The project has received funding from the LIFE Programme of the European Union under GA number LIFE19 ENV/GR/000100

Process Equipment Design Laboratory AUTh

Energy efficiency of Demo Houses and Naval Academy: Simulation Results

Prof. Agis Papadopoulos

Dr. Effrosyni Giama

On behalf of PEDL RESEARCH TEAM

fgiama@auth.gr

LIFE VISIONS
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The European Green Deal

- Strong linkage between energy and environmental policies
- The EU should be climate neutral by 2050
- Reaching this target will require action by all sectors of our economy, including
  - investing in environmentally-friendly technologies
  - supporting industry to innovate
  - rolling out cleaner, cheaper and healthier forms of private and public transport
  - decarbonising the energy sector
  - ensuring buildings are more energy efficient
  - working with international partners to improve global environmental standards

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Key pillars in EU Energy Policy for Buildings

- Energy Efficiency
- Renewable Energy
- Energy Performance
- Decarbonisation

Clean energy for all Europeans package - legislative process

	European Commission Proposal	EU Inter-institutional Negotiations	European Parliament Adoption	Council Adoption	Official Journal Publication
Energy Performance in Buildings	30/11/2016	Political Agreement	17/04/2018	14/05/2018	19/06/2018 - Directive (EU) 2018/844
Renewable Energy	30/11/2016	Political Agreement	13/11/2018	04/12/2008	21/12/2018 - Directive (EU) 2018/2001
Energy Efficiency	30/11/2016	Political Agreement	13/11/2018	04/12/2018	21/12/2018 - Directive (EU) 2018/2002
Governance of the Energy Union	30/11/2016	Political Agreement	13/11/2018	04/12/2018	21/12/2018 - Regulation (EU) 2018/1999
Electricity Regulation	30/11/2016	Political Agreement	26/03/2019	22/05/2019	14/06/2019 - Regulation (EU) 2019/943
Electricity Directive	30/11/2016	Political Agreement	26/03/2019	22/05/2019	14/06/2019 - Directive (EU) 2019/944
Risk Preparedness	30/11/2016	Political Agreement	26/03/2019	22/05/2019	14/06/2019 - Regulation (EU) 2019/941
ACER	30/11/2016	Political Agreement	26/03/2019	22/05/2019	14/06/2019 - Regulation (EU) 2019/942

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Methodology in brief

Measurements – Simulations in Demo Houses and in real scale application in Naval Academy

Simulations with DesignBuilder and Contam

- Energy consumption
- CO_2 emissions
- Thermal comfort

The target was to identify the correlation of ventilation rates and photocatalysis (ventilation is related to energy consumption).

Indirect reduction of energy consumption because of the ventilation rate reduction.

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Indoor conditions measurement equipment

System	Measurements	Measurement equipment
DEMO HOUSES	Air temperature Relative Humidity Air velocity Radiant temperature PMV/PPD CO_2	• Comfort and air quality conditions using testo 480 and the necessary sensor probes (temperature, radiant temperature, relative humidity, CO2, air velocity, pmv/ppd) • HOBO MX1102 (temperature, relative humidity, CO2). The installation and methodology is based on the international standards ISO 7726:1998 and ASHRAE 55

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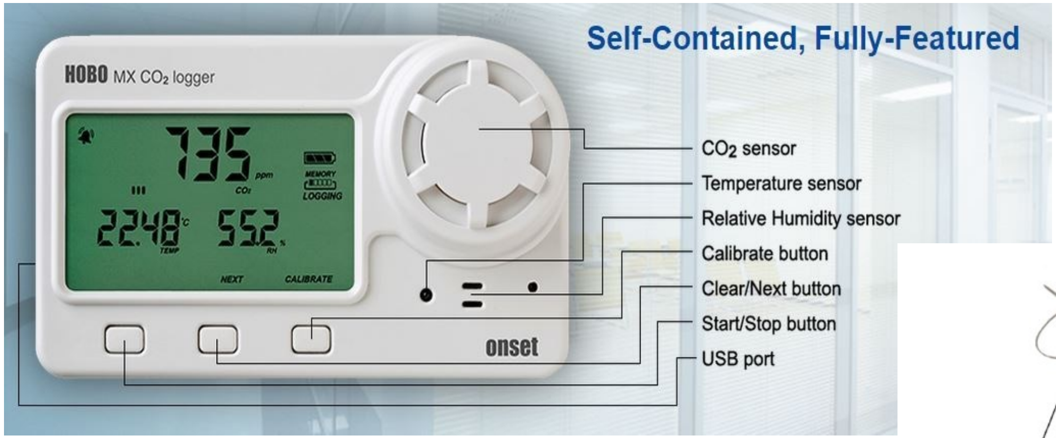
Indoor conditions data loggers



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Simulation parameters and outputs

Parameters:

- Mechanical ventilation (ASHRAE 62.1)
- Natural ventilation
- Photocatalysis

Output data:

- Energy consumption
- CO_2 emissions
- Thermal comfort

The concept is to validate the measurements data with the simulation tool DesignBuilder

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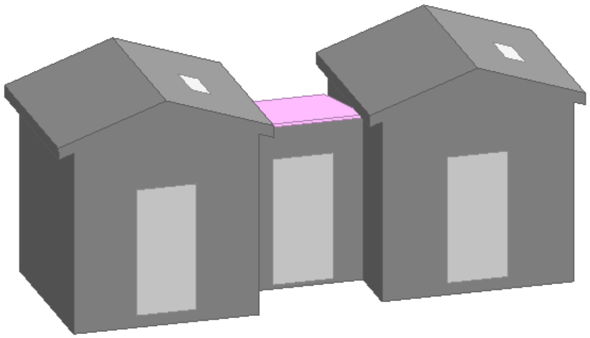
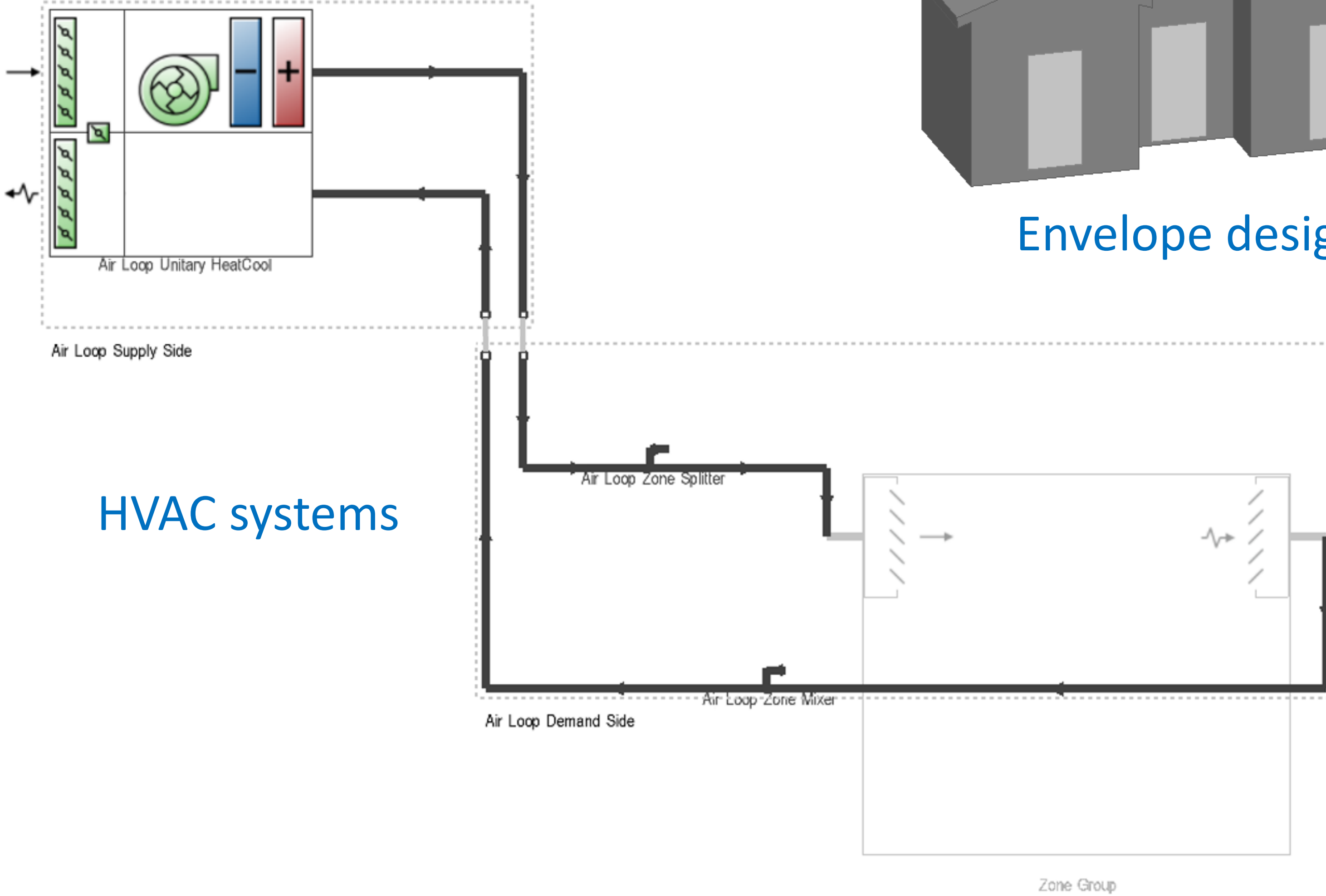
Building & HVAC modelling



Envelope design



HVAC systems

PEDL
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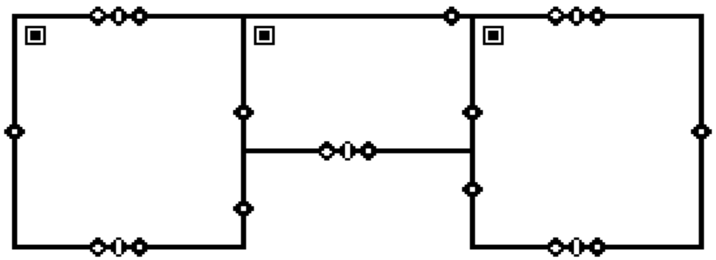
Further Analysis – CONTAM simulation

- Emission results CONTAM based on nitrogen oxides NOx and the photocatalysis process.
- More specific energy oriented impact of photocatalysis in relation to ventilation and CO2 and NOx
- Based on CONTAM results regarding the emissions concentration with TRNSYS the cooling load was measured.
- The simulation was implemented for 14 summer when the photocatalysis impact is more intensive.
- Some basic input data in relation to simulations scenarios: 3zones (each block one zone, one person with 1MET in the two zones, initial CO2 concentration CO_2 343ppm (ASHRAE), NO 31.6 μg/m^3 and NO_2 38 μg/m^3 natural ventilation from door 21.07 m^3/h (TOTEE) and window 10.12 m^3/h(TOTEE), mechanic ventilation 25W, cooling efficiency coefficient 3.5, emission factor CO2 0.81 kgCO2/kWh



CONTAM

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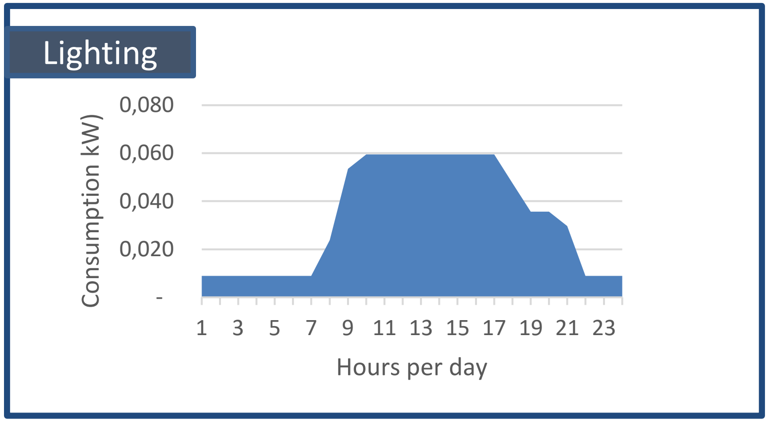
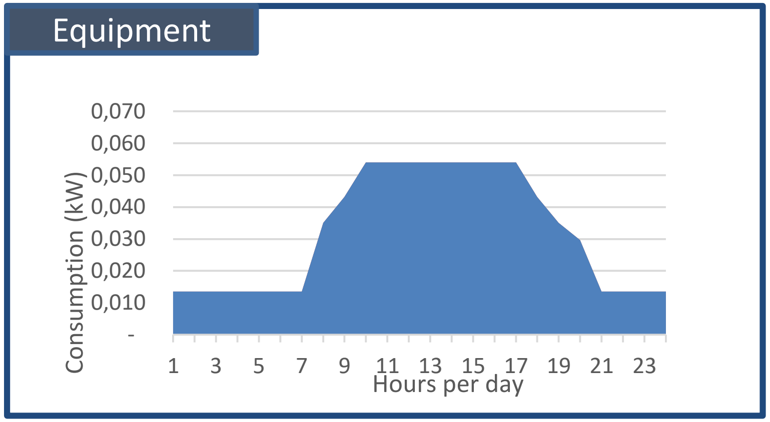
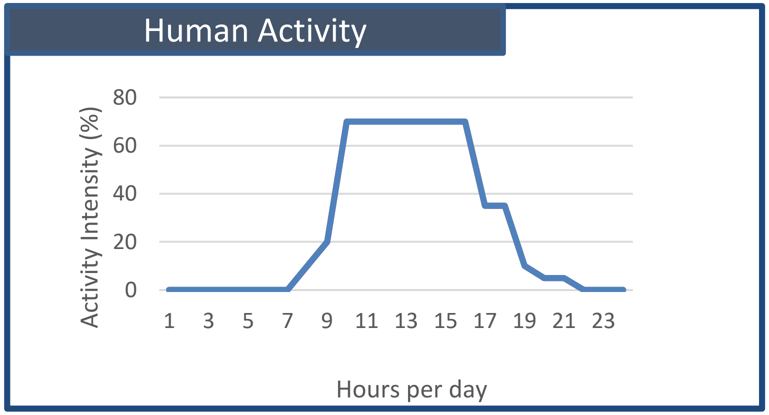
CONTAM simulation(2/2)







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CONTAM Scenarios Description

Scenario	Scenario description	Ventilation m3/h, Air changes per hour	Concentration NO,NO2,CO2	Pollutants reduction efficiency
Baseline	Conventional without photocatalysis and not adequate mechanical ventilation	17.57 m3/h, 0.74 ACH	NO:27μg/m3 NO2:32μg/m3 CO2:455 ppm	
1	Photocatalysis and mechanical ventilation	17.57 m3/h, 0.74 ACH	NO:10μg/m3 NO2:12.6μg/m3 CO2:455 ppm	NO:63% NO2:60.6%
2	Increased mechanical ventilation in order to accomplish the same emission reduction as with photocatalysis	151.2m3/h, 6.36 ACH	NO:10.7μg/m3 NO2:12.9μg/m3 CO2:400 ppm	NO:60.3% NO2:59.6%
3	Maximum of natural ventilation	72.68m3/h, 3 ACH	NO:14μg/m3 NO2:17μg/m3 CO2:447 ppm	NO:48% NO2:46.8%
4	Night ventilation	35.2m3/h, 1.5 ACH 7:00 p.m-17:00a.m. 151.2m3/h, 6.36 ACH	NO:15.1μg/m3 NO2:18.1μg/m3 CO2:419.4 ppm	NO:44.1% NO2:43.4%

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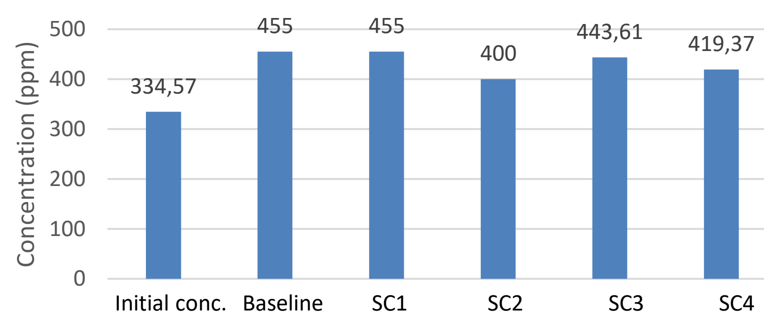
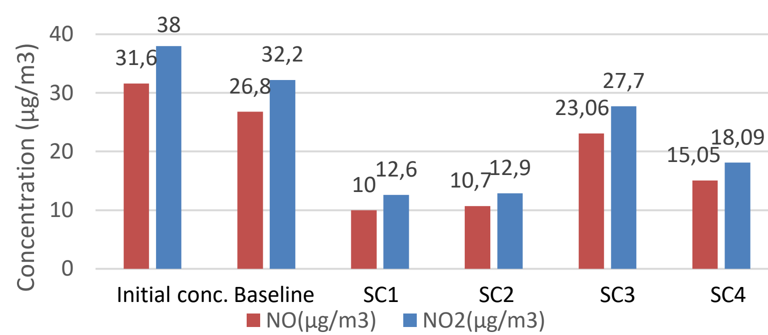
Results – Emission rate

	% change of the emission concentration				
	[redacted]				
CO_2	36.0%	36.0%	19.6%	32.6%	25.3%
[redacted]					
NO_2	-15.3%	-66.8%	-66.1%	-27.1%	-52.4%





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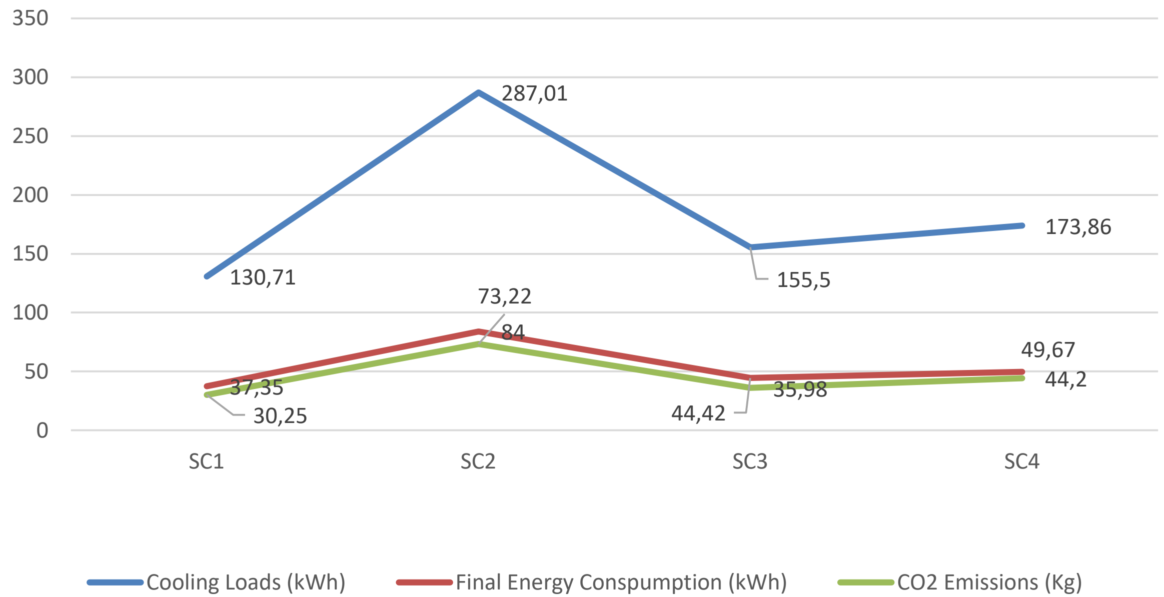
Scenarios Comparison



The issue is to find the scenario that can achieve the same emissions reduction as with photocatalysis with the least energy consumption in regards to ventilation

	Cooling Loads (kWh)	Final Energy Conspumption (kWh)	CO2 Emissions (Kg)
SC1	130,71	37,35	30,25
SC2	287,01	84	73,22
SC3	155,5	44,42	35,98
SC4	173,86	49,67	44,2

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Results in connection to energy consumption

	% reduction to emissions concentration			
	[redacted]			
NO	-68.40%	-66.10%	-27.00%	-52.40%
[redacted]				

	% increase			
	[redacted]			
Cooling loads	-	54.40%	15.94%	24.81%
[redacted]				

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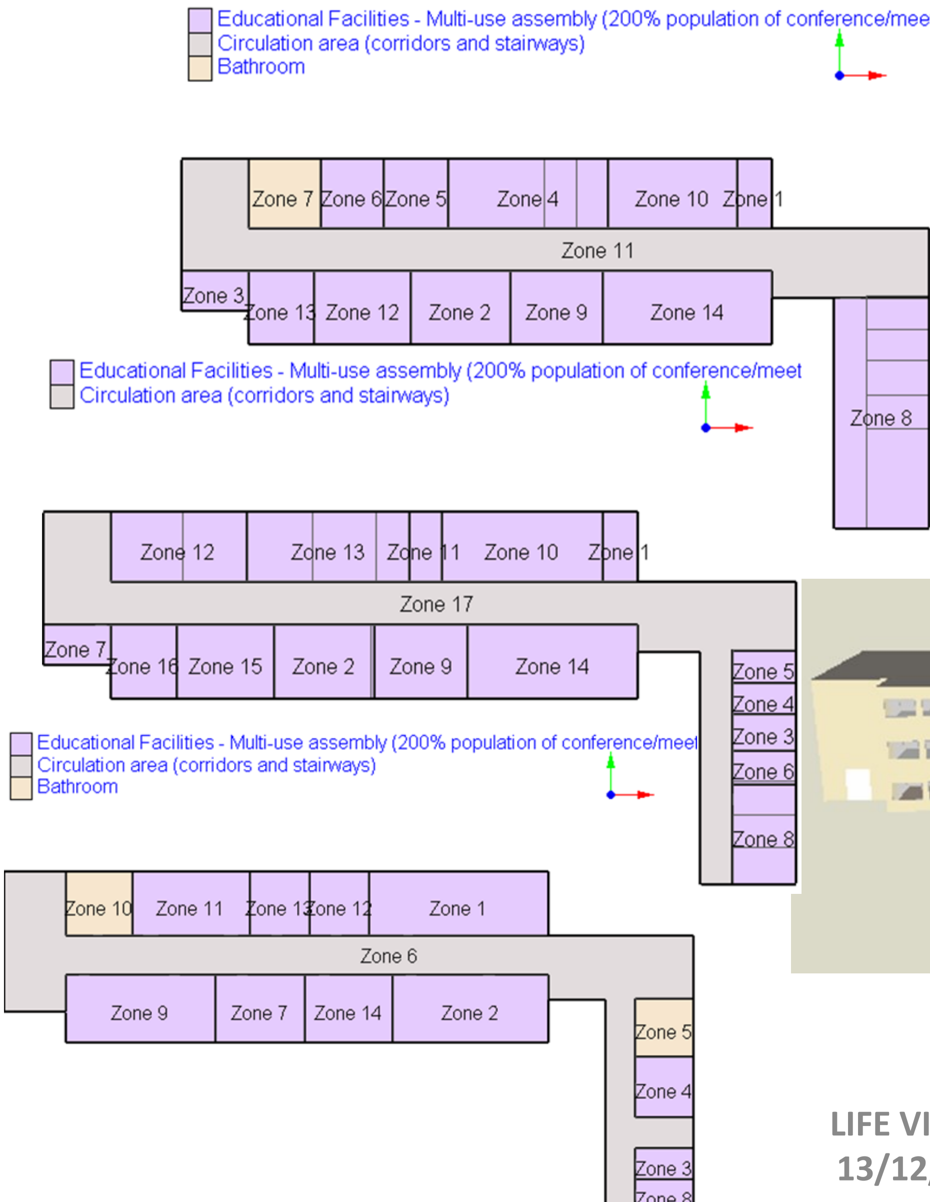
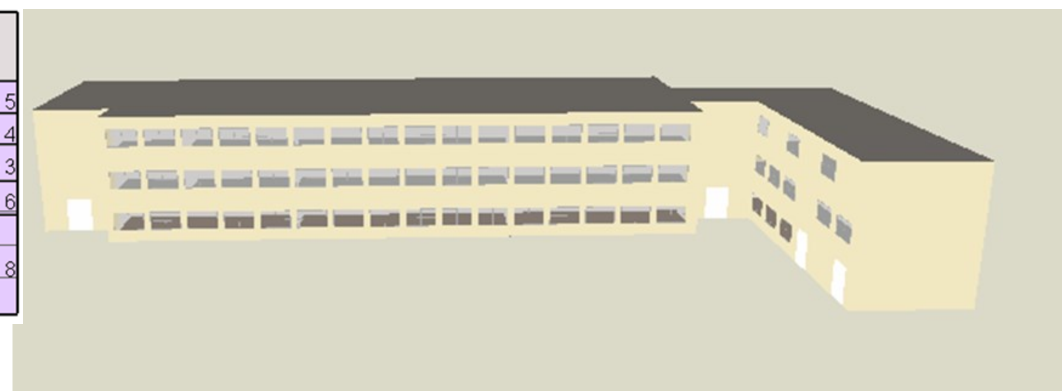
Navy academy-3D building & Zoning





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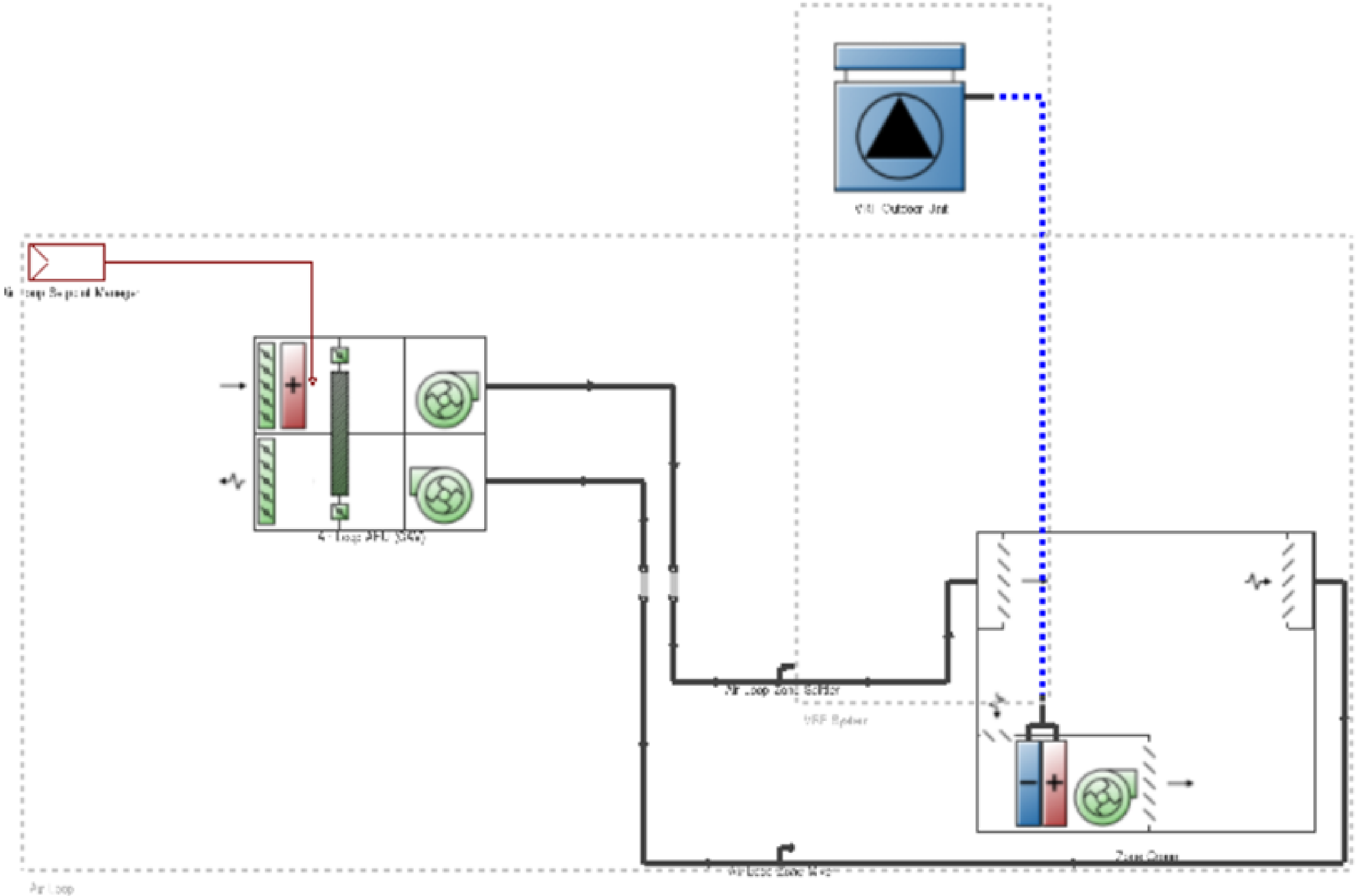
Navy academy-VRF (Variable Refrigerant Flow) system simulation



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Navy academy

- 3 scenarios according to Demo Houses initial simulation

	Energy Per Total Building Area [kWh/m2]	Energy Per Conditioned Building Area [kWh/m2]	Total Energy [kWh]
Total Site Energy	148.42	236.76	544103.64
Total Source Energy	470.05	749.82	1723176.24

	Energy Per Total Building Area [kWh/m2]	Energy Per Conditioned Building Area [kWh/m2]	Total Energy [kWh]
Total Site Energy	133.33	212.69	488796.48
Total Source Energy	422.27	673.6	1548018.45

	Energy Per Total Building Area [kWh/m2]	Energy Per Conditioned Building Area [kWh/m2]	Total Energy [kWh]
Total Site Energy	122.2	194.93	447965.8
Total Source Energy	386.99	617.33	1418707.67

The parameter related with the photocatalysis use is the ventilation rate. The photocatalysis helps the indoor air quality thus reduces the need for ventilation. The reduction of ventilation rates leads to both reduced energy consumption for ventilation, but also decreased energy consumption for heating and cooling due to decreased ventilation heat losses and gains, respectively.

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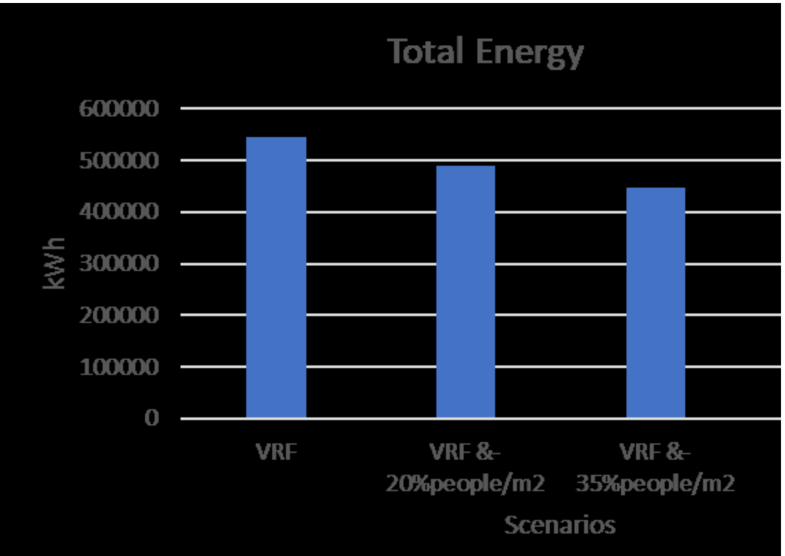
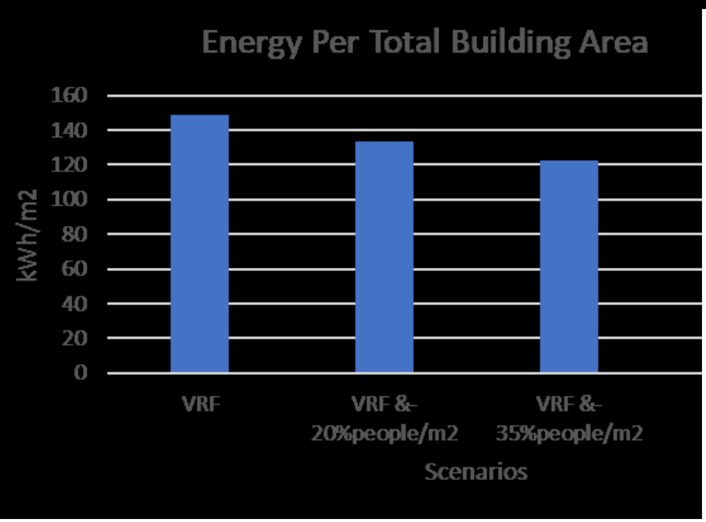
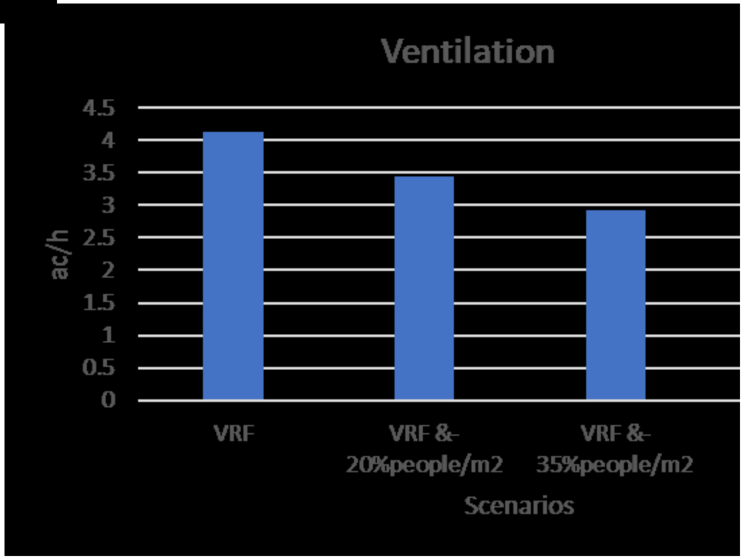


In the 1st scenario (without photocatalysis) the energy consumption reaches 544103.64 kWh and 236.76 kWh/m^2 of conditioned building area.

In the 2nd scenario, a simulation was carried out with the photocatalytic approach operation, assuming people density reduced by 20%. As it was expected in the second scenario where the ventilation rate has decreased the energy consumption was reduced. Specifically, in the 2nd scenario the energy consumption reaches 488796.48 kWh and 212.69 kWh/m^2 of conditioned building area.

In case the ventilation rate reduces more the energy reduction is also more noticeable. More specific and based on case 3 where the photocatalytic impact is higher the energy consumption reaches 447965.8 kWh and 194.93 kWh/m^2 of conditioned building area.





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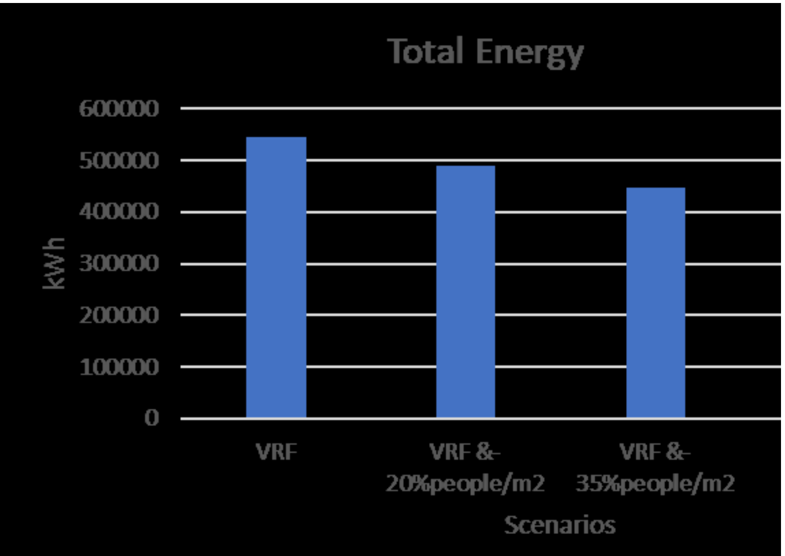
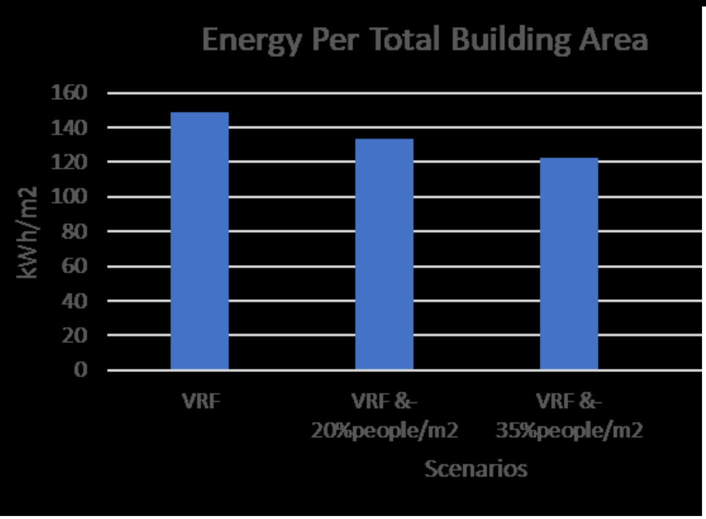
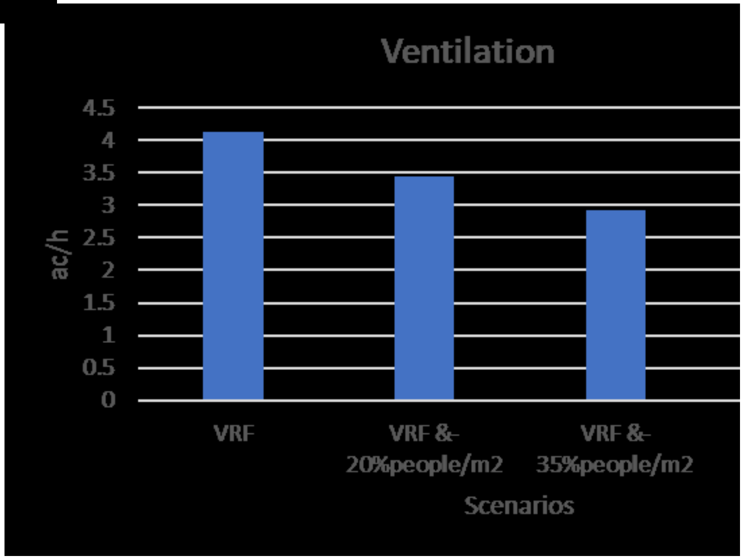
During the application of photocatalysis in the building, the energy consumption for both heating and cooling is reduced, which results from the reduction of the required air renewals. Energy usage decreased by 11.31% in the scenario assuming a 20% decrease in population density and by 21.46% in the scenario assuming a 35% decrease.

CO_2 emissions are reduced by 11.31% in the first scenario and by 21.46% in the second, following a similar trend to the reduction in consumption.

Also, there is a corresponding reduction in air renewals as can be seen. The decrease is on the order of 20% in the first case and 41% in the second.







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Results & Discussion

- There is a correlation of ventilation rates and photocatalysis (ventilation is related to energy consumption).
- The simulations determined significant energy consumption reduction compared to the conventional scenario (without photocatalysis) because of the ventilation rate reduction.
- The effect of photocatalysis in the emissions reduction is declared based on measurements in Demo Houses.
- The defined emissions reduction and the need for less ventilation are the key issue for the reduction of energy consumption.
- Implementation of the initial scenarios in the Naval Academy leads to up to 18% decrease of energy consumption.
- Contam simulations were applied to correlate the reduction of ventilation rate based on the emissions reduction in order to validate the percentage of energy reduction because of photocatalysis.
- The results in real scale application showed a correlation of ventilation rates and photocatalysis (ventilation is related to energy consumption). The simulations determined about 11 – 22% energy reduction compared to the conventional scenario (without photocatalysis) because of the ventilation rate reduction. The ventilation rate was determined by the occupancy in the photocatalytic scenarios.
- The increased percentage of energy saving is because the simulation included only summer period and based on experimental, controlled emissions concentration in the Demo Houses. So we definitely have energy consumption reduction but not in such high percentage.

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Results & Discussion

Two level of analysis

Focused on the AQ measurements it was calculated that by activating the VISIONS photo paint (turn on the light) the pollution level in the 'Green House' was reduced up to 61.7% for the organic paint, 36.8% for the inorganic paint while in the conventional one up to 24.6%. In the scenario that the windows were not covered and sun light (UV light) enter the room the reduction of NO were even higher, up to 70.1% To that end the organic paint were selected to be applied to the real-world application of the project (Hellenic Naval Academy)

Focused on the energy measurements and simulations

The models yielded results indicating a potential energy reduction of up to 22% when compared to the baseline scenario, primarily due to the reduction in ventilation rates.

The ventilation rate in the photocatalytic scenarios was determined based on the occupancy.

The impact of photocatalysis on air pollutants reduction is assessed through the assessment of indoor air quality levels. The primary concern for reducing energy consumption is in the defined reduction of pollutants levels and the imperative for decreased ventilation.

In the second scenario, a simulation was conducted utilizing the photocatalytic reaction, under the assumption that the population density was lowered by 20%.

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