Low2No

Implementation of sustainable principles after design competition

REHVA Annual Conference

May 19-20 2011, Tallinn

Vasilis Maroulas,

Arup Consulting, UK

ARUP

Integrated Team Members

International Consortium

ARUP

sauerbruch hutton

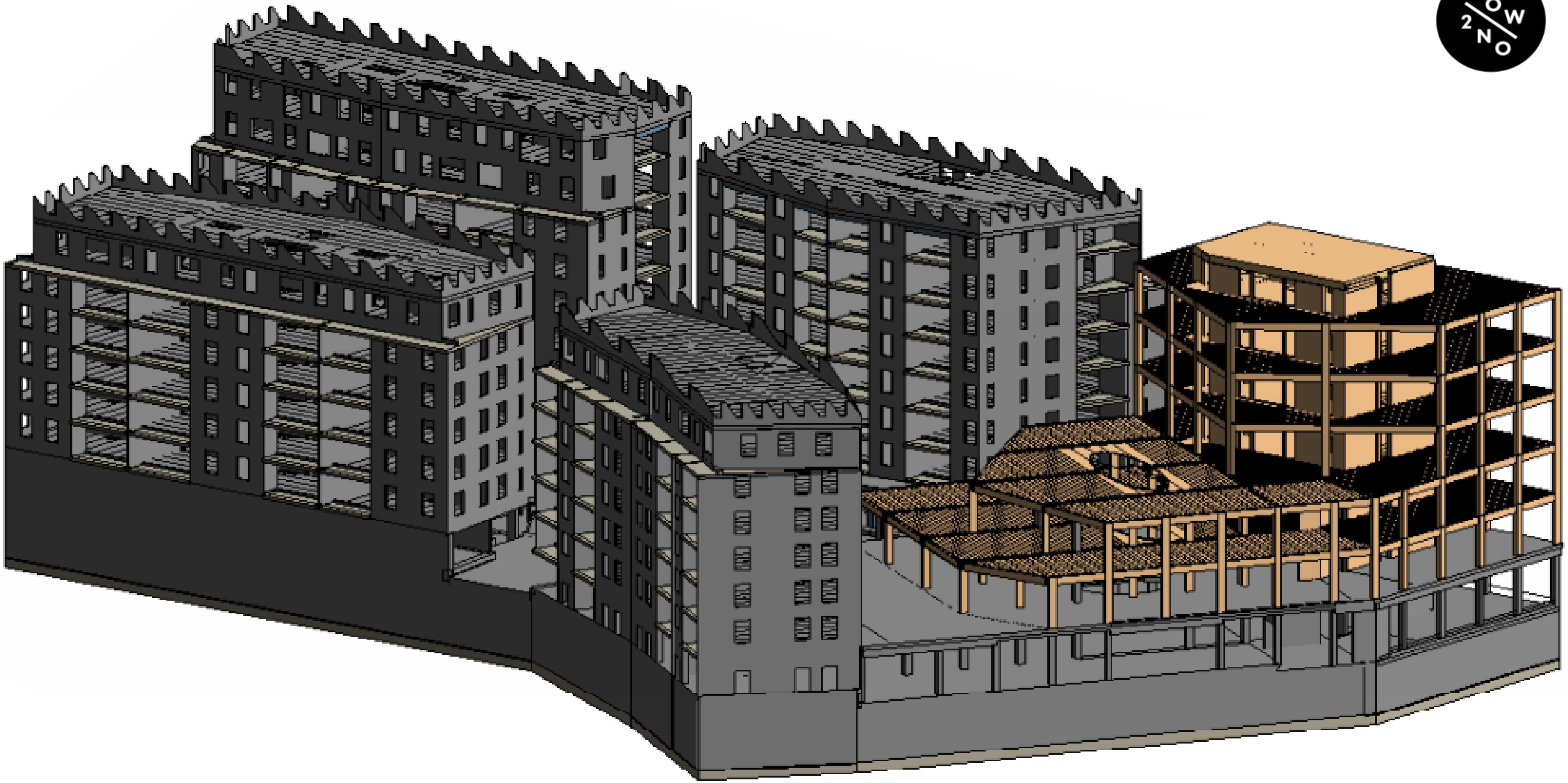
experientia
PUTTING PEOPLE FIRST

Local Finnish Consortium

SARC
Architects

GRANLUND

VAHANEN



Main Themes

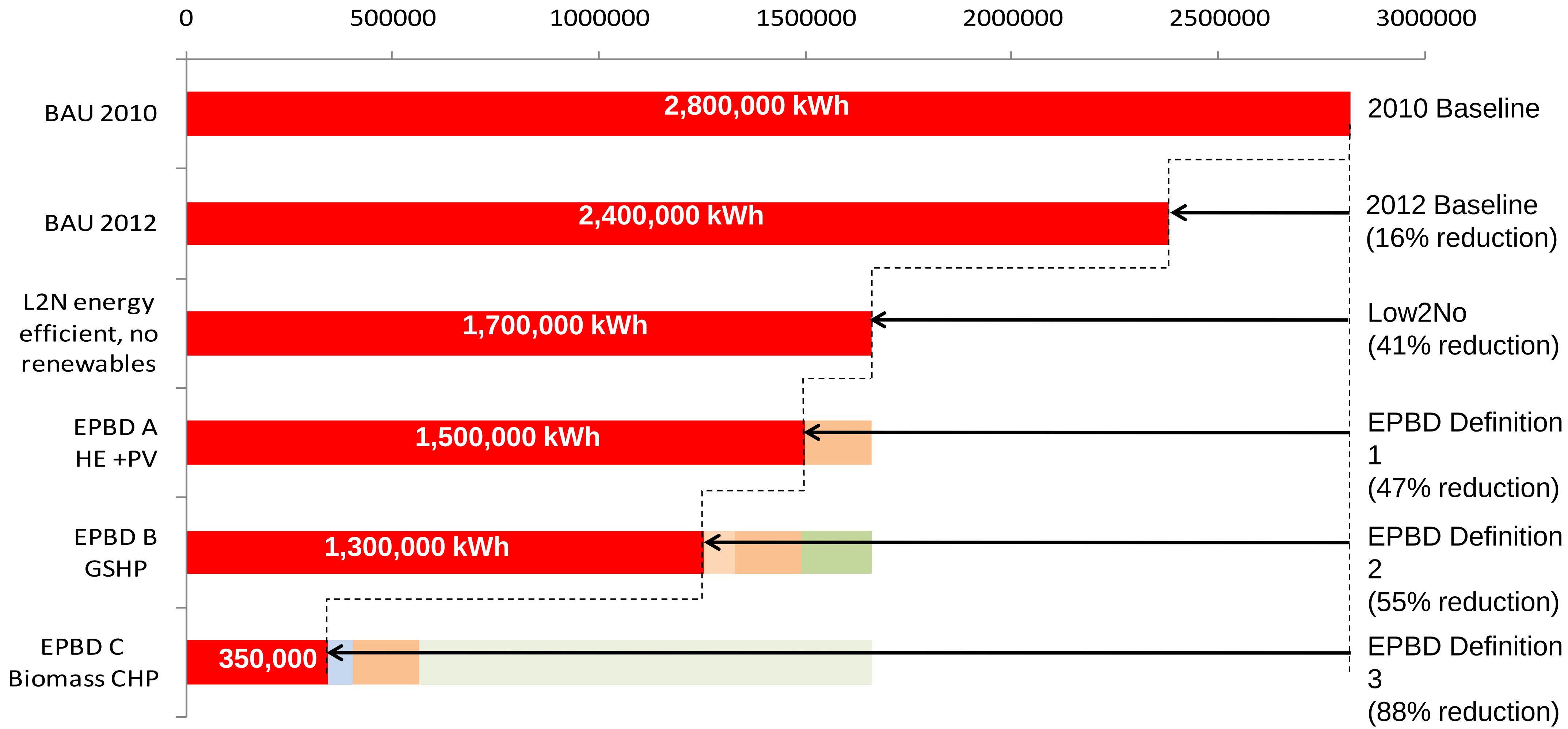
- Nearly zero energy building design
- EPBD 2020 compliance - Cost effectiveness
- Optimising the mass - mixed mode ventilation building
- Climate change scenaria - Future overheating

DIRECTIVE 2010/31/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL
of 19 May 2010
on the energy performance of buildings
(recast)

the Member State's detailed application in practice of the definition of nearly zero-energy buildings, reflecting their national, regional or local conditions, and including a numerical indicator of primary energy use expressed in kWh/m^2 per year. Primary energy factors used for the determination of the primary energy use may be based on national or regional yearly average values and may take into account relevant European standards;

ARUP

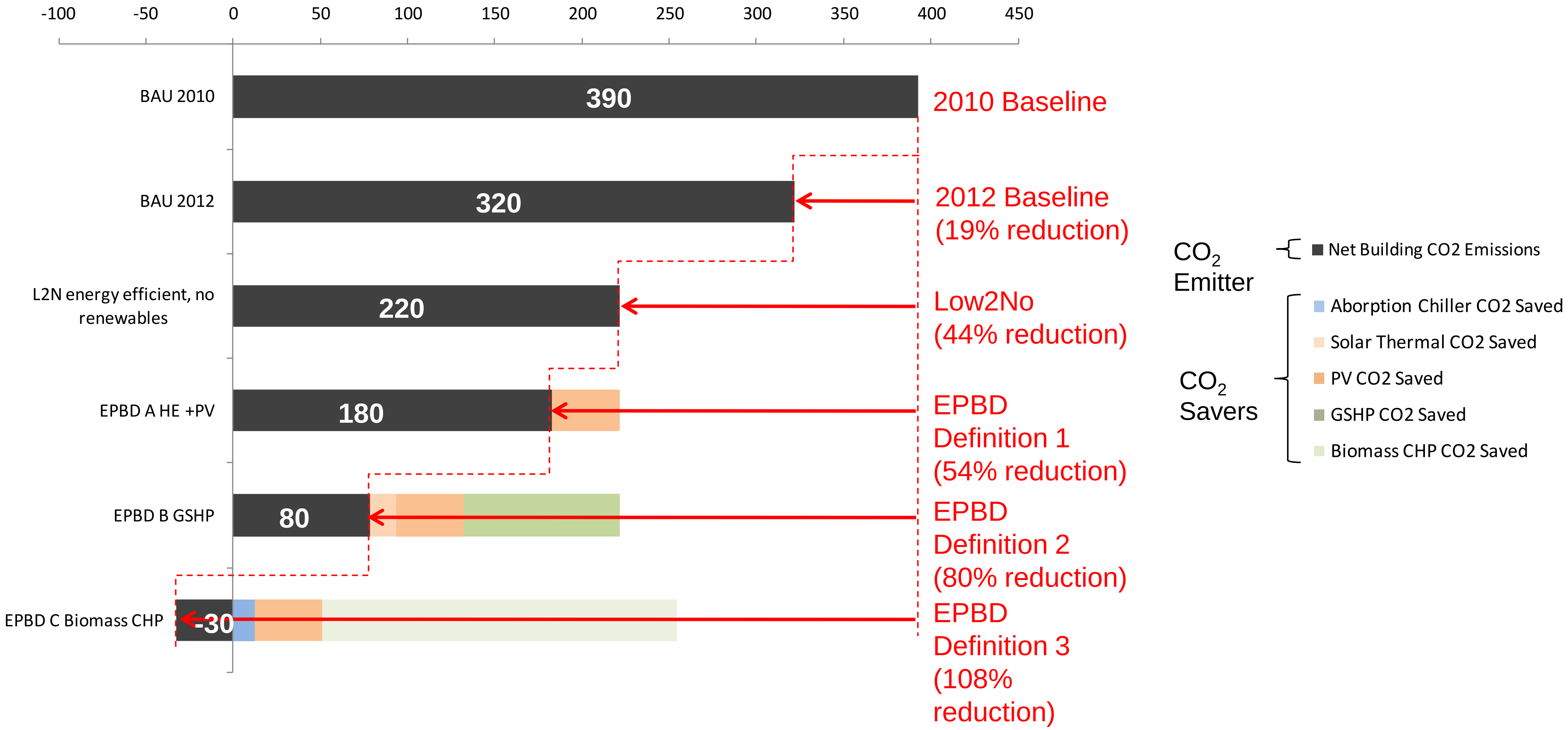
Primary energy kWh/yr



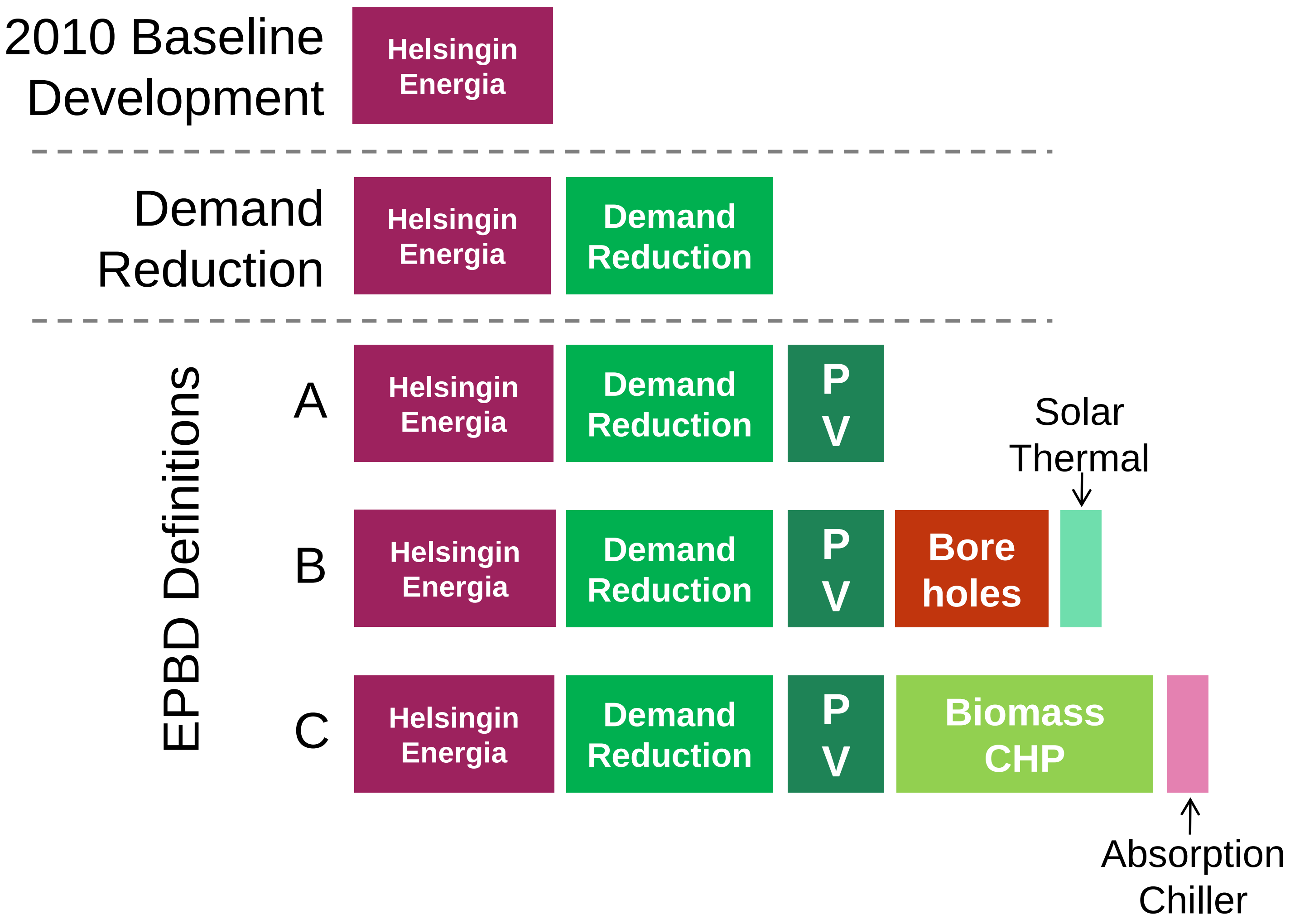
Excludes Occupant Equipment load

ARUP

Tonnes CO_2 /yr

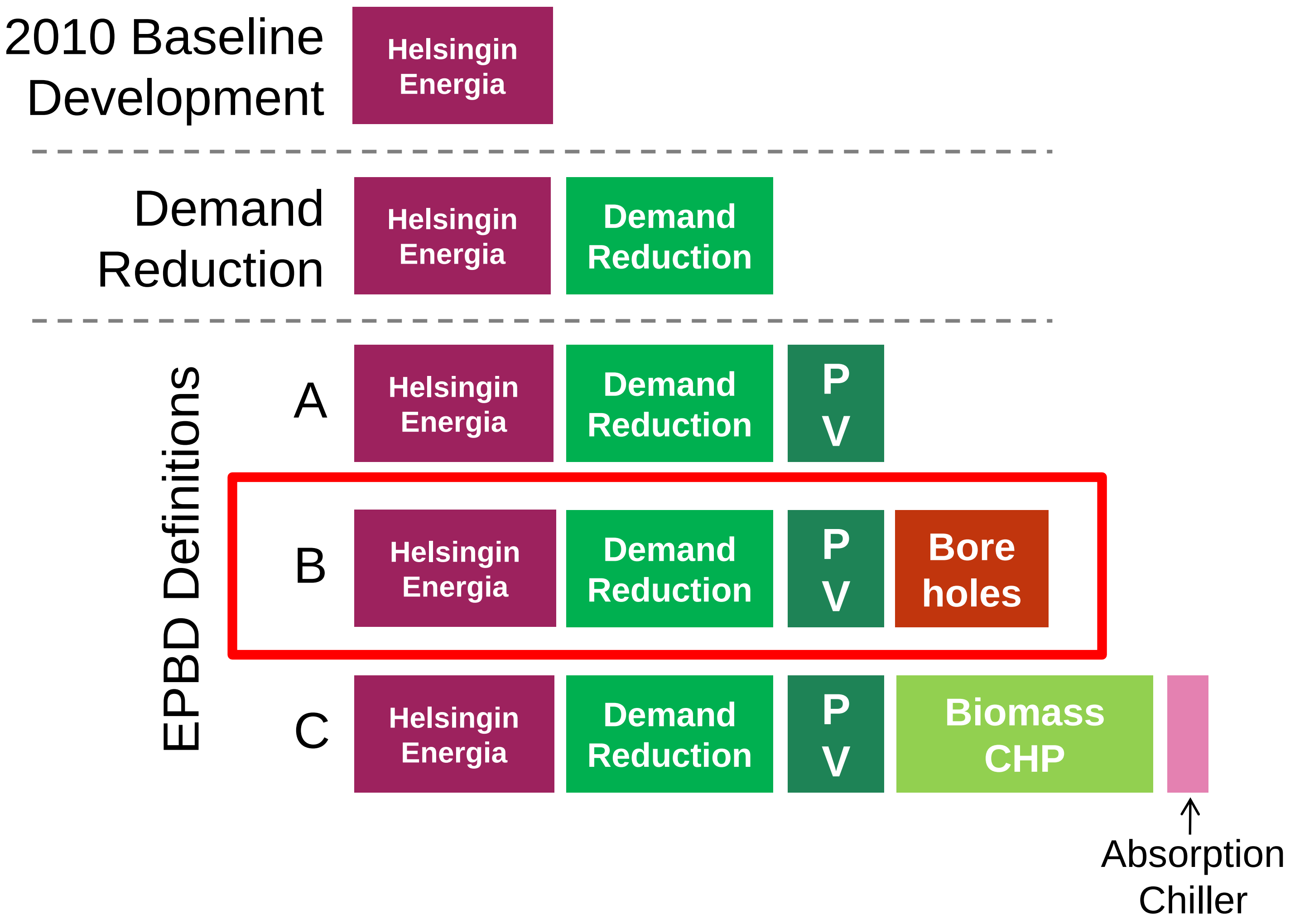


Bundles and EPBD Definitions



ARUP

Bundles and EPBD Definitions



Target energy benchmarks

The target energy benchmarks developed during the scoping and concept design stages are presented in the table below. These are given as **primary energy** values (they include the weighted energy factors for heating, cooling and electricity).

Office Area — **Primary Energy Use (kWh/m2/yr)**

	BAU 2010	BAU 2012	Concept Design Low2NO	Sitra Target
Space and vent heating	43	33	21	21
Hot water heating	7	4	4	4
Heating sub total	50	37	25	25
Cooling Electrical	12	18	2	
Cooling	8	13	1	8
Fans and pumps	24	30	10	14
Lighting	76	44	36	30
Equipment	54	48	48	44
Electrical sub total	154	122	94	88
PV			-14.1	-18
Total	**212**	**172**	**106**	**103**
Reduction from BAU2010	**0%**	**19%**	**50%**	**52%**

Targets set by the client (Sitra)

ARUP

Cost effectiveness - Life cycle analysis - Net present value

The objective of cost-effective or cost-optimal energy efficiency levels may, in certain circumstances, for

DIRECTIVE 2010/31/EU

Demand reduction and NPV results

The demand reduction measures that have been modelled are :

Fabric

- Wall U Values
- Window U Values
- Air tightness
- External Shading

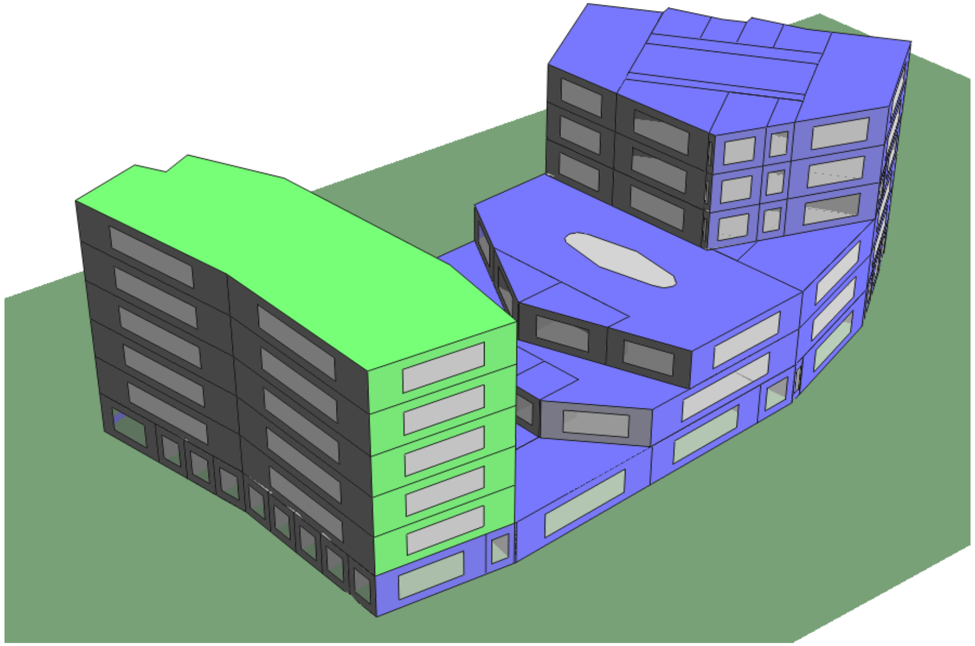
M&E

- Heat recovery + SFP
- Low energy lighting
- Daylighting Control
- Thin Client IT
- Elevators
- Domestic Hot water

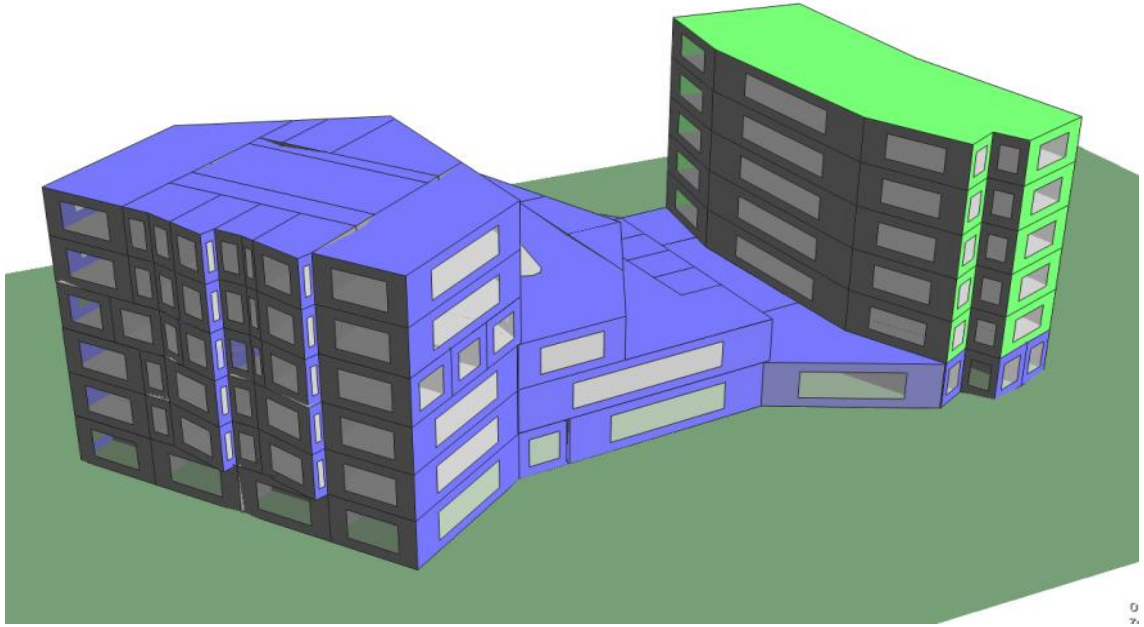
Behavioural change

- Evening and Weekend Turn down

Dynamic thermal modelling



North West View



South East View

The full office space, shown here in blue, has been modelled in IES (Integrated Environmental Solutions Software) in order to calculate the heating and cooling demands of all the Business As Usual(BAU) and energy saving measures. The residential block, Hitas (green), has also been modelled in order to generate an accurate shading file. Spreadsheets have been used to develop these results and model different electrical energy saving measures.

Dynamic reduction measures

Business as Usual (BAU)

Energy Reduction Measures

Affected energy demand; % demand above BAU 2010

Level of demand reduction	Wall U Value	Window U Value	Airtightness	Heat recovery	Hot Water demand reductions	Solar Shading	Low energy lighting	Office Daylight control	Thin Client	SFP	Elevators	Occupant turndown (evenings and weekends)
BAU 2010 'Baseline'	0.170	1.0	0.10	65%	BAU - Normal flow	None	BAU	BAU Normal	Fat Client	2.5/1.8	BAU	Some weekend turn down
Energy demand affected	heating/ cooling	heating/ cooling	heating/ cooling	heating	hot water	heating/ cooling	elec- lighting/ cooling/	Elec -lighting	elec- lighting/ cooling/	elec- fans and pumps	elec- other	elec- lighting/ cooling/ heating

ARUP

Dynamic reduction measures

Parametric study

Energy Reduction Measures

Affected energy demand; % demand above BAU 2010

Level of demand reduction	Wall U Value	Window U Value	Airtightness	Heat recovery	Hot Water demand reductions	Solar Shading	Low energy lighting	Office Daylight control	Thin Client	SFP	Elevators	Occupant turndown (evenings and weekends)	
	0.100	0.6		80%		Option 2		Daylighting Control (With atrium)			Kone Mini Space + EE		
	0.135	0.8	0.05	73%	low flow	Option 1	Task Lighting	Daylighting Control (No	Thin Client	1.5/1.0	Kone Mini Space	More weekend turn down	
	0.170	1.0	0.10	65%	BAU - Normal flow	None	BAU	BAU Normal	Fat Client	2.5/1.8	BAU	Some weekend turn down	**BAU 2010 'Baseline'**
		1.2	0.15										
			0.20										
Energy demand affected	heating/ cooling	heating/ cooling	heating/ cooling	heating	hot water	heating/ cooling	elec- lighting/ cooling/	Elec -lighting	elec- lighting/ cooling/	elec- fans and pumps	elec- other	elec- lighting/ cooling/ heating	

ARUP

Dynamic thermal modelling

Whole energy results

Total Primary Energy of Impacted Energy Field (kWh/m^2/yr)

Affected energy demand; % demand above BAU 2010

Level of demand reduction	Wall U Value	Window U Value	Airtightness	Heat recovery	Hot Water demand reductions	Solar Shading	Low energy lighting	Office Daylight control	Thin Client	SFP	Elevators	Occupant turndown (evenings and weekends)	
Better													
	51.6	49.4		33.4		51.9		74.9			4.9		
	52.4	51.2	50.1	38.3	3.8	52.3	90.3	75.1	62.19	14.66	6.6	78.32	
	53.1	53.1	53.1	43.3	7.0	53.1	142.1	76.0	74.39	24.78	11.3	100.13	**BAU 2010 'Baseline'**
		54.9	55.9										
			58.9										
Worse													
Energy demand affected	heating/ cooling	heating/ cooling	heating/ cooling	heating	hot water	heating/ cooling	elec- lighting/ cooling/	Elec -lighting	elec- lighting/	elec- fans and	elec- other	elec- lighting/ cooling/	

Dynamic thermal modelling: Whole energy results (%)

Total Primary Energy of Impacted Energy Field (%)

Affected energy demand; % demand above BAU 2010

Level of demand reduction	Wall U Value	Window U Value	Airtightness	Heat recovery	Hot Water demand reductions	Solar Shading	Low energy lighting	Office Daylight control	Thin Client	SFP	Elevators	Occupant turndown (evenings and weekends)	
Better													
	-3%	-7%		-29%		-2.3%		-1%			-131%		
	-1%	-4%	-6%	-13%	-85%	-1.5%	-57%	-1%	-20%	-69%	-71%	-28%	
	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	**BAU 2010 'Baseline'**
		3%	5%										
			10%										
Worse													
Energy demand affected	heating/ cooling	heating/ cooling	heating/ cooling	heating	hot water	heating/ cooling	elec- lighting/ cooling/	Elec -lighting	elec- lighting/ cooling/	elec- fans and pumps	elec- other	elec- lighting/ cooling/ heating	

Net Present Value (NPV) summary table

NPV, **Euros**

Affected energy demand; % demand above BAU 2010	Level of demand reduction	Wall U Value	Window U Value	Airtightness	Heat recovery	Hot Water demand reductions	Solar Shading	Low energy lighting	Office Daylight control	Thin Client	SFP	Elevators	Occupant turndown (evenings and weekends)	
	Better													
		-52,494	-21,614		89,551		-134,610		-1,739			TBC		
		-19,315	-7,813	-	44,889	23,311	-71,539	196,951	2,718	346,931	89,551	TBC	131,203	
		-	-	-	-	-	-	-	-	-	-	-	-	BAU 2010 'Baseline'
			-293	-										
				-										
	Worse													
Energy demand affected		heating/ cooling	heating/ cooling	heating/ cooling	heating	hot water	heating/ cooling	elec- lighting/ cooling/	Elec -lighting	elec- lighting/ cooling/	elec- fans and pumps	elec- other	elec- lighting/ cooling/ heating	

Assumptions

1. *Cost taken from Arup, Granlund, and various manufactures*
2. *NPV over system lifetime (30 years in most cases)*
3. *Discount factor set at 4%*

Final energy benchmarks

Having implemented the cost effective measures in all areas of energy use the final energy benchmarks for the L2N scheme proposed at scheme design stage are presented here on the right.

Office Area — **Primary Energy Use (kWh/m2/yr)**

	BAU 2010	BAU 2012	Concept Design Low2NO	Sitra Target	L2N Scheme Prosposed
Space and vent heating	43	33	21	21	28
Hot water heating	7	4	4	4	4
Heating sub total	50	37	25	25	32
Cooling Electrical	12	18	2		
Cooling	8	13	1	8	5
Fans and pumps	24	30	10	14	9
Lighting	76	44	36	30	30
Equipment	54	48	48	44	37
Electrical sub total	154	122	94	88	76
PV			-14.1	-18	-18
Total	**212**	**172**	**106**	**103**	**95**
Reduction from BAU201(	**0%**	**19%**	**50%**	**52%**	**55%**

ARUP

PV Life cycle analysis

NPV Analysis

Three NPV analyses have been carried out to demonstrate the cost effectiveness of the PV for different assumed phasing and allocation of feed in tariffs.

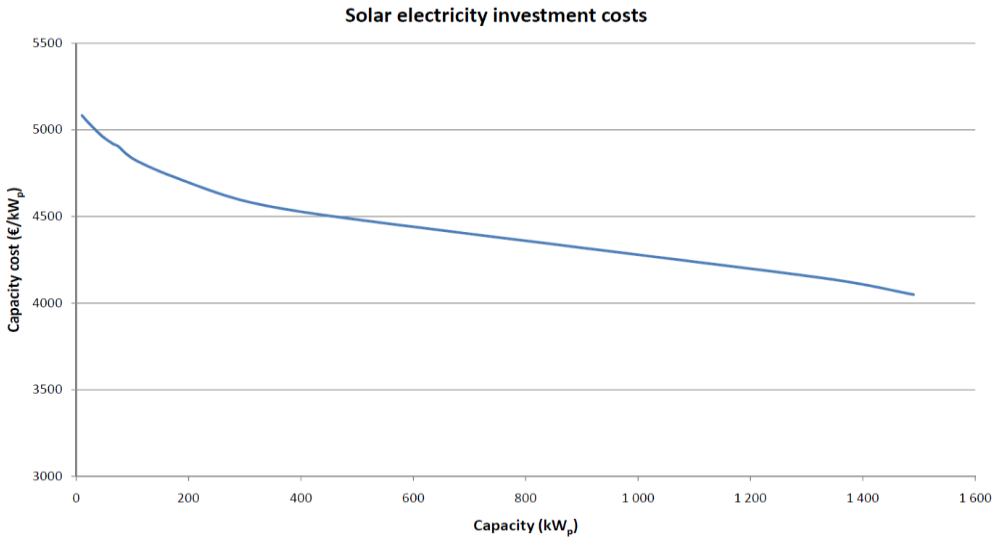
NPV Analysis 1 – full facade and roof installation in **2012**

NPV Analysis 2 – full facade installation in **2012**; full roof installation in **2020**

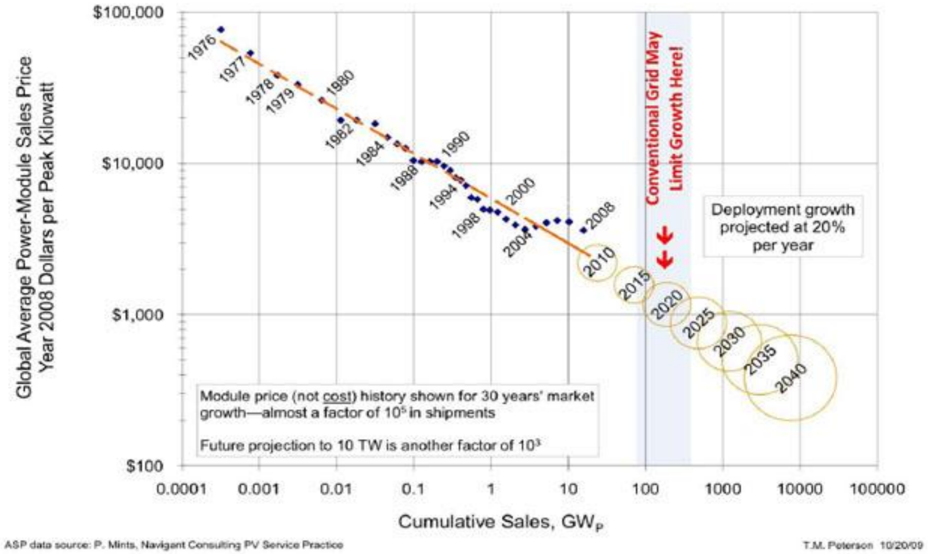
NPV Analysis 3 – full facade and roof installation in **2020**

ARUP

PV Cost Study



Polycrystalline/Monocrystalline installed costs in Finland, provided by Granlund



This Navigant graph is typical of most available PV cost trends and shows that a 50% reduction in average PV installed costs is possible in the next 10 years

The cost of PV has been volatile in the past 5 years due to surges in demand and the development of new manufacturing techniques.

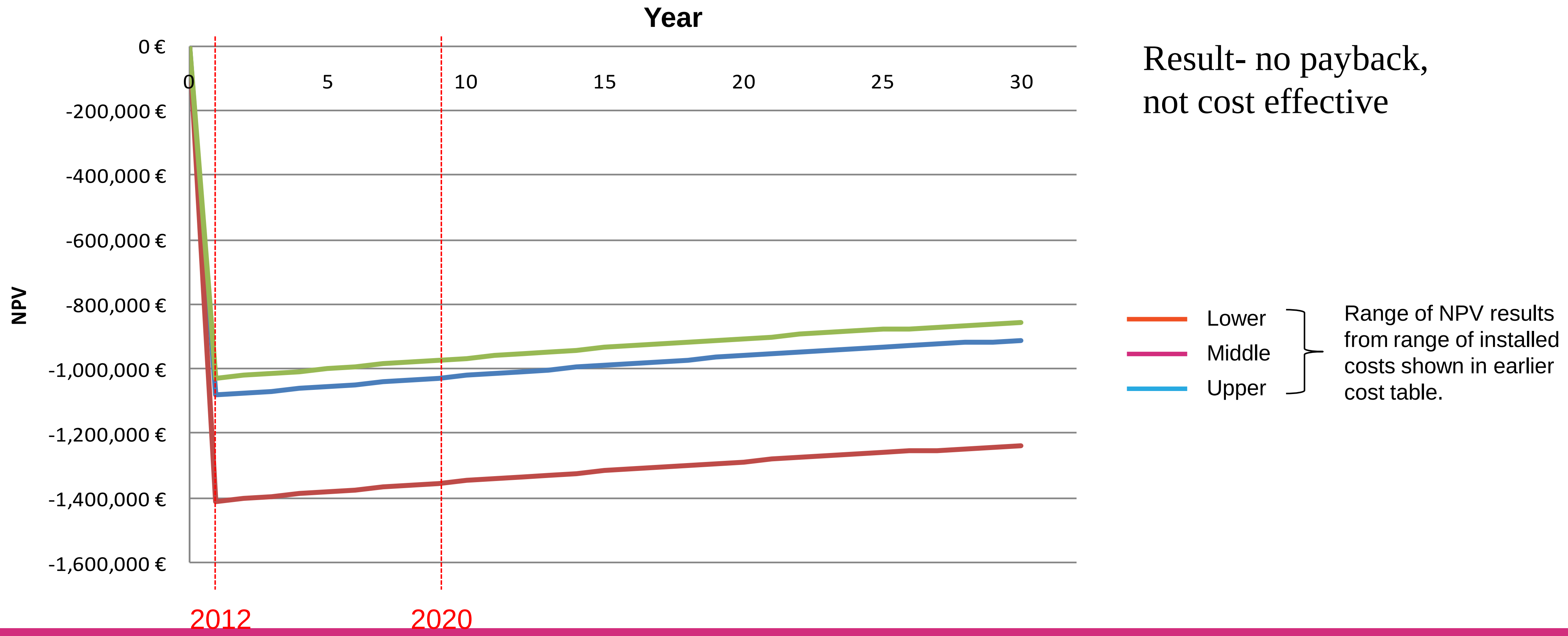
The Navigant graph is typical of most available PV cost trends and shows that a 50% reduction in average PV installed costs is possible in the next 10 years.

	PV Cost Range (€/kWp)					
	Lower		Middle		Upper	
	2012	2020	2012	2020	2012	2020
Monocrystalline	4750	2375	5000	2500	6500	3250
Polycrystalline	4750	2375	5000	2500	6500	3250
Hybrid	5714	2857	6015	3007	7819	3910
Thin film	4385	2192	4615	2308	6000	3000
	-5%		Midrange		+30%	

NPV Analysis 1

Modelling assumptions:

- Option F Array Modelled
- Facade and roof arrays both installed in 2012
- No feed in tariff
- CO_2 savings traded (€32- € 45/tonne, 60 tonnes/yr)
- 4% discount factor



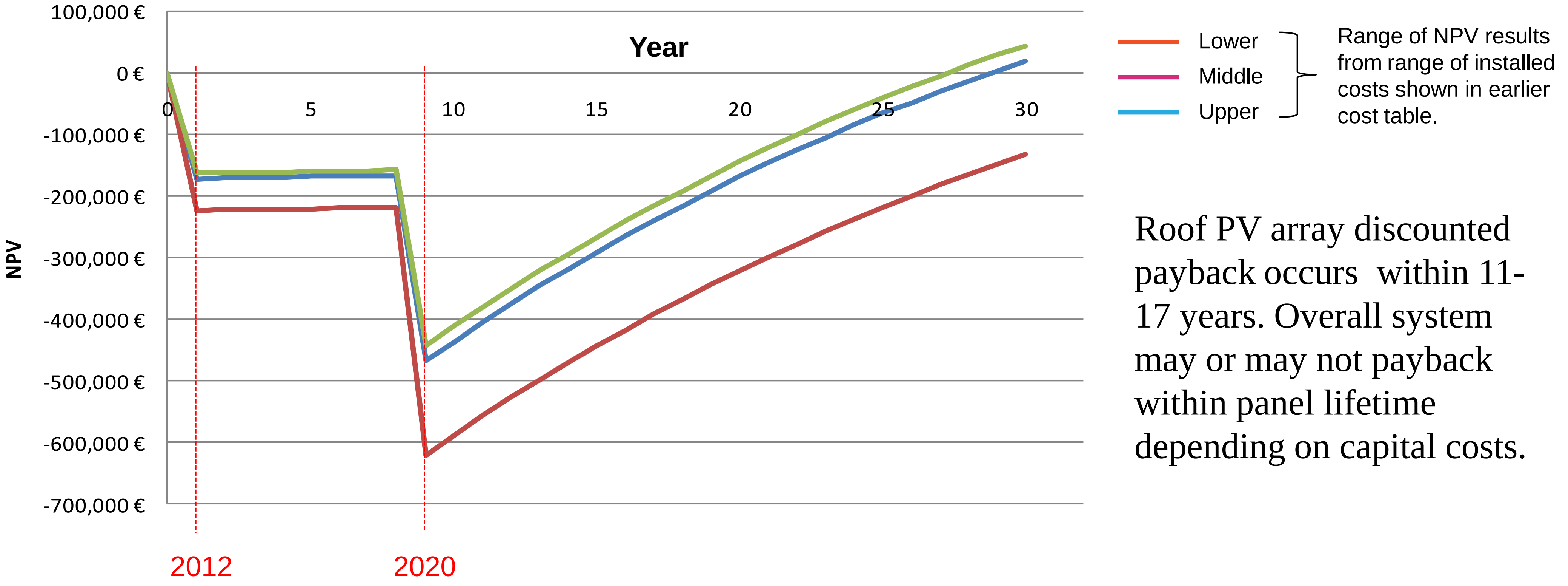
Result- no payback, not cost effective

ARUP

NPV Analysis 2

Modelling assumptions:

- Option F Array Modelled
- Facade installed in 2012 and roof array installed in 2020
- No feed in tariff for the facade array, 30c/kWh feed in tariff for roof array
- CO_2 savings traded (€32- € 45/tonne, 60 tonnes/yr)
- 4% discount factor



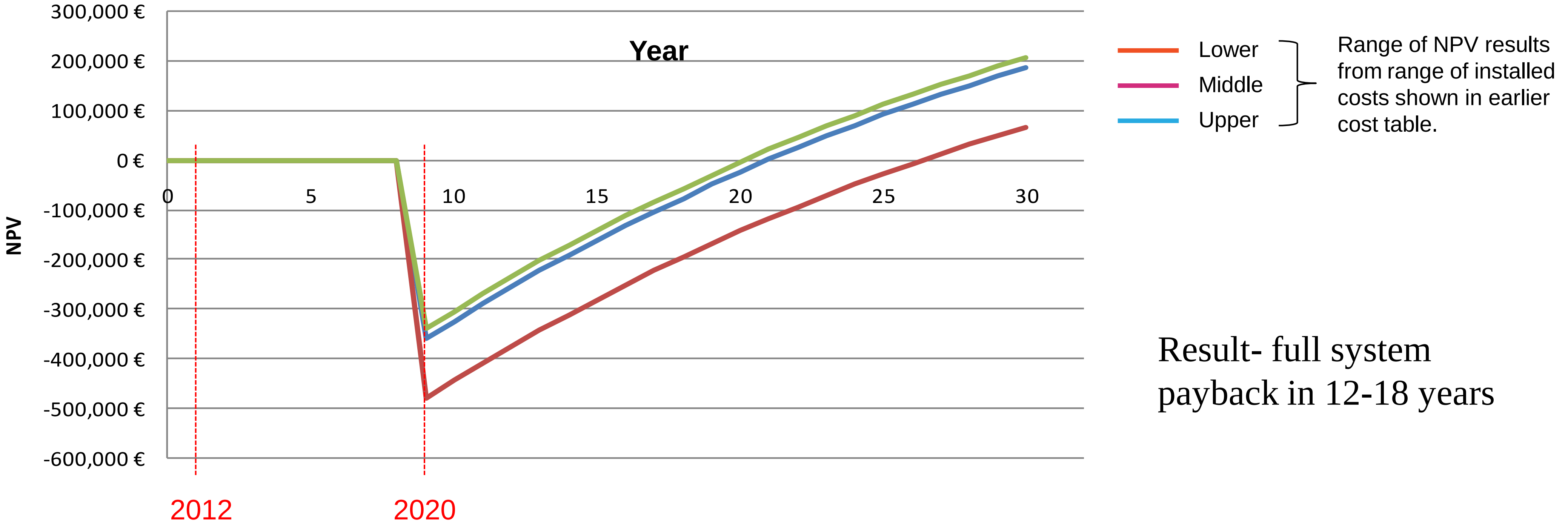
Roof PV array discounted payback occurs within 11-17 years. Overall system may or may not payback within panel lifetime depending on capital costs.

ARUP

NPV Analysis 3

Modelling assumptions:

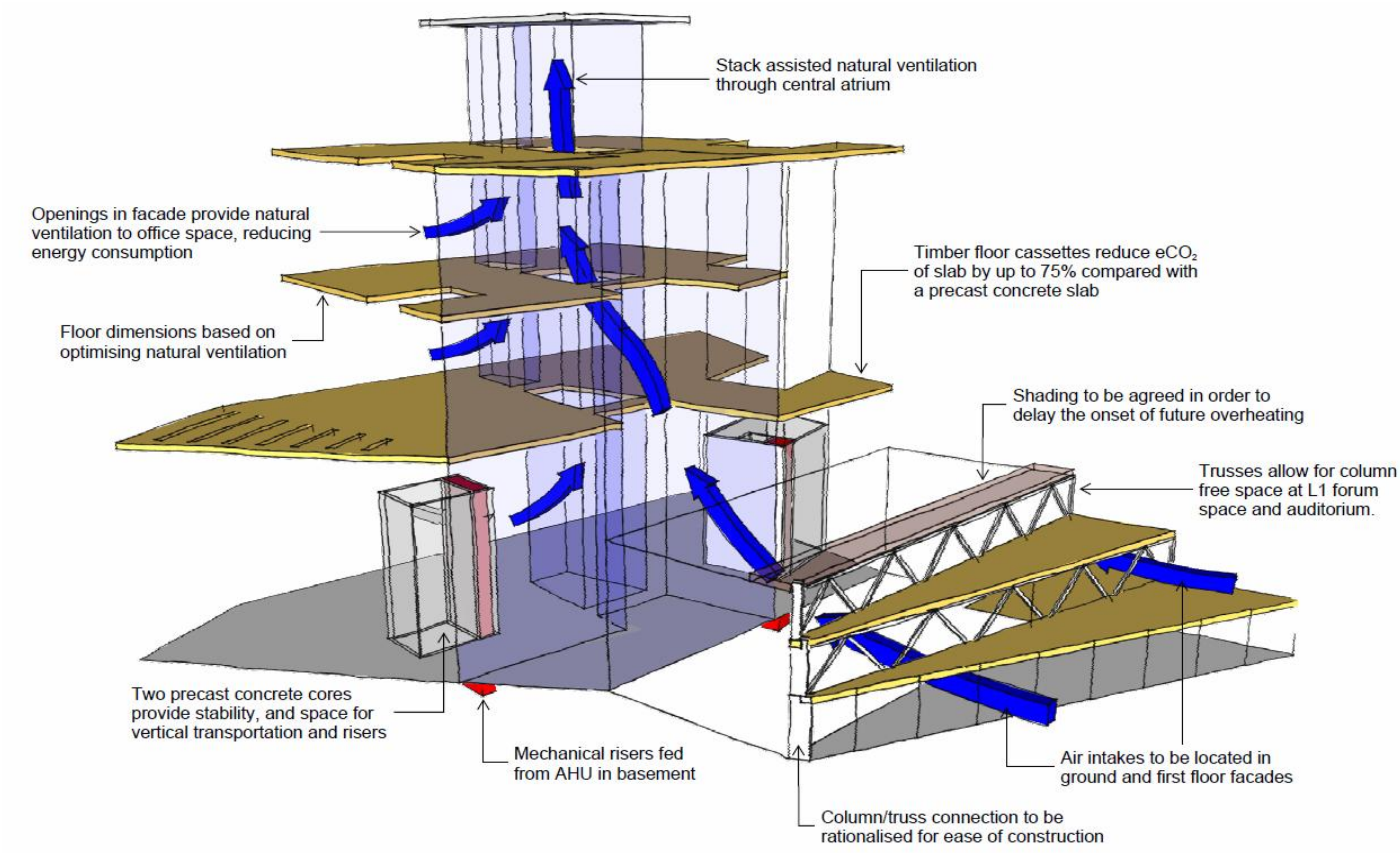
- Option F Array Modelled
- Facade and roof arrays both installed in 2020
- 30c/kWh feed in tariff for the whole array
- CO_2 savings traded (€32- € 45/tonne, 60 tonnes/yr)
- 4% discount factor



Result- full system payback in 12-18 years

ARUP

Mixed mode - Naturally Ventilated Office



ARUP

Mechanical Services – Mixed System

Mechanical ventilation in winter

-Air tight construction

-Low U-value fabric

-High efficiency heat recovery

Minimise energy for heating

Natural ventilation when possible

-Openable windows

-Exposed thermal mass interior

-Night cooling

Eliminate energy for comfort cooling and ventilation + Increase occupant satisfaction

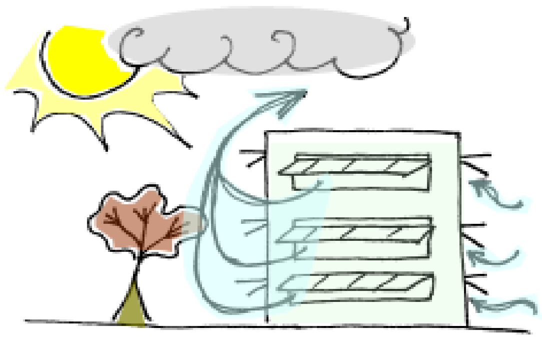
Mechanical cooling in peak summer

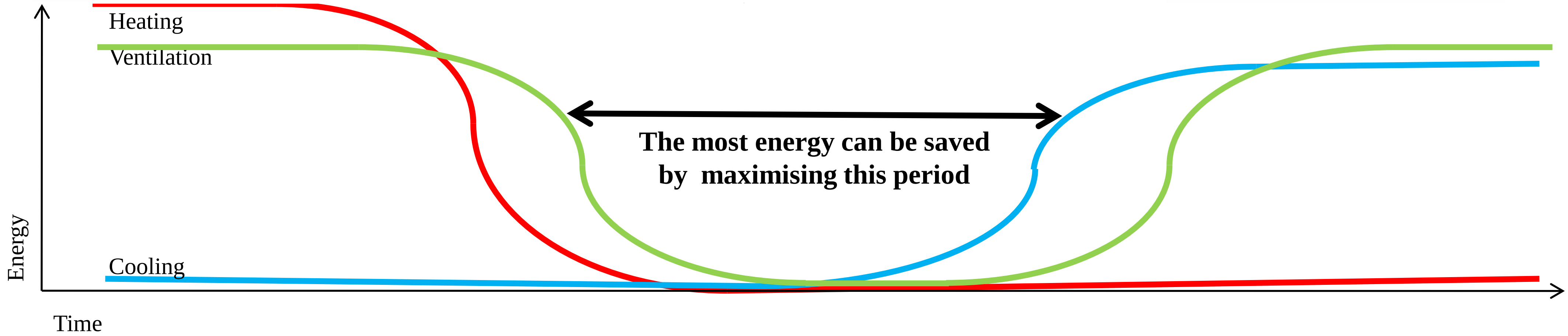
-Deployable and permanent shading

-Exposed thermal mass interior

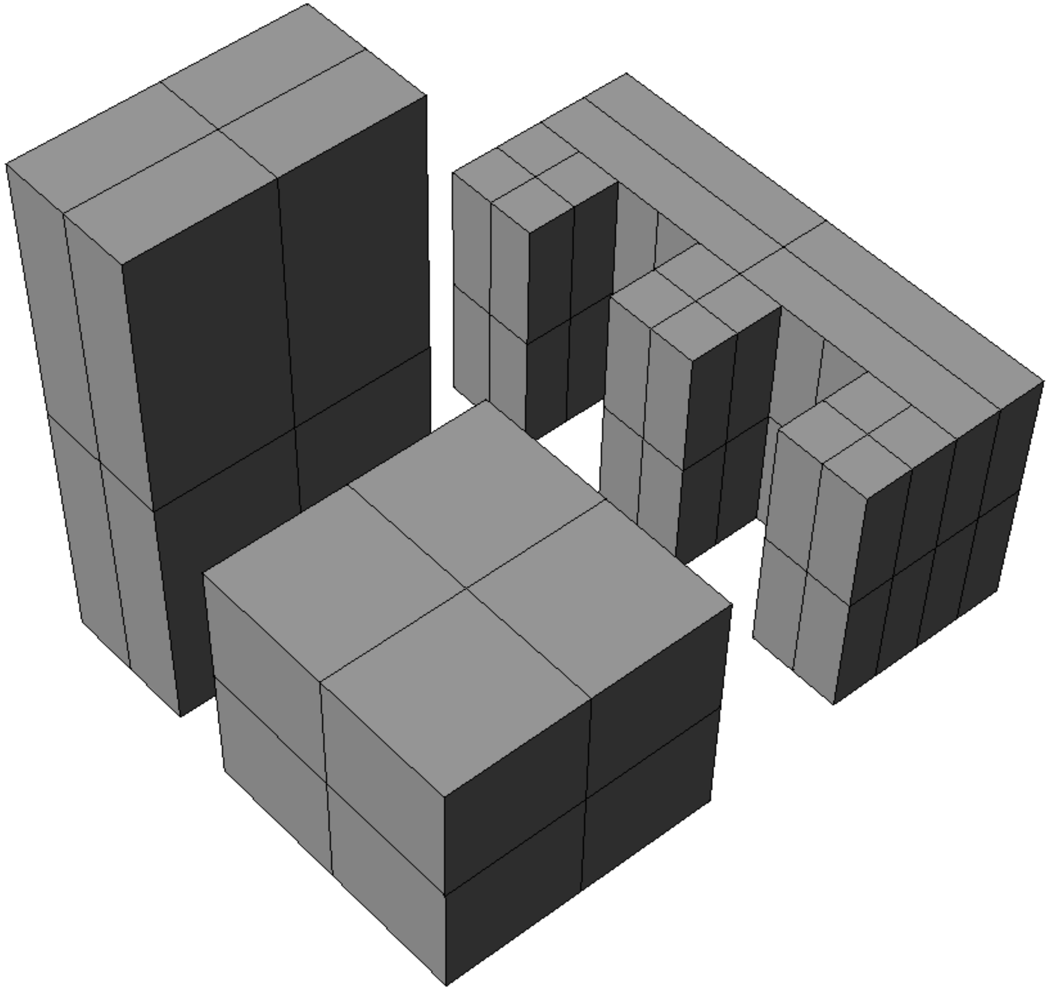
-Night cooling

Minimise energy for comfort cooling

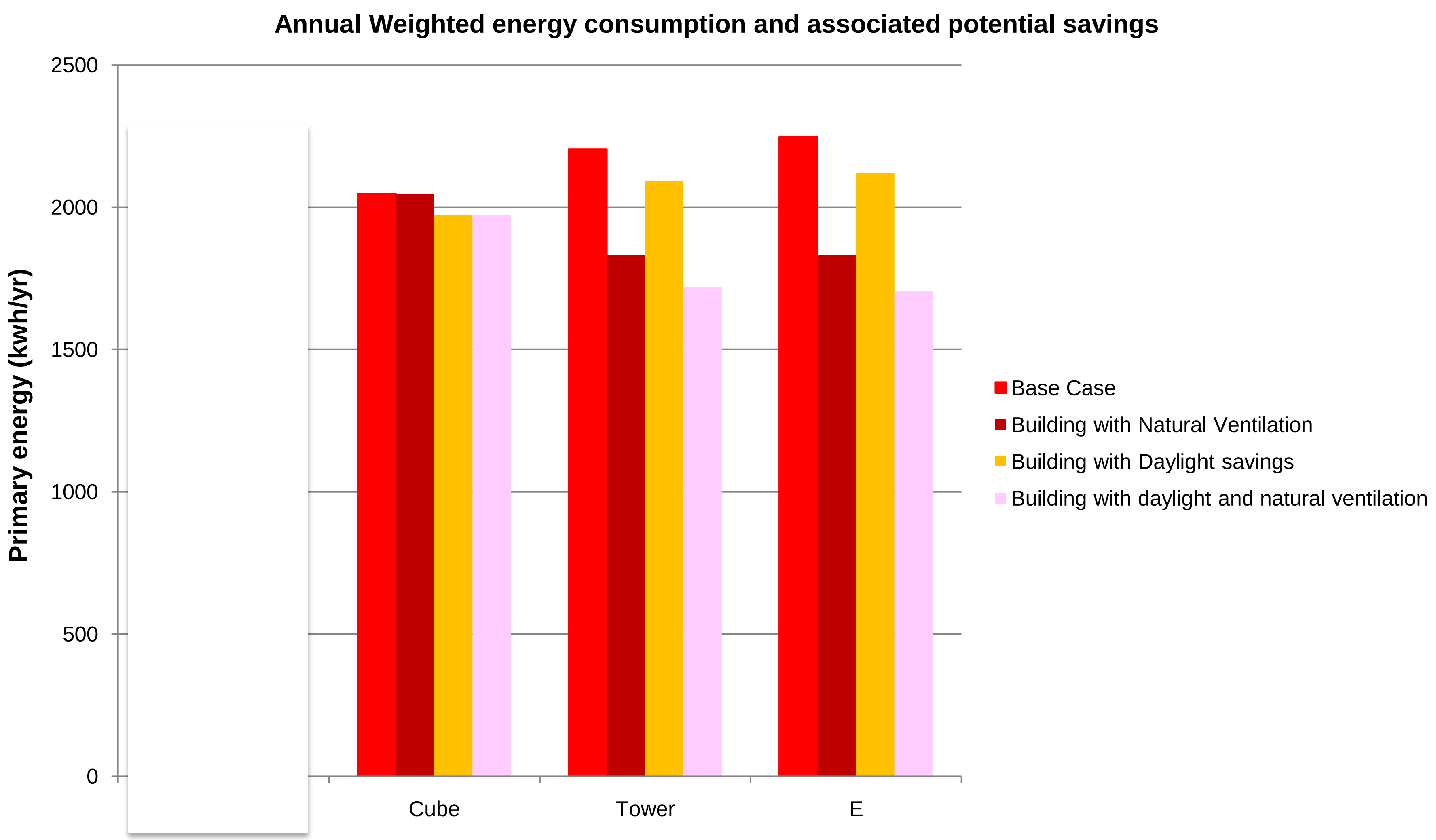




The three geometries

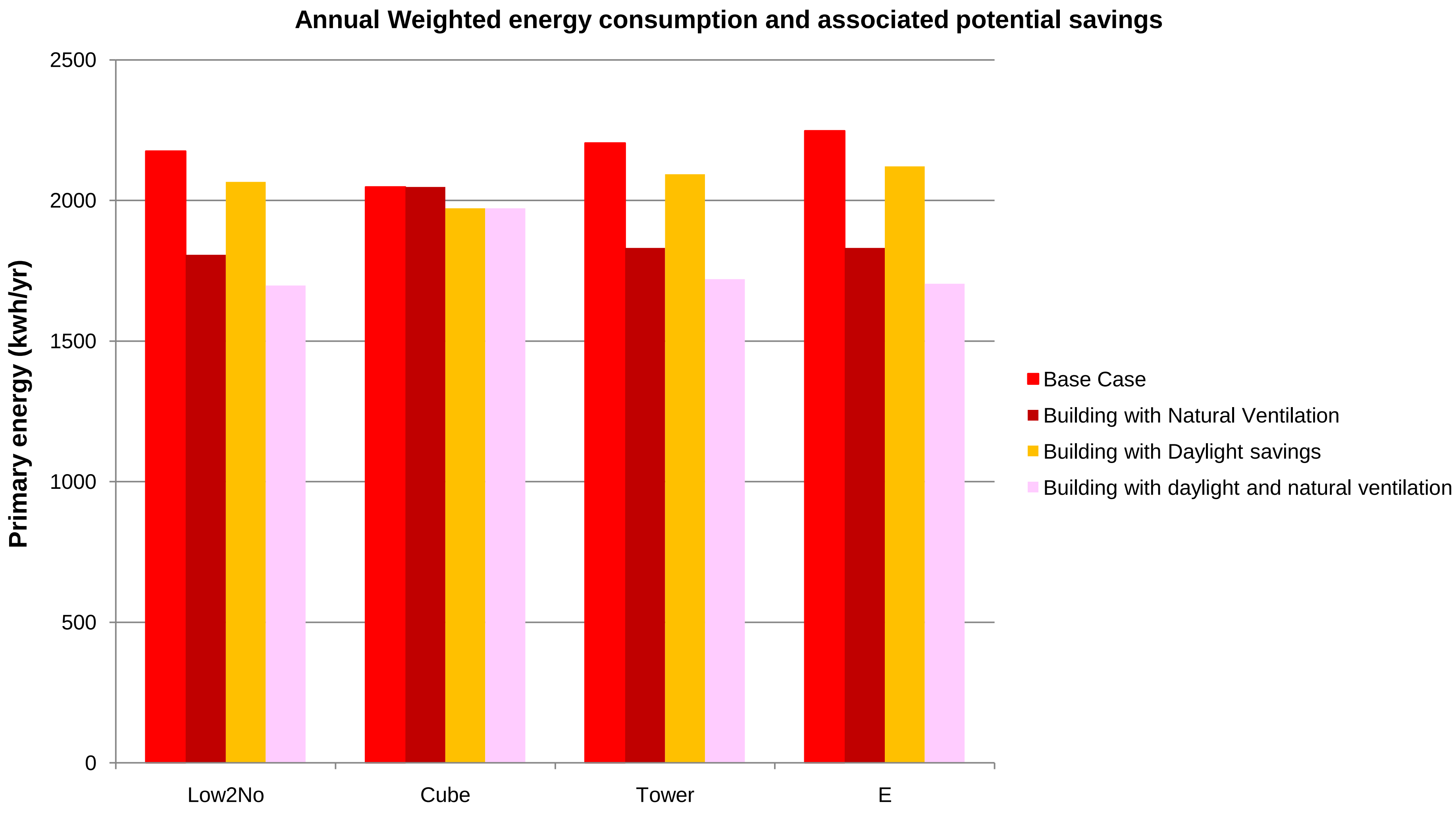


Mass optimisation



ARUP

Mass optimisation

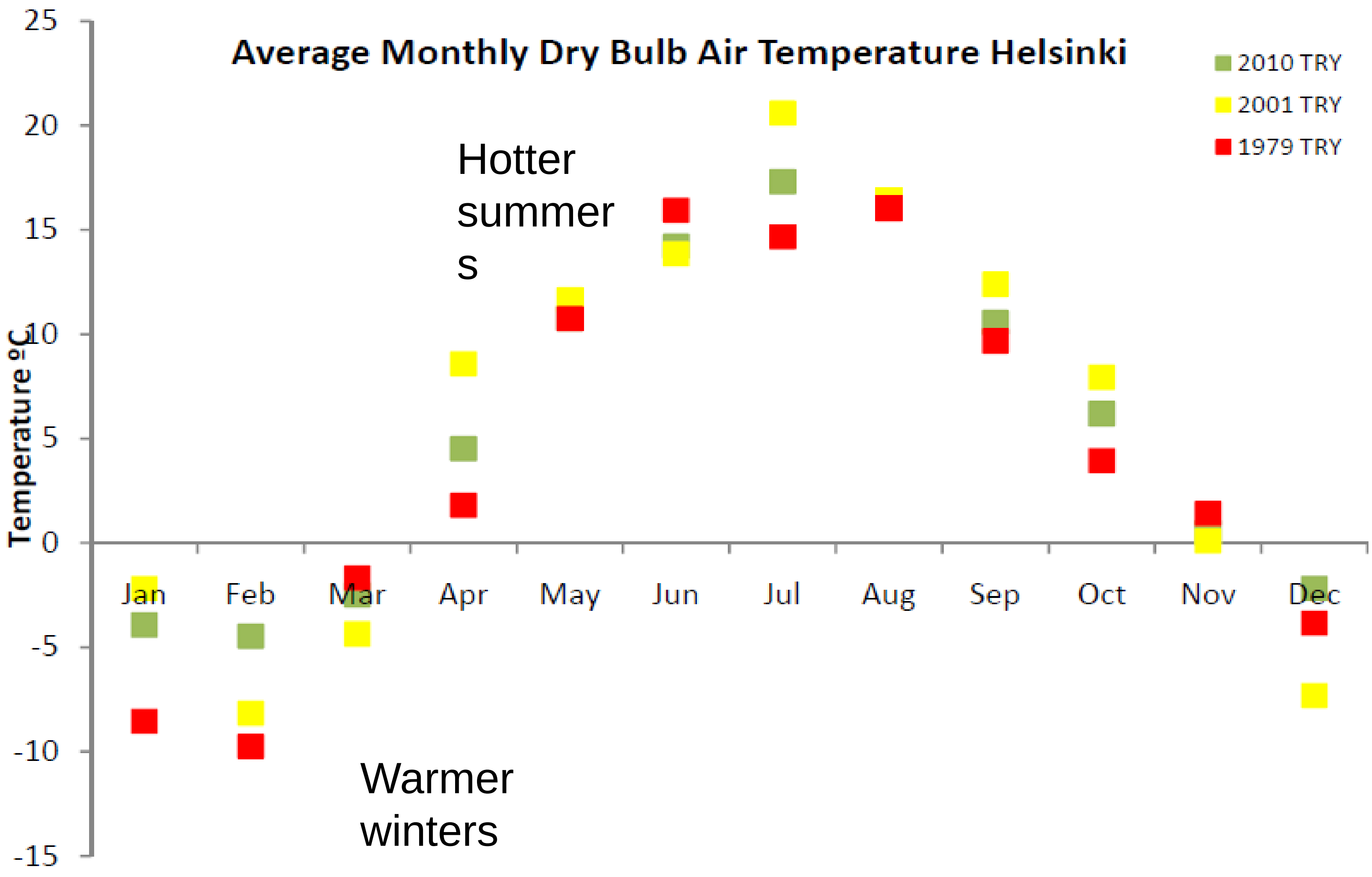


ARUP

Climate change – overheating studies

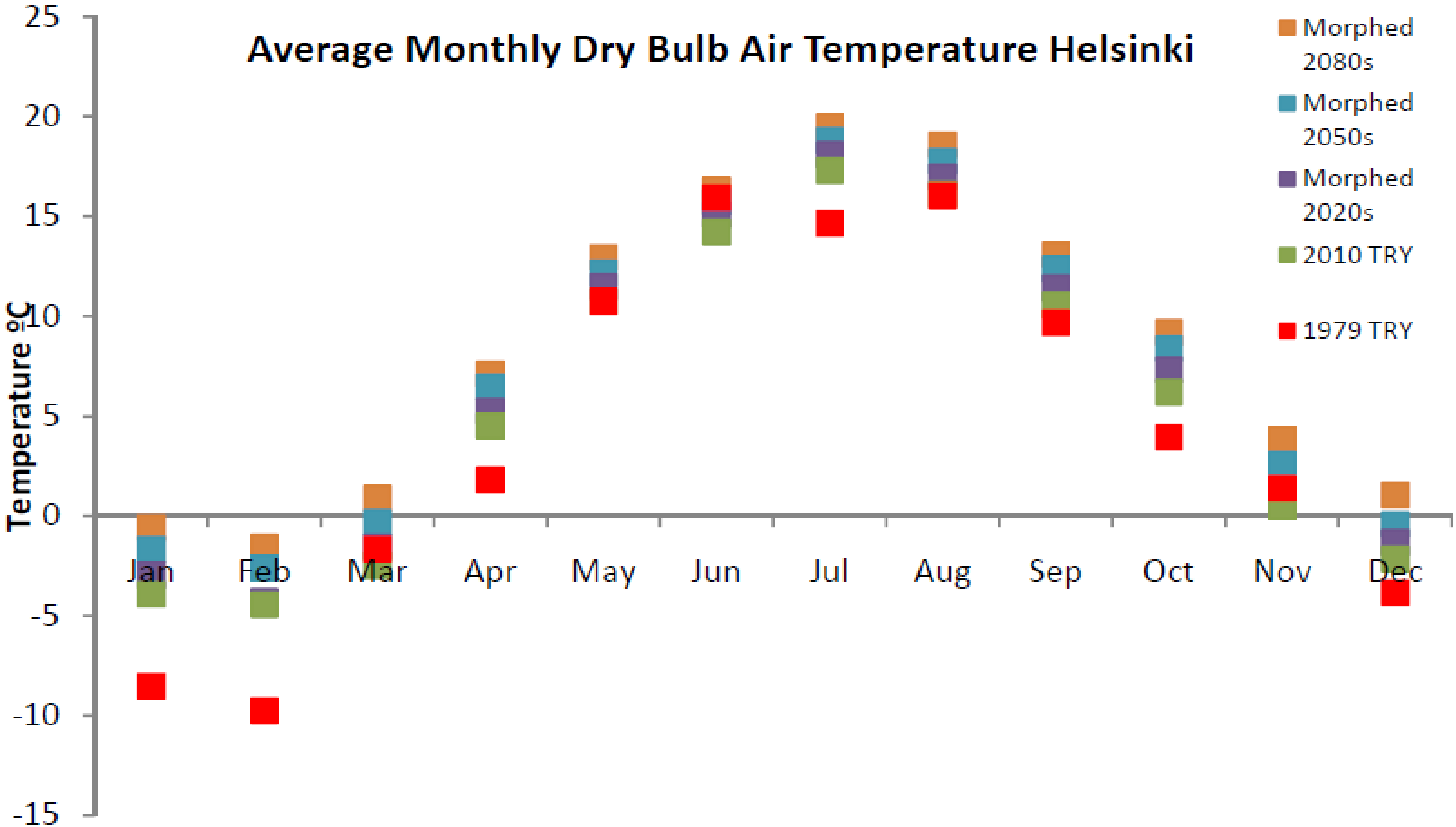
ARUP

Helsinki TRY



ARUP

Morphed 2010 TRY



ARUP

Overheating study residential block

Five steps have been modelled to demonstrate the relative impacts of each of the following measures:

Basecase – 30% Glazing, no openable windows

Step 1 – 30% glazing - 15% openings for Natural Ventilation

Step 2 – 20% glazing, 15% openings for Natural Ventilation

Step 3 – 20% glazing, 30% openings for Natural Ventilation

Step 4 – More Thermal Mass

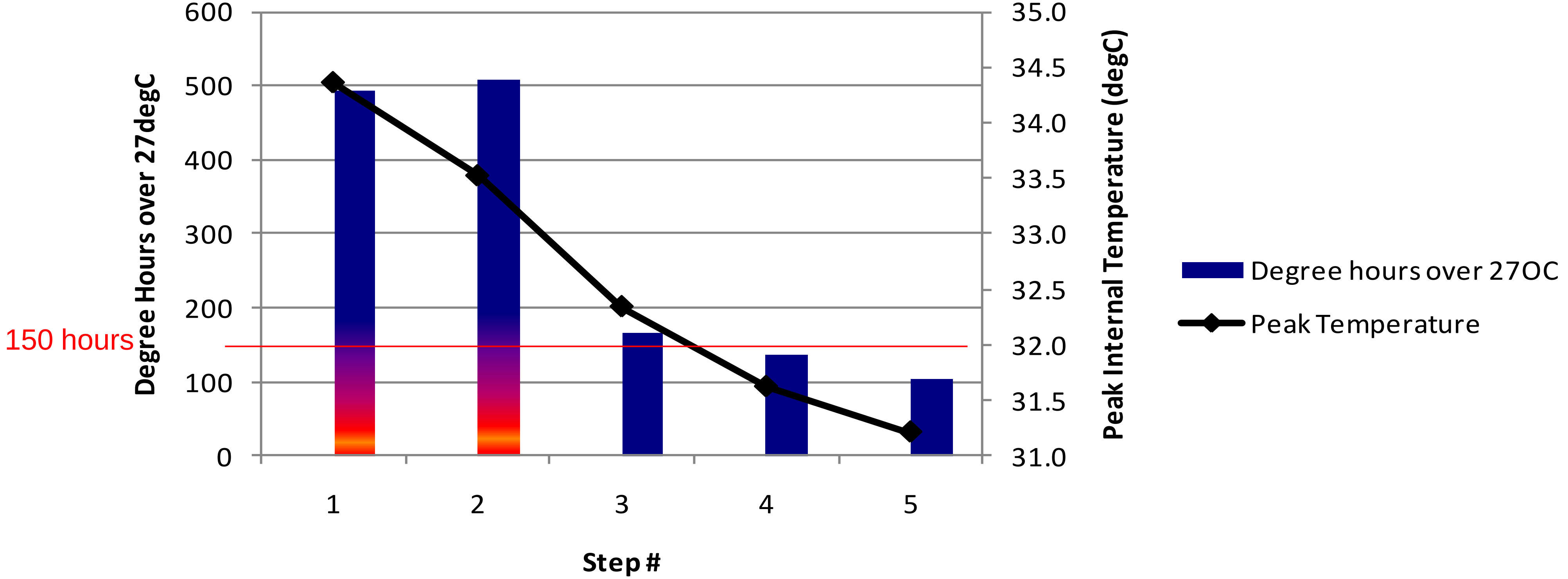
Step 5 – External Shading

The Finnish 2012 D3 Regulations defines overheating in residential spaces as occurring at more that **150degree hours above 27^{O}C per year**.

ARUP

Results (excluding basecase)

Step	1	2	3	4	5
Glazing (% of external wall)	30%	20%	20%	20%	20%
Size of opening (% of window size)	15%	15%	30%	30%	30%
Thermal Mass	Lightweight	Lightweight	Lightweight	Heavyweight	Heavyweight
Shading	None	None	None	None	Louvered Shading
Degree hours over 27^{O}C	492	508	166	137	104
Peak Temperature	34.4	33.5	32.3	31.6	31.2



ARUP

Overheating study – Future weather data

4 more additional steps have been modelled

Step 6 – Step 5 with 2020 predicted weather file

Step 7 – Step 5 with 2050 predicted weather file

Step 8 – Step 5 with 2080 predicted weather file

Step 9 – Step 5 with 2080 predicted weather file and lower internal gains as

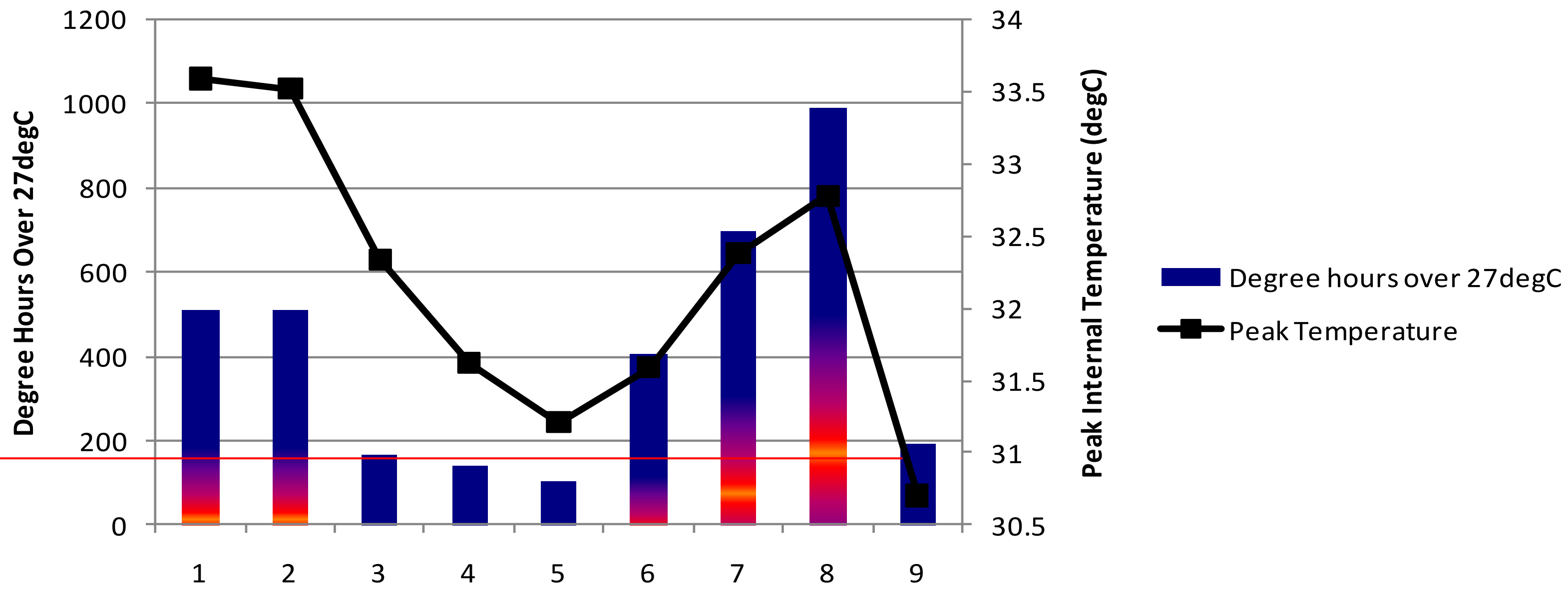
specified by Finnish Building Code on overheating D3 -2012

The Finnish 2012 D3 Regulations defines overheating in residential spaces as occurring at more **that 150degree hours above 27^{O}C per year.**

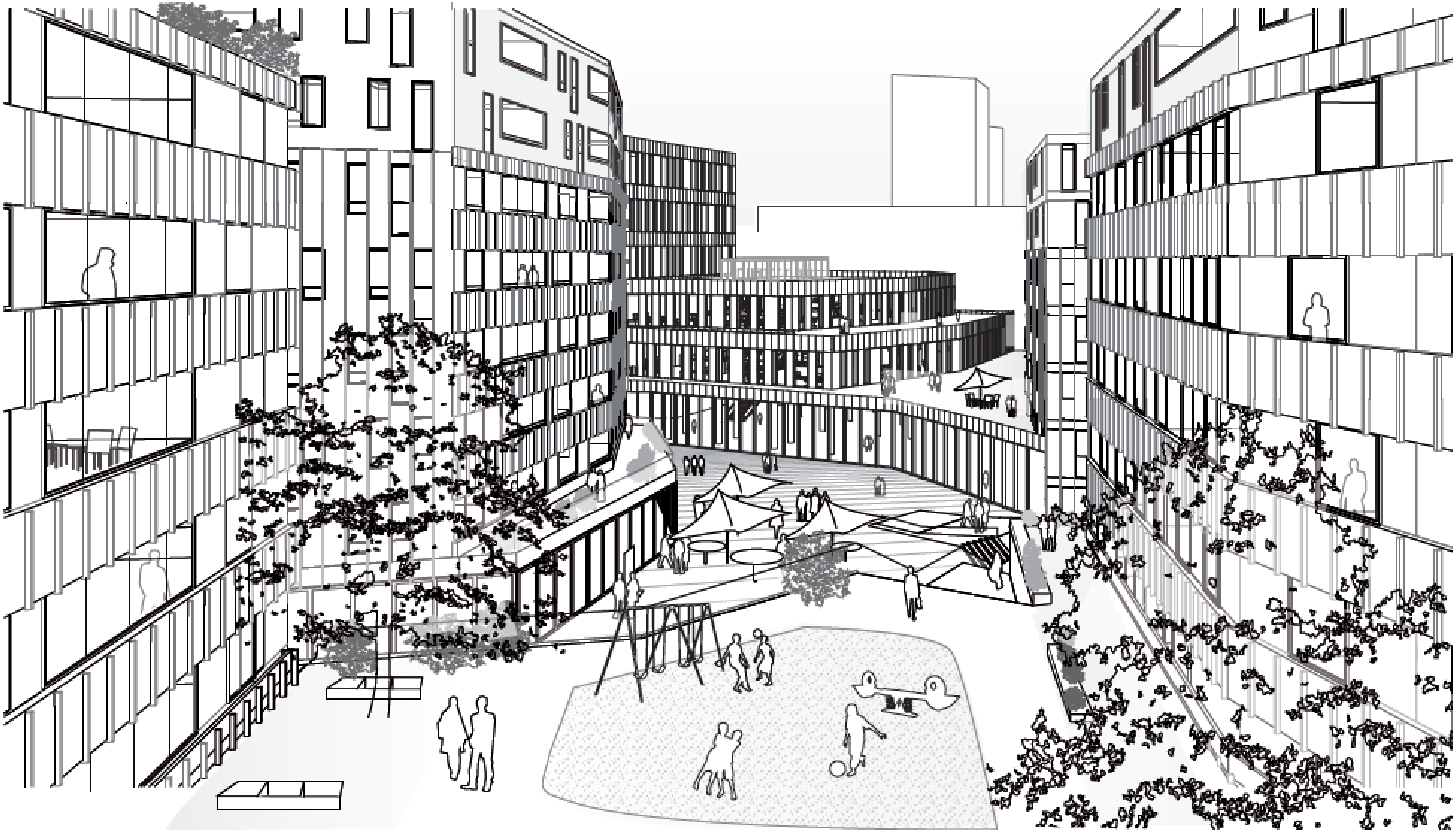
ARUP

Results (excluding basecase)

Step	1	2	3	4	5	6	7	8	9
Glazing (% of external wall)	30%	20%	20%	20%	20%	20%	20%	20%	20%
Size of opening (% of window size)	15%	15%	30%	30%	30%	30%	30%	30%	30%
Thermal Mass	Lightweight	Lightweight	Lightweight	Heavyweight	Heavyweight	Heavyweight	Heavyweight	Heavyweight	Heavyweight
Shading	None	None	None	None	Louvered Shading	Louvered Shading	Louvered Shading	Louvered Shading	Louvered Shading
Weather File	2010		2010	2010		2020	2050	2080	2080
Internal Gains	L2N	L2N	L2N	L2N	L2N	L2N	L2N	L2N	D3
Degree hours over 27^{deg}C	510	508	166	137	104	406	697	990	190
Peak Temperature	33.59	33.52	32.34	31.6	31.2	31.6	32.38	32.78	30.7



150 hours



Vasilis.maroulas@arup.com
Arup
13 Fitzroy Street
W1T 4BQ, London, UK

THANK YOU

ARUP