

ENERGY AND
ENVIRONMENTAL
TECHNOLOGIES FOR
BUILDING SYSTEMS
SKETCHUP&OPENSTUDIO
REPORT

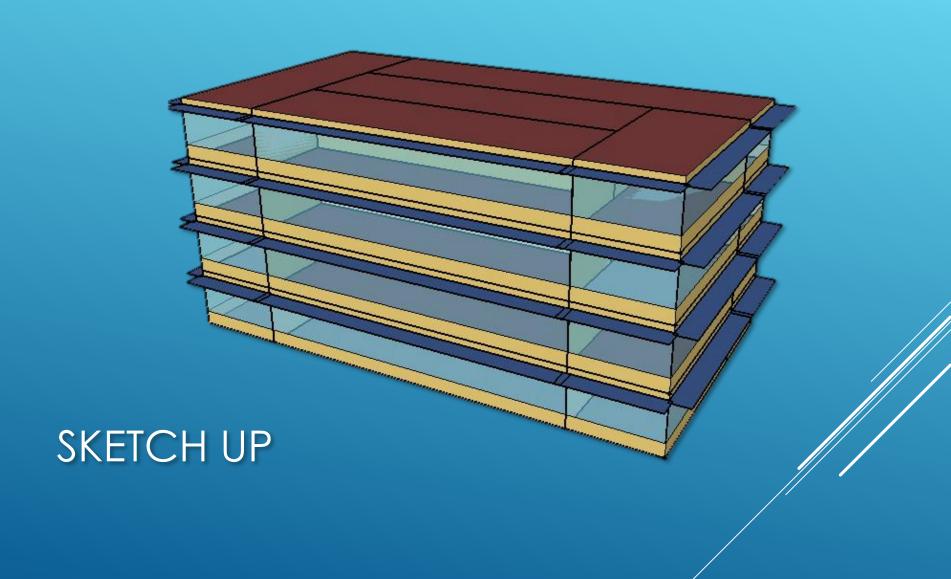
Project by

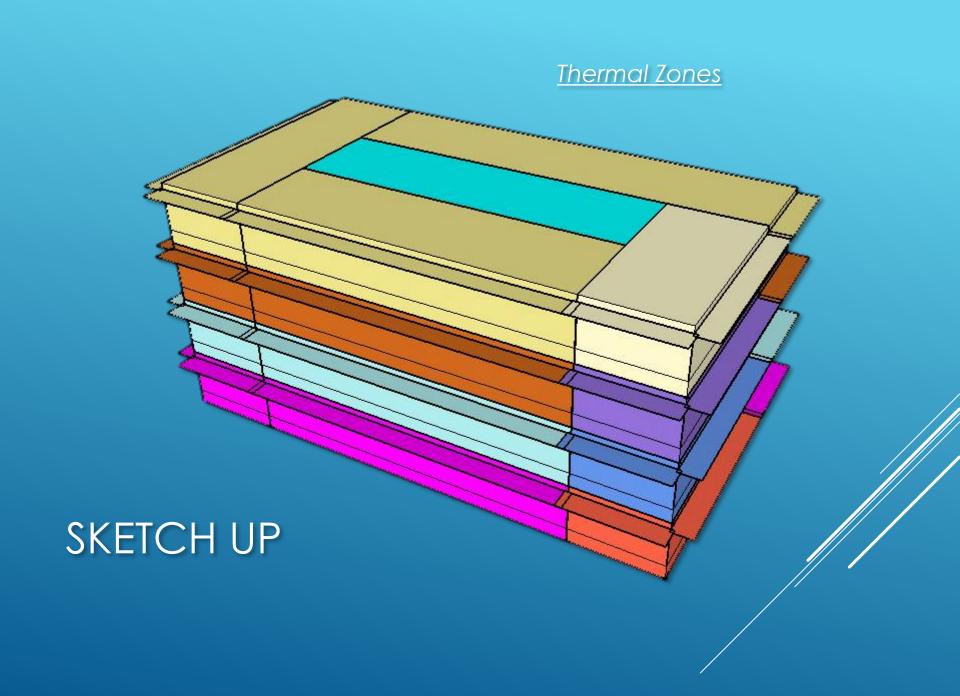
Cremona Riccardo Depalo Monica Diaz Lacharme Maria

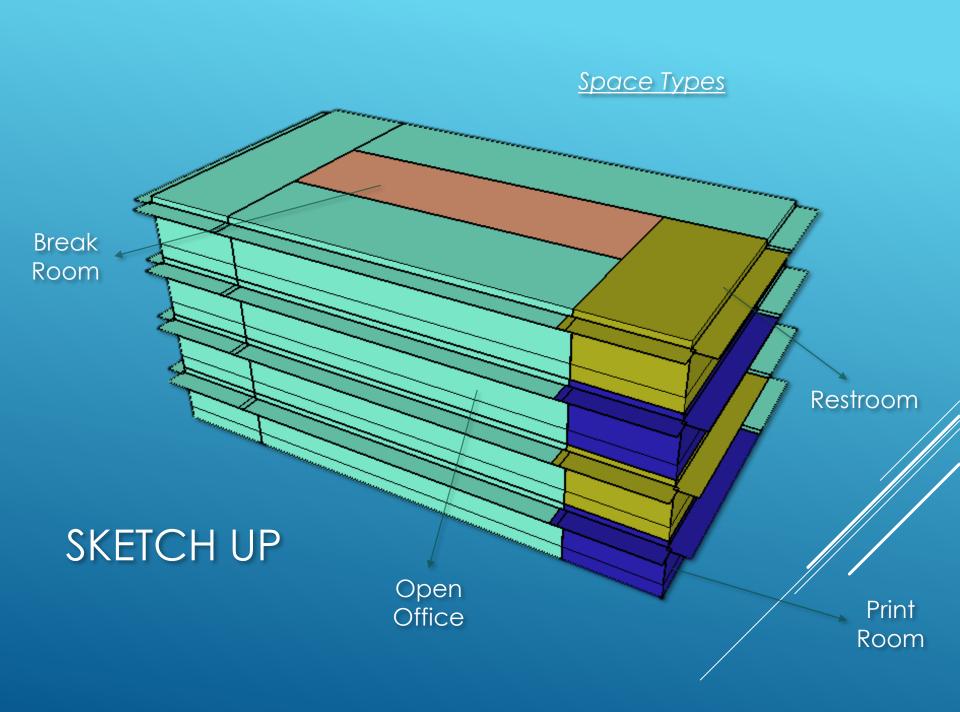
- We started building the <u>geometry</u> of a commercial building in SketchUp
- Using OpenStudio we defined the other characteristics of the building such as <u>schedule</u> sets, <u>definitions</u> (light, people...)
- We then calculated the yearly heating and cooling <u>consumption</u> of the building for a **base case**
- We investigated the effects of changing the <u>location</u>, <u>wall</u> characteristics, and <u>window</u> type on energy consumption
- A total of three different cities and three different walls/windows have been **compared** with the corresponding base case.

### INTRODUCTION

### The building







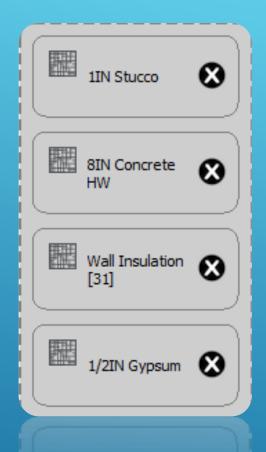
# We defined different cases according to different construction sets:

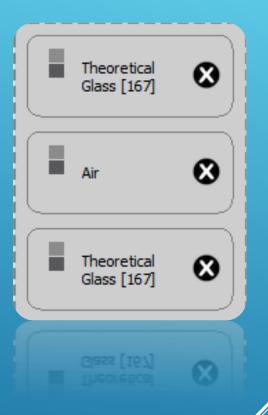
- Base: default OpenStudio sets
- Worst: worse building characteristics compared to base case
- Better: slight improvements to the base case
- Best: extreme improvements to the base case

All cases have the same schedule sets and definitions.

## BASE, WORST, BETTER, BEST CASES

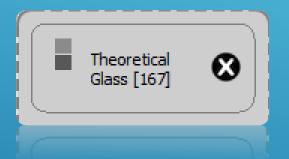
#### Base case





#### Worst case







#### <u>Better case</u>



#### Best case





A							FIRE	NZE/PER	ETOLA,	Italy					WMO#:	161700	
	Lat	43.80N	Long:	11.20E	Elev	38	StdP	100.87		Time Zone:	1.00 (EU	W)	Period:	95-10	WBAN:	99999	
١	Annual H	eating and H	lumidificat	ion Design C	conditions												4
1	Coldest		- 00		Hur	midification DF	P/MCDB and	d HR			Coldest mon	th WS/MCD	В	MCWS	/PCWD	1	
1	Month	Heatin	-		99.6%			99%		0.	4%	1	%	to 99.	6% DB		
1	MOHIN	99.6%	99%	DP	HR	MCDB	DP	HR	MCDB	WS	MCDB	WS	MCDB	MCWS	PCWD	]	
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(1)	(j)	(k)	(1)	(m)	(n)	(0)		
	1 Annual C	-3.1	-1.2	-10.6	1.5	3.2	-8.4	1.9	2.9	10.4	5.2	8.4	5.9	8.0	80		
	Annual C	ooling, Dehu	midification	on, and Enth	alpy Desig	n Conditions	3				Evaporation	WB/MCD8	3		Mcws		1
		Hottest Month	midification of the control of the c	on, and Enth	Cooling	n Conditions DB/MCWB	2	1%	0.	4%	Evaporation 1	WB/MCDB	3 2	%	MCWS to 0.4	% DB	
	Hottest Month	Hottest Month DB Range	midification 0	and Enth	Cooling DB	DB/MCWB	DB	% MCWB	0. WB	4% MCDB	Evaporation 1 WB	WB/MCD6 % MCDB	3 WB	% MCDB	MCWS to 0.4 MCWS	% DB PCWD	]
	Hottest	Hottest Month DB Range	DB (c)	.4% MCWB	Cooling DB	DB/MCWB	DB (g)	% MCWB	0. WB	4% MCDB (/)	Evaporation 1 WB	WB/MCDB MCDB	2 WB (m)	% MCDB	MCWS to 0.4 MCWS	% DB PCWD	]
	Hottest Month	Hottest Month DB Range	midification 0	and Enth	Cooling DB	DB/MCWB	DB	% MCWB	0. WB	4% MCDB	Evaporation 1 WB	WB/MCD6 % MCDB	3 WB	% MCDB	MCWS to 0.4 MCWS	% DB PCWD	]
	Hottest Month	Hottest Month DB Range	DB (c)	.4% MCWB (d) 22.2	Cooling  DB (e) 33.8	DB/MCWB	DB (g) 32.1	% MCWB	0. WB	4% MCDB (/) 31.4	Evaporation 1 WB (k) 23.5	WB/MCDB  MCDB  (1)  30.3  Enthalp	2 WB (m) 22.7 y/MCDB	%   MCDB (n) 29.4	MCWS to 0.4 MCWS (0) 3.7	% DB PCWD (p) 250 Hours	]
	Hottest Month (a)	Hottest Month DB Range (b) 12.2	0 DB (c) 35.1	.4% MCWB (d) 22.2 Dehumidifi	Cooling  DB  (e) 33.8 cation DP/N	DB/MCWB 1% MCWB (f) 22.0	DB (g) 32.1	% MCWB (h) 21.4	0. WB (/) 24.3	4%   MCDB (//) 31.4	Evaporation 1 WB (k) 23.5	WB/MCDE % MCDB (1) 30.3 Enthalp	WB (m) 22.7 y/MCDB	% MCDB (n) 29.4	MCWS to 0.4 MCWS (0) 3.7	% DB PCWD (p) 250 Hours 8 to 4 &	]
	Hottest Month (a) 7	Hottest Month DB Range (b) 12.2	0 DB (c) 35.1	MCWB (d) 22.2 Dehumidifi	Cooling  DB  (e) 33.8 cation DP/N 1% HR	DB/MCWB 1% MCWB (f) 22.0 MCDB and HR	DB (g) 32.1	% MCWB (h) 21.4	0. WB (1) 24.3	4% MCDB (J) 31.4 0. Enth	Evaporation 1 WB (k) 23.5	MCDB (//) 30.3 Enthalp	WB (m) 22.7 y/MCDB % MCDB	% MCDB (n) 29.4	MCWS to 0.4 MCWS (0) 3.7	% DB PCWD (p) 250 Hours 8 to 4 & 12.8/20.6	]
	Hottest Month (a)	Hottest Month DB Range (b) 12.2	0 DB (c) 35.1	.4% MCWB (d) 22.2 Dehumidifi	Cooling  DB  (e) 33.8 cation DP/N	DB/MCWB 1% MCWB (f) 22.0	DB (g) 32.1	% MCWB (h) 21.4	0. WB (/) 24.3	4%   MCDB (//) 31.4	Evaporation 1 WB (k) 23.5	WB/MCDE % MCDB (1) 30.3 Enthalp	WB (m) 22.7 y/MCDB	% MCDB (n) 29.4	MCWS to 0.4 MCWS (0) 3.7	% DB PCWD (p) 250 Hours 8 to 4 &	]

						KC	DEBENH	IAVN/KA	STRUP,	Denmar	k				WMO#:	061800
	Lat	55.62N	Long:	12.65E	Elev	5	StdP	101.26		Time Zone:	1.00 (EU	W)	Period	86-10	WBAN:	99999
Annu	ual He	ating and H	umidificat	ion Design C												
Cole	idest	Heatin	a DB			nidification DF	P/MCDB and				oldest mon	th WS/MCD	В	MCWS	/PCWD	1
	onth				99.6%			99%		0.6		1			6% DB	1
		99.6%	99%	DP	HR	MCDB	DP	HR	MCDB	WS	MCDB	WS	MCDB	MCWS	PCWD	J
	a)	(b)	(0)	(d)	(e)	(f)	(g)	(h)	(1)	(1)	(k)	(1)	(m)	(n)	(0)	
	2 ual Co	-7.9 poling, Dehu	-6.0	-11.2 on, and Enth	1.4 alpy Desig	-5.7 n Conditions	-9.4	1.7	-4.3	14.9	4.8	13.5	3.8	4.6	60	
Annu	-	Hottest	midification	on, and Enth	alpy Desig	DB/MCWB	3				Evaporation	n WB/MCDB			Mcws	PCWD
Annu	ual Co	Hottest Month	midificatio	on, and Enth	Cooling	DB/MCWB	2	2%	0.	4%	Evaporation 1	n WB/MCDB	2	%	MCWS to 0.4	% DB
Annu Hot Mo	ual Co	Hottest Month DB Range	midification 0	4% MCWB	Cooling DB	DB/MCWB	DB	% MCWB	0. WB	4% MCDB	Evaporation 1 WB	wB/MCDB	WB	% MCDB	MCWS	% DB PCWD
Annu Hot Mo	ual Co	Hottest Month DB Range	DB	4% MCWB	Cooling DB (e)	DB/MCWB	DB (g)	2% MCWB	0. WB	4% MCDB (/)	Evaporation 1 WB	WB/MCDB	WB (m)	% MCDB	MCWS to 0.4 MCWS	PCWD
Hot Mo	ual Co	Hottest Month DB Range	midification 0	.4% MCWB (d) 18.1	Cooling  DB (e) 24.0	DB/MCWB 1% MCWB (f) 17.5	DB (g) 22.4	% MCWB	0. WB	4% MCDB	Evaporation 1 WB	MCDB (1) 22.2	WB (m) 17.7	% MCDB	MCWS	% DB PCWD (p) 160
Annu Hot Mo	ual Co	Hottest Month DB Range	DB	.4% MCWB (d) 18.1	Cooling  DB  (e) 24.0	DB/MCWB	DB (g) 22.4	% MCWB (h) 16.8	0. WB	4% MCDB (/) 23.2	Evaporation 1 WB (k) 18.6	MCDB (// 22.2 Enthalp	WB (m) 17.7 y/MCDB	% MCDB (n) 21.2	MCWS to 0.4 MCWS (o) 4.6	% DB PCWD (p) 160 Hours
Hot Mo	ttest onth	Hottest Month DB Range (b) 7.8	0 DB (c) 25.5	MCWB (d) 18.1 Dehumidifie	Cooling  DB  (e) 24.0  cation DP/W	DB/MCWB    MCWB    17.5	DB (g) 22.4	% MCWB (h) 16.8	0. WB (/)	4% MCDB (//) 23.2	Evaporation 1 WB (k) 18.6	MCDB (1) 22.2 Enthalp	WB (m) 17.7 y/MCDB %	%   MCDB (n) 21.2	MCWS to 0.4 MCWS (0) 4.6	(p) 160 Hours 8 to 4 &
Hot Mo	ttest onth a)	Hottest Month DB Range (b) 7.8	0 DB (c) 25.5	MCWB (d) 18.1 Dehumidifie	Cooling  DB  (e) 24.0 cation DP/M  1%  HR	DB/MCWB    MCWB    17.5    MCDB and HR	DB (g) 22.4	% MCWB (h) 16.8	0. WB (/) 19.5	4% MCDB (/) 23.2	Evaporation 1 WB (k) 18.6  MCDB	MCDB  (/)  22.2  Enthalp  Enth	WB (m) 17.7 y/MCDB % MCDB	% MCDB (n) 21.2	MCWS to 0.4 MCWS (0) 4.6	PCWD (p) 160 Hours 8 to 4 & 12.8/20.6
Hot Mo	ttest onth	Hottest Month DB Range (b) 7.8	0 DB (c) 25.5	MCWB (d) 18.1 Dehumidifie	Cooling  DB  (e) 24.0  cation DP/W	DB/MCWB    MCWB    17.5	DB (g) 22.4	% MCWB (h) 16.8	0. WB (/)	4% MCDB (//) 23.2	Evaporation 1 WB (k) 18.6	MCDB (1) 22.2 Enthalp	WB (m) 17.7 y/MCDB %	%   MCDB (n) 21.2	MCWS to 0.4 MCWS (0) 4.6	PC (/ 1t Ho 8 to

## WEATHER DATA

						1	MALAG	A/AEROP	PUERTO	, Spain					WMO#:	084820
	Lat	36.67N	Long:	4.48W	Elev	. 7	StdP	101.24		Time Zone:	1.00 (EU	N)	Period	: 86-10	WBAN:	99999
A	Annual He	ating and H	umidificati	on Design C	Conditions											
Г	Coldest	Heatin	- 00		Hur	midification DF	P/MCDB and	1 HR			Coldest mon	h WS/MCD	IB	MCWS	/PCWD	1
П	Month				99.6%			99%			4%		%		6% DB	
L	MOTILIT	99.6%	99%	DP	HR	MCDB	DP	HR	MCDB	WS	MCDB	WS	MCDB	MCWS	PCWD	]
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(1)	(1)	(k)	(1)	(m)	(n)	(0)	
					2.7	11.1	-1.8	3.3	11.5	13.5	12.7	12.1	13.4	4.3	300	
A	1 Annual Co		5.3 midificatio	-4.1 n, and Enth	alpy Desig	n Conditions		0.0								
	1 Annual Co	Hottest	midificatio	n, and Enth	alpy Desig						Evaporation	WB/MCDE	3		MCWS	PCWD
		Hottest Month	midificatio 0.	n, and Enth	Cooling	DB/MCWB	2	%	0.	4%	Evaporation 1	WB/MCDB	3	2%	MCWS to 0.4	% DB
	Hottest Month	Hottest Month DB Range	0. DB	n, and Enth	Cooling DB	DB/MCWB 1% MCWB	DB	% MCWB	0. WB	4% MCDB	Evaporation 1'	WB/MCDB % MCDB	3 WB	2% MCDB	MCWS to 0.4	% DB PCWD
	Hottest Month	Hottest Month DB Range	0. DB (c)	4% MCWB	Cooling DB (e)	DB/MCWB 1% MCWB	DB (g)	% MCWB	0. WB	4%   MCDB (/)	Evaporation 1 WB	WB/MCDB MCDB	WB (m)	2%   MCDB (n)	MCWS to 0.4 MCWS	% DB PCWD
	Hottest Month	Hottest Month DB Range	0. DB	4% MCWB (d) 20.3	Cooling DB (e) 32.9	DB/MCWB 1% MCWB (1) 20.2	DB (g) 30.9	% MCWB	0. WB	4% MCDB	Evaporation 1'	WB/MCDB MCDB (1) 27.5	WB (m) 22.8	2% MCDB	MCWS to 0.4	% DB PCWD (p) 180
	Hottest Month	Hottest Month DB Range	0. DB (c)	4% MCWB (d) 20.3	Cooling  DB (+0) 32.9  cation DP/M	DB/MCWB 1% MCWB	DB (g) 30.9	% MCWB	0. WB	4%   MCDB (/) 28.1	Evaporation 1 WB (*) 23.4	WB/MCDB % MCDB (1) 27.5 Enthalp	WB (m) 22.8	2% MCDB (n) 27.0	MCWS to 0.4 MCWS (0) 5.0	% DB PCWD (p) 180 Hours
	Hottest Month (a) 8	Hottest Month DB Range (b) 9.4	0. DB (c) 35.0	MCWB (d) 20.3 Dehumidific	Cooling  DB  (e) 32.9  cation DP/N 1%	DB/MCWB 1% MCWB (f) 20.2	DB (g) 30.9	% MCWB (h) 20.0	0. WB (1) 24.0	4%   MCDB (/) 28.1	Evaporation 1 WB (*) 23.4	WB/MCDB % MCDB (1) 27.5 Enthalp	WB (m) 22.8 my/MCDB	2%   MCDB (n) 27.0	MCWS to 0.4 MCWS (0) 5.0	% DB PCWD (p) 180 Hours 8 to 4 &
	Hottest Month (a) 8	Hottest Month DB Range (b) 9.4	0. DB (c) 35.0	MCWB (d) 20.3 Dehumidific	Cooling  DB  (+)  32.9  cation DP/M  1%  HR	DB/MCWB 1% MCWB (f) 20.2 MCDB and HR	2 DB (g) 30.9	% MCWB (h) 20.0	0. WB (1) 24.0	4% MCDB (//) 28.1 0. Enth	Evaporation 1 WB (k) 23.4 W6 MCDB	WB/MCDE MCDB (1) 27.5 Enthalp	WB (m) 22.8 y/MCDB % MCDB	2% MCDB (n) 27.0 Enth	MCWS to 0.4 MCWS  (0)  5.0  MCDB	% DB PCWD (p) 180 Hours 8 to 4 & 12.8/20.6
	Hottest Month (a) 8	Hottest Month DB Range (b) 9.4	0. DB (c) 35.0	MCWB (d) 20.3 Dehumidific	Cooling  DB  (e) 32.9  cation DP/N 1%	DB/MCWB 1% MCWB (f) 20.2	DB (g) 30.9	% MCWB (h) 20.0	0. WB (1) 24.0	4%   MCDB (/) 28.1	Evaporation 1 WB (*) 23.4	WB/MCDB % MCDB (1) 27.5 Enthalp	WB (m) 22.8 my/MCDB	2%   MCDB (n) 27.0	MCWS to 0.4 MCWS (0) 5.0	% DB PCWD (p) 180 Hours 8 to 4 &

### <u>Base</u>

	Electricity [GJ]	Natural Gas [GJ]	Additional Fuel [GJ]	District Cooling [GJ]	District Heating [GJ]	Water [m3]
Heating	0.00	0.00	0.00	0.00	279.23	0.00
Cooling	0.00	0.00	0.00	292.08	0.00	0.00

### <u>Worst</u>

		Electricity [GJ]	Natural Gas [GJ]	Additional Fuel [GJ]	District Cooling [GJ]	District Heating [GJ]	Water [m3]
ı	Heating	0.00	0.00	0.00	0.00	391.80	0.00
	Cooling	0.00	0.00	0.00	320.04	0.00	0.00

### <u>Better</u>

	Electricity [GJ]	Natural Gas [GJ]	Additional Fuel [GJ]	District Cooling [GJ]	District Heating [GJ]	Water [m3]
Heating	0.00	0.00	0.00	0.00	228.90	0.00
Cooling	0.00	0.00	0.00	289.57	0.00	0.00

#### <u>Best</u>

	Electricity [GJ]	Natural Gas [GJ]	Additional Fuel [GJ]	District Cooling [GJ]	District Heating [GJ]	Water [m3]
Heating	0.00	0.00	0.00	0.00	194.24	0.00
Cooling	0.00	0.00	0.00	289.30	0.00	0.00

## **FIRENZE**

#### <u>Base</u>

	Electricity [GJ]	Natural Gas [GJ]	Additional Fuel [GJ]	District Cooling [GJ]	District Heating [GJ]	Water [m3]
Heating	0.00	0.00	0.00	0.00	608.27	0.00
Cooling	0.00	0.00	0.00	82.98	0.00	0.00

#### <u>Worst</u>

	Electricity [GJ]	Natural Gas [GJ]	Additional Fuel [GJ]	District Cooling [GJ]	District Heating [GJ]	Water [m3]
Heating	0.00	0.00	0.00	0.00	901.17	0.00
Cooling	0.00	0.00	0.00	81.00	0.00	0.00

### <u>Better</u>

	Electricity [GJ]	Natural Gas [GJ]	Additional Fuel [GJ]	District Cooling [GJ]	District Heating [GJ]	Water [m3]
Heating	0.00	0.00	0.00	0.00	485.62	0.00
Cooling	0.00	0.00	0.00	89.90	0.00	0.00

### <u>Best</u>

	Electricity [GJ]	Natural Gas [GJ]	Additional Fuel [GJ]	District Cooling [GJ]	District Heating [GJ]	Water [m3]
Heating	0.00	0.00	0.00	0.00	405.89	0.00
Cooling	0.00	0.00	0.00	96.26	0.00	0.00

## COPENHAGEN

<u>Base</u>

	Electricity [GJ]	Natural Gas [GJ]	Additional Fuel [GJ]	District Cooling [GJ]	District Heating [GJ]	Water [m3]
Heating	0.00	0.00	0.00	0.00	90.80	0.00
Cooling	0.00	0.00	0.00	358.49	0.00	0.00

### <u>Worst</u>

	Electricity [GJ]	Natural Gas [GJ]	Additional Fuel [GJ]	District Cooling [GJ]	District Heating [GJ]	Water [m3]
Heating	0.00	0.00	0.00	0.00	137.12	0.00
Cooling	0.00	0.00	0.00	400.13	0.00	0.00

### <u>Better</u>

	Electricity [GJ]	Natural Gas [GJ]	Additional Fuel [GJ]	District Cooling [GJ]	District Heating [GJ]	Water [m3]
Heating	0.00	0.00	0.00	0.00	72.08	0.00
Cooling	0.00	0.00	0.00	355.07	0.00	0.00

### <u>Best</u>

	Electricity [GJ]	Natural Gas [GJ]	Additional Fuel [GJ]	District Cooling [GJ]	District Heating [GJ]	Water [m3]
Heating	0.00	0.00	0.00	0.00	57.94	0.00
Cooling	0.00	0.00	0.00	356.35	0.00	0.00



Energy consumption is noticeably reduced in the better case, where relatively small improvements are applied to the base case.

The best case, instead, doesn't considerably improve the situation, with respect to the better case, specially for cooling load (which for Copenhagen gets even worse because of the highly reduced heat transmission through surfaces).

We therefore suggest to apply modifications as illustrated in the better case in order to have a significant energy saving but restrained expenses on construction costs.

### CONCLUSIONS