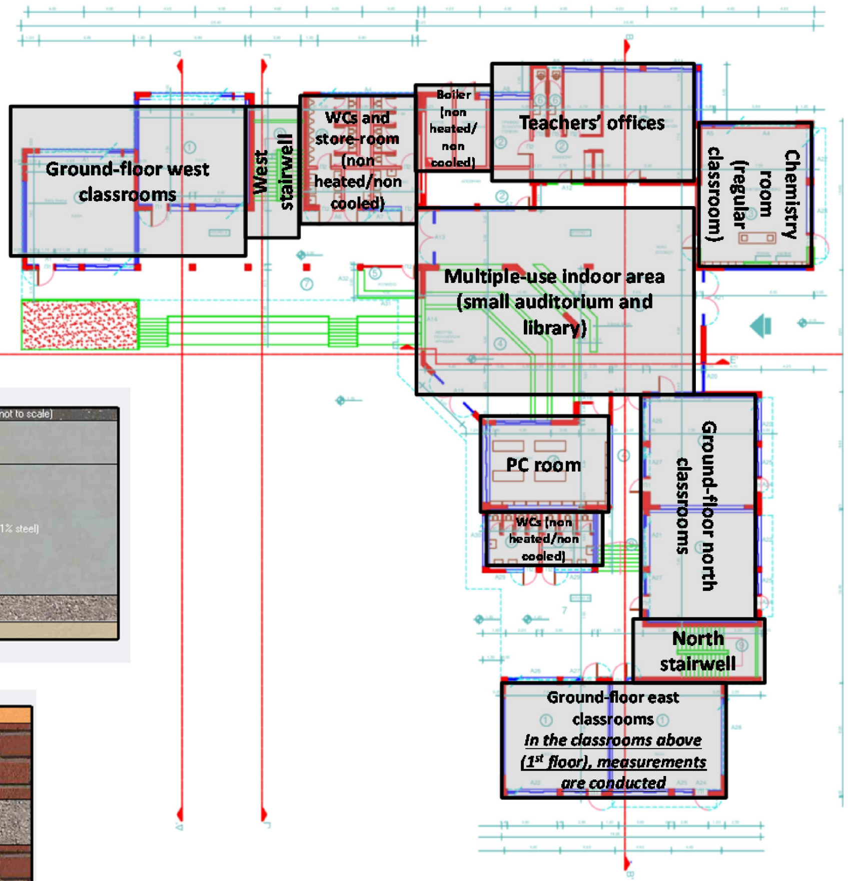
Project

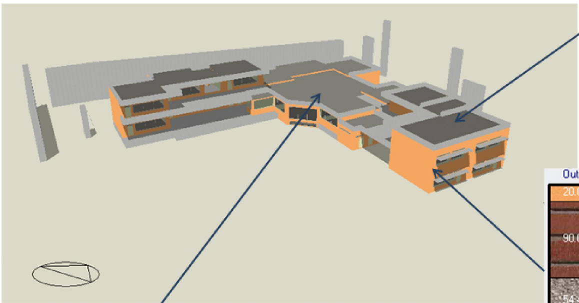
Cool **R**oof **I**mpacts on **BU**ilding's **T**hermal P**E**rformance (**CRIBUTE**)

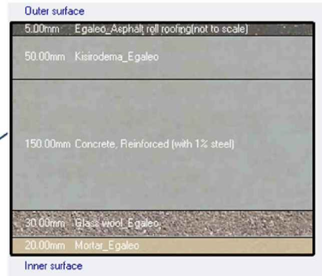
Partners

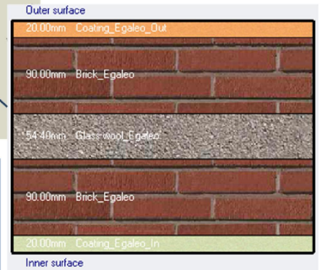
Pilot building characteristics [1/2]

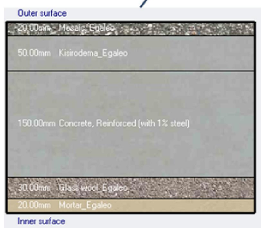












Other:
-Single glazed Skylight windows (Aluminum frames)
-Double glazed windows (Aluminum frames)
-Wooden doors

Pilot building characteristics [2/2]

Single glazed windows

Double glazed windows

Building occupancy schedule:
9 Sep. to 15 June: All rooms are operating all working days (all days except weekends) from 08.00-16.00, except of 15 days in end December/early January, and in April due to Christmas and Easter holidays, respectively.

16 June to 30 July: Ground-floor is in full operation as the aforementioned working days, while the 1st floor remains unoccupied.

1 Aug. to 9 Sep.: The School remains unoccupied (Summer holidays).

Appliance	System	Properties	Operation schedule
Heating	Central heater unit: natural-gas boiler Terminals: Radiators Auxiliary units: two circulators	Heater installed capacity: 220 kW Heater internal efficiency: 89.8% Circulators' capacity: 400W Well-insulated heater and network tubes Set-point: 20°C	07.30-11.30 on working days
Ventilation	2 ceiling fans in each occupied room	Installed capacity of each fan: 82 W	All winter working hours only when ambient air temperature reaches 29 °C or above (observation obtained during onsite inspections in relation to measurements)
Cooling	1 AC split unit in the PC room	Cooling capacity: 6.7 kW Input power: 2.57 kW EER: 2.6 Set-point: 26°C	All summer working hours
Lighting	~ 24 fluorescent lamps in each occupied room	T8 36 W	Winter: All working hours Summer: 07.30-10.00 on working days

Application of the cool roof

Material properties:

- Emissivity: 0.89
- Reflectance: 0.89
- Thermal conductivity (W/(mK)): 0.87

Measuring procedure

Measurements of Thermal Performance Indicators (TPIs) in both the Pilot and the Reference Building.

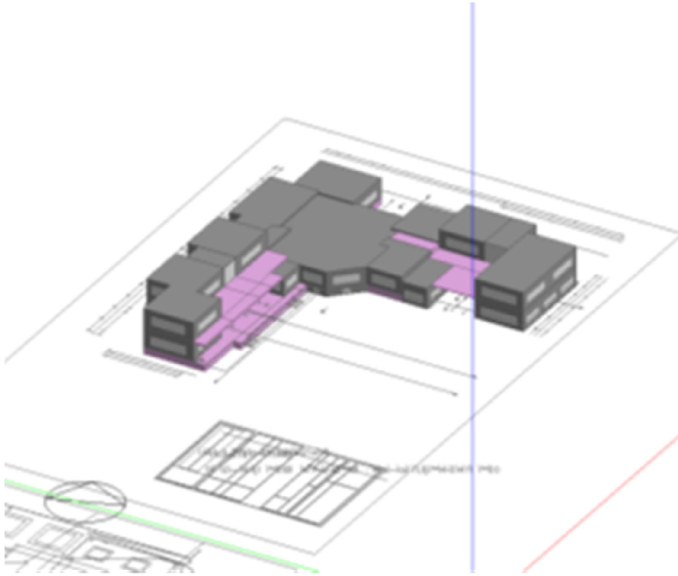
The data logging of the sensors readings was performed on a **10 minutely basis** in a flash memory card.

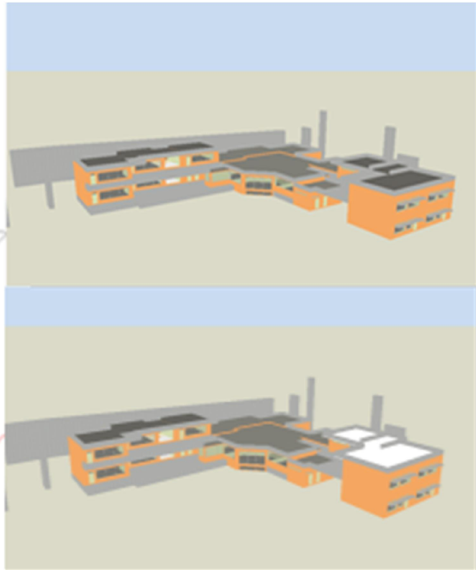
Two phases are distinguished:

Phase 1 (ex-ante): From June 23 to July 9, in which both school buildings are monitored to gain knowledge about their thermal behavior.

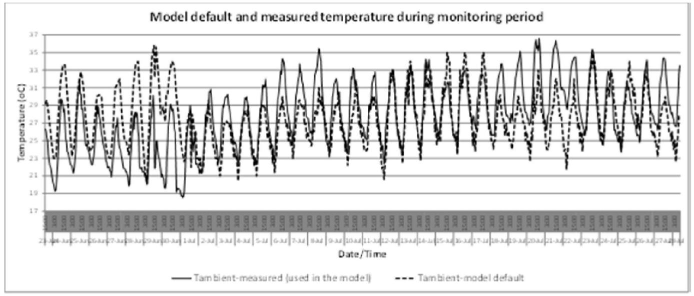
Phase 2 (ex-post): From July 11 to July 29, in which both school buildings are again monitored after the application of the cool roof on the roof of the 7th school class rooms.

Numerical model





Pilot building (ex-ante)=Reference building



Pilot building (ex-post)

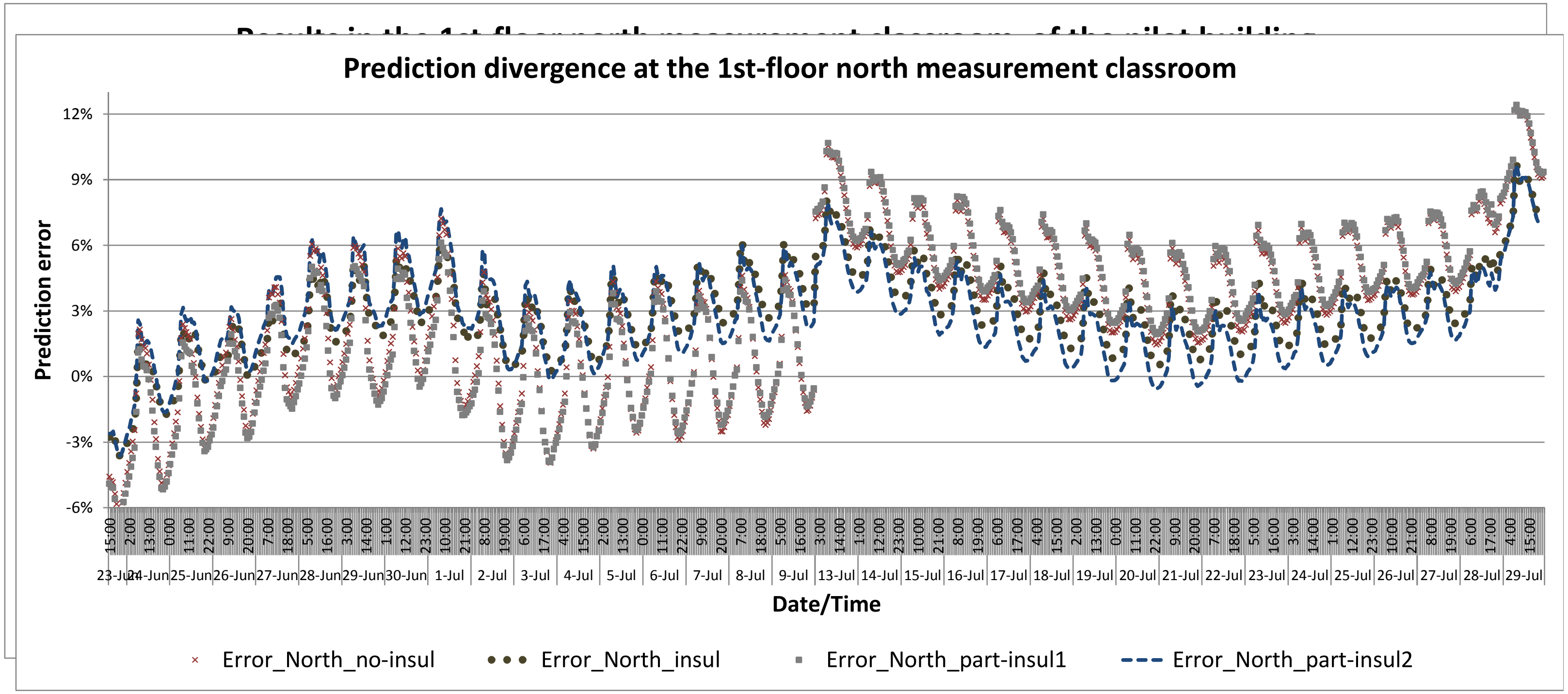
Systems and Occupancy properties & Schedules

Material	Membrane grey – old roof top cover	Red coating – East wall 7th primary school	Yellow coating – East wall 7th primary school	White coating – East wall 15th primary school
Reflectance, R (%)	17.2	30.2	44.7	81.3
Sample picture				

Impact:

TPIs difference between the Reference and the Pilot building in the 2^{nd} Phase.

Model validation/calibration



Parametric cases:

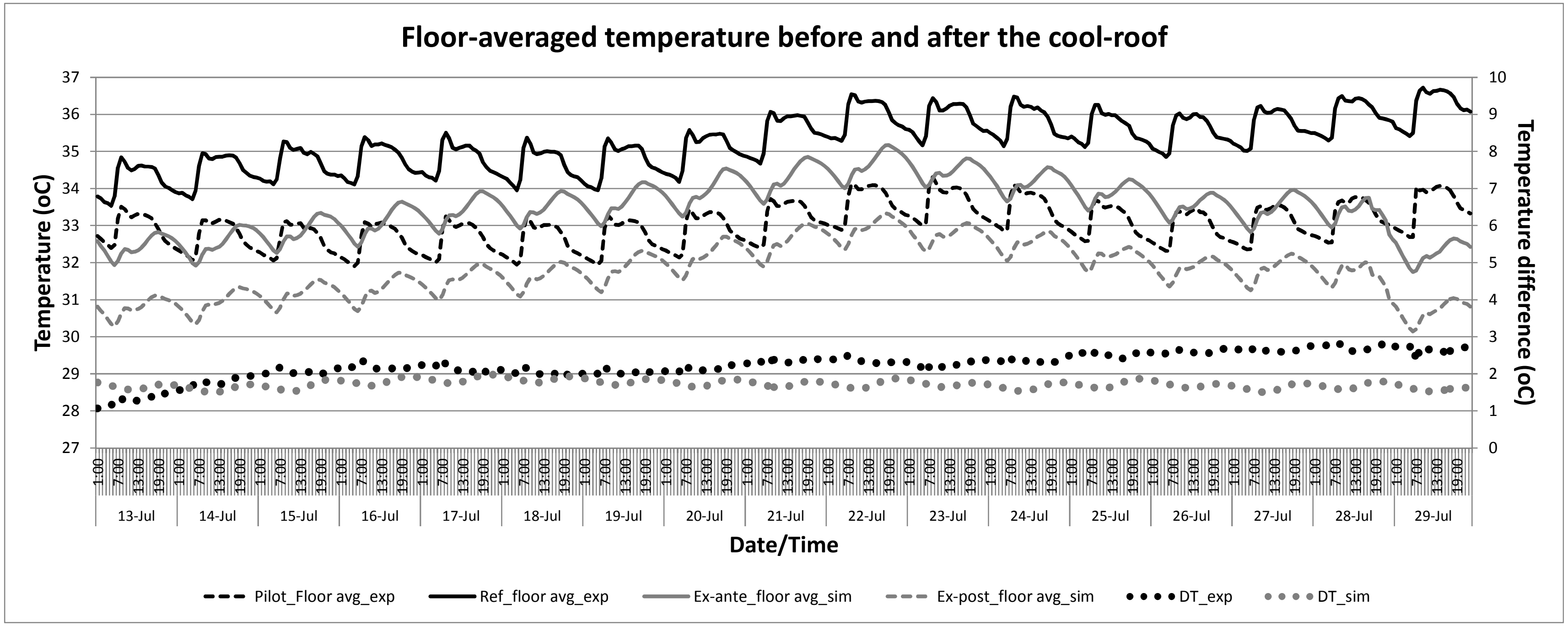
•Insulated envelope.

•Non-insulated envelope.

•Partly-insulated 1: Insulated brick-wall and roof and non-insulated bearing structure.

•Partly-insulated 2: Non-insulated wall and insulated roof.

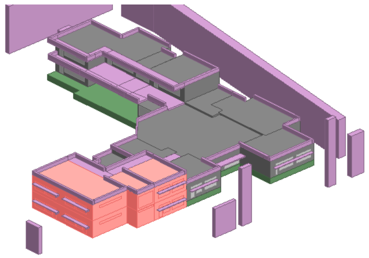
Building thermal response



Both measurements and simulations converge to **an indoor air temperature reduction after the cool-roof application of about 2°C, being most obvious during the first 10 days** after the application. Interestingly, an increasing trend of the recorded temperature reduction is observed **after the 23rd July reaching a maximum value of 2.6°C**, contrary to the simulated reduction which presents a quite constant behaviour throughout the ex-post period.

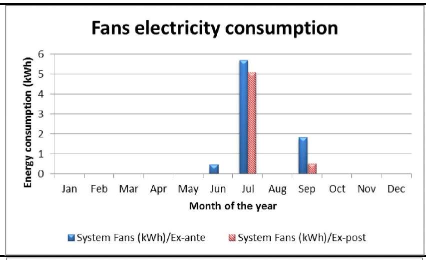
Impacts on building energy performance

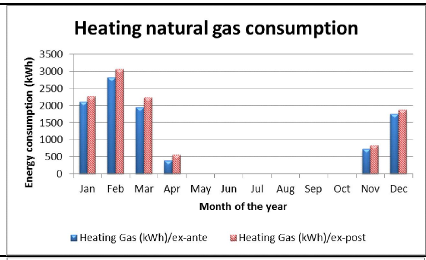
Base-case: Pilot building with operating conditions and systems as observed during the inspection (*free-floating* 1st floor after 15th June).
Scenario1: Pilot building with ACs instead of fans and the 1st floor is fully operating after 15th June until 30 July.

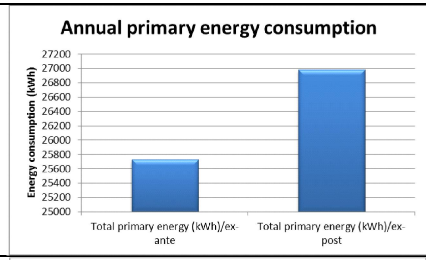


Adopted building part marked in pink colour

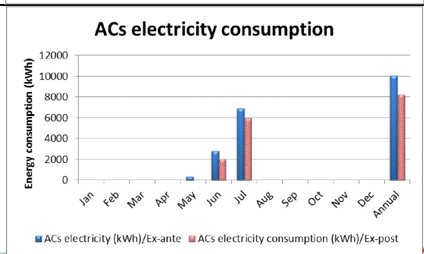
case

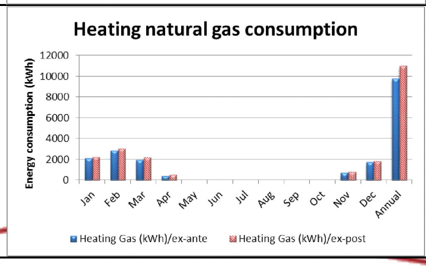


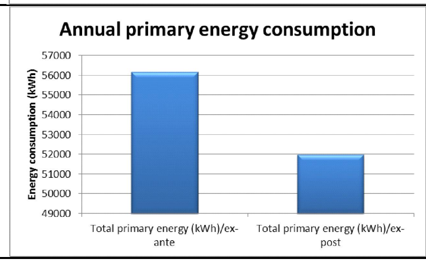




rio1







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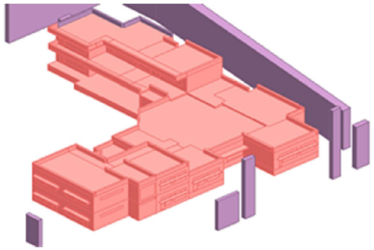

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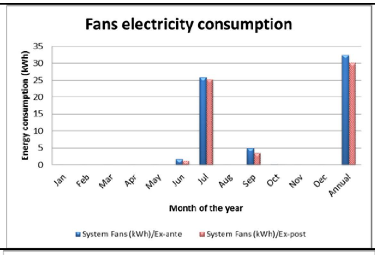

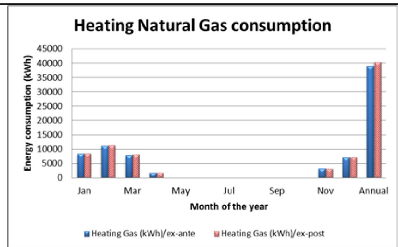

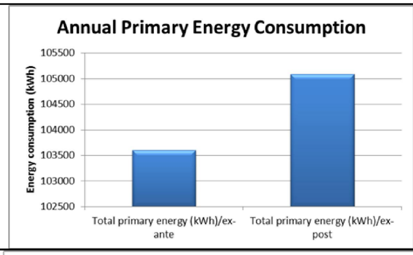

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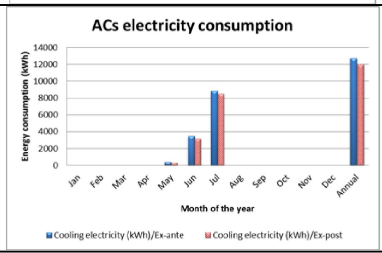
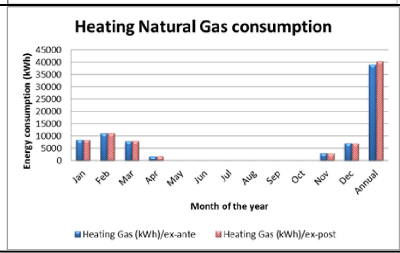
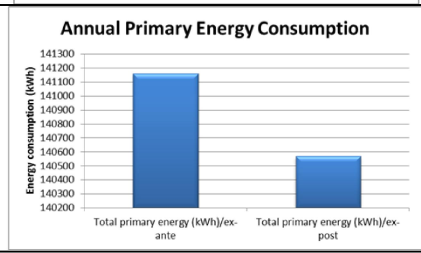


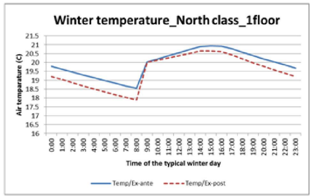
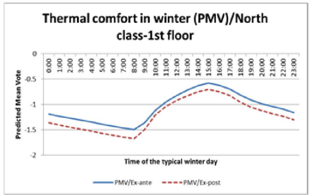
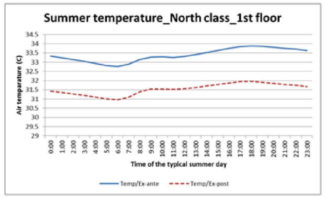
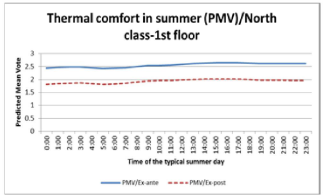
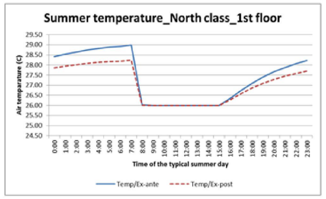
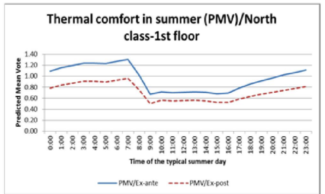




Building energy summary results

Impacts on EPIs	Base-case		Scenario2	
	Building-block (below cool roof)	Whole-building	Building-block (below cool roof)	Whole-building
$\%\Delta E_{Fans}$ or $\%\Delta E_{ACs}$	29.28	7.19	18.57	5.64
$\%\Delta E_{heating}$	-12.22	-3.65	-12.22	-3.65
$\%\ \Delta E_{tot,prim}$	-4.85	-1.43	7.41	0.41

Thermal comfort impacts

What-if scenario	Winter day	Summer day	Change of mean PMV within working hours (08.00-16.00) after cool roof
Base-case	 	 	Winter: ↓13% (deterioration) Summer: ↓23% (improvement)
Scenario1	As above in the base-case	 	Winter: ↓13% (deterioration) Summer: ↓23% (improvement)

Conclusions

- **Indoor air temperature reduction below the cool roof (in summer): 2-2.6°C**.
- **Associated heating penalty: up to 12%**. Leading to **not more than 5% increase of annual primary energy consumption in the case of ceiling fans**.
- Ventilation **energy demand in summer** is significantly **reduced** after the application of the cool roof reaching **30%** in the case of ceiling fans use.
- **Thermal comfort on warm summer days is improved by at least 20%**.
- In the AC-use case, thermal comfort conditions are improved by at least 23% under a **reduction of cooling loads by 20%**. **Any heating penalty is fully compensated ensuring 4.5-7.5% savings** in annual total primary energy consumption.
- **Cool-roof: Energy-Saving** and **Thermal-Comfort Potential even in summer-paused buildings in warm Climates** => **Efficient and affordable solution in the MENA (Middle-East North Africa) Region**.

Acknowledgments

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ΕΥΧΑΡΙΣΤΩ ΠΟΛΥ!

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