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Thermal Simulation: parametric study of industrial sheds

ROBUST Project: WP 2.3

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Summary

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The report presents the scope and outcome of an extensive parametric study using IES (Integrated Environmental Solutions) dynamic thermal simulation software. The study involved two (small and medium sized) industrial sheds. The purpose of the parametric study is to provide heating demand data for the derivation of empirical relationships for the estimation of energy demands of industrial buildings “Before” and “After” renovation. This will facilitate the estimation of the energy savings and related cost savings due to the renovation work. The developed empirical relationship for heating demand has been implemented in the Economic Justification Tool developed in WP 5.1.

A total of 216 analyses were carried out and within those, the following parameters were varied:

- Building location (London, Berlin and Helsinki climates)
- Building dimensions (two sizes were looked at respectively 30 x 60 x 6m and 60 x 120 x 10m)
- Building orientation (NS and EW)
- Percentage of roof lights (12 % and 20%)
- U-values (wall, roof, floor, window, rooflight and door)
- Airigthness
- Lighting
- Daylighting
- Daylight dimming
- Occupancy sensor
- Heating and ventilation systems

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Thermal Simulation: parametric study of industrial sheds

1. Introduction

This report discusses the scope and outcome of an extensive parametric study carried out as part of ROBUST project. The purpose of the parametric study is to provide heating demand data for the derivation of empirical relationships for the estimation of energy demands of industrial buildings “Before” and “After” renovation. This will enable the estimation of the energy savings and related cost savings due to the renovation work. The developed empirical relationship for heating demand has been implemented in the Economic Justification Tool developed in WP 5.1.

The report describes the boundary conditions in terms of building specification, construction build up, recipe for the thermal analyses and the matrix for the parametric study. The results of the study are presented and discussed. Finally, conclusions are drawn from the results.

2. Description of boundary conditions for the thermal analysis

This section provides a brief overview of the boundary conditions for the thermal analysis and the scope of the parametric study carried out using IES dynamic thermal simulation software.

2.1 Building Specification

Table1 collates the size of the building, buildings locations, orientation and operation and occupancy profile considered for the thermal simulations. Both Figure 1 and 2 show building model for the analysis. As can be seen in Table 1, three weather sets (Berlin, Helsinki and London) considered for the thermal simulations of a small and medium size industrial sheds.

Table 2 shows the construction built-up of the building envelopes for base case, current, good, better and best practice. The base case represents “Before renovation” while current, good, better and best practice represent “After renovation”.

Table 1: Building Specification

<table>
<tr><td rowspan="2">SIZE
LOCATION</td><td>Small</td><td>Medium</td><td rowspan="5"></td><td rowspan="5">• Orientation: North/South and East/West
• NCM Operation and Occupancy profile:
o Warehouse
▪ Naturally ventilated
▪ 7am – 7pm for 7 days</td></tr>
<tr><td>30x60x6</td><td>60x120x10</td></tr>
<tr><td>Berlin</td><td>x</td><td>x</td></tr>
<tr><td>Helsinki</td><td>x</td><td>x</td></tr>
<tr><td>London</td><td>x</td><td>x</td></tr>
</table>

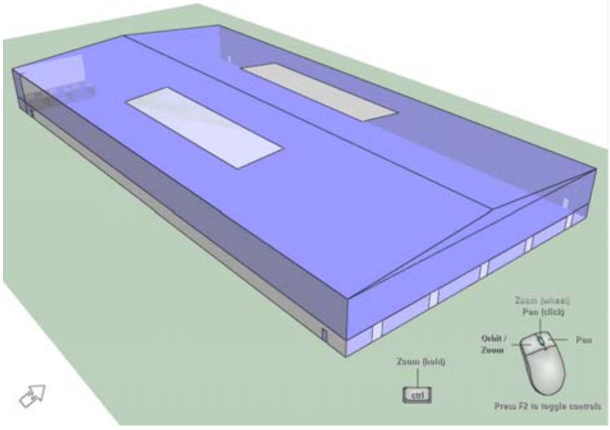

Figure 1: Model of small-size industrial shed used in the thermal simulation

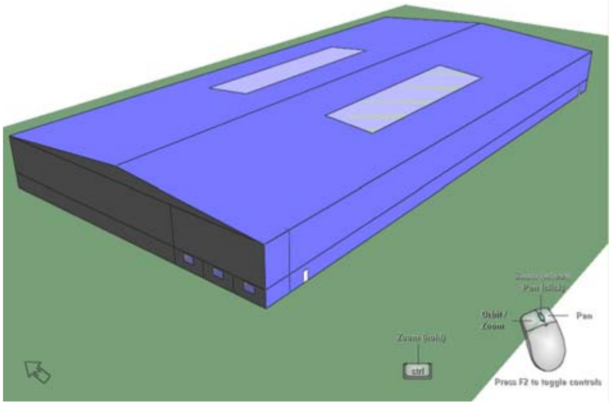

Figure 2: Model of medium-size industrial shed used in the thermal simulation

Table 2: Construction Element Build-up of Building Envelope

Construction Element	Construction				
	Base Case	**Current practice**	**Good**	**Better**	**Best**
Ground Floor	Uninsulated cast concrete	Uninsulated cast concrete	Uninsulated cast concrete	Uninsulated cast concrete	Uninsulated cast concrete
External Dwarf Wall	Uninsulated Brick and Block wall	Insulated Brick and Block wall	Insulated Brick and Block wall	Insulated Brick and Block wall	Insulated Brick and Block wall
External Wall Cladding	Asbestos cement sheet, cavity, steel sheet	Steel composite panel	Steel composite panel	Steel composite panel	Steel composite panel
Internal Wall	Brickwork wall with plaster both sides	Brickwork wall with plaster both sides	Brickwork wall with plaster both sides	Brickwork wall with plaster both sides	Brickwork wall with plaster both sides
Internal Floor	Cast concrete	Cast concrete	Cast concrete	Cast concrete	Cast concrete
Roof	Asbestos cement sheet, cavity, steel sheet	Steel composite panel	Steel composite panel	Steel composite panel	Steel composite panel
Personnel Door	Steel, cavity, steel door	Insulated steel faced door	Insulated steel faced door	Insulated steel faced door	Insulated steel faced door
Vehicle Door	Aluminium skin	Insulated aluminium faced door	Insulated aluminium faced door	Insulated aluminium faced door	Insulated aluminium faced door
External Glazing	Single glazed, steel frame	Double glazed unit	Triple glazed unit	Triple glazed unit	Triple glazed unit
Rooflights	Single polycarbonate sheet	Triple layer polycarbonate sheet	Double layer polycarbonate sheet with insulated core	Double layer polycarbonate sheet with insulated core	Double layer polycarbonate sheet with insulated core

2.2 Parameters for thermal analysis

This section describes the parameters for the parametric study. Table 3 presents the key parameters for the thermal analysis. Table 4 collates the assumed parameters for occupancy, equipment, ventilation, lighting and HVAC (heating, ventilation and cooling). These parameters are default values in the thermal simulation tool used for this analysis and are typical values for industrial sheds in the UK.

Table 3: Recipe for thermal analyses

No			Base Case	Current Practice (Part L1A)	Good	Better	Best
1	Airtightness $m^3/(h.m^2)$@50 Pa		27	10	7	4	1
2	U-value (W/m^2K)	Cavity wall	1.7	0.35	0.25	0.20	0.15
		Wall panel	2.3	0.35	0.25	0.20	0.15
		Internal wall	1.7	1.7	1.7	1.7	1.7
		Roof	1.95	0.25	0.20	0.15	0.10
		Grd floor	1.0	0.25	0.20	0.15	0.10
		Window	5.4	2.20	1.50	1.10	0.70
		Rooflight	6.6	2.20	1.80	1.50	1.20
		Solar shading (effective g-value)	0.85	0.65	0.50	0.35	0.20
		Entrance door	3.0	2.20	1.50	1.10	0.70
		Vehicle access door	5.9	1.50	1.30	1.10	0.90
		Roof ventilators	-	-	-	-	-
3	Rooflights (%)		20, 12	20, 12	20, 12	20, 12	20, 12
4	Psi values (W/mK)	Gutter (Valley)	Default method in NCM* to add 10% to U value for each element	Default method in NCM to add 10% to U value for each element	Default method in NCM to add 10% to U value for each element	Default method in NCM to add 10% to U value for each element	Default method in NCM to add 10% to U value for each element
		Drip (wall ground fl.)					
		Roof –wall (Eaves + Verges)					
		Wall – corner wall					
		Wall – floor not grd.					
		Lintel (window/door)					
		Sill below window					
		Jamb (window/door)					
Lighting ($W/(m^2.100$ lux)): office, storage & shed			4.5	3.75	2.5	1.75	1.25
Lighting ($W/(m^2.100$ lux)): other spaces			6.0	5.2	4.0	3.3	2.5
Daylight Dimming			No	No	Yes	Yes	Yes
Occupancy Sensing			No	No	Yes	Yes	Yes
Specific fan power (W/(ls-1)): centralised balanced			3	1.8	1.5	1.1	0.9
Heat recovery effectiveness (%)			0	0	60	70	80
Heat generator seasonal efficiency			0.65	0.84	0.9	0.95	1.15
Cooling generator SEER			-	-	-	-	-
Hot water generator seasonal efficiency			0.50	0.70	0.8	0.90	0.95

*NCM: National Calculation Method

Table 4: NCM Default Parameters for Warehouse Building Areas

Zone	Occupancy (m2/person)	Equipment (W/m2)	Ventilation (ac/hr)	Lighting (lux)	HVAC
Office	14.29	10	0.84	500	Radiator
Common room	9.09	5	0.1	150	Radiator
Shed	100	2	0.0319	300	Air heating
Toilet	9.09	5	1.584	100	Radiator

3. Results

The output of the parametric study is collated in the Tables below. Table 5 presents the annual operational heating demand for both small and medium sized sheds using three locations (London, Berlin and Helsinki) weather datasets along with orientation and rooflights percentage for Base case, Current, Good, Better and Best practice. Table 6 collates the associated annual operational carbon emission for all the case studied. These results are plotted in Figure 3 – 6.

Table 5: Comparison of Annual Operational Energy Demand

				Energy (MWh)				
Size	Location	Orientation	Rooflights	BaseCase	Current Practice	Good Practice	Better Practice	Best Practice
60x120x10	London	NS	12% rooflights	3750	1083	787	604	422
			20% rooflights	3763	1078	778	608	423
		EW	12% rooflights	3751	1084	787	604	422
			20% rooflights	3764	1079	779	608	423
	Berlin	NS	12% rooflights	5035	1343	977	737	463
			20% rooflights	5106	1358	984	754	480
	Helsinki	NS	12% rooflights	7398	1830	1344	990	556
			20% rooflights	7526	1881	1379	1028	595
Size	Location	Orientation	Rooflights	BaseCase	Current Practice	Good Practice	Better Practice	Best Practice
30x60x6	London	NS	12% rooflights	861	250	184	141	94
			20% rooflights	865	250	183	142	97
	Berlin	NS	12% rooflights	1150	304	224	170	108
			20% rooflights	1169	309	227	175	113
	Helsinki	NS	12% rooflights	1672	403	297	224	134
			20% rooflights	1706	418	308	234	144

Table 6: Comparison of Annual Operational Carbon emission

				Carbon (kg CO2)				
Size	Location	Orientation	Rooflights	BaseCase	Current Practice	Good Practice	Better Practice	Best Practice
60x120x10	London	NS	12% rooflights	996304	382027	260426	209892	174450
			20% rooflights	998764	381025	257221	209134	171399
		EW	12% rooflights	996445	382156	260498	209951	174462
			20% rooflights	998925	381191	257316	209206	171423
	Berlin	NS	12% rooflights	1245918	432516	297778	236332	183230
			20% rooflights	1259623	435578	297667	237951	183478
	Helsinki	NS	12% rooflights	1704310	527127	370369	286763	204575
			20% rooflights	1729179	536985	375812	292685	208930
Size	Location	Orientation	Rooflights	BaseCase	Current Practice	Good Practice	Better Practice	Best Practice
30x60x6	London	NS	12% rooflights	238532	92015	66758	50741	37015
			20% rooflights	239440	92087	65890	50693	37303
	Berlin	NS	12% rooflights	294720	102497	74769	56525	39742
			20% rooflights	298344	103492	74653	57082	40530
	Helsinki	NS	12% rooflights	396090	121800	89875	67368	45080
			20% rooflights	402589	124574	91210	69036	46718

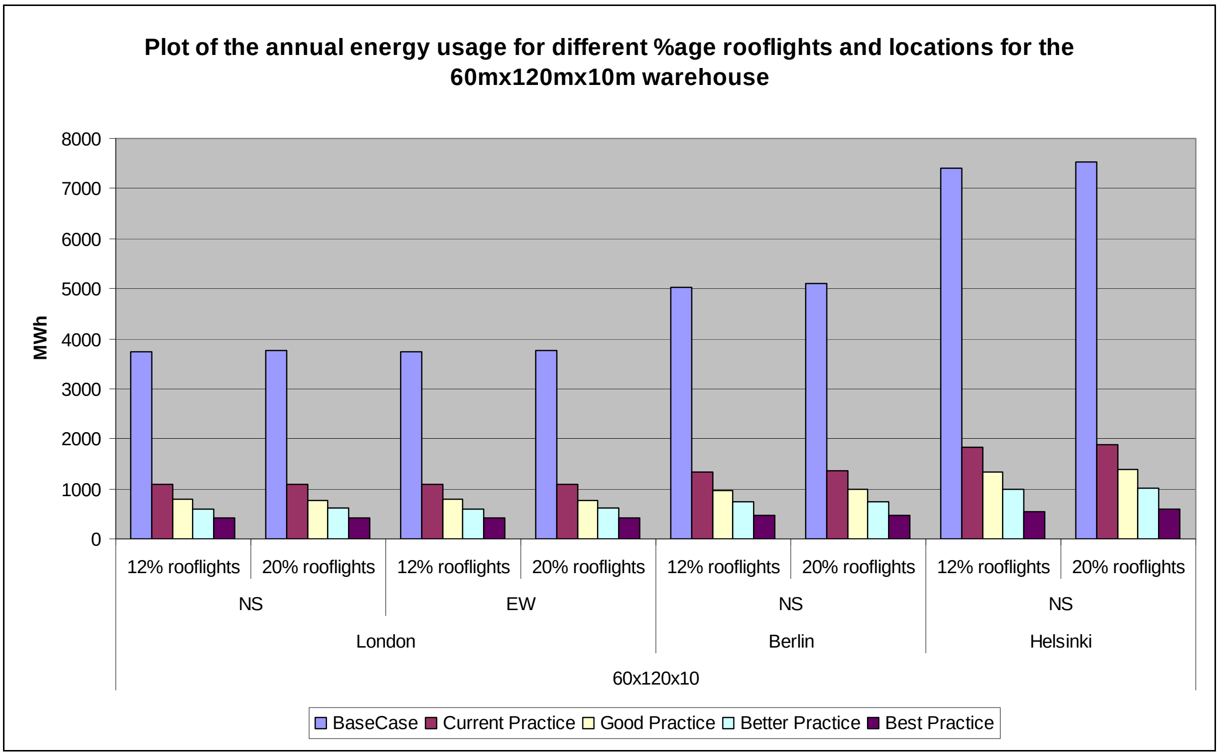

Figure 3: Annual Energy Demand for 60 x 120 x 10m Warehouse

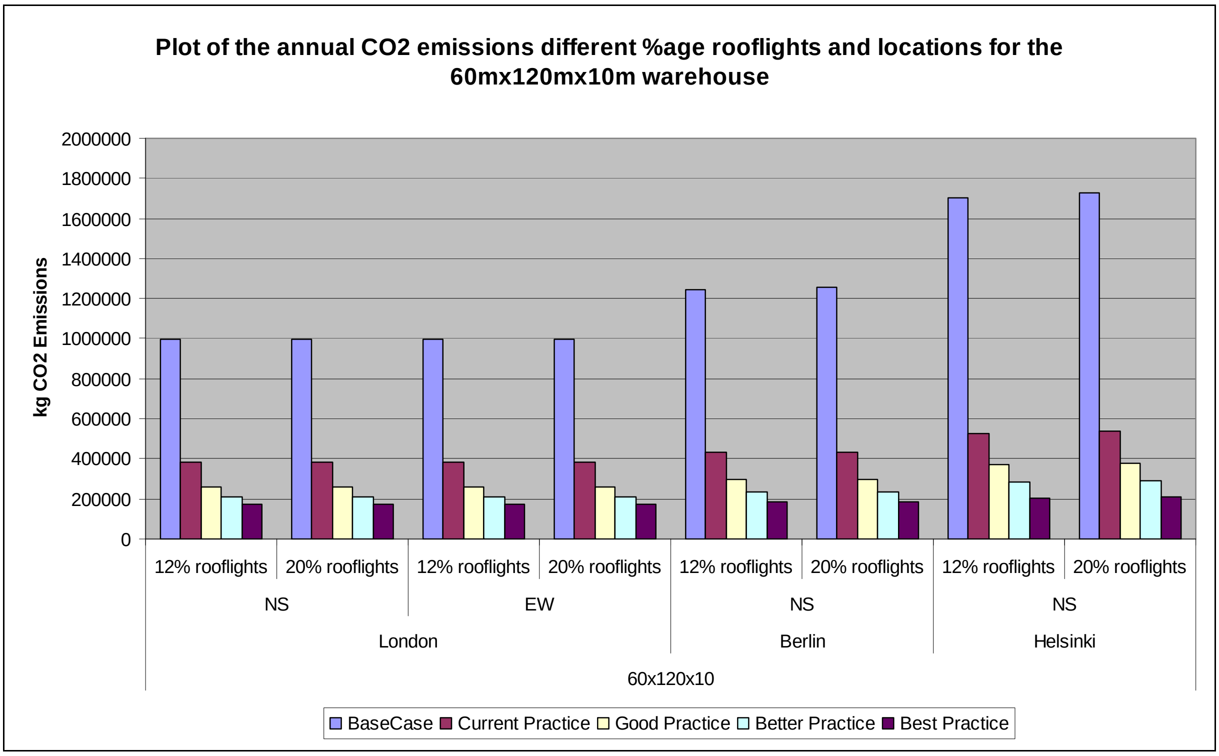

Figure 4: Annual Carbon Emission for 60 x 120 x 10m Warehouse

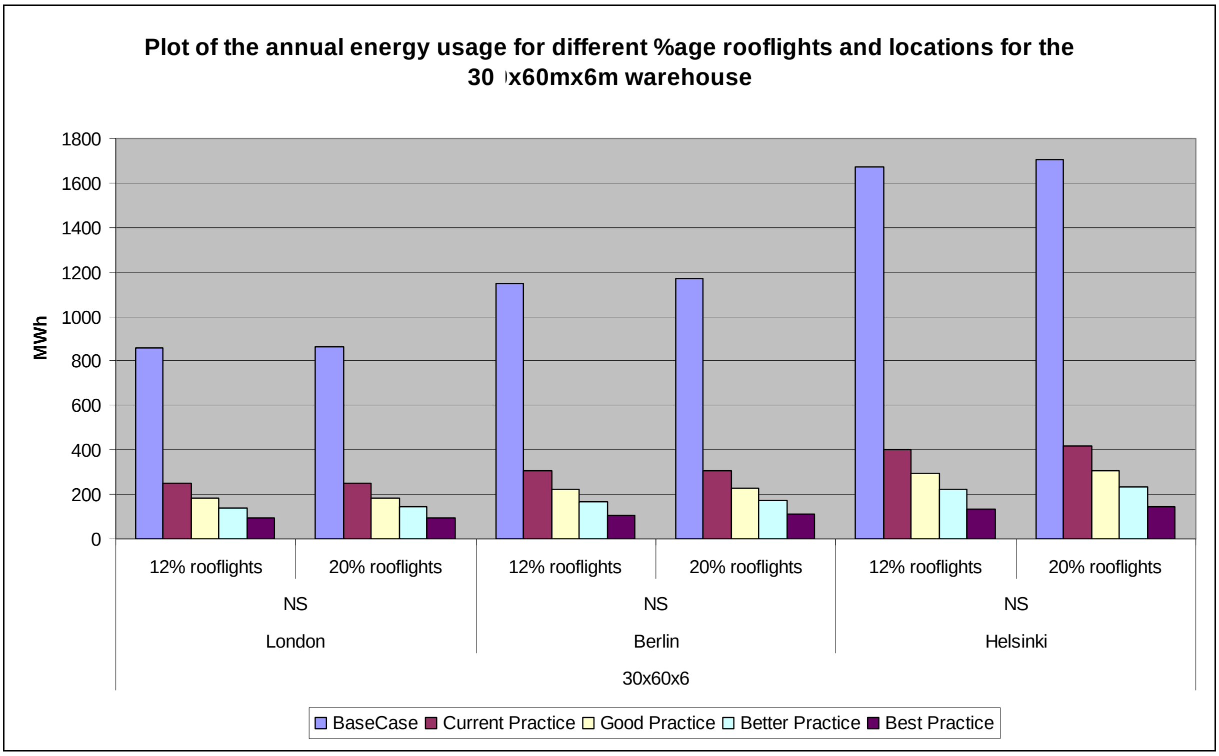

Figure 5: Annual Energy Demand for 30 x 60 x 6m Warehouse

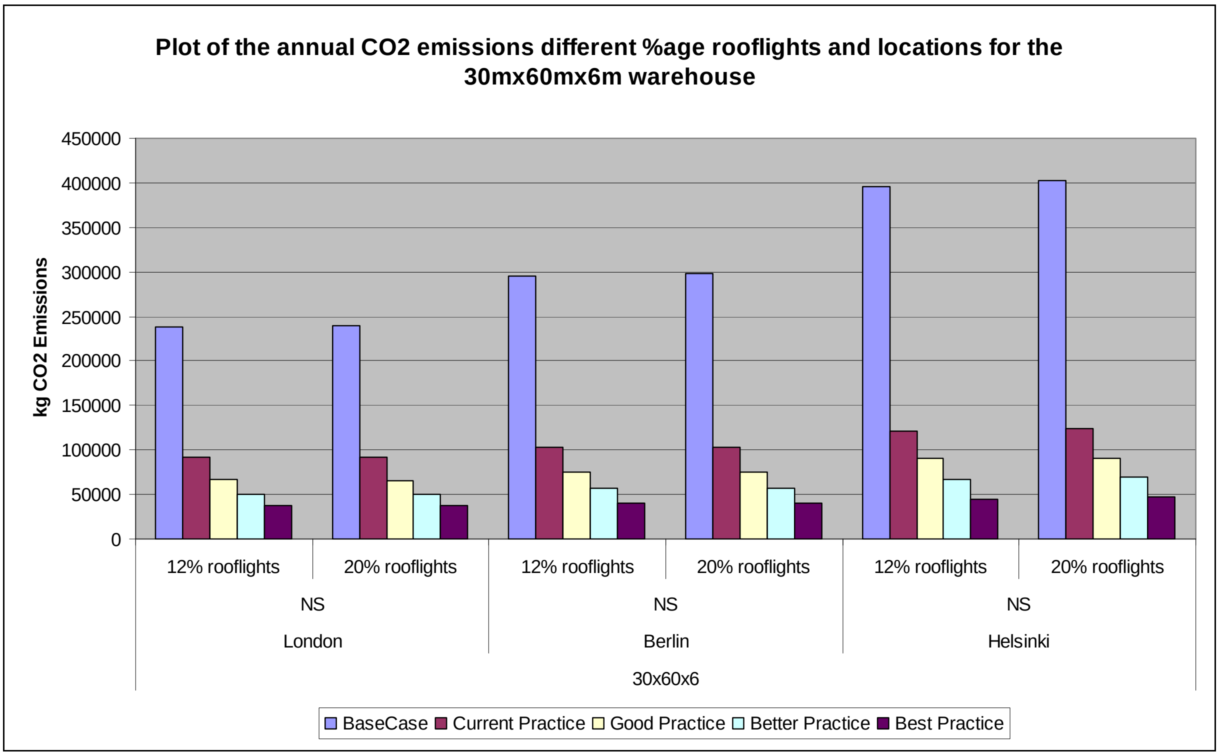

Figure 6: Annual Carbon Emission for 30 x 60 x 6m Warehouse

4. Discussion of thermal analysis results

As can be seen from the results, the location of a building has a considerable impact on the total heading demand. The result indicates lower heating demand in London compared to Berlin and Helsinki. This is can be associated to a number of factors such higher solar irradiation, lower heating period and so on for buildings located in London.

It can be deduced from the results that building orientation (NS and EW) and roof lights percentage (12% and 20%) have very little impact on the total annual heating demands for the three locations. However, the impact of orientation and roof lights percentage will be higher if overheating and cooling demand were considered in the analysis.

Overall, the result highlights a considerable energy savings and reduction in carbon emission when buildings are renovated. The best practice renovation option provides the biggest energy savings. Nonetheless, the decision on the level and scope of renovation (e.g. current, good, better or best practice) largely depends on the drivers for renovation such as national regulatory requirements and acceptable level of return on investment in different countries.

5. Conclusion

This report documented the outcome of parametric study using IES (Integrated Environmental Solutions) dynamic thermal simulation software. The study involved two small and medium sized industrial sheds. The purpose of the parametric study was to provide heating demand data for the derivation of empirical relationships for the estimation of energy demands of industrial buildings “Before” and “After” renovation. This will enable the estimation of the energy savings and related cost savings due to the renovation work. The developed empirical relationship for heating demand has been implemented in the Economic Justification Tool developed in WP 5.1.

For the parametric study, a total of 216 analyses were carried out by altering the following parameters:

- Building location (London, Berlin and Helsinki climates)
- Building dimensions (two sizes were looked at respectively 30 x 60 x 6m and 60 x 120 x 10m)
- Building orientation (NS and EW)
- Percentage of roof lights (12 % and 20%)
- U-values (wall, roof, floor, window, rooflight and door)
- Airigthness
- Lighting
- Daylighting
- Daylight dimming
- Occupancy sensor
- Heating and ventilation systems

The results indicated that building location has a considerable impact on heating energy demand. The result also showed that both orientation and percentage of rooflights have a very little impact on heating demand. Overall, there is a major reduction in heating demand and associate carbon emission when buildings are renovated.