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Thermal retrofit

Introduction to passive design

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Technical Workshop on Sustainable Energy, Beirut, 06/11/2021

Introduction to passive design



1. Introduction

Climate change and efforts for mitigation

Nearly Zero Energy Buildings

Deep Renovation - the need for energy renovation

2. Thermal comfort, heat transfer and energy balance

3. Passive mechanisms for energy management

Thermal inertia – insulation – solar control – ventilation

Introduction to passive design



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Introduction



What is passive design ?

Better: design of measures to create a building of highest comfort (thermal, visual, acoustic, air quality, etc.) by choosing well its location, orientation, openings, composition of the skin, materials, with minimum supply of energy other than coming directly from the sun.

In retrofit, most of those decisions were already taken by the previous stakeholders, and the required modifications range from impossible or very costly up to easy to implement and cost-effective.



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What is cost effective ?

Return of the investment costs by energy bill savings in two years ?
In five ? In ten ? In twenty years ?

The European legislation considers 30 years for all life-cycle costs analysis and therefore as base of decision-making ! Compulsory.

So, in building retrofit something is considered cost effective if it returns the investment in 30 years, ... but are your clients – or their Banks - accepting this to finance the important upfront payment ?



And ... are we in a position to require cost-effectiveness?



How the Middle East is suffering on the front lines of climate change



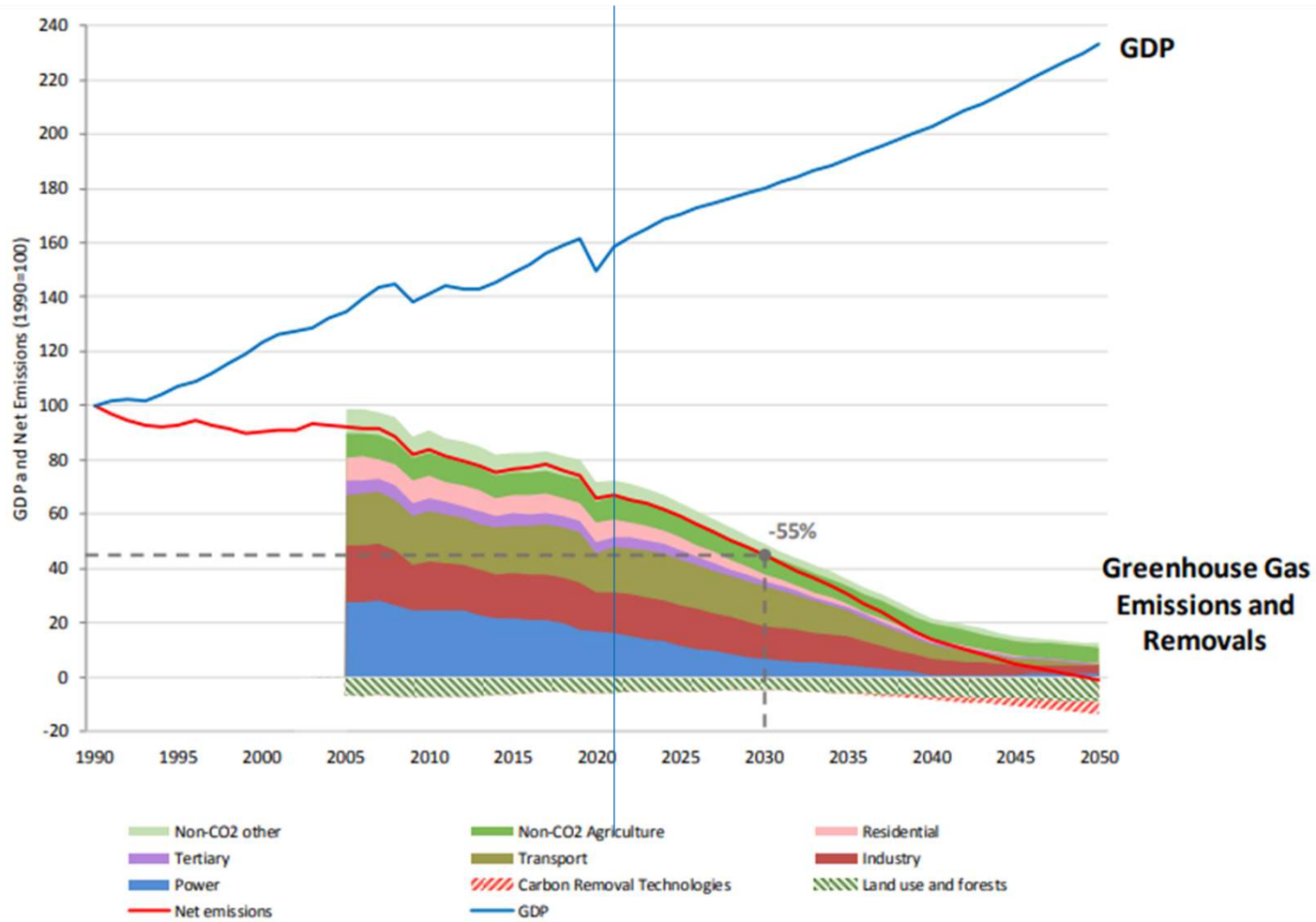
**Why do we measure particularly Building renovation in economic terms of “pay-back”?
What is the pay-back of our car ?**

Are we in time to think in short term pay-back measures ?



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17.09.2020 European Commission's Communication: **"Stepping up Europe's 2030 Climate Ambition"**.

Greenhouse Gas Emission Reduction Target of 55% by 2030, compared to 1990..



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Introduction



Published on 17/03/2021, 2:32pm

While battling political upheaval, coronavirus and its worst economic crisis in 30 years, Lebanon has strengthened its 2030 emissions target



In Mid March 2021, Lebanon submitted to the UN its updated version of the “**Nationally Determined Contribution**” to mitigate Climate Change.

“Despite its hardships, Lebanon remains committed to fighting the climate crisis,”.

<https://www.climatechangenews.com/2021/03/17/lebanon-increases-climate-goal-despite-political-economic-turmoil/>

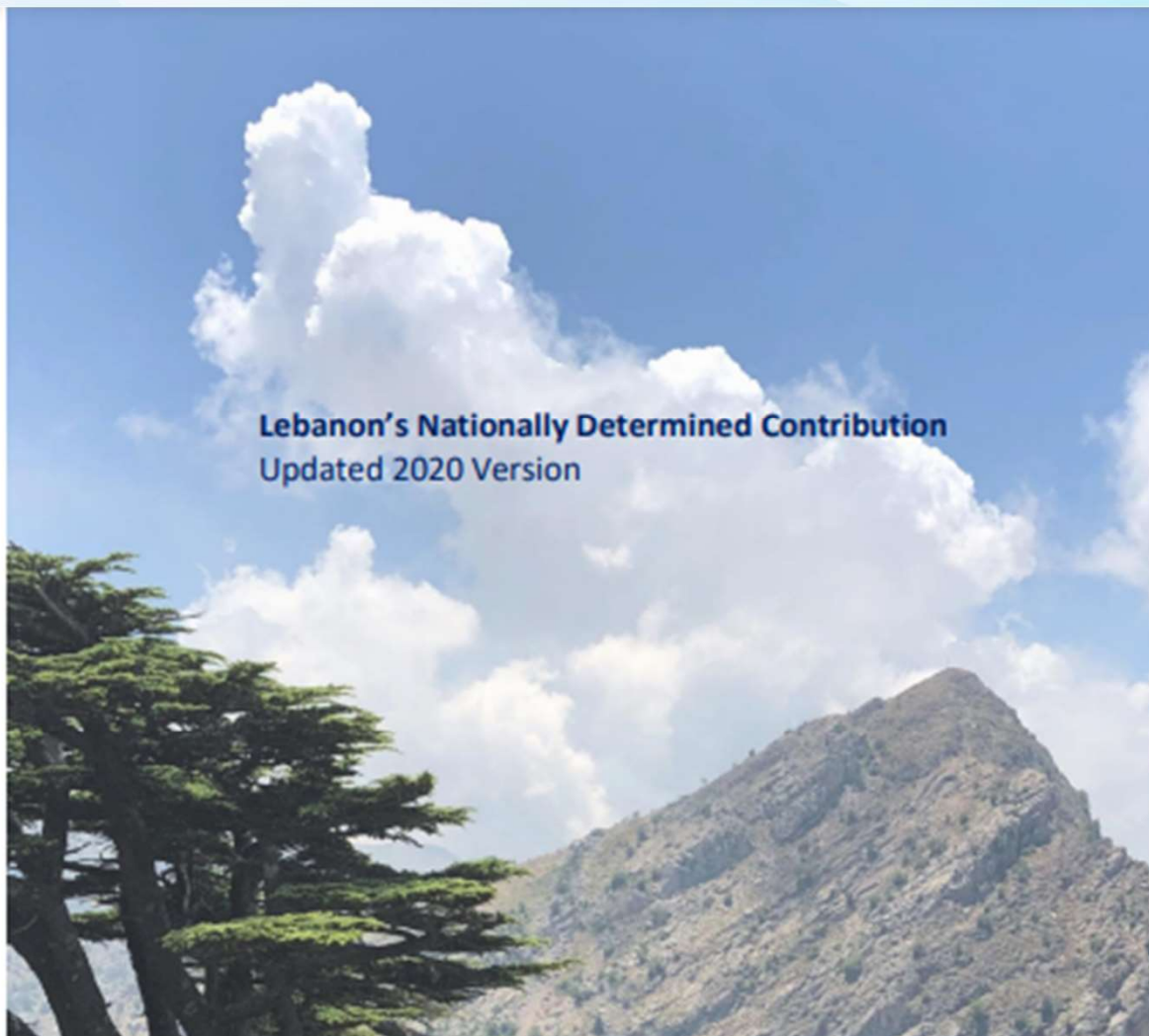


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“Lebanon commits to unconditionally increase its greenhouse gas emission reduction target relative to the Business-as-Usual (BAU) ¹ scenario from 15% to 20%” for 2030.

There are no direct targets for Buildings Retrofit but to “unconditionally reduce power demand through energy efficiency measures by 3% under the BAU scenario.”

¹ The BAU does not take into consideration mitigation actions implemented after 2011.

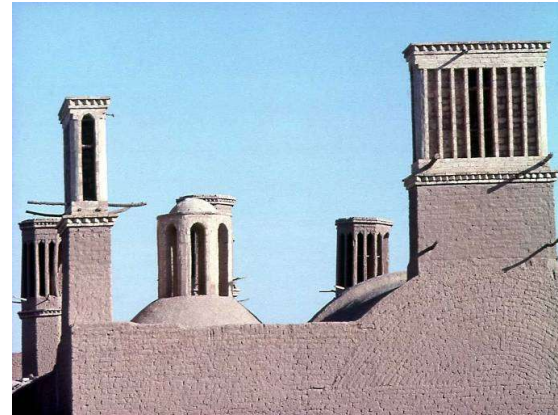


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Introduction



¿But, what are buildings to do with this ?



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Introduction



Lack of urban density requires transportation



High ratio surface – volume – high energy exchange



Unlimited use of lighting

Poor Air Conditioning systems trying to mitigate the consequences of deficient Building skins

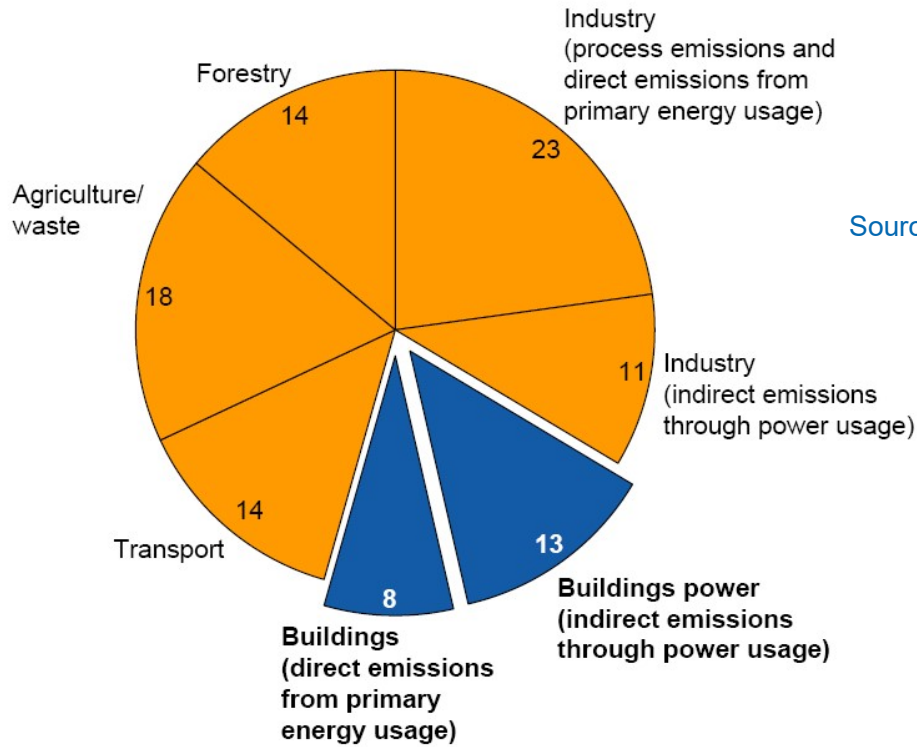


Trama
TecnAmbiental



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Introduction



Source: IEA

Source: Global Mapping of Greenhouse Gas Abatement Opportunities up to 2030 Building Sector deep dive Vattenfall - June 2007

- The buildings sector contributes to 21% of the global CO₂e emissions
- 8% through emissions from primary fuel types (coal, gas, oil)
 - 13% generated from power production to meet electricity demand from residential and commercial buildings



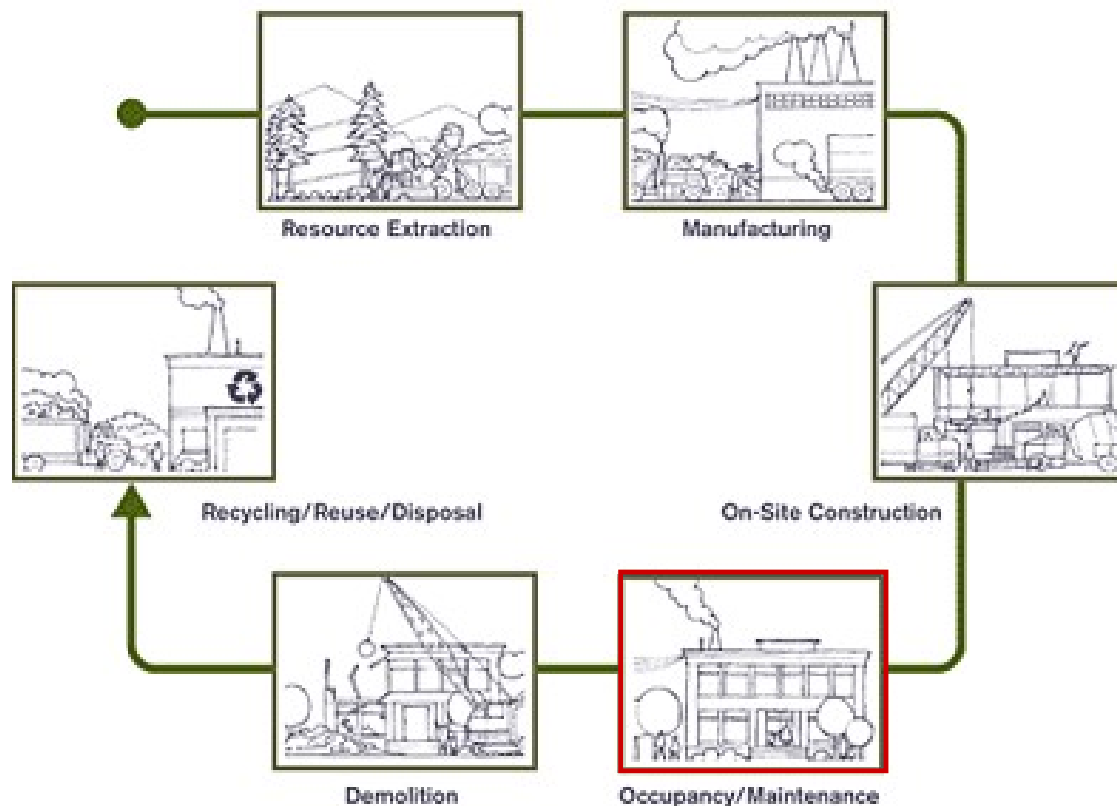


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LIFE CYCLE OF BUILDING PRODUCTS



Font: Life-Cycle Cost Analysis (LCCA)
Sieglinde Fuller



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Considering the entire life-cycle of buildings, the sector is responsible for:

40% of CO₂ eq emissions

60% of material use

worldwide.

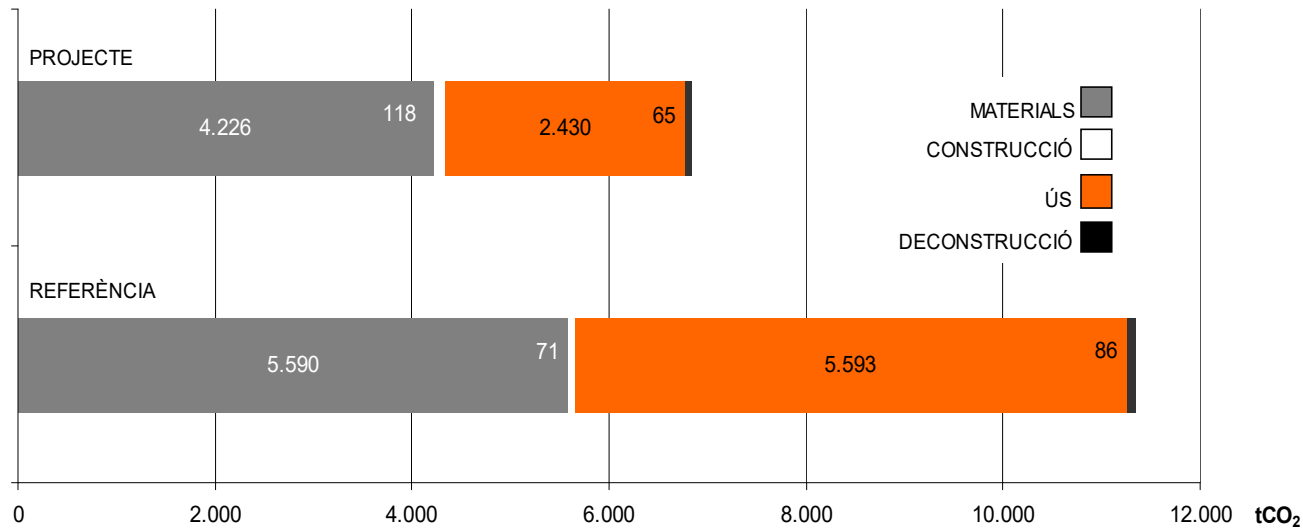


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Fase de cycle de vida	Consum d'energia			Emissions de CO ₂		
	Referència MWh	Projecte MWh	Reducció %	Referència t CO ₂	Projecte t CO ₂	Reducció %
Materials	16.333	12.589	23%	5.590	4.226	24%
Construcció	167	289	-73%	71	118	-66%
Ús	23.388	10.162	57%	5.593	2.430	57%
Deconstrucció	251	194	23%	86	65	24%
Total	40.139	23.234	42%	11.340	6.839	40%



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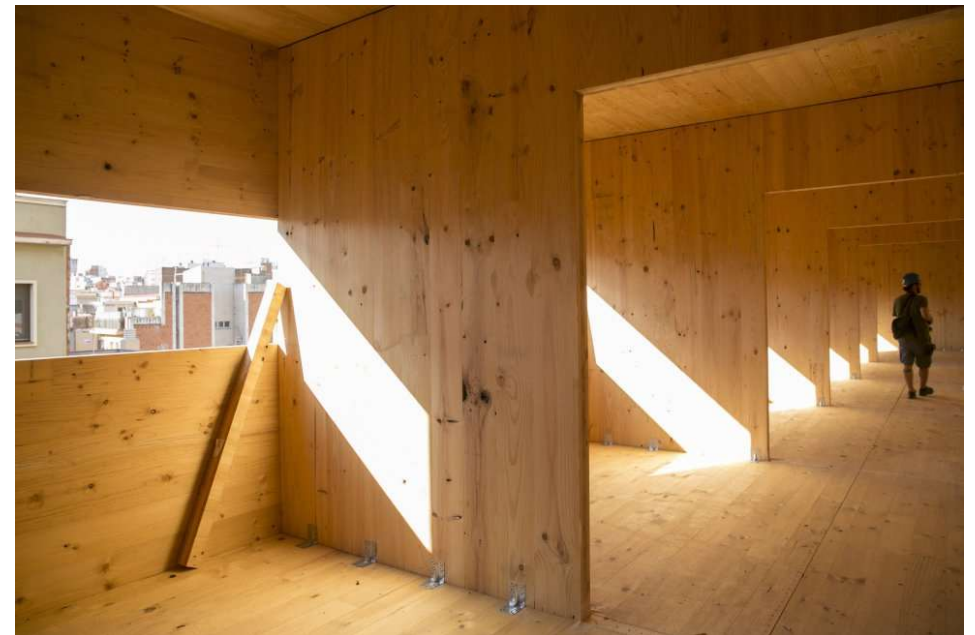
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Timber buildings as CO₂ storage (sequestration)

Life-cycle of wood, derivatives and other material from the biosphere.



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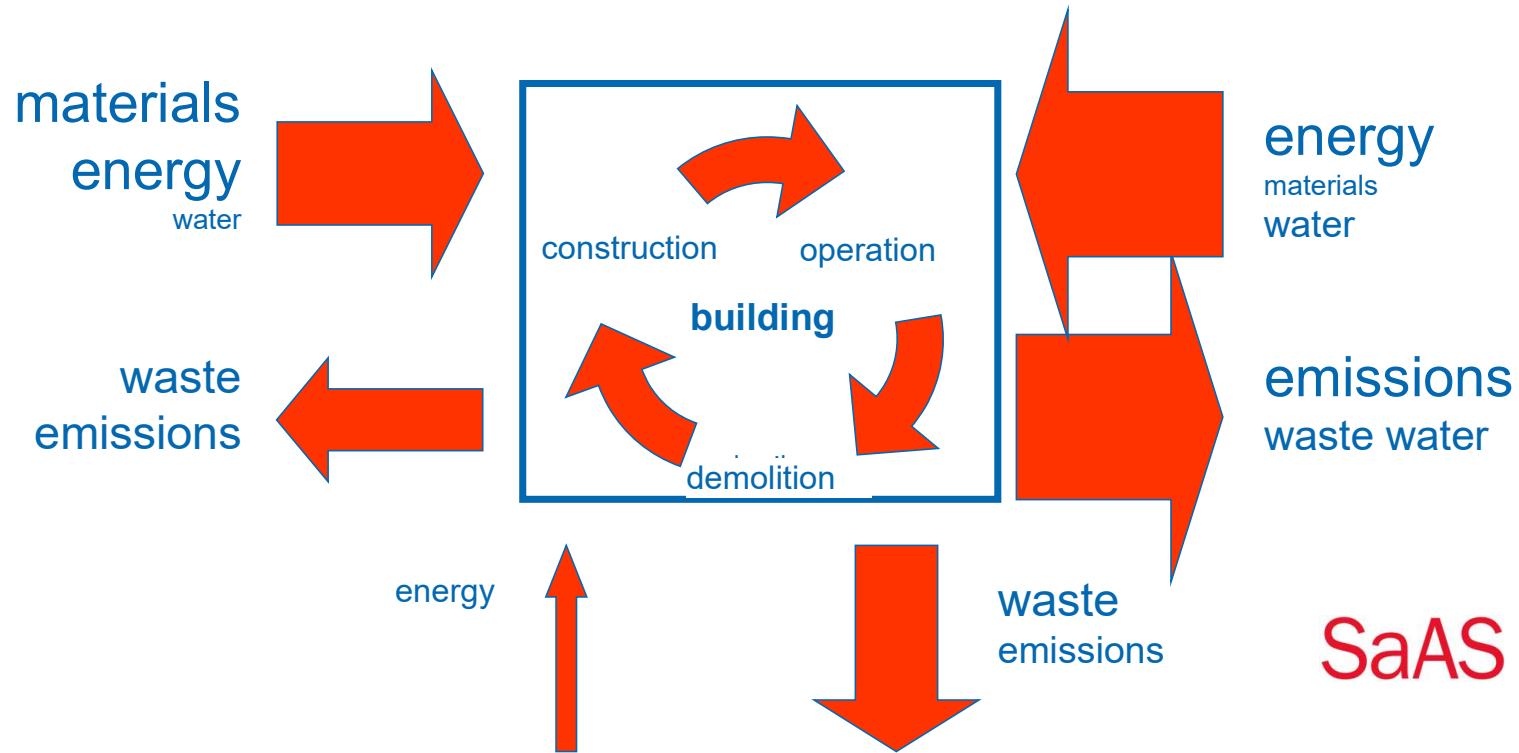


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Flux analysis of materials, energy and water



SaaS



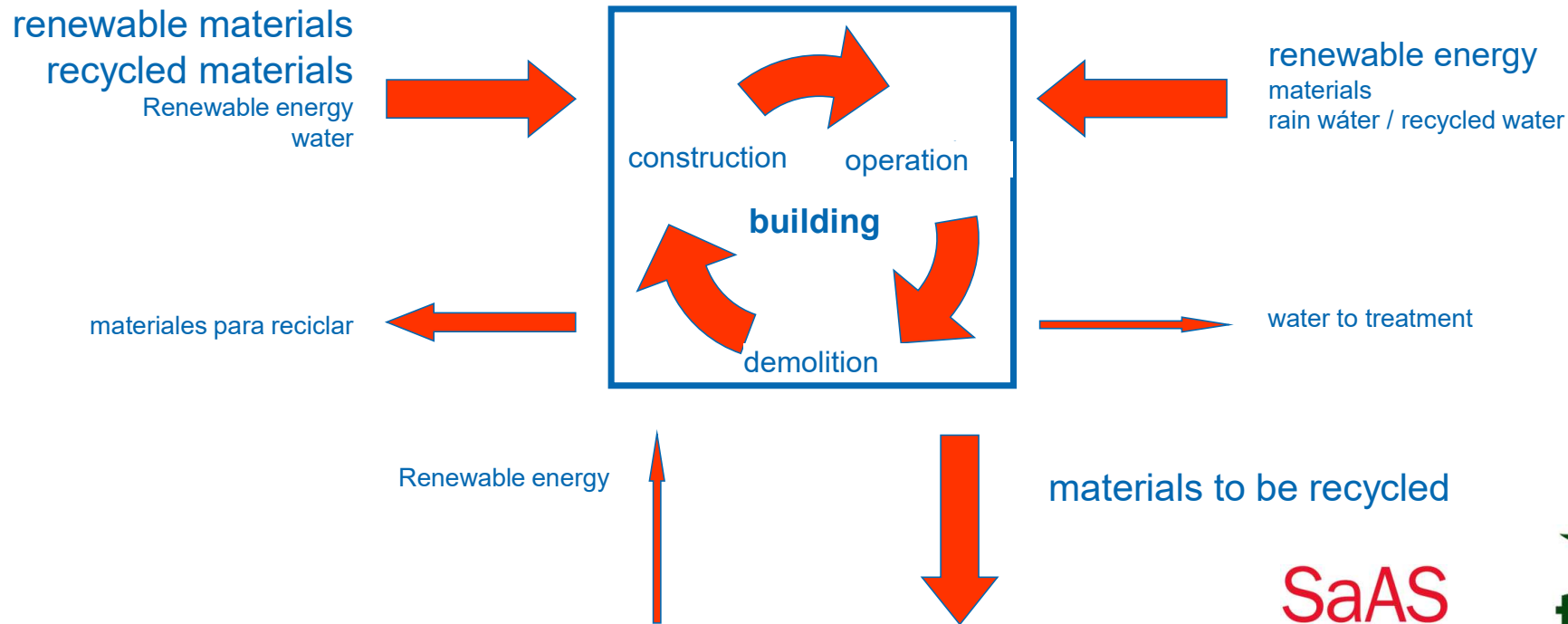


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...and its reduction targets



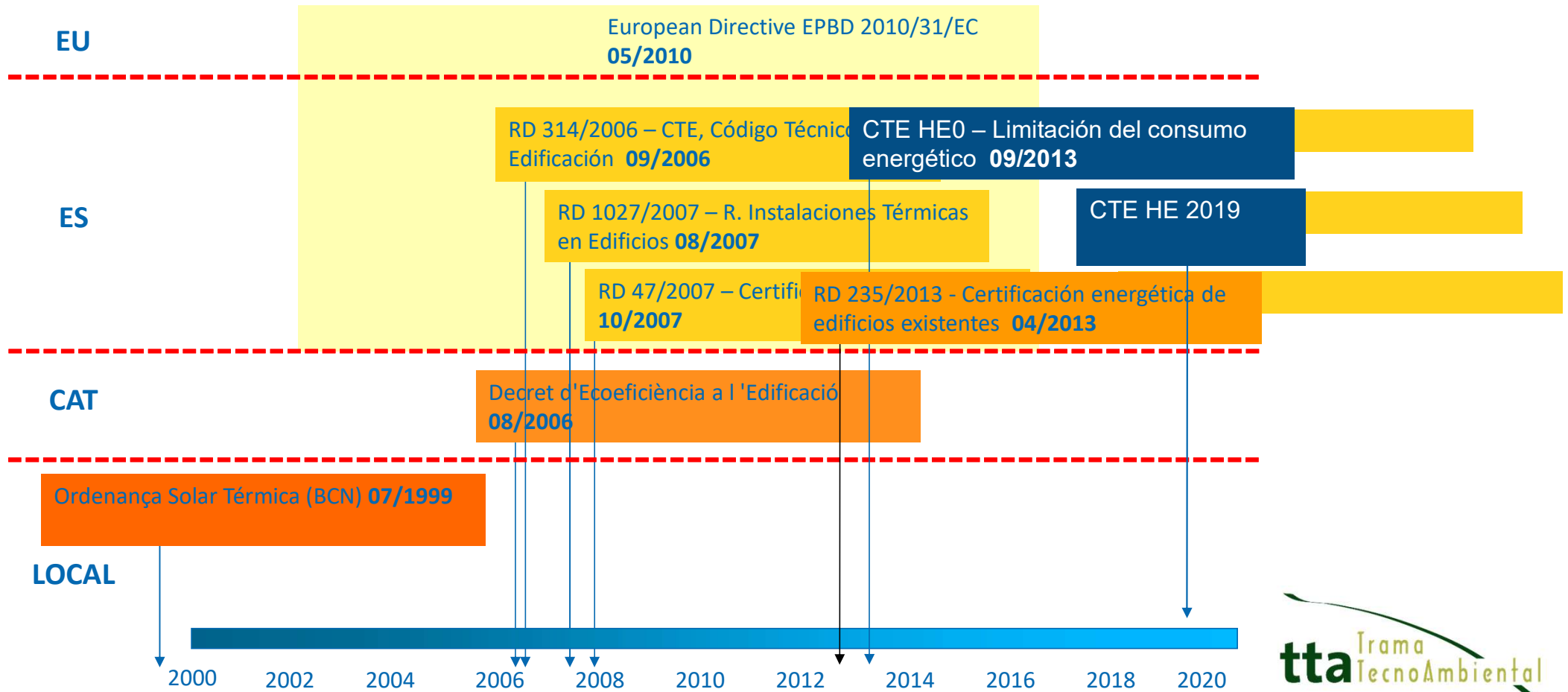
SaAS





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Introduction



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nZEB - nearly Zero Energy Building



18.6.2010

EN

Official Journal of the European Union

L 153/13

DIRECTIVE 2010/31/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

of 19 May 2010

on the energy performance of buildings

(recast)

Compulsory requirement for “Nearly-Zero-Energy Buildings” all over Europe in a horizon of ten years.

31.12.2018 - all new built public buildings

31.12.2020 - all new built private buildings



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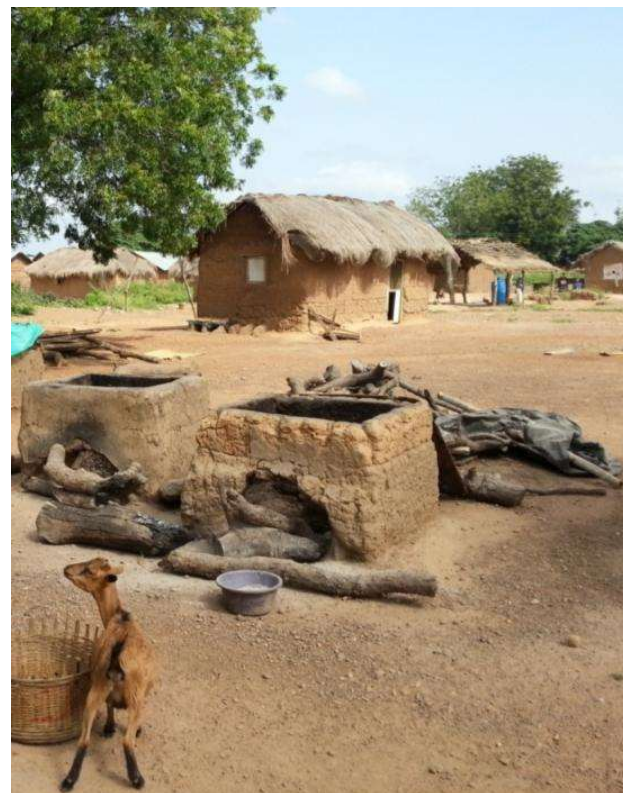


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nZEB - nearly Zero Energy Building



What is a nZEB ??? 1,300 million people (20% of the world's population) already live in nearly zero energy buildings !



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nZEB - nearly Zero Energy Building

The challenge is to achieve nZEB with the requirements of our society

- Independence from climate conditions
- Thermal, visual, acoustic comfort
- High indoor air quality
- Productivity and services
- Well-being and leisure



Residential building complex Passivhaus, 2009, Frankfurt, Arq. Rook



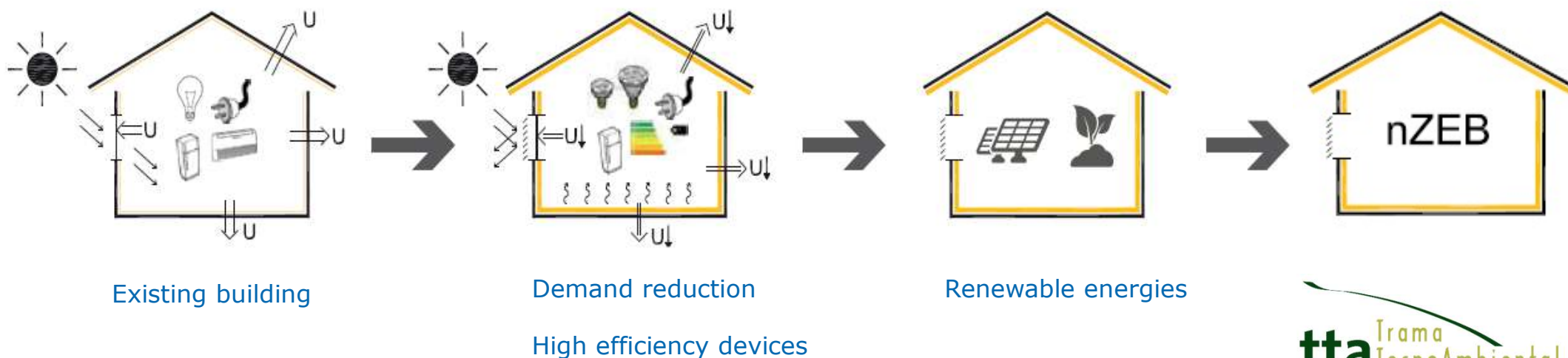
NZEB Tüschow, Moresby Hous, Hamburg

nZEB - nearly Zero Energy Building

EPBD Article 2. Definitions.

*'nearly zero-energy building' means a building that has a **very high energy performance**.....*

*The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from **renewable sources**, including energy from renewable sources produced on-site or nearby;*



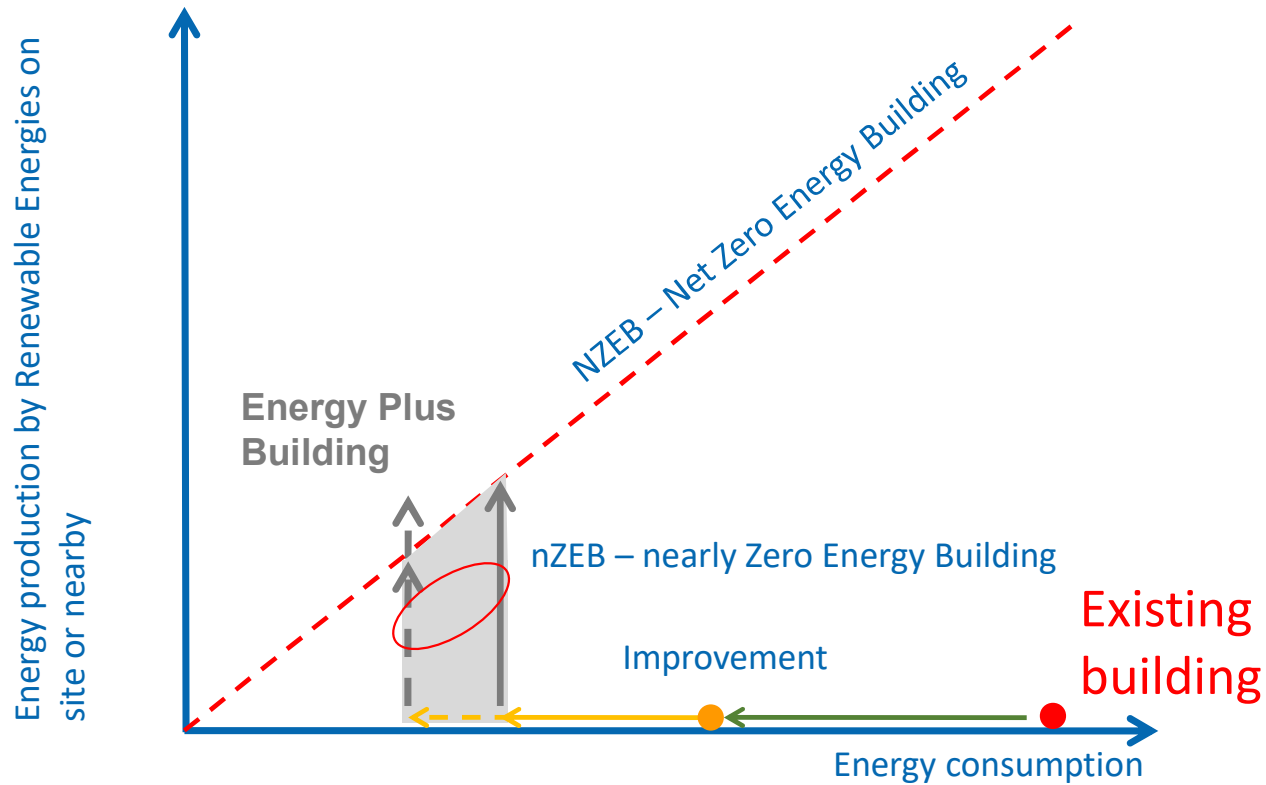


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nZEB - nearly Zero Energy Building



nZEB → NZEB → Energy Plus



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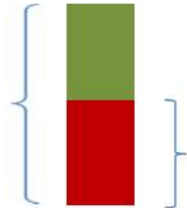
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nZEB - nearly Zero Energy Building

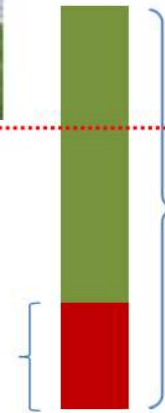


..... Need to limit the total energy consumption

Total energy consumption building 1



Total non-renewable energy consumption building 1 = building 2



Total energy consumption building 2

Source: Concepto nZEB i cost òptim. Estado actual de la normativa. Luis Vega Catalán. Coordinador Unidad de Edificación Sostenible, Subdirección General de Arquitectura y Edificación, Ministerio de Fomento. Barcelona. 18/10/2016

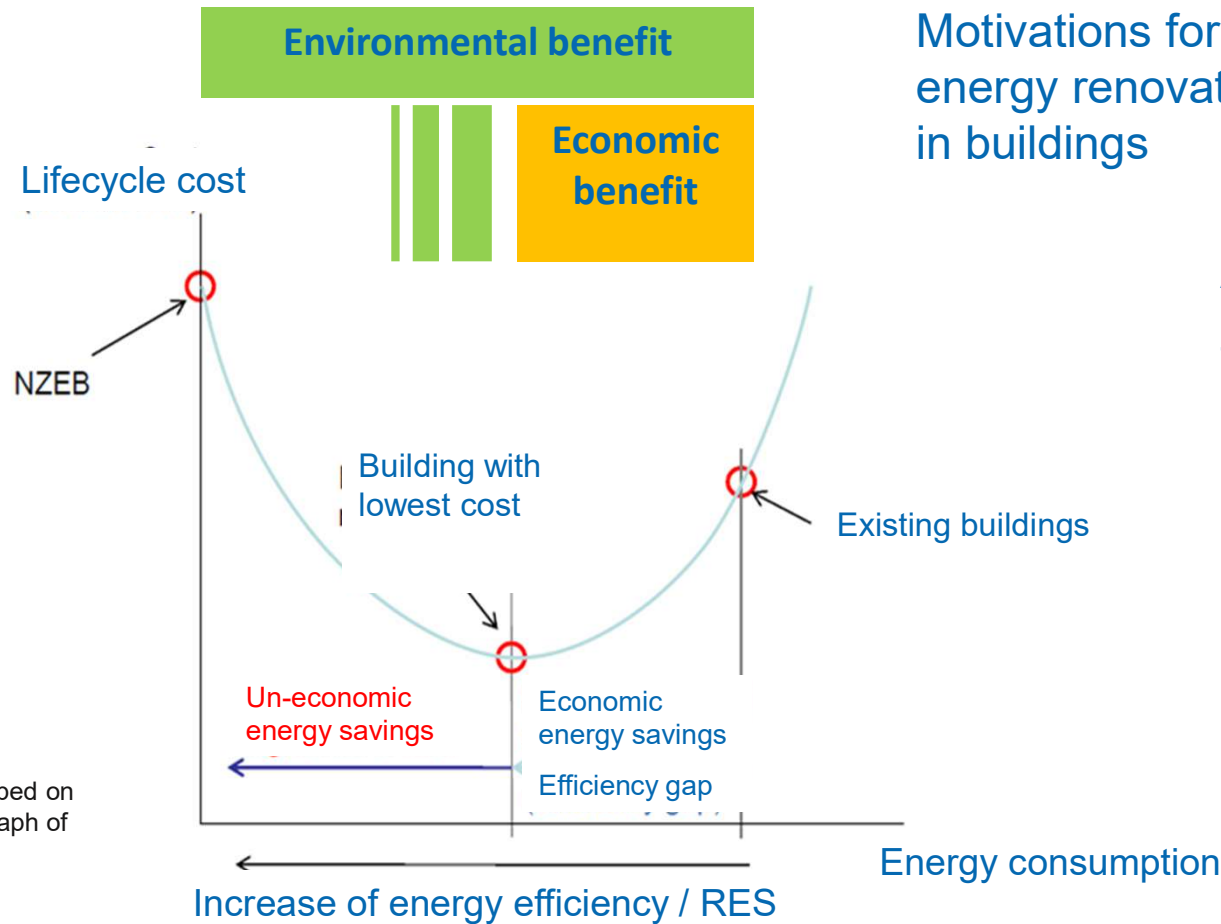




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nZEB - nearly Zero Energy Building



Motivations for energy renovation in buildings

Approach:

the economically beneficiary measures should pull at least some of the non-beneficiary measures.

Scheme developed on the base of a graph of



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Deep renovation



DEEP RENOVATION:

SHIFTING FROM EXCEPTION

TO STANDARD PRACTICE IN EU POLICY

November 2021 by the Buildings
Performance Institute Europe (BPIE)



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Deep renovation

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WHY IS DEEP RENOVATION CRUCIALLY IMPORTANT?

THE CRITICAL PATH TO ACHIEVING THE EU 2030 AND 2050 CLIMATE TARGETS

To achieve its 2030 climate target and climate-neutrality by 2050, the EU must address the energy consumption of its buildings sector. **There is no climate-neutrality possible by 2050 without fully decarbonising the buildings sector.** First, if the buildings sector is not addressed, it will leave a gap in terms of GHG emissions reduction – a gap for which other sectors cannot compensate for.



If the building sector fails to deliver its share of GHG emission cuts, it will leave a GHG reduction gap of 10 to 14 percentage points (i.e., GHG emissions are only reduced to 86% to 90% below 1990 level). This gap cannot be filled even if other sectors were to decarbonise fully.⁶

November 2021 by the Buildings Performance Institute Europe (BPIE)



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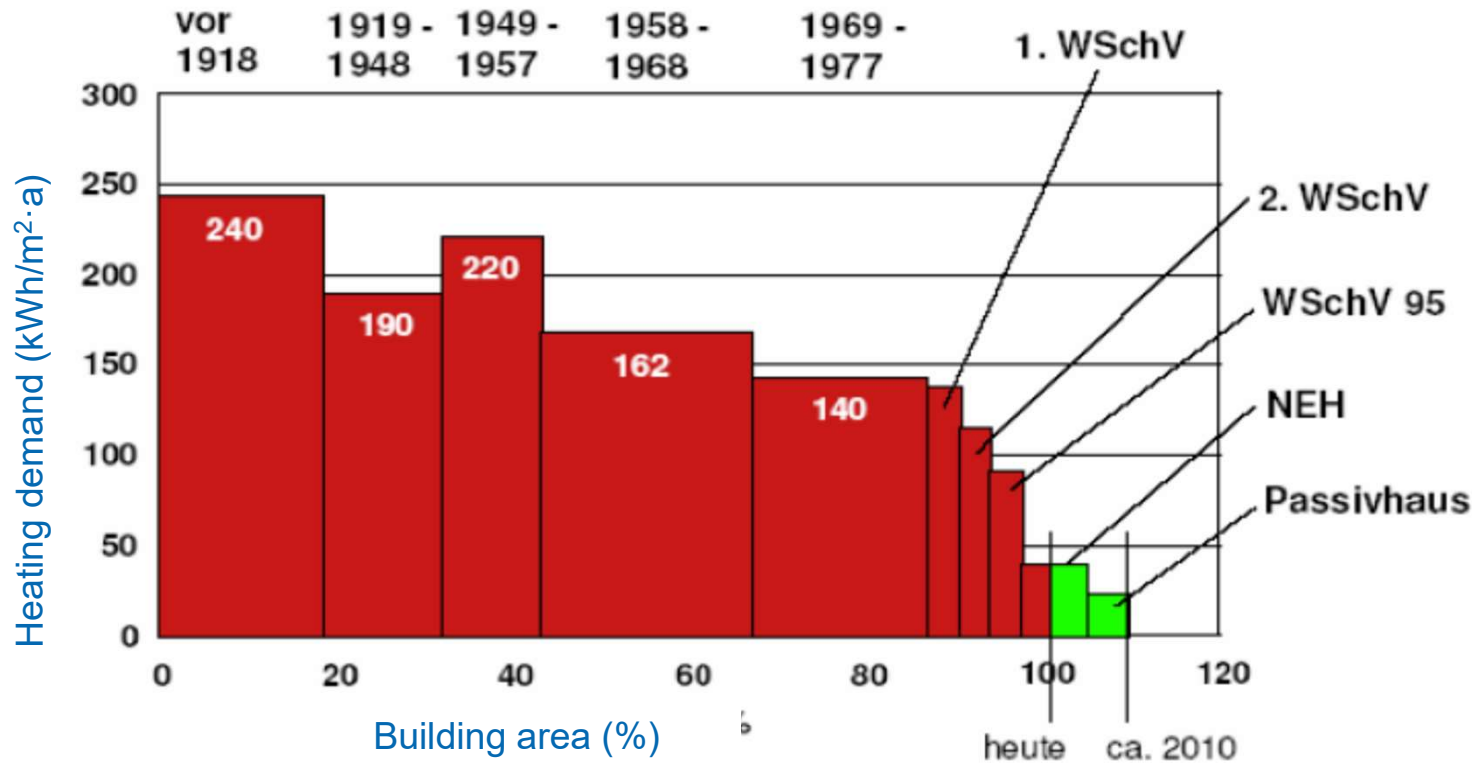


Deep renovation

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Necessity for energy renovation of buildings (building stock Germany)



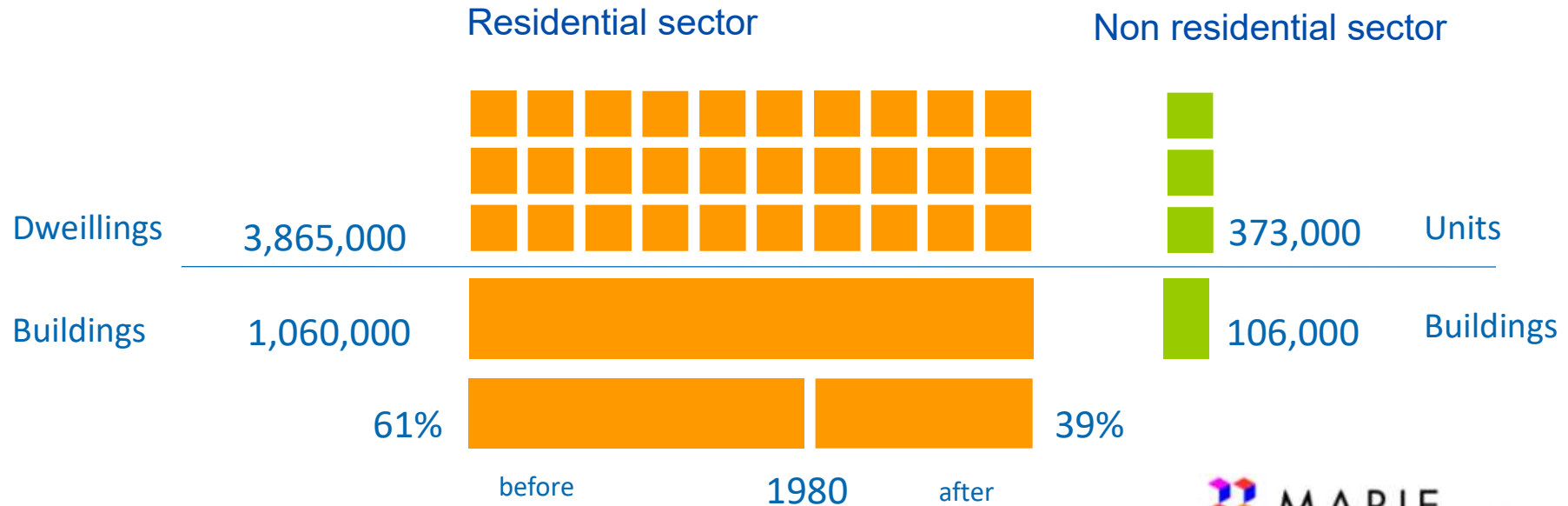


Deep renovation

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Building sector in Catalonia



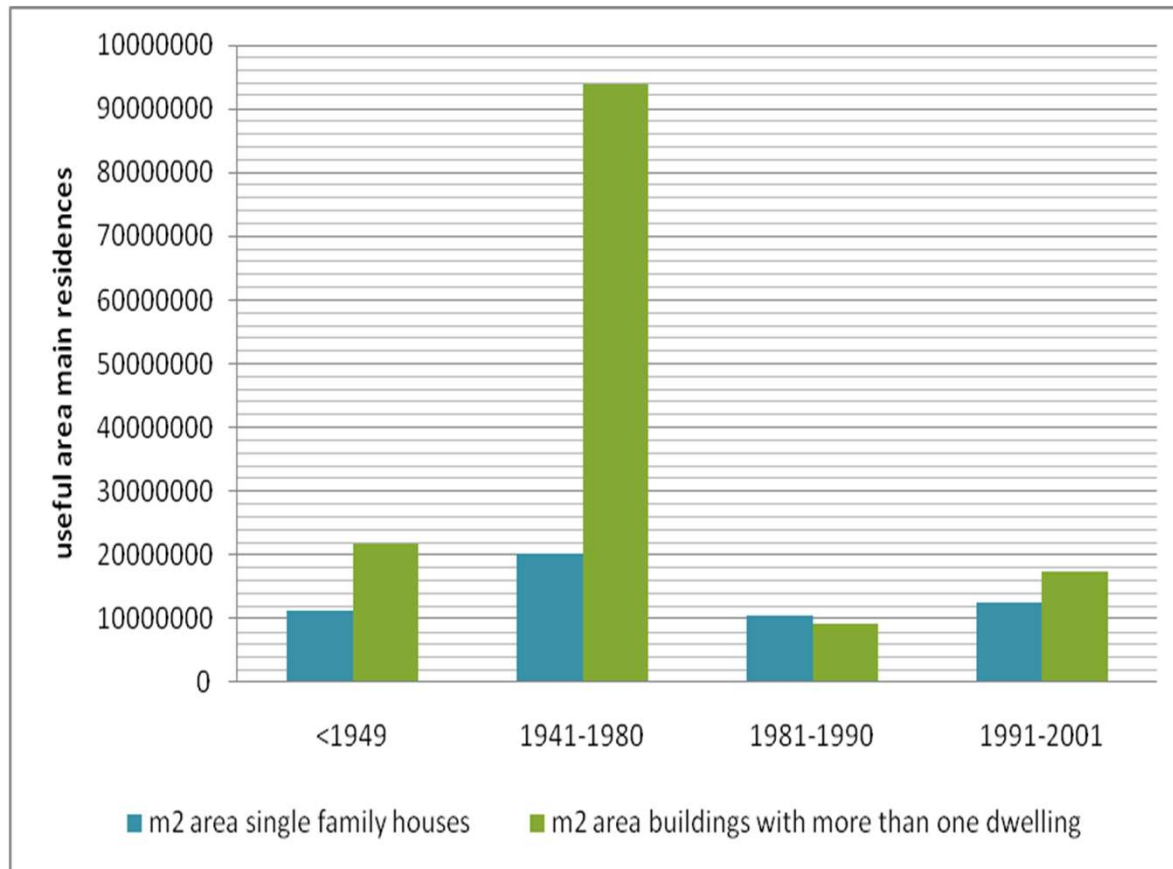
Source. Associació LIMA – Low Impact Mediterranean Architecture, “Regional Benchmark Analysis” project:





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Deep renovation



Source: Associació LIMA – Low Impact Mediterranean Architecture, “Regional Benchmark Analysis” project:

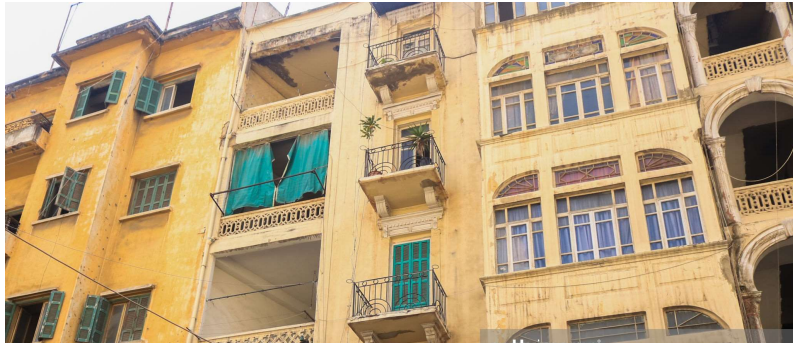


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Deep renovation



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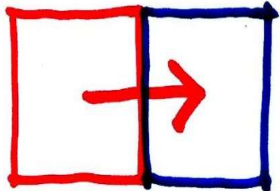


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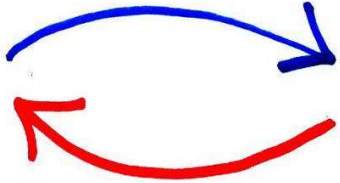
Thermal comfort



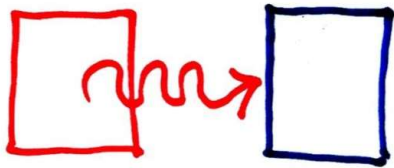
Heat transfer



Conduction: heat transport by molecular excitation that occurs between solids that are in contact



Convection: heat transport by movement of molecules as given in liquids or gases



Radiation: heat transport by electromagnetic radiation, it can move through the vacuum. All hot material is a radiation emitter, and all colder material can become a sink

It's usual unit is Watt (1 J/s); formerly also kilocaloria/hour (1 kcal/h=1'16 W).



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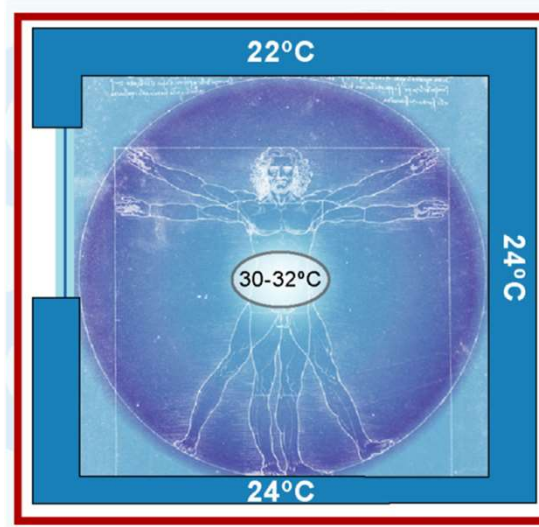
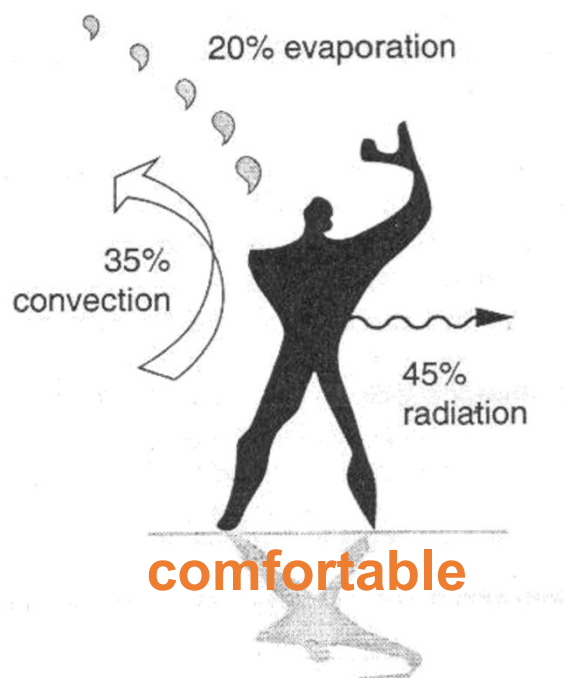


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Thermal comfort



A combination of several parameters: operative temperature, relative humidity, air movement, activity, cloth, etc.



Operative temperature: 50% air temperature
50% medium radiant temperature of
surrounding surfaces)



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Thermal comfort



Indoor design conditions according to Spanish legislation

Taula 1.4.1.1 - Condicions interiors de disseny

Estació	Temperatura operativa °C	Humitat relativa %
Estiu	23...25	45...60
Hivern	21...23	40...50



For people with a metabolic activity of 1,2 met and a clothing of 0,5 clo in summer and 1,0 clo in winter, PPD between 10-15%.

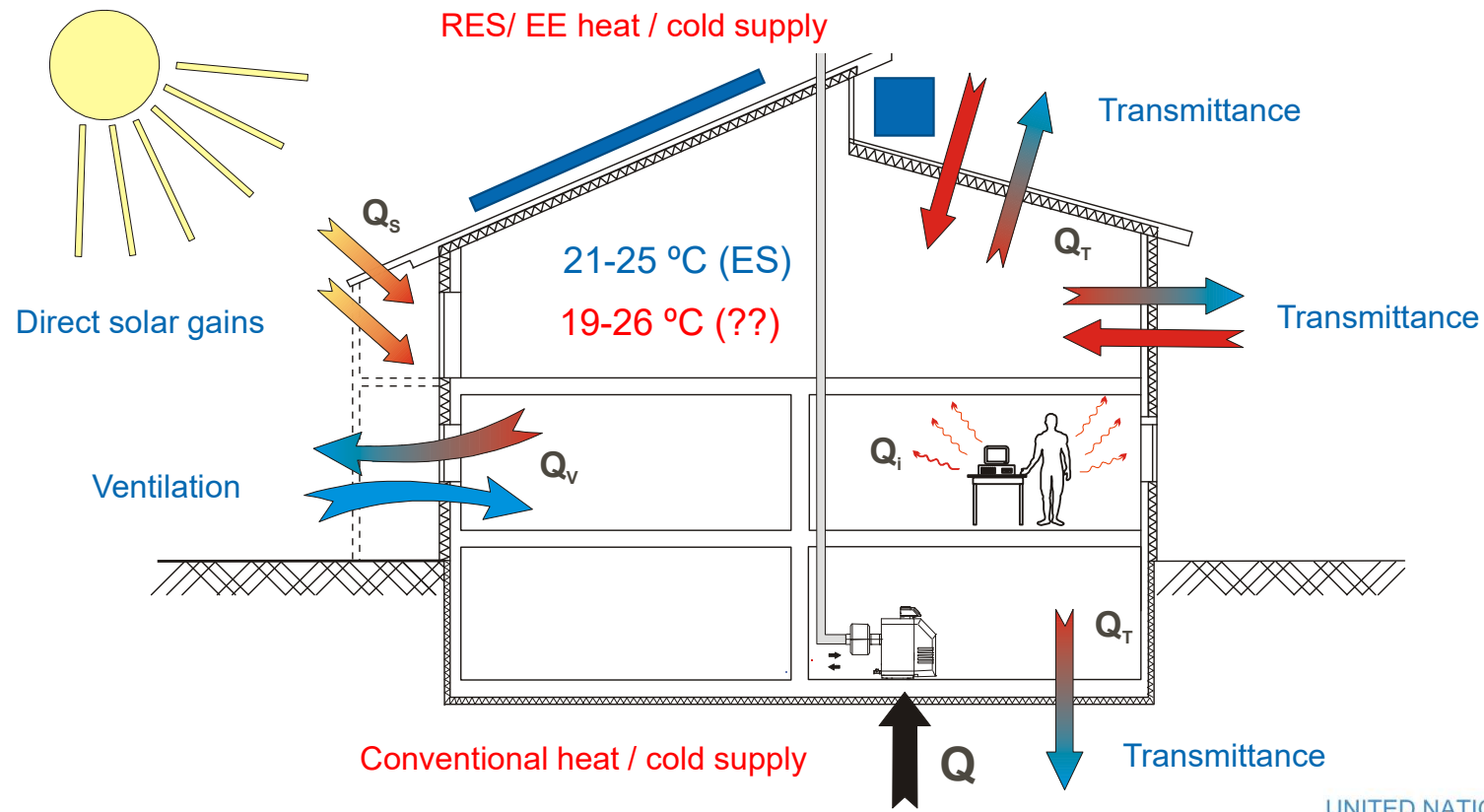


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Thermal comfort



Thermal energy balance



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Thermal comfort

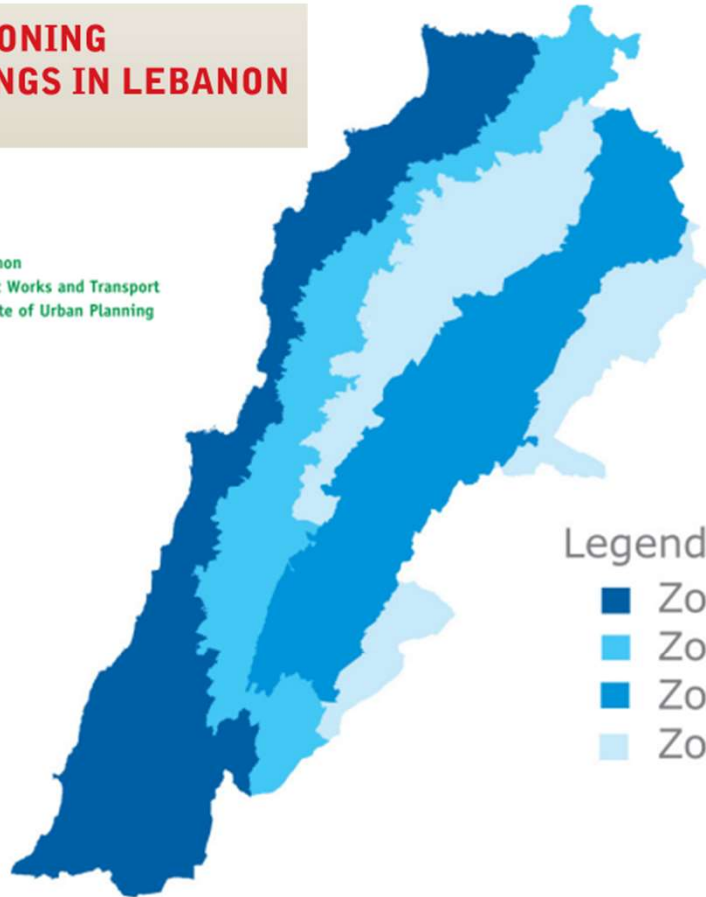
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CLIMATIC ZONING FOR BUILDINGS IN LEBANON

2005

Republic of Lebanon
Ministry of Public Works and Transport
General Directorate of Urban Planning



Legend

- Zone 1
- Zone 2
- Zone 3
- Zone 4

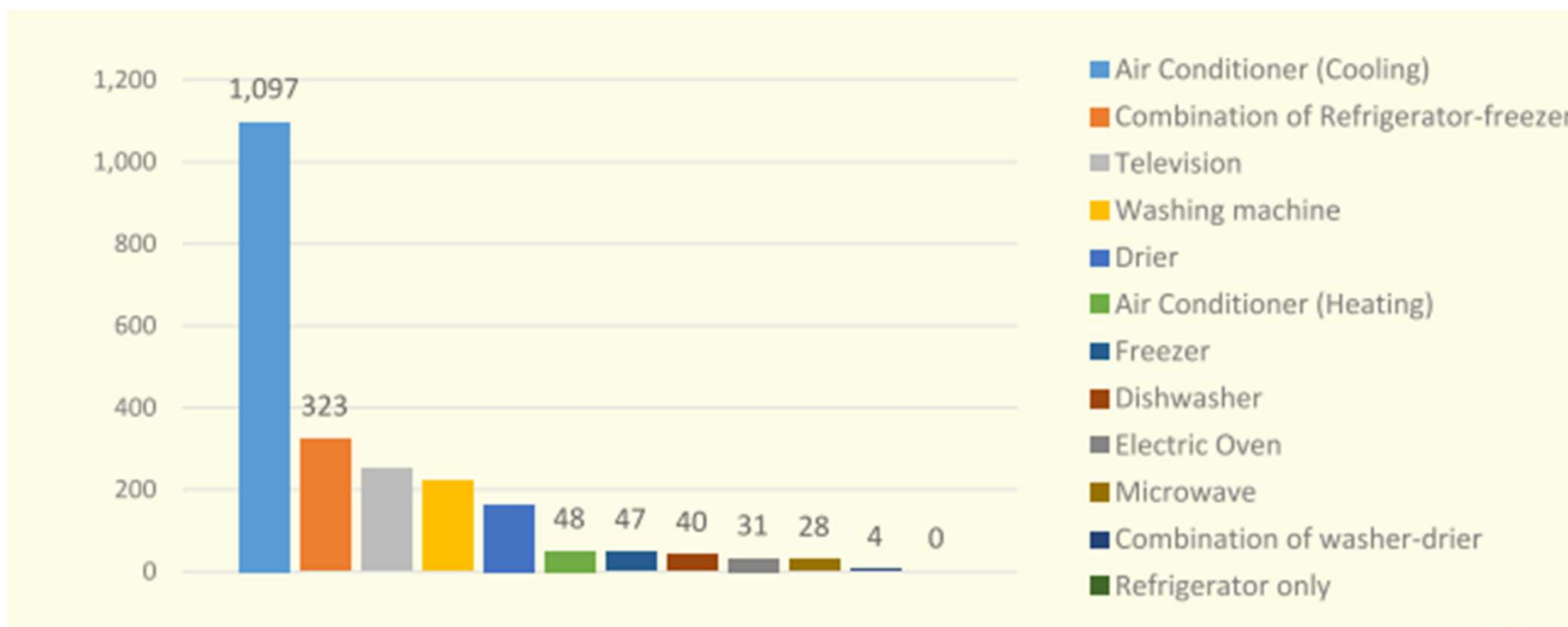
Station Name	Atlas Region	Altitude (m)	HDD (18)	CDD (21)
Aéroport (Beyrouth)	LC	15	472	511
Qornet-Chehwan	LC	603	799	233
Arbaniyé-Jisr	LC	510	956	340
Bhamdoun-Btalloun	MC	1090	1539	37
El-Qrayé	MC	1010	1622	74

Table 7 – Approximate Altitude and Degree-day Threshold for Four Zones

Climatic Zone	Approximate Altitude range	Approximate HDD(18) and CDD(21) Thresholds
Zone 1: Coastal	0-700 m	300 < HDD < 1200 120 < CDD < 1050
Zone 2: Western Mid-Mountain	700-1400 m	1200 < HDD < 2000 0 < CDD < 120
Zone 3: Inland Plateau	700-1150 m	1200 < HDD < 1800 120 < CDD < 600
Zone 4: High Mountain	Littoral side +1400m	HDD > 2000 CDD = 0
	Inland side +1150 m	HDD > 1800 0 < CDD < 120

Thermal comfort

Overall annual electricity consumption from selected appliances, per type of appliance, for Coastal 1A, in GWh/yr



Source: Lebanese Center for Energy Conservation (LCEC): "Availability, Efficiency & Use of Home Appliances in Lebanon", December 2020.

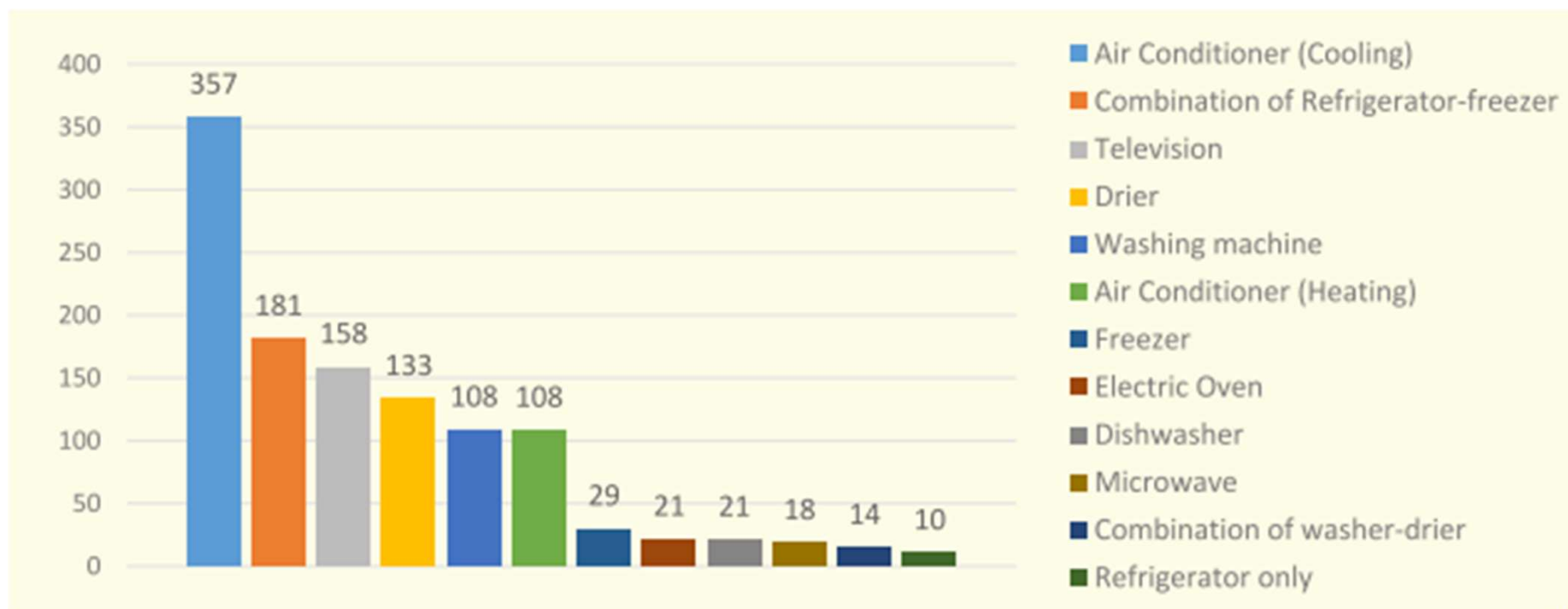


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Thermal comfort



Overall annual electricity consumption from selected appliances, per type of appliance, for Coastal 1B, in GWh/yr



Source: Lebanese Center for Energy Conservation (LCEC): "Availability, Efficiency & Use of Home Appliances in Lebanon", December 2020.



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Passive mechanisms for energy management



Sustainable building design criteria

1. Use of materials with a low environmental impact and which require as little energy as possible for their production and reuse, recycling or destruction.
2. Energy demand reduction through architectural design with particular attention to building skin.
3. Use of highly efficient HVAC (heating, ventilating, air conditioning) and lighting systems.
4. Use of natural resources, incorporating rainwater harvesting and greywater recycling systems, installation of solar thermal and solar photovoltaic systems.



HEAVY

MONO-LAYER

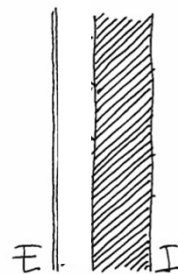
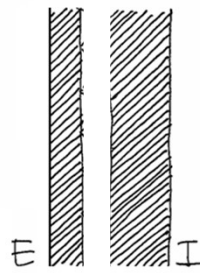
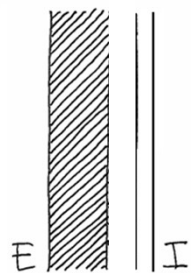
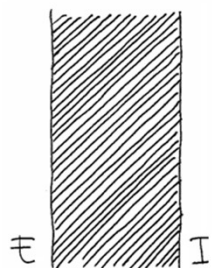
MULTI-LAYER

CONVENTIONAL

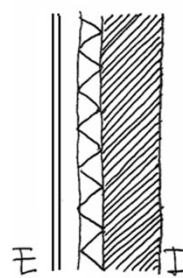
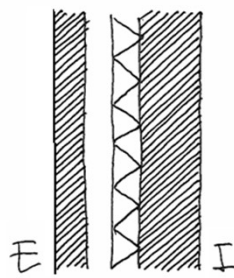
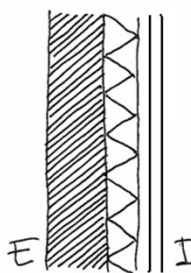
DOBLE LAYER

CLADDED

WITHOUT INSULATION



WITH SOME INSULATION AND AIR GAP



LIGHT

WALL TYPES





Passive mechanisms for energy management



Thermal inertia

The ability of a body to store heat.

It is the fundamental strategy in Mediterranean climates with a strong day / night contrast and in mineral construction cultures.

Insulation

Materials to control the resistance to thermal heat transfer.

Appearance of multilayer facades and special materials.

Solar control

Devices to control the amount of solar radiation to enter the building.

This is an essential aspect both to take advantage of radiation in winter and to limit overheating in summer.

Ventilation

Air exchange and natural process of refrigeration by evaporation.

It is a desirable mechanism in hot environments and particularly with low thermal mass constructions.





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Thermal inertia in the Mediterranean



Although the specific heat of the stone or mud are not very high (0.7 KJ / Kg.K), compact mineral walls take advantage of the very considerable mass to generate a great thermal inertia.

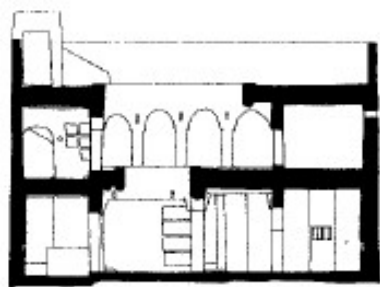


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Thermal inertia in the Mediterranean



Vall M'Zab, Algeria



Typical farmhouse, Catalonia



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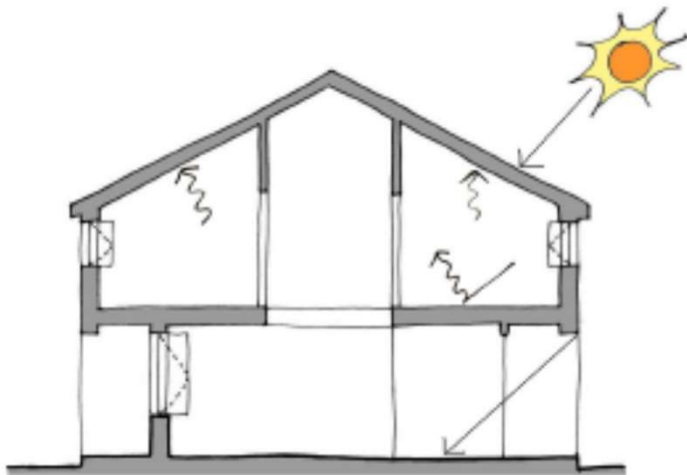


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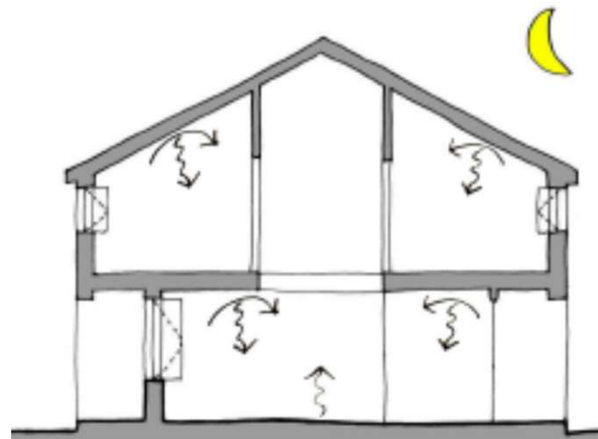
Thermal inertia in the Mediterranean



Mass is buffering the solar radiation's impact on the indoor temperature

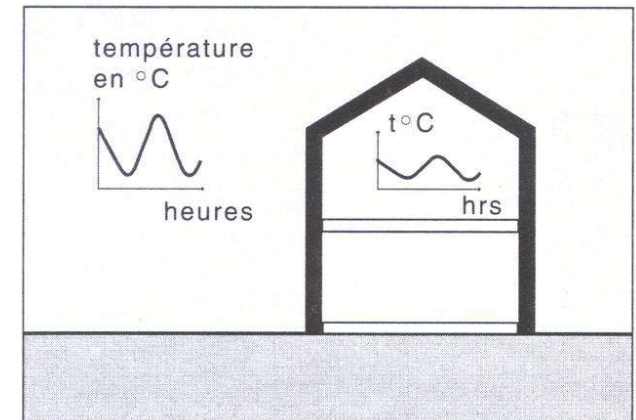


Absorption of solar radiation during the day



Release of cumulated heat during night hours, towards the inside and outside.

Atenuation of the exterior temperatura conditions, with a time lag depending on the wall composition and thickness.



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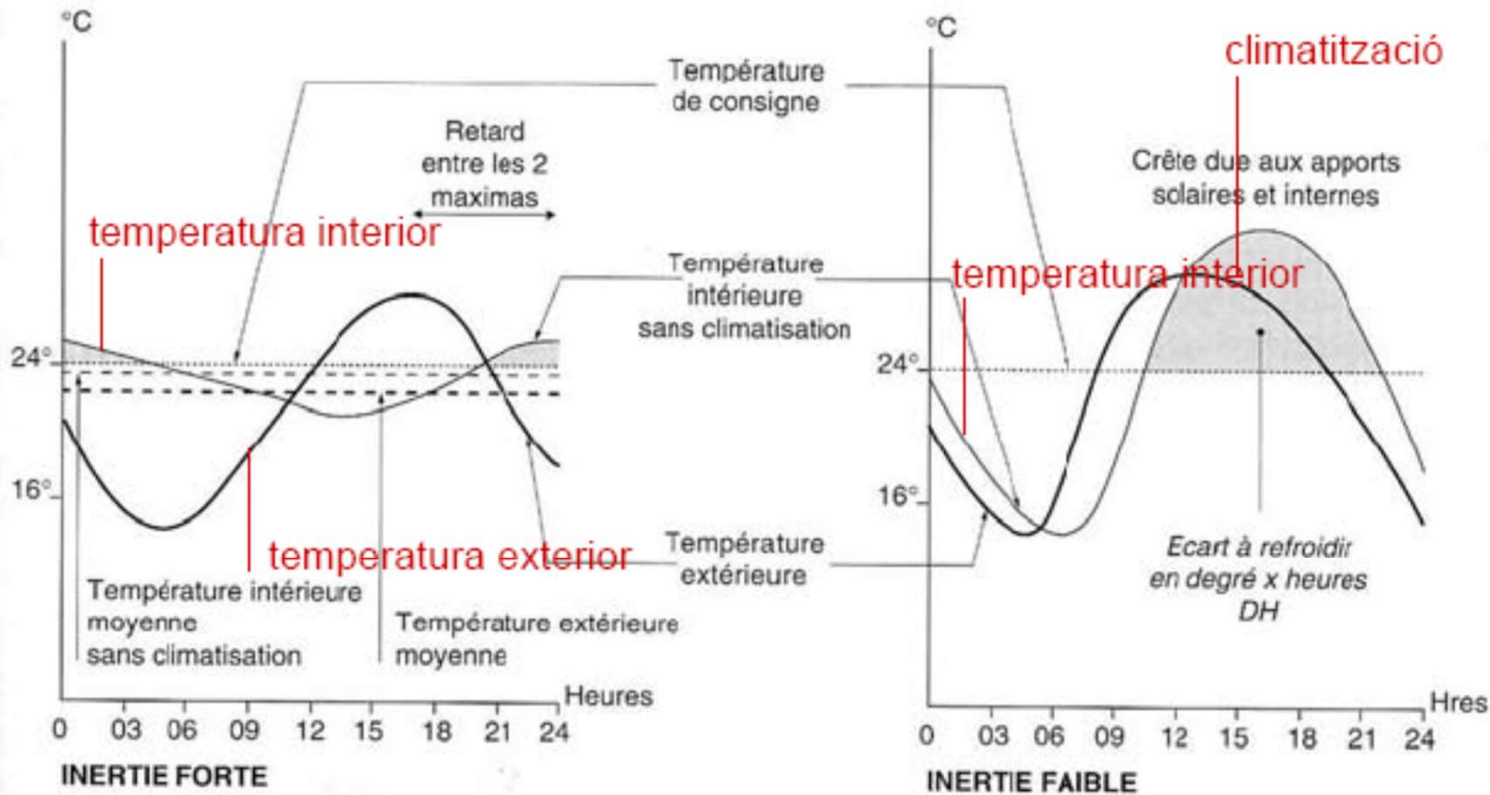


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Thermal inertia in the Mediterranean



Comparison of high and low inertia on a sunny day in hot season



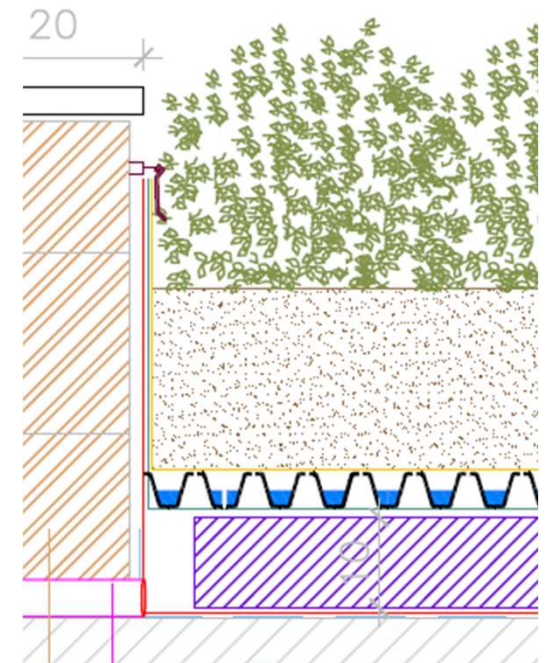


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Thermal inertia in the Mediterranean



The most likely real application in renovation are green roofs, combining thermal inertia with evaporative cooling



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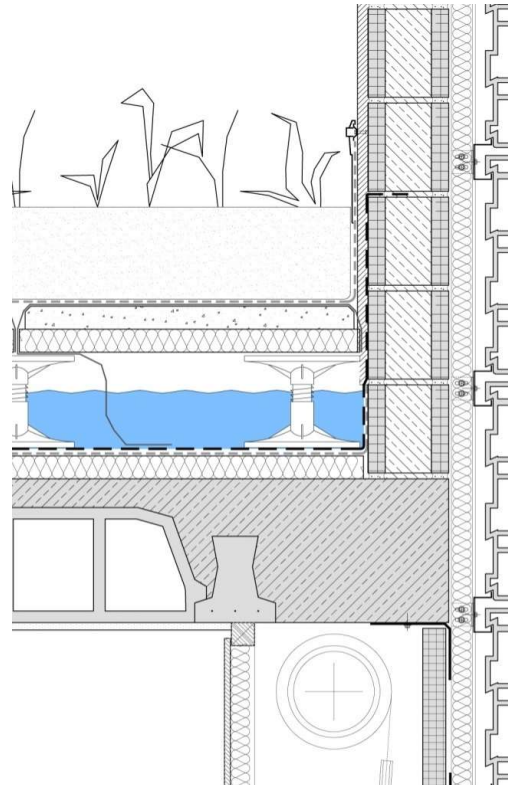


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Thermal inertia in the Mediterranean



The most likely real application in renovation are green roofs, combining thermal inertia with evaporative cooling



Green roof with water storage

- soil, 150 mm
- Geotètil felt
- Filtering pavement with XPS, 80 mm
- Adjustive supports PVC, 100-150 mm
- Geotètil felt
- Water up to 80 mm
- Insulation XPS, 40mm
- Waterproofing EPDM
- Slab, 250mm
- Gypsum plaster, 12 mm



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Thermal insulation



Thermal insulation slows down the exchange of energy between two bodies but does not prevent their passage; so if there is no power supply the outside and inside temperatures will end up equalizing.

The increase in insulation can be obtained by increasing the thickness of the enclosures or by incorporating a specific material thickness.

Reference values for thermal conductivity coefficient λ :

Metals	> 50	m·K/W
Stone, concrete, bricks, glass	1-10	
Timber, wood fibres...	0'1-0'5	
Insulation materials	< 0'05	



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Thermal insulation



Three possibilities of locating the insulation material in existing building façades

	Measure	Advantages	Disadvantages
M 1	Façade insulation from the inside	No neighborhood agreement needed	Inconveniences for users Space reduction Thermal bridges not improved
M 2	Façade insulation within the air gap	No neighborhood agreement needed Ease of implementation	Thermal bridges not improved Difficult quality control
M 3	Façade insulation from the outside	Thermal bridges solved	Neighborhood agreement needed Scaffold



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Thermal insulation



Interior insulation

Perforated brick, 140 mm

Not ventilated air gap, 50 mm

Light brick, 90 mm

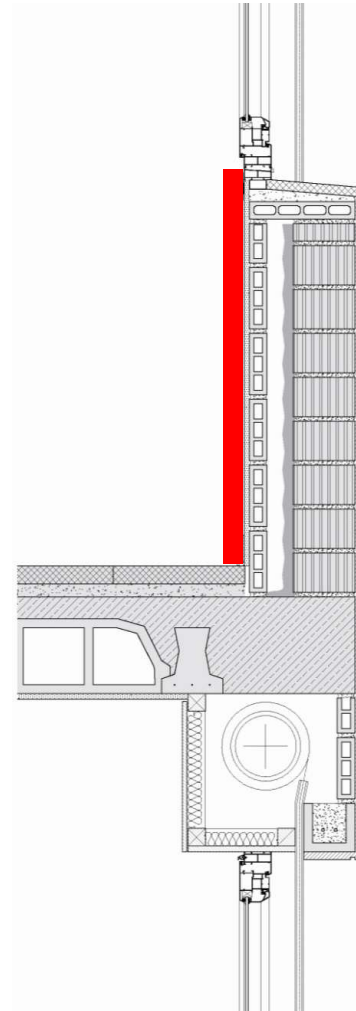
Gypsum platster, 12 mm

Interior insulation within galvanized steel structure, 40mm

Gypsum board, 12.5mm

Thermal transmittance

0,48 – 0,52 W/m²K



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Thermal insulation



Sheep wool 0,043 W/m·K (12% polystyrene fiber)



Source: Victermofix

Polystyrene on wooden or metal structure



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Thermal insulation



Wood fibre on wooden structure
Gypsum fibre board (fermacell)



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Thermal insulation



Insulation	Primary energy (MJ/kg)	Emissions (kgCO _{2eq} /kg)	Source
Extruded polystyrene (XPS)	92,4	9,580	EMPA
Expanded polystyrene (EPS)	105,0	4,120	EMPA
Poliuretane (PUR)	100,0	4,210	EMPA
Glasswool	45,1	1,490	EMPA
Mineral wool	21,7	1,480	EMPA
Cellular glass	16,5	0,600	PROVEIDOR
Sheep wool	14,7	0,045	PASSIVHAUS
Cork	25,0	0,021	EMPA
Wood fiber	13,7	-0,183	PROVEIDOR
Cellulose	7,2	-0,907	PASSIVHAUS



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Thermal insulation



Reet mats, perfect for indoor mud plastering



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Thermal insulation



Insulation of air gap

Perforated brick, 140 mm

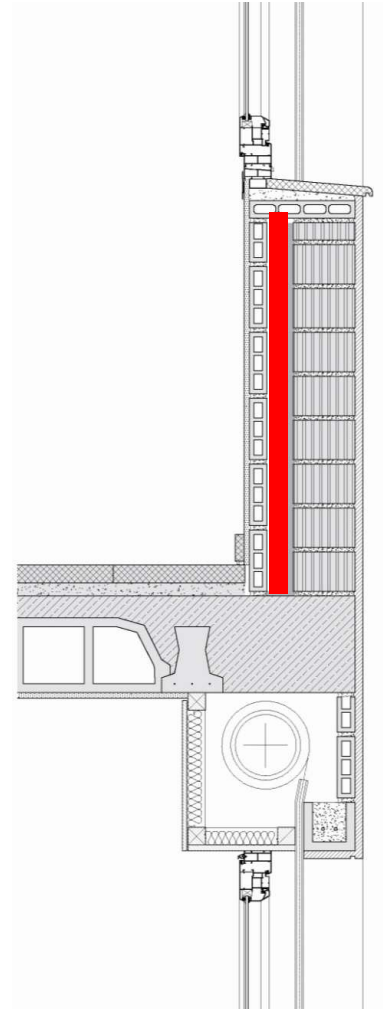
Injected insulation material, 40 mm

Light brick, 90 mm

Gypsum plaster, 12 mm

Thermal transmittance

0,54 – 1,42 W/m²K



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Thermal insulation



Injection of Supafil



Injection of EPS with graphit from the outside *Agència de l'Habitatge de Catalunya*



Cellulose projected: 0,040 W/m·K (newspaper, 10% Borax for fire resistance and as fungicide)



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Thermal insulation



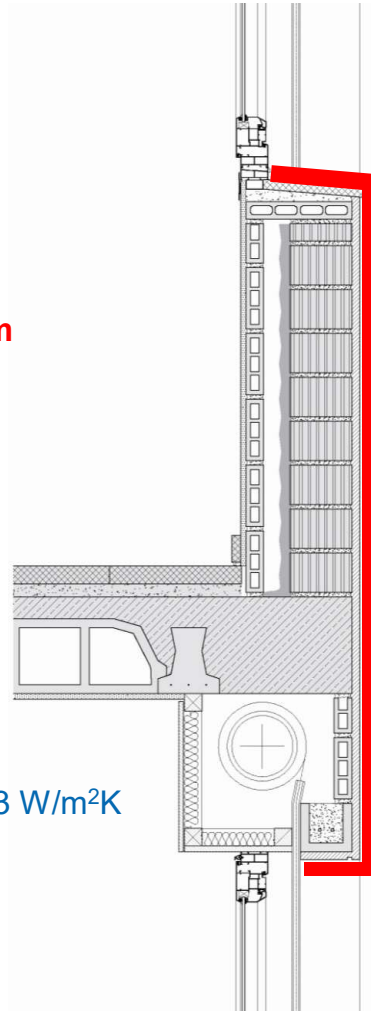
Exterior insulation

Exterior Insulation System, 40mm / 80mm

Perforated brick, 140 mm
Not ventilated air gap, 50 mm
Light brick, 90 mm
Gypsum platster, 12 mm

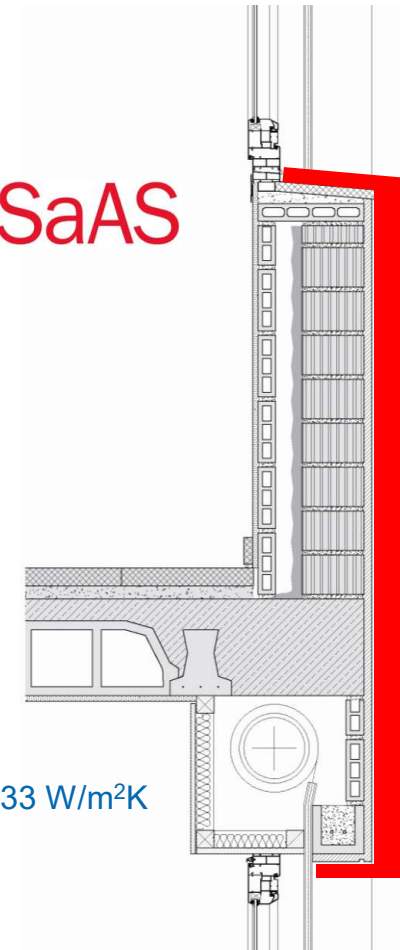
Thermal transmittance

0,49 – 0,53 W/m²K



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0,31 – 0,33 W/m²K



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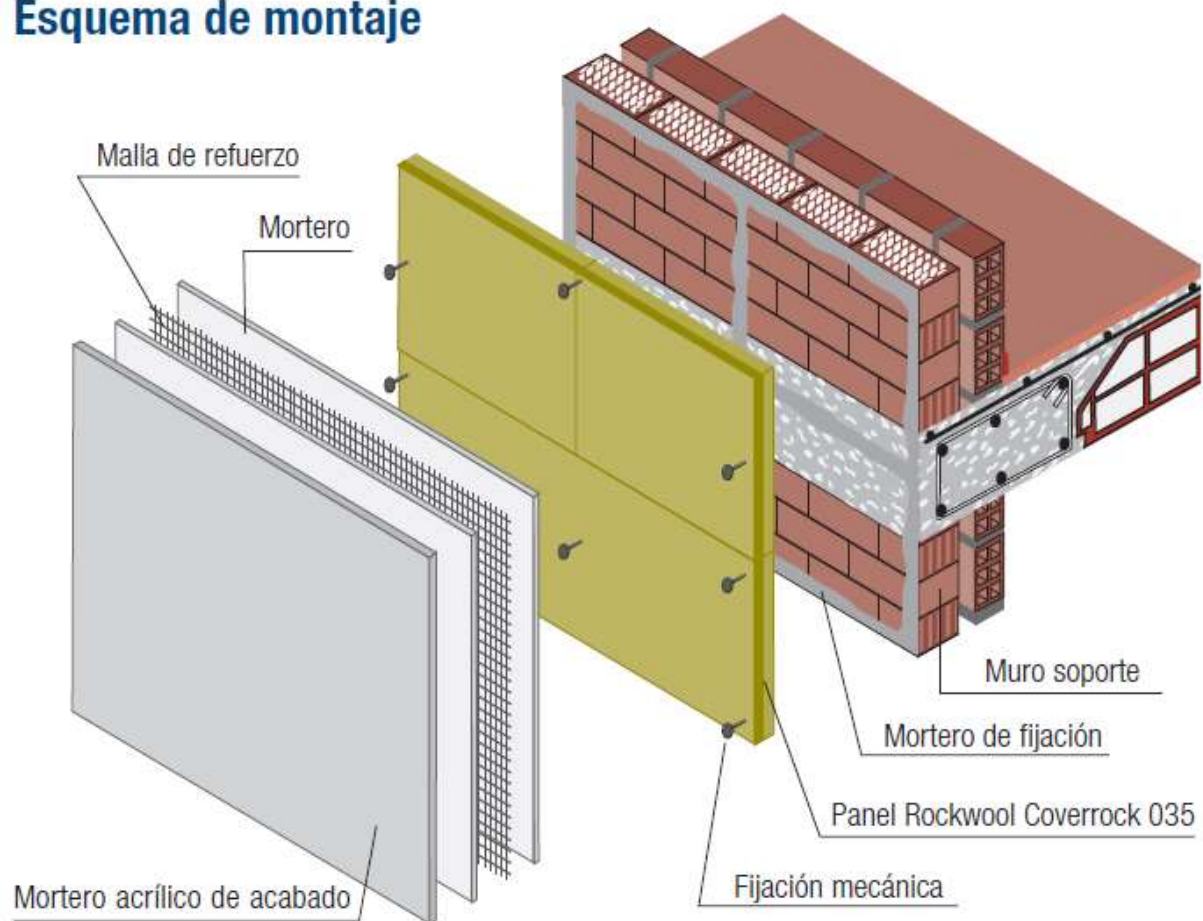


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Thermal insulation



Esquema de montaje



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Thermal insulation



➤ Multi property buildings

Challenge: huge number of owners
involved in the decision making
process



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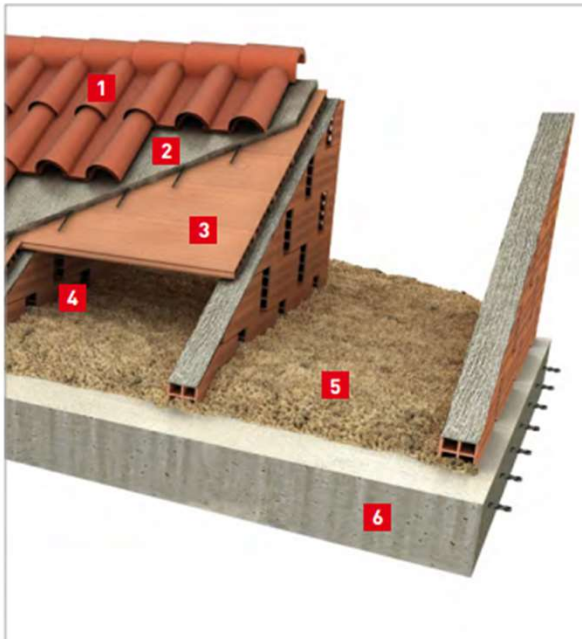


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Thermal insulation



Roof insulation



80mm insulation on the slab of a tilt roof



40mm insulation with finishing on a flat roof

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Thermal insulation

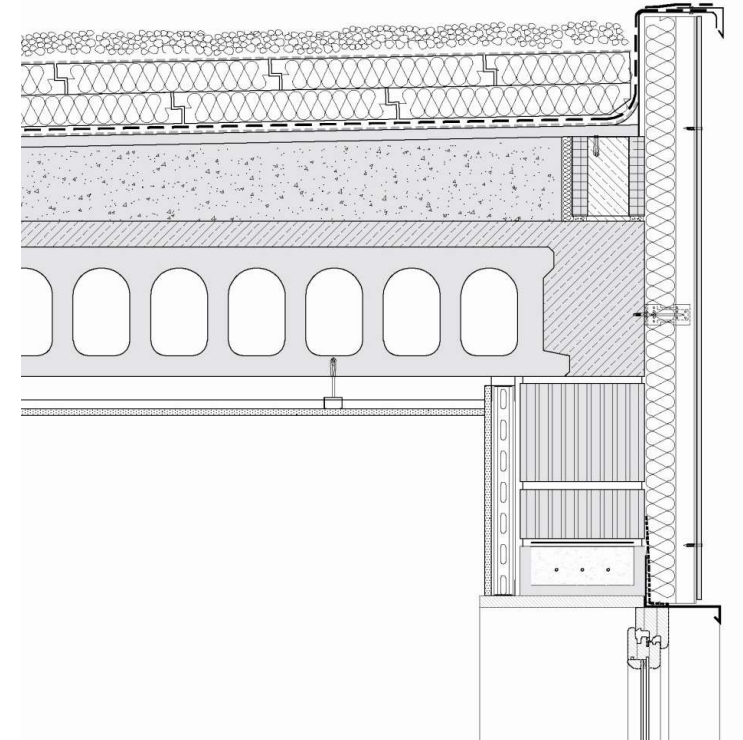


Roof refurbishment

Inaccessible inverted roof

- Recycled gravel, 60 mm
- Geotextil felt
- Extruded polystyrene, XPS, 120 mm
- Geotextil felt
- Waterproofing EPDM
- Cement mortar 20 mm
- Slope mortar, 80 mm (average)
- Structural slab
- Interior finishing

Thermal characteristics: $0,26 \text{ W/m}^2\text{K}$



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Thermal insulation



Window substitution

Combines improved thermal insulation with air tightness



Glazing characteristics

Thermal transmittance

Simple	6.0 W/m ² ·K
Double	3.0 W/m ² ·K
Low emission	1.5 W/m ² ·K
Low emission + argon	1.1 W/m ² ·K



Wooden frames or metal with thermal bridge break !



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Thermal insulation



Passivhaus-Standard - Components

Windows with triple glazing and thermal bridge break in wood



Location of the window in the insulation layer of the wall !



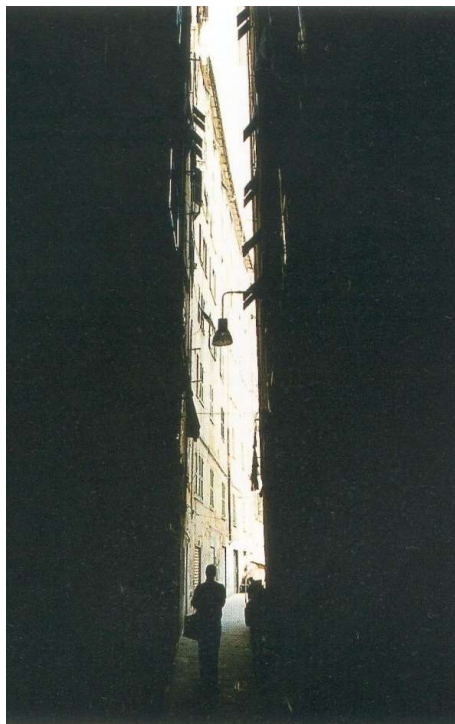
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Solar control



Shading of urban space by density or stores



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Solar control



Shading of public space by vegetation –
Beja - Tunisia



Shading by wooden canopies or marquisades

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Solar control



Madrid - Spain



Sidi Bou Said - Tunisia



Corte, Corse - France

Shading of private space –horizontal or vertical



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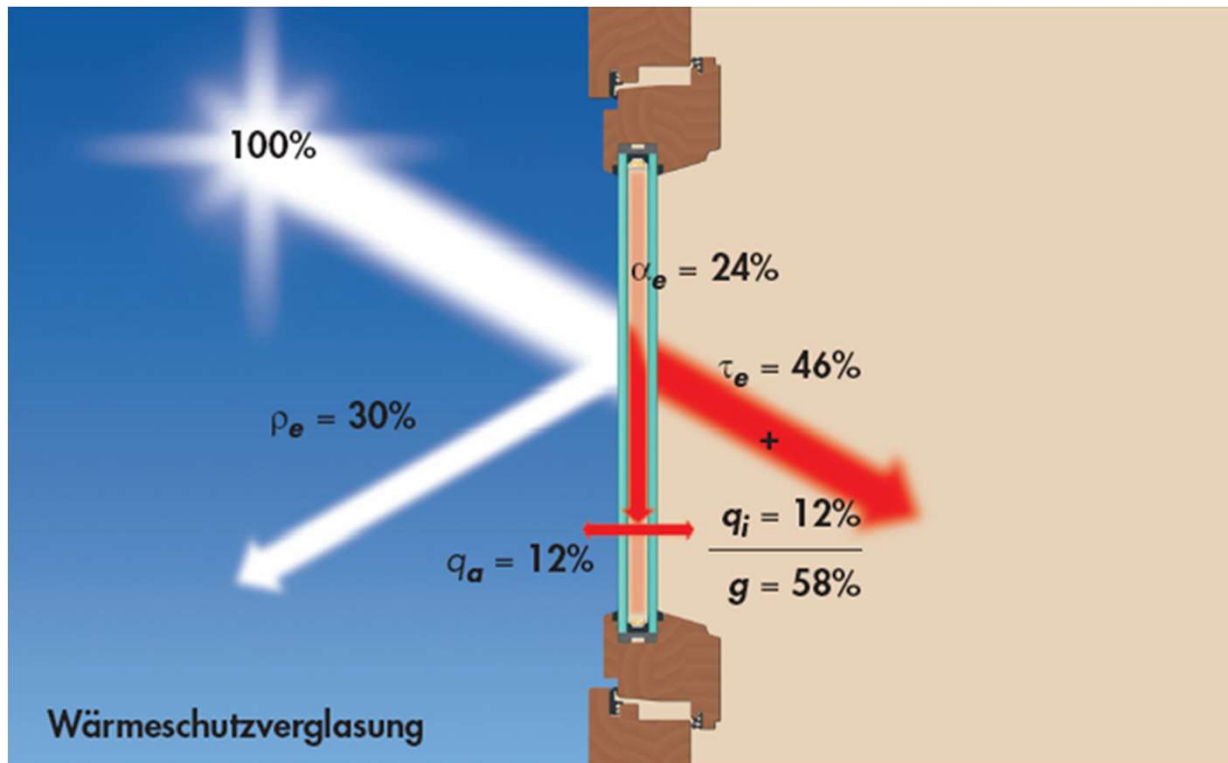


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Solar control



Solar radiation and glazing



Performance of double glazing regarding solar radiation

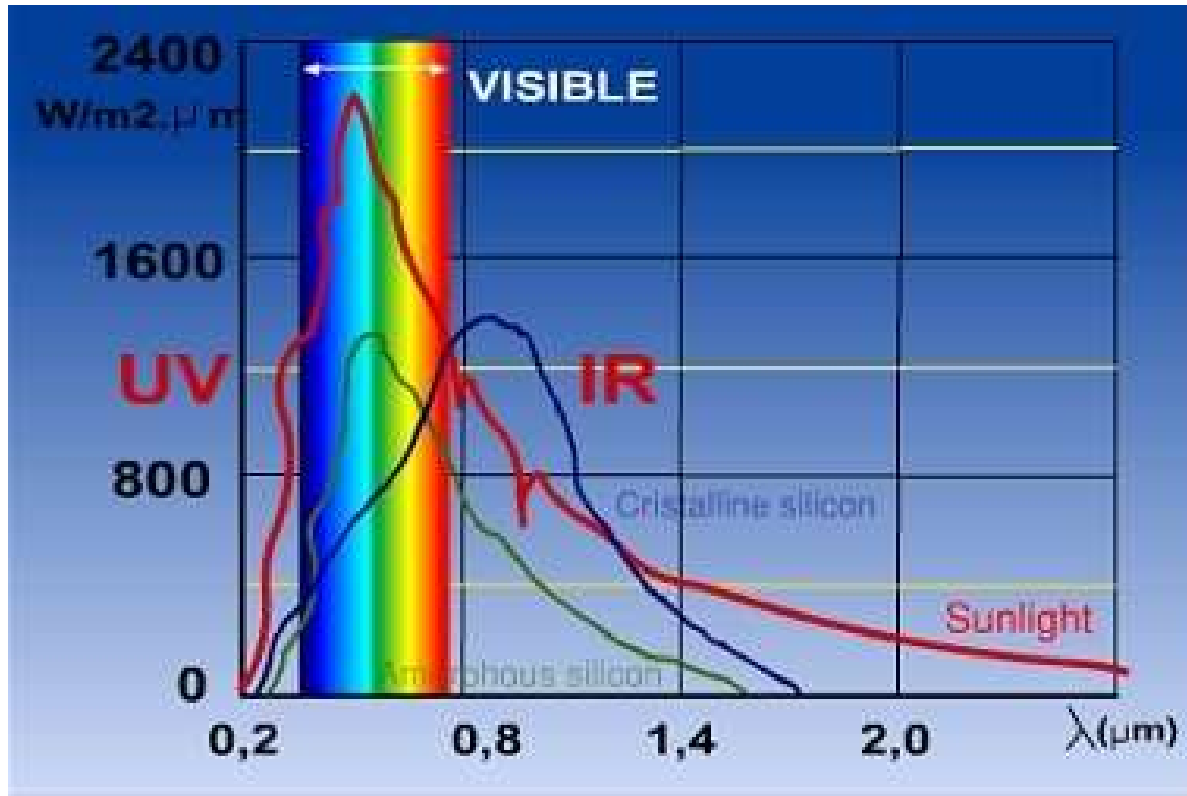


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Solar control



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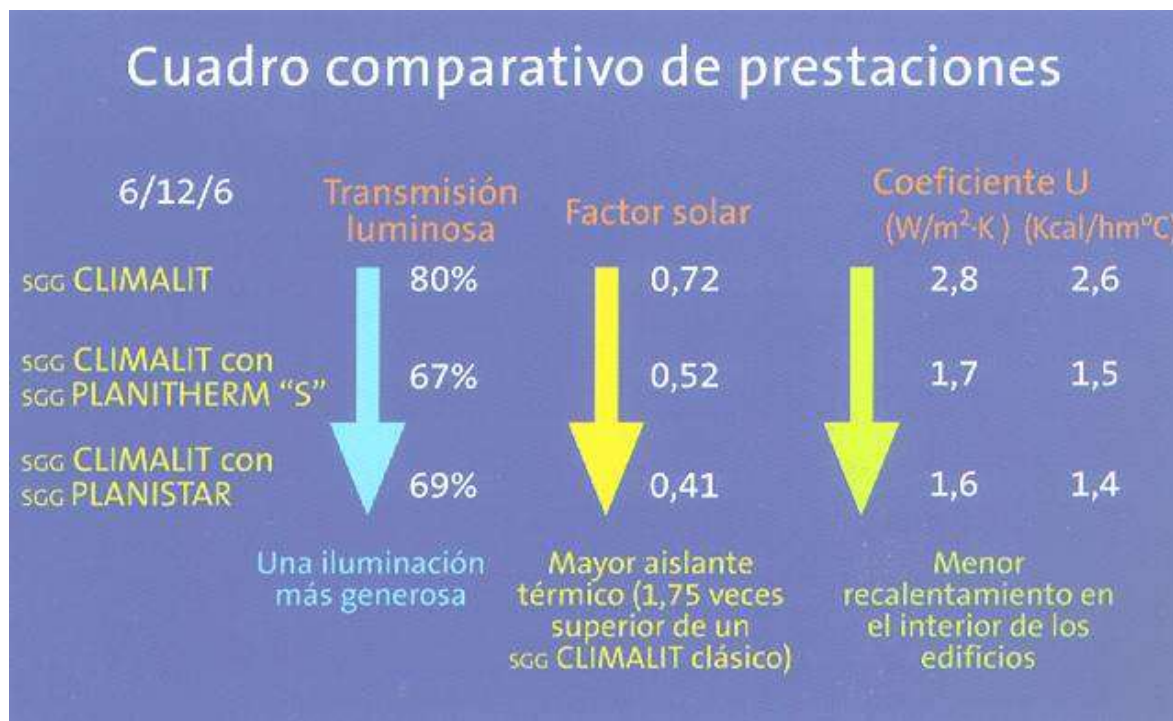
Solar control

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Glazing parameters

Low solar factor also has a low daylight factor, but



Source: La Veneciana de Saint Gobain

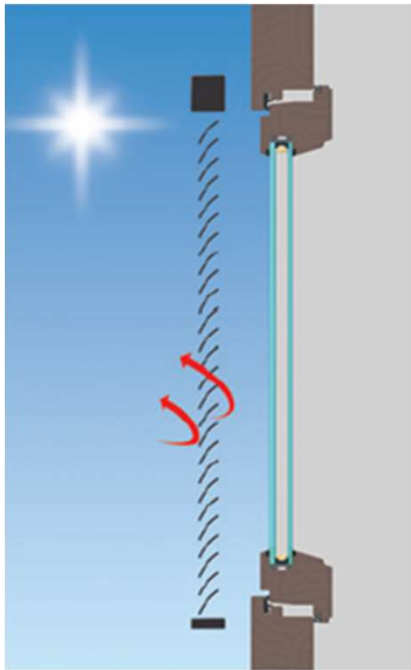


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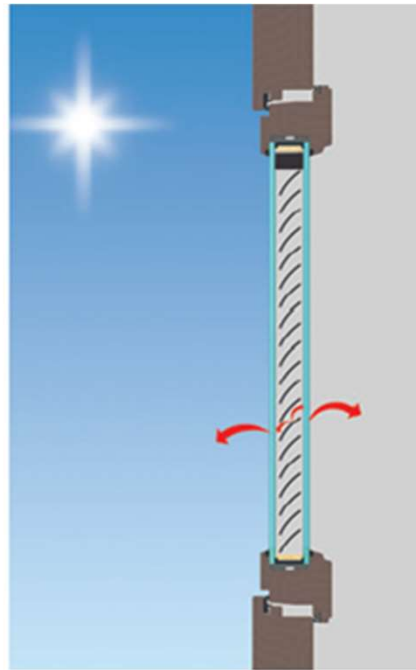
Solar control



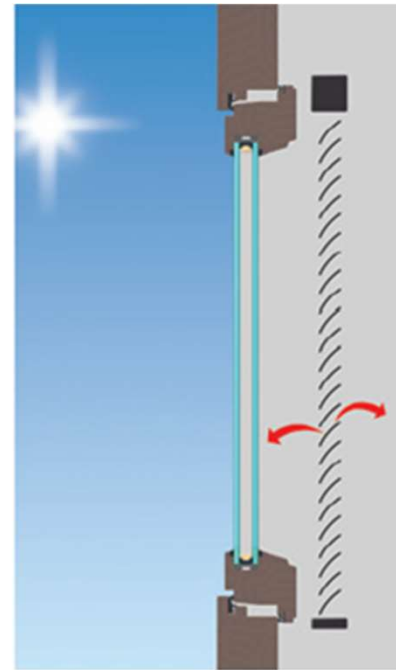
Location of the shading device: outside, inside, between glasses



$F_c = 0,09$



$F_c = 0,21$



$F_c = 0,6$

Source WAREMA Renkhoff GmbH

(the lower the F_c value, the higher the shading)



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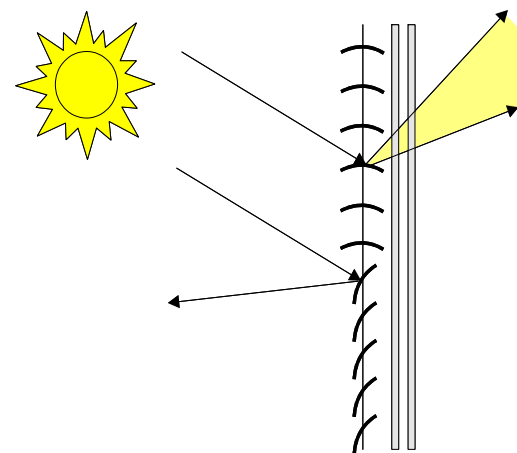


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Solar control – natural lighting



Natural lighting to the back of the room without glare



- Glare protection
- Natural light reflection
- Energy savings for lighting and cooling !

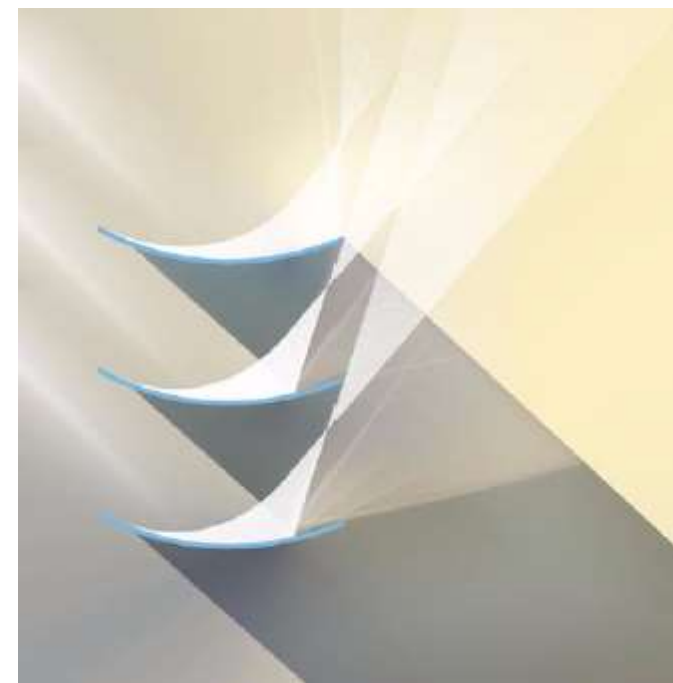


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Solar control – natural lighting



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Ventilation

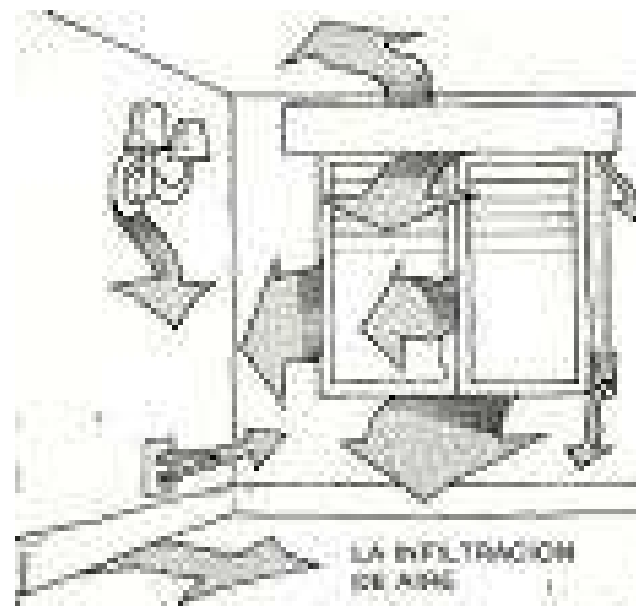


Objectives

- guarantee an excellent indoor air quality for the well being of the occupants (CO₂ concentration, emissions, odeurs).
- Minimize heat gains in summer and heat losses in winter through air exchange.



In seasons when the inside temperature is inferior to the outside temperature or in hot seasons, minimize the air exchange to the hygienically required: **25 m³/pers·h.**



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Ventilation



IT 1.1.4 Caracterització i quantificació de les exigències

Categoria	Qualitat	Aplicacions
IDA 1	òptima	Hospitals, laboratoris, guarderies etc.
IDA 2	Bona	Oficines, residències, aules etc.
IDA 3	Mitja	Edificis comercials, cinemes, restaurants, gimnassos etc.

Classificació de l'aire interior

Categoria	dm ³ /s per persona	Decipols (dp)	Concentració CO ₂ (en ppm*)
IDA 1	20 (72 m ³ /h)	0.8	350
IDA 2	12.5 (45 m ³ /h)	1.2	500
IDA 3	8 (29 m ³ /h)	2.0	800



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Ventilation



Ventilation versus air tightness

Part of the renovation is provided by infiltrations through the skin of the building, mainly carpentry, but in an uncontrolled manner, with significant side effects such as annoying airflows and energy losses in case of more ventilation than hygienically necessary.

In order to be able to control the ventilation, the infiltrations are limited by means of a hermetically sealed skin of the building, providing controlled openings, with mechanisms to close in cases of high wind, located in areas of greater occupation.



Infiltration control by “Blower-Door-Test”.





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Ventilation



Blower door tests at the LIMA prototype Low Impact Mediterranean Architecture

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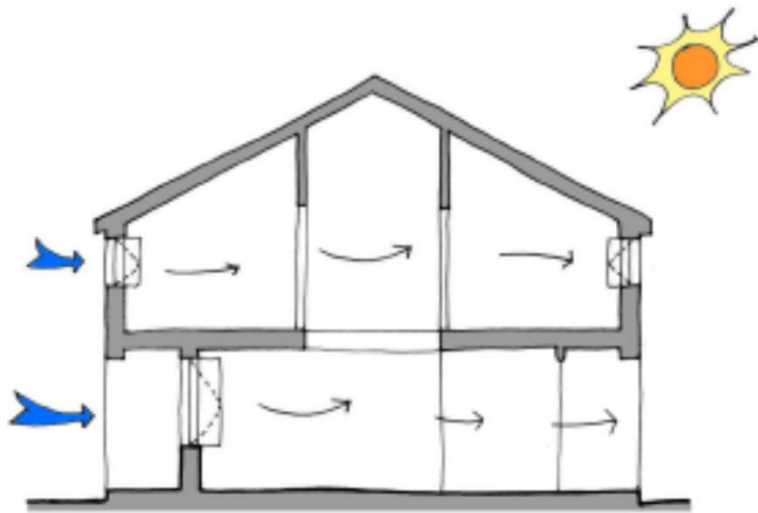


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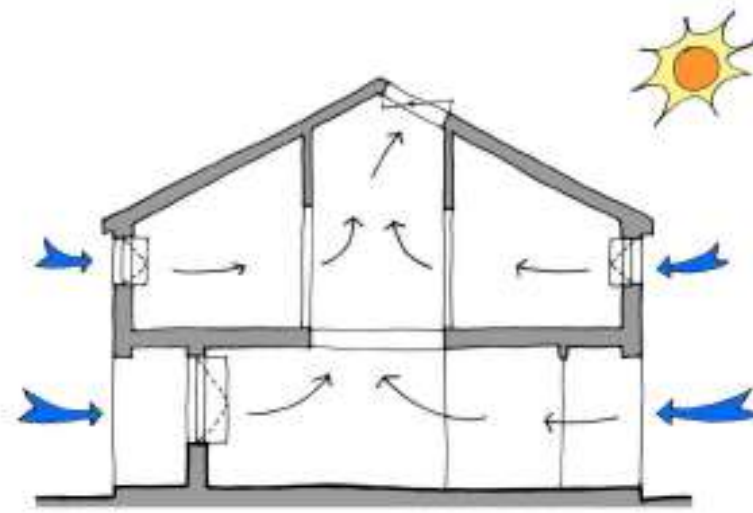
Ventilation



Ventilation versus air tightness



Cross - ventilation



Ventilation by atriums



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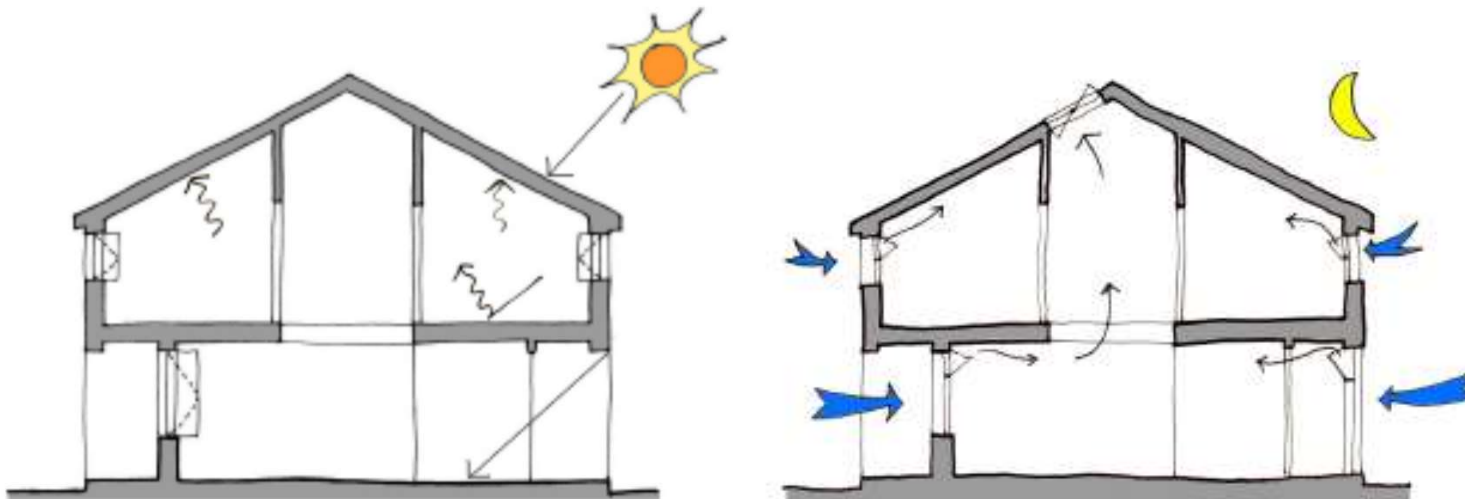


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Ventilation



Night ventilation



High air Exchange ratio at night in climates with important day-night temperature oscillation (continental climates).



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Ventilation

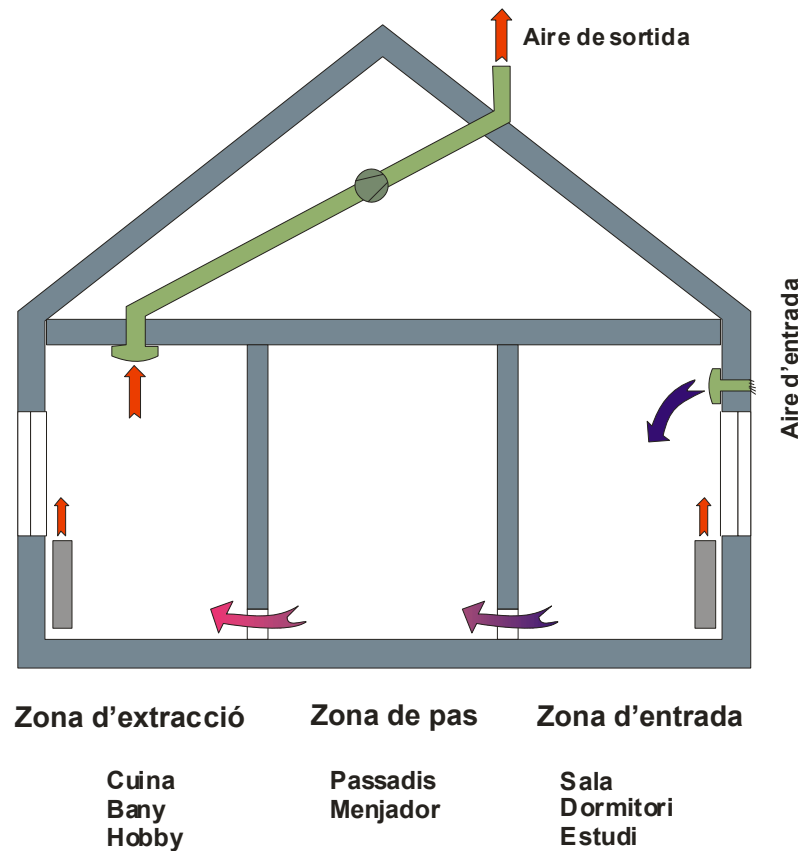


Ventilation versus air tightness

Mechanical ventilation

A low consumption ventilator creates a constant underpressure in the Building.

Differentiation in spaces for retrieving exhaust air (bathroom, kitchen) and for providing supply air (bedroom, living room).



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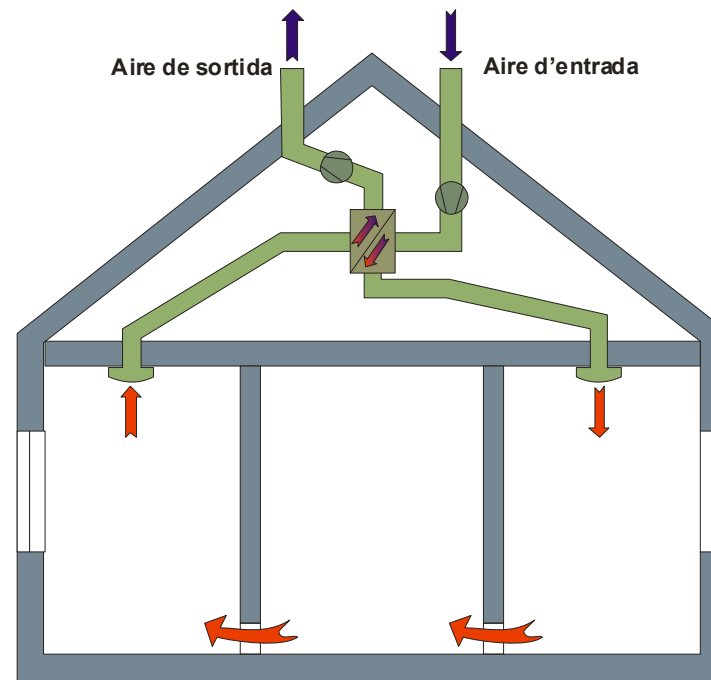
Ventilation



Mechanical ventilation with heat recovery

Mechanical ventilation System recovering up to 90% of the energy contained in the exhaust air warming up the supply air.

Double conduits with certainly difficult implementation in Building renovation.



Zona d'extacció	Zona de pas	Zona d'entrada
Cuina Bany Hobby	Passadis Menjador	Sala Dormitori Estudi





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Ventilation



Mechanical ventilation with heat recovery



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Ventilation

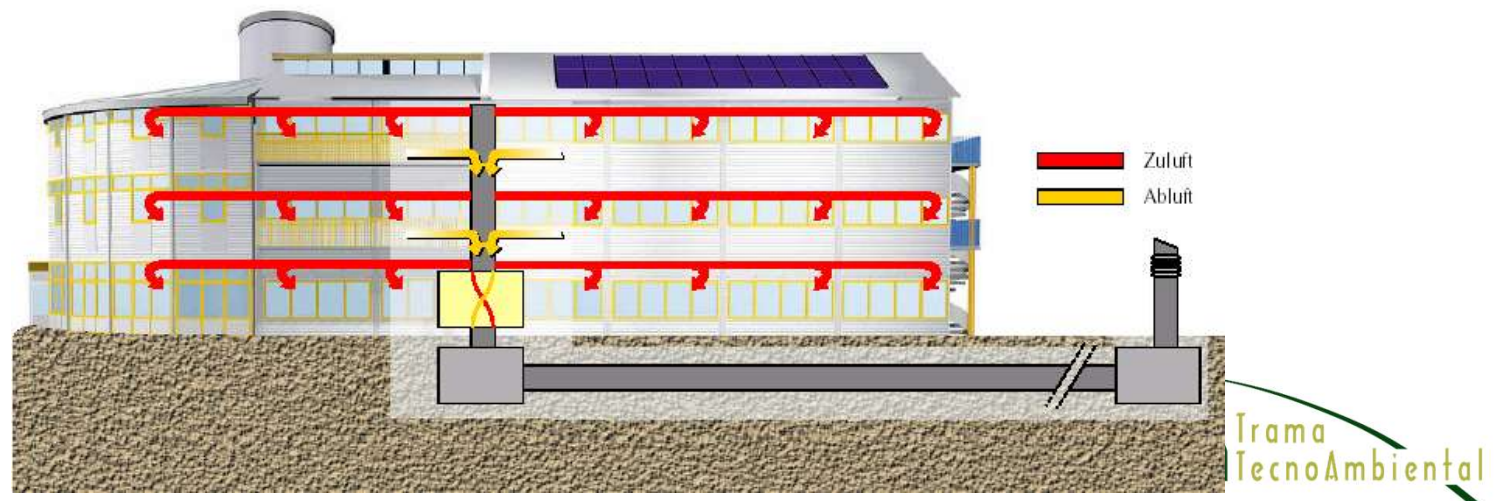


Mechanical ventilation with underground heat exchange

Taking advantage of the thermal inertia of the ground from a certain depth onwards. Supply air is captured away from the Building and conducted through conduits getting closer to comfort temperature.

Cooling in hot season.

Heating in cold season.



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Thank you for your attention !



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Thermal retrofit

Retrofit design

Arch. Christoph Peters

Head of Technical and Construction Department, TTA

Technical Workshop on Sustainable Energy, Beirut, 06/11/2021

Retrofit design

1. **Basic calculations and paràmetres**
2. **Example 1 – only envelope retrofit**
3. **Example 2 – nZEB deep renovation**
4. **Example 3 – envelope versus RES**
5. **Conclusions**



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Retrofit design



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- 1. Basic calculations and parameters**
2. Example 1 – only envelope retrofit
3. Example 2 – nZEB deep renovation
4. Example 3 – envelope versus RES
5. Conclusions



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Steps to define the proper energy renovation measures

- ➔ **Characterization of the energy consumption of heating and cooling to achieve thermal comfort / and compare with invoices.**
 - Climate conditions
 - Building envelope components
 - HVAC systems

- ➔ **Definition of the target to be achieved (beyond legislation)
Dynamic simulation of different improvement measures and determination of the energy and environmental savings**
 - Building envelope
 - HVAC systems
 - Renewable Energy integration

- ➔ **Determination of the investment cost to achieve the energy improvements and calculation of the economic amortization period (Cost-Benefit-Analysis)**





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Calculation methods

- sheet of paper (xls)
- Thermal simulation tools
 - National / Regional Certification tools
 - Energy Plus (Design Builder interface)
 - Ecotect
 - Etc.

Certification methodologies

- LEED / BREEAM / ETC.



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The difference between standards and certifications

Standards: PASSIVHAUS or MINERGIE

- you get it or not



MINER*G*IE-ECO®

Certifications: LEED, BREEAM, VERDE, DGNB

- You achieve a certain level: silver, gold, platinum, or similar



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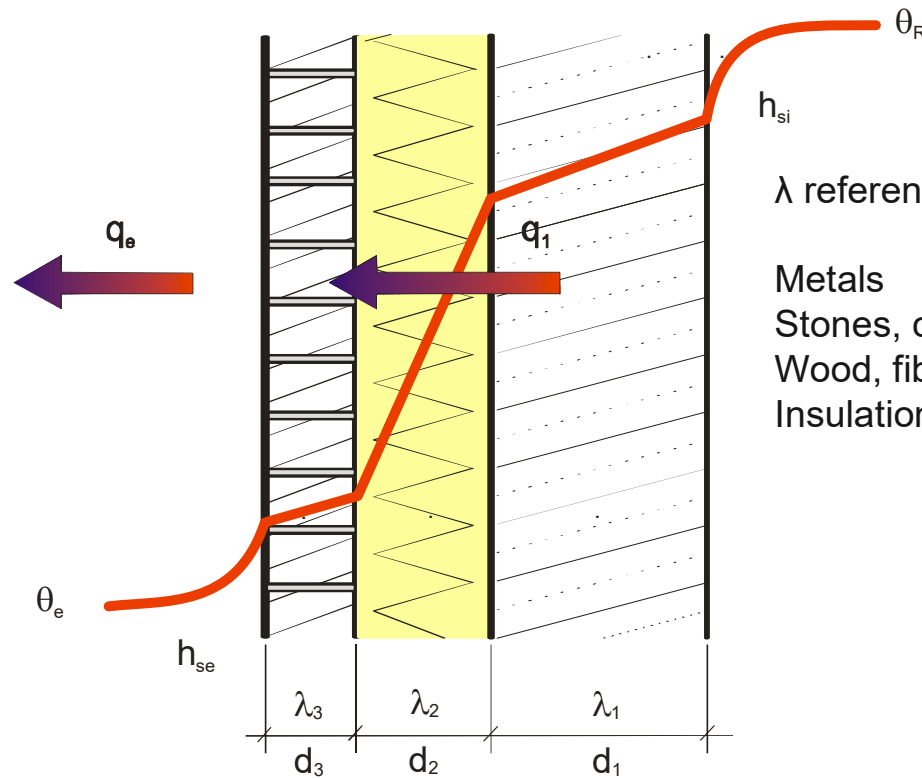
Energy flux through an opaque building component

$$Q = U \cdot A \cdot \Delta T [W]$$

$$U = \frac{1}{R_T} = \frac{\lambda}{e} \left[\frac{W}{m^2 \cdot K} \right]$$

$$R = \frac{e}{\lambda} \left[\frac{m}{W / mK} \right] \left[\frac{m^2 K}{W} \right]$$

- Q: energy
- U: thermal transmittance
- A: Surface
- T: Temperature
- R: thermal resistance
- λ : heat transfer coefficient
- e: thickness



λ reference values:

Metals	> 50
Stones, concrete, bricks	1-10
Wood, fibres...	0'1-0'5
Insulation material	<0'05



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Limits of thermal transmittance according to Spanish Building Code, 2019

Element	Zone A	Zone B	Zone C	Zone D	Zone E
Façades	0,70	0,56	0,49	0,41	0,37
Roofs	0,50	0,44	0,40	0,35	0,33
Windows	2,7	2,3	2,1	1,8	1,8

U (W / m²·K)



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Limits of thermal transmittance according to RoL / UNDP / GEF publication, 2005

:: Table 2 - Reference Thermal Transmittance Values per Component

Climatic Zone	Building Category	Maximum U-value ¹ (W/m ² .K)				
		Roof	Wall	Vertical Glazing ²	Skylight ²	Exposed Floor ³
Zone 1: Coastal	1	0.57	2.10	6.2	4.3	2.60
	2	0.57	2.10	6.2	4.3	2.60
Zone 2: Western Mid-mountain	1	0.57	0.77	4.3	4.3	0.76
	2	0.57	0.77	4.3	4.3	0.76
Zone 3: Inland Plateau	1	0.57	0.77	4.3	4.3	0.66
	2	0.57	0.77	4.3	4.3	0.66
Zone 4: High Mountain	1	0.44	0.55	2.8	2.8	0.55
	2	0.44	0.55	2.8	2.8	0.55

THERMAL STANDARD FOR BUILDINGS IN LEBANON 2005



Republic of Lebanon
Ministry of Public Works and Transport
General Directorate of Urban Planning



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Calculation methods: simple xls file

Façade (opaque)	Thickness (e) (m)	Density (kg/m ³)	Lambda (λ) (W/m·K)	Resistènce (K·m ² /W)	U lím Climate zone
Outside air resistance				0,040	
Exterior insulation					
Mortar	0,018	1500	0,800	0,023	
Perforated brick	0,140	900	0,540	0,259	
Non ventilated air gap	0,040	—	—	0,180	
Light brick	0,040	1000	0,444	0,090	
Gypsum mortar	0,012	1200	0,570	0,021	
Inside air resistance				0,130	
TOTAL (Rt)	0,25 m			,74 K·m ² /W	
				U = 1,35 W/m²·K	C2
				U(+P.T.)= 1,68 W/m²·K	0.73 W/m²·K

Good for rough estimation and to understand the basics



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Calculation methods: simple xls file

Façade (opaque)	Thickness (e) (m)	Density (kg/m ³)	Lambda (λ) (W/m·K)	Resistènce (K·m ² /W)	U lím Climate zone
Outside air resistance				0,040	
Exterior insulation	0,04		0,040	1,000	
Mortar	0,018	1500	0,800	0,023	
Perforated brick	0,140	900	0,540	0,259	
Non ventilated air gap	0,040	—	—	0,180	
Light brick	0,040	1000	0,444	0,090	
Gypsum mortar	0,012	1200	0,570	0,021	
Inside air resistance				0,130	
TOTAL (Rt)	0,25 m			1,74 K·m²/W	
			U =	0,57 W/m²·K	C2
			U(+P.T.)=	0,72 W/m²·K	0.73 W/m²·K

Good for rough estimation and to understand the basics





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Calculation methods: simple xls file

Façade (opaque)	Thickness (e) (m)	Density (kg/m ³)	Lambda (λ) (W/m·K)	Resistènce (K·m ² /W)	U lím Climate zone
Outside air resistance				0,040	
Exterior insulation	0,08		0,040	2,000	
Mortar	0,018	1500	0,800	0,023	
Perforated brick	0,140	900	0,540	0,259	
Non ventilated air gap	0,040	—	—	0,180	
Light brick	0,040	1000	0,444	0,090	
Gypsum mortar	0,012	1200	0,570	0,021	
Inside air resistance				0,130	
TOTAL (Rt)	0,25 m			2,74 K·m ² /W	
			U =	0,36 W/m ² ·K	C2
			U(+P.T.)=	0,46 W/m ² ·K	0.49 W/m ² ·K

Good for rough estimation and to understand the basics



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Example 1 – social housing block

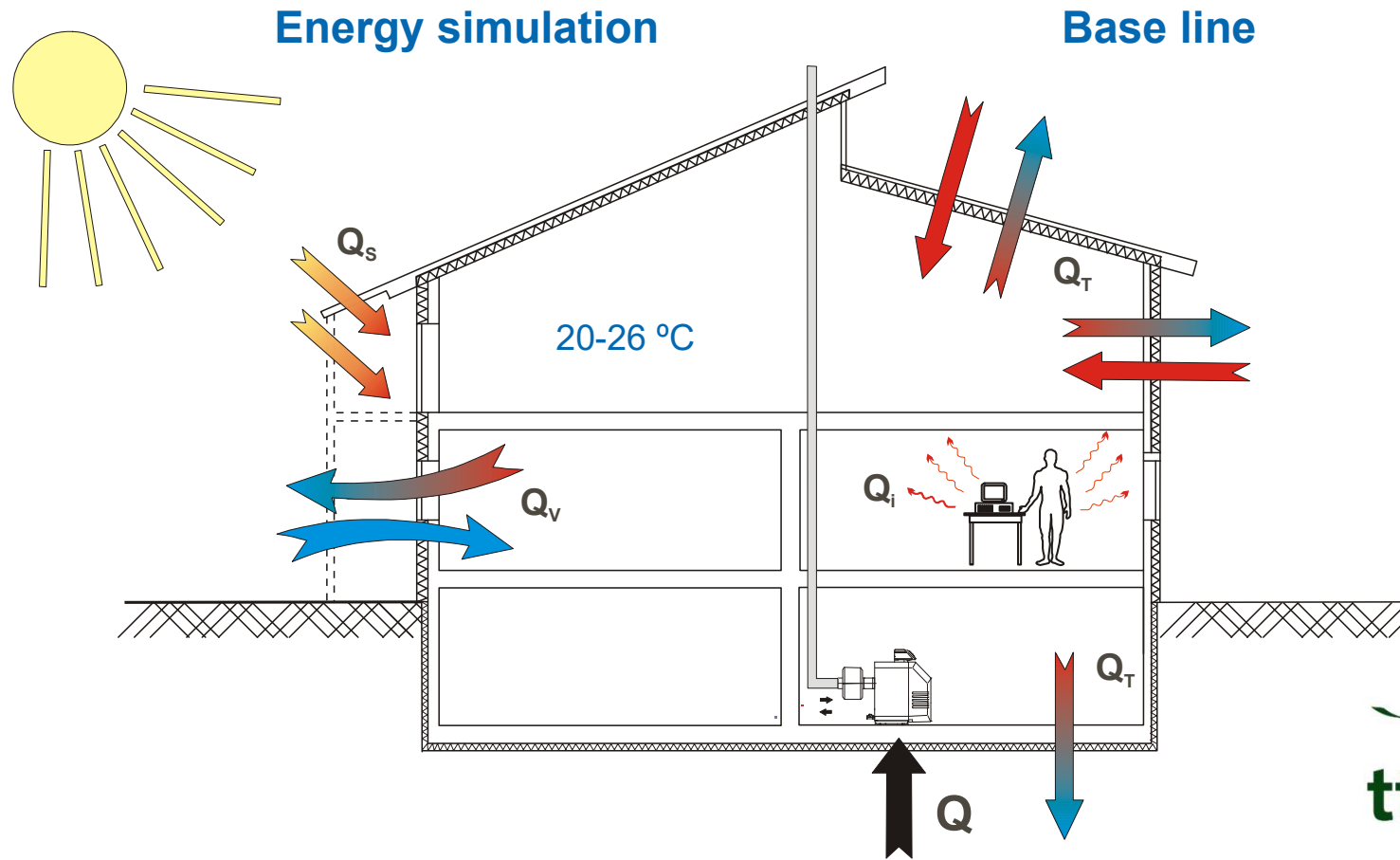


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Example 1 - parameters

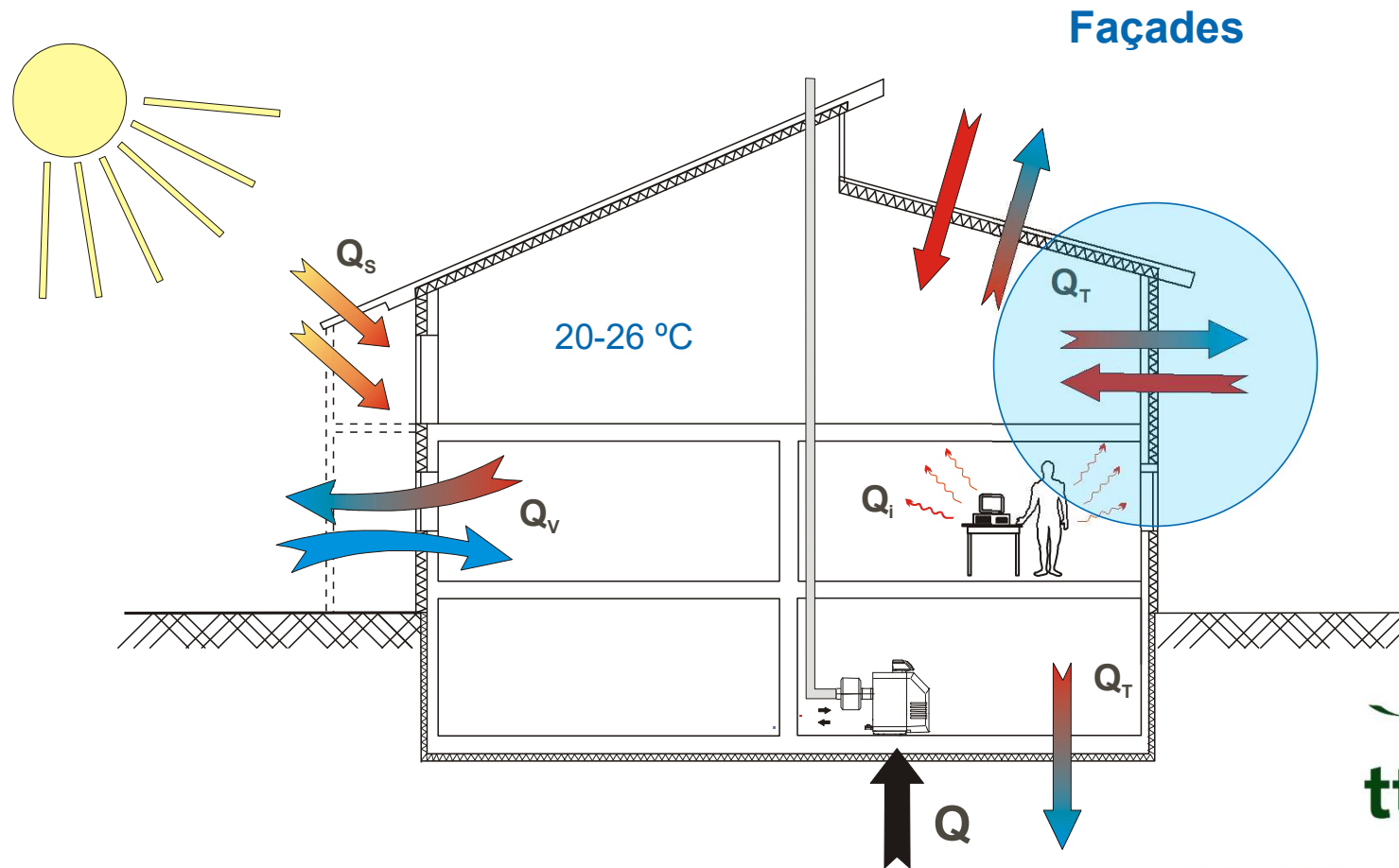


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Example 1 - parameters



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Example 1 - parameters



Façade

- Perforated brick, 140 mm
- Not ventilated air gap, 50 mm
- Light brick, 90 mm
- Gypsum plaster, 12 mm

Thermal characteristics

1.15 W/m²K

Façade below windows

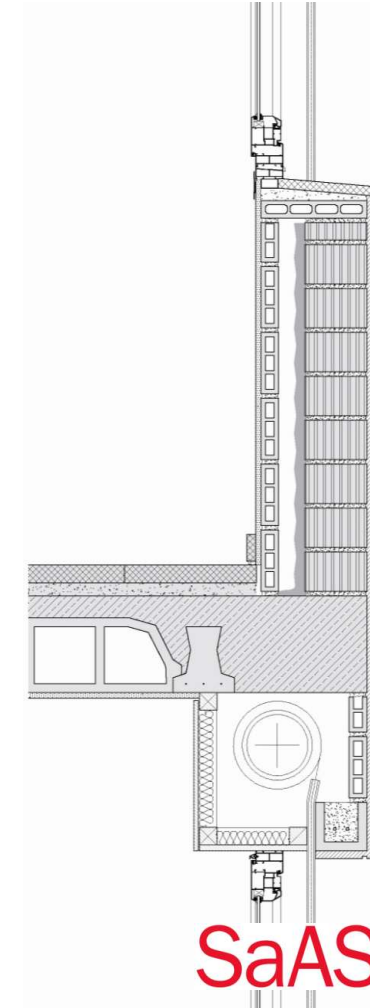
- Cement plaster, 15 mm
- Light brick, 90 mm
- Not ventilated air gap, 50 mm
- fàbrica de maó foradat, 90 mm
- emblanquinat de guix, 12 mm

1.22 W/m²K

Façana a brancals i cantonades i planta baixa sencera

- fàbrica de maó calat, 290 mm
- emblanquinat de guix, 12 mm

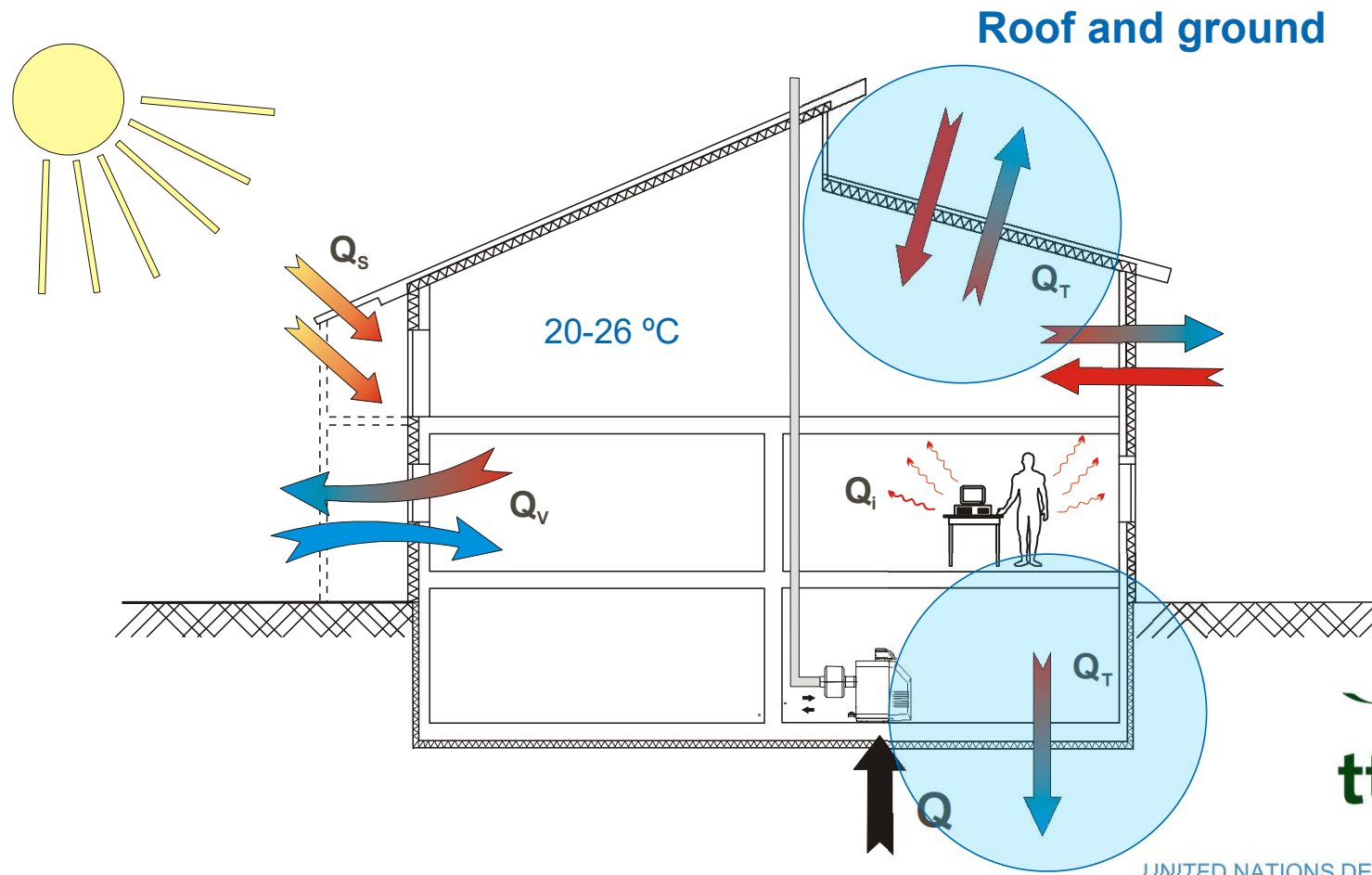
1.42 W/m²K





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Example 1 - parameters

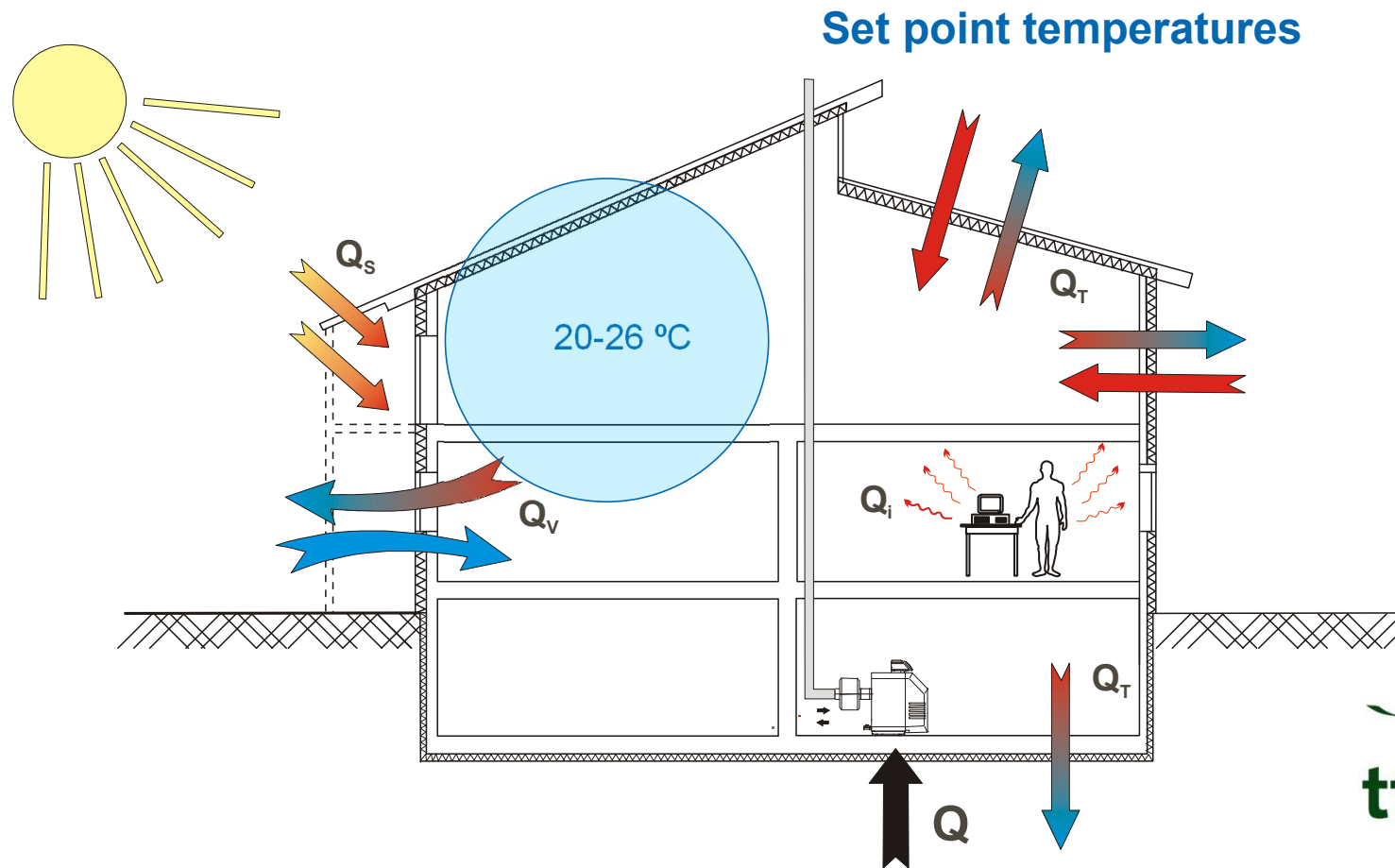


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Example 1 - parameters



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Example 1 - parameters



Set point temperatures

schedule 7	schedule 8
heating temperature	cooling temperature
habitatge	habitatge
T_calefaccion_vivienda	T_refrigeracion_vivienda
through 5/31 alldays until 07 = 17 until 23 = 20 until 24 = 17 through 9/30 alldays until 24 = 5	through 5/31 alldays until 24 = 28 through 9/30 alldays until 07 = 27 until 13 = 27 until 23 = 25 until 24 = 27
through 12/31 alldays until 07 = 17 until 23 = 20 until 24 = 17	through 12/31 alldays until 24 = 50



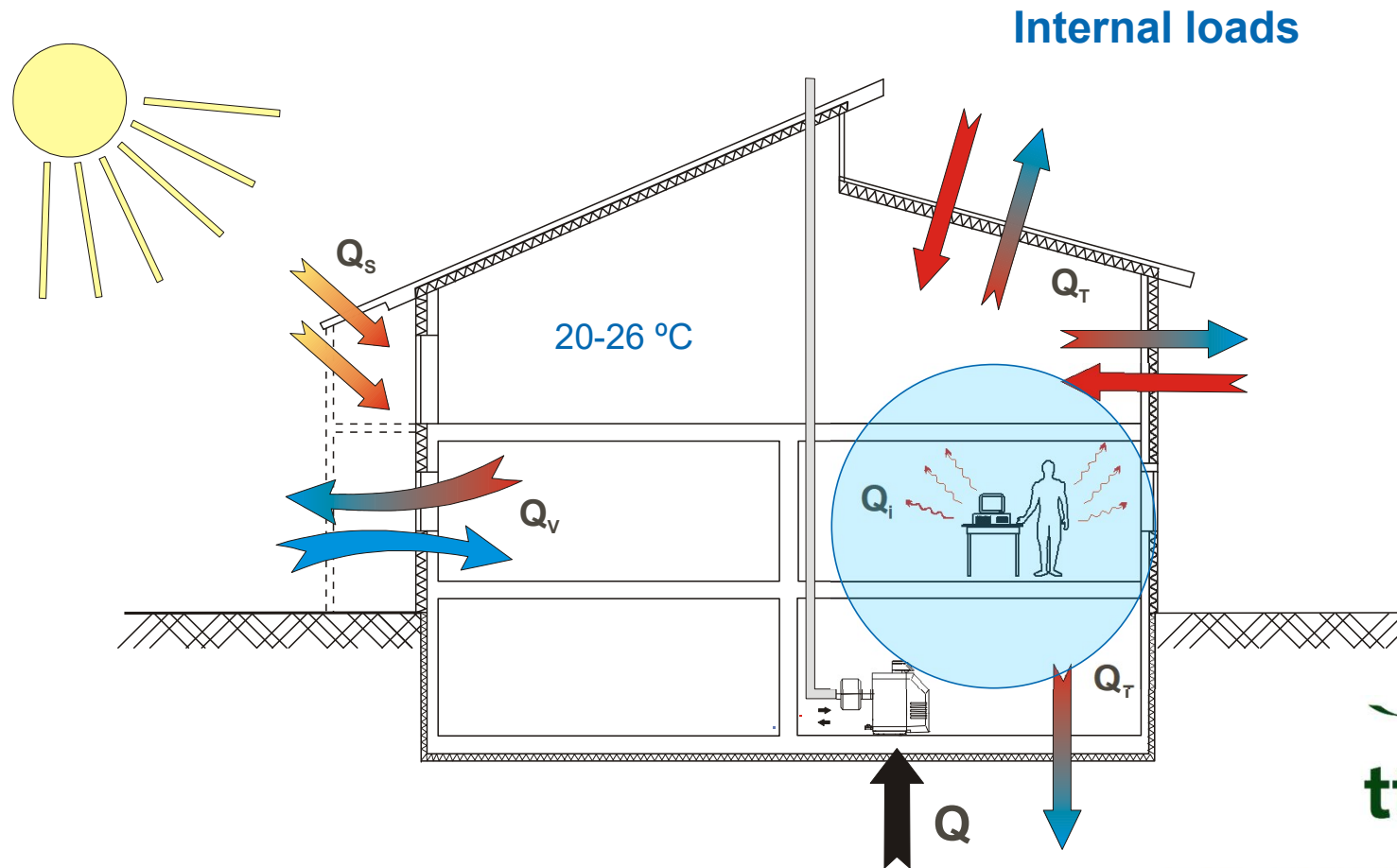
Changing, depending on the time of the day and season of the year





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Example 1 - parameters



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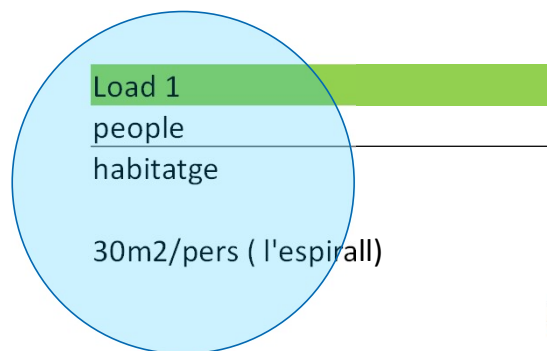


Example 1 - parameters

Internal heat

schedule 1	schedule 2	schedule 3	schedule 4
ocupació	people activity	lighting	electric equipment
habitatge	habitatge	habitatge	habitatge
ocup-vivi-fraccion	actividad personas	ilum-vivi-fraccion	equip-vivi-fraccion
through 12/31 weekdays	through 12/31 alldays	through 12/31 alldays	through 12/31 alldays
until 07 = 1	until 7 = 80	until 07 = 0.2	until 07 = 0.2
until 15 = 0.25	until 24 = 125	until 15 = 0.6	until 15 = 0.6
until 23 = 0.5		until 19 = 0.6	until 19 = 0.6
until 24 = 1		until 23 = 0.6	until 23 = 0.6
for AllOtherDays		until 24 = 1	until 24 = 1
until 24 = 1			

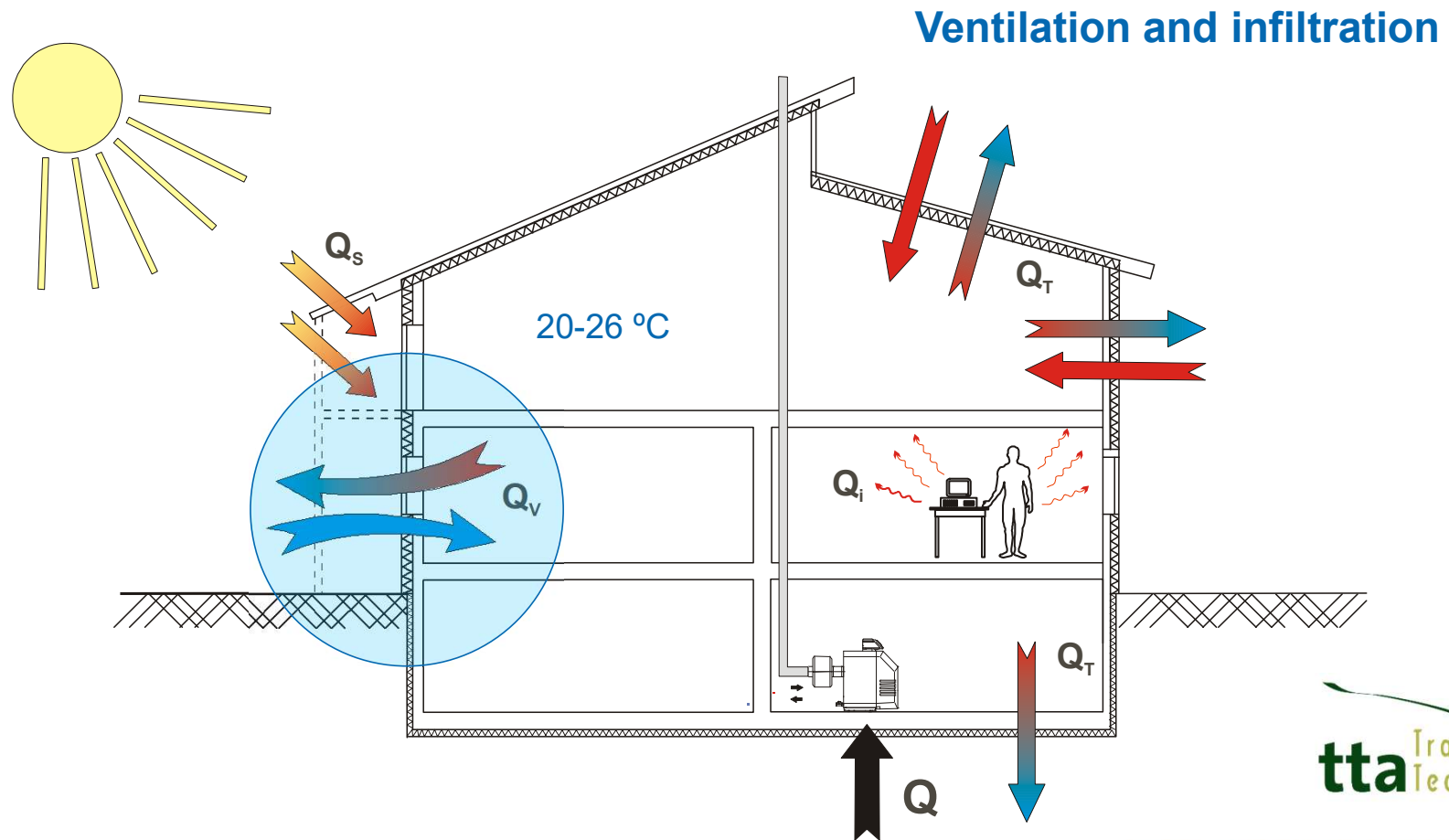
Occupancy according to dwellings and users





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Example 1 - parameters



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Example 1 - parameters

schedule 5

ventilacio

habitatge

ventilació

through 4/15

alldays

until 8 = 0

until 9 = 0.25

until 24 = 0

through 5/31

alldays

until 12 = 0

until 17 = 0.25

until 24 = 0

through 8/31

alldays

until 8 = 1

until 24 = 0

through 9/30

alldays

until 12 = 0

until 17 = 0.25

until 24 = 0

through 12/31

alldays

until 8 = 0

until 9 = 0.25

until 24 = 0

Load 5

ventilació

habitatge

zone ventilation

4 ach

schedule name

ventilacio

Load 6

infiltracions

habitatge

zone infiltration

0.5 ach

schedule name

siempre 1

0,5 ach per finestres

poc estanques

0,2 ach per finestres

estanques

Ventilation and infiltration

Night ventilation in hot season

Day ventilation in intermedium seasons

Mínimum ventilation in hot and cold season

Infiltrations according to airtightness of the windows

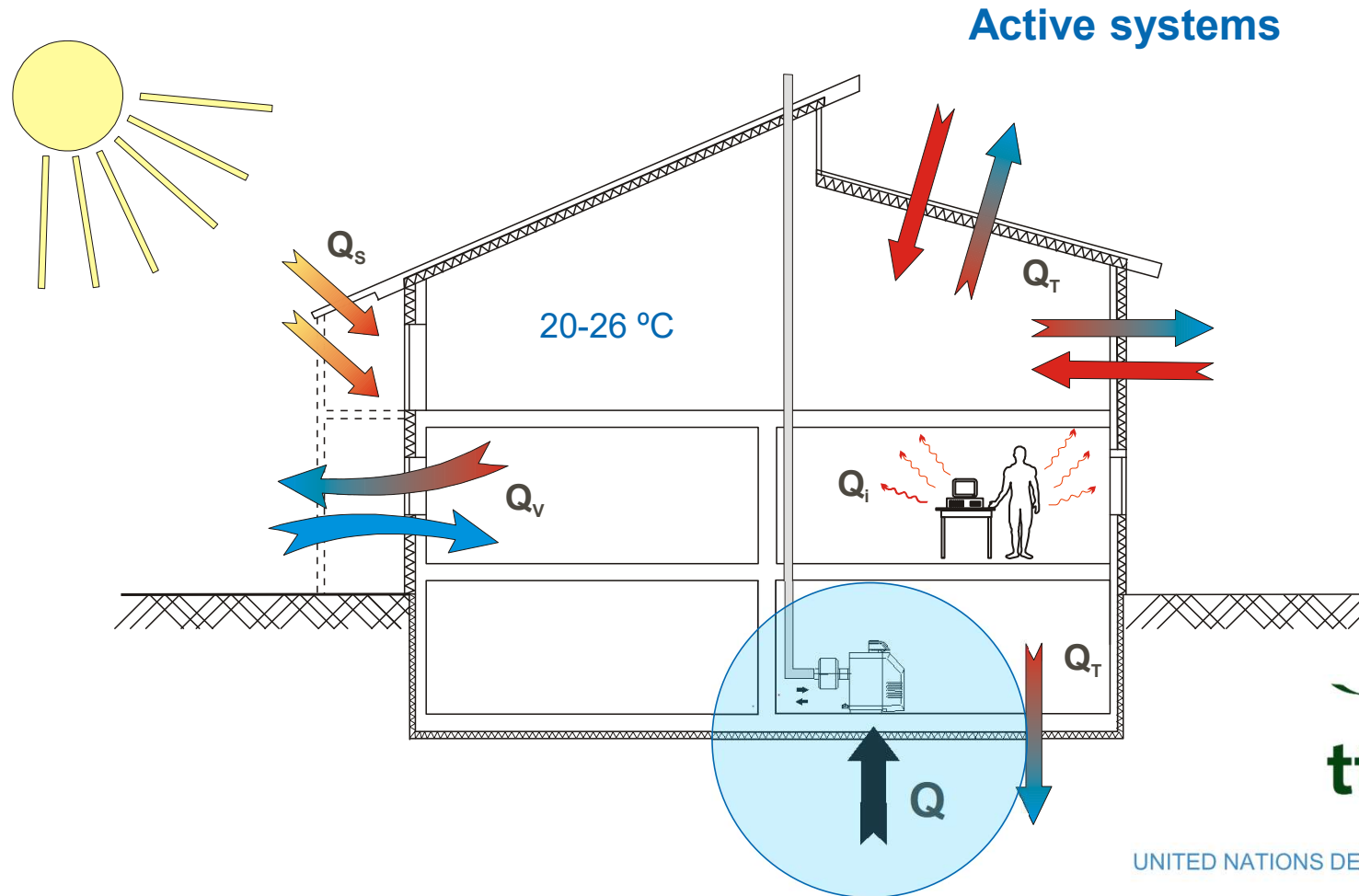


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Example 1 - parameters



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Example 1 - parameters



Active systems

use	energy source	distribution	performance	€/kWh
heating	gas	90 %	0.70	0.06
	electricity	10 %	0.90	0.13
cooling	electricity	100 %	0.98	0.13

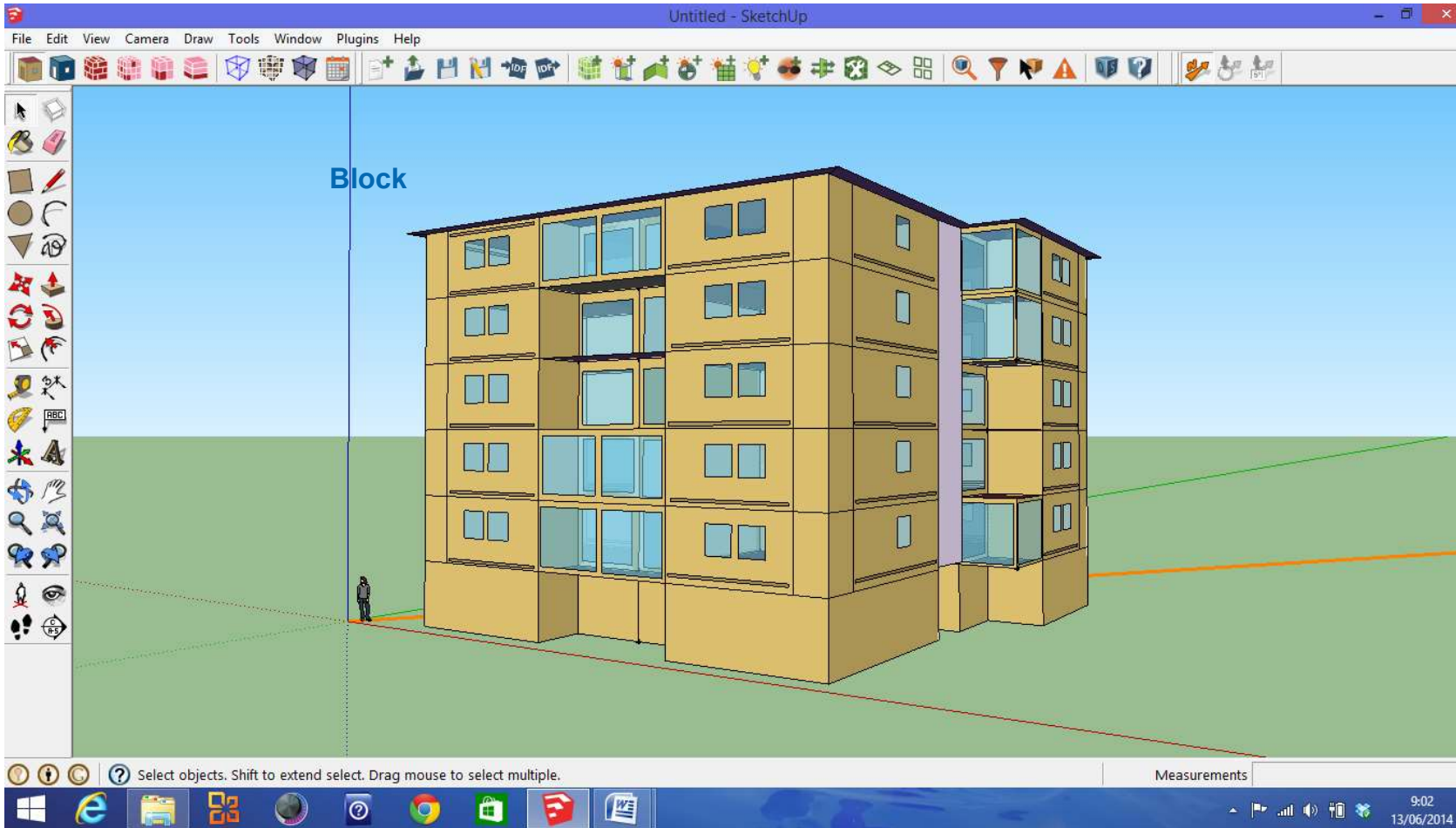


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Example 1 – thermal simulation



Type of surface

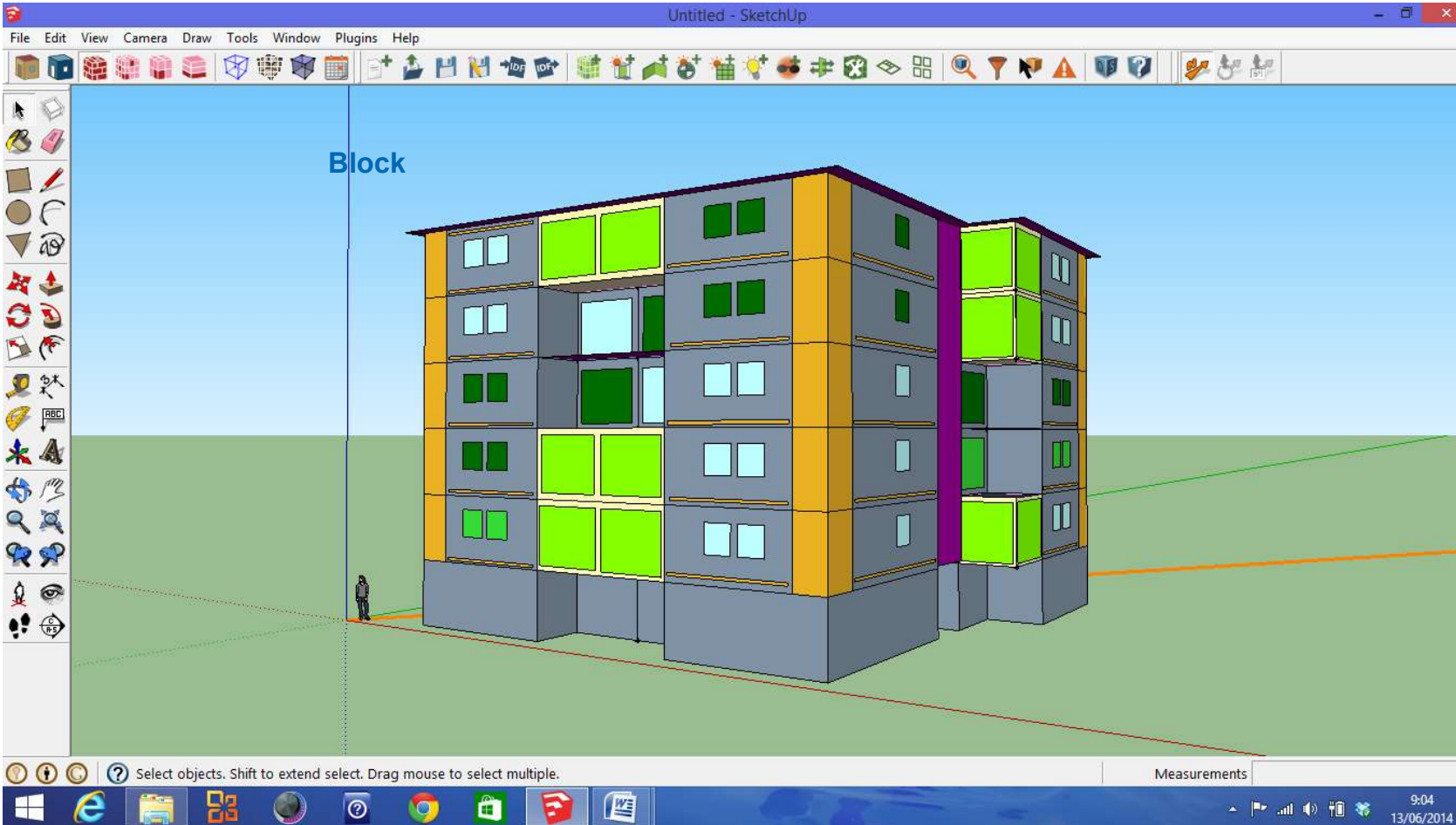


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Example 1 – thermal simulation



Materials

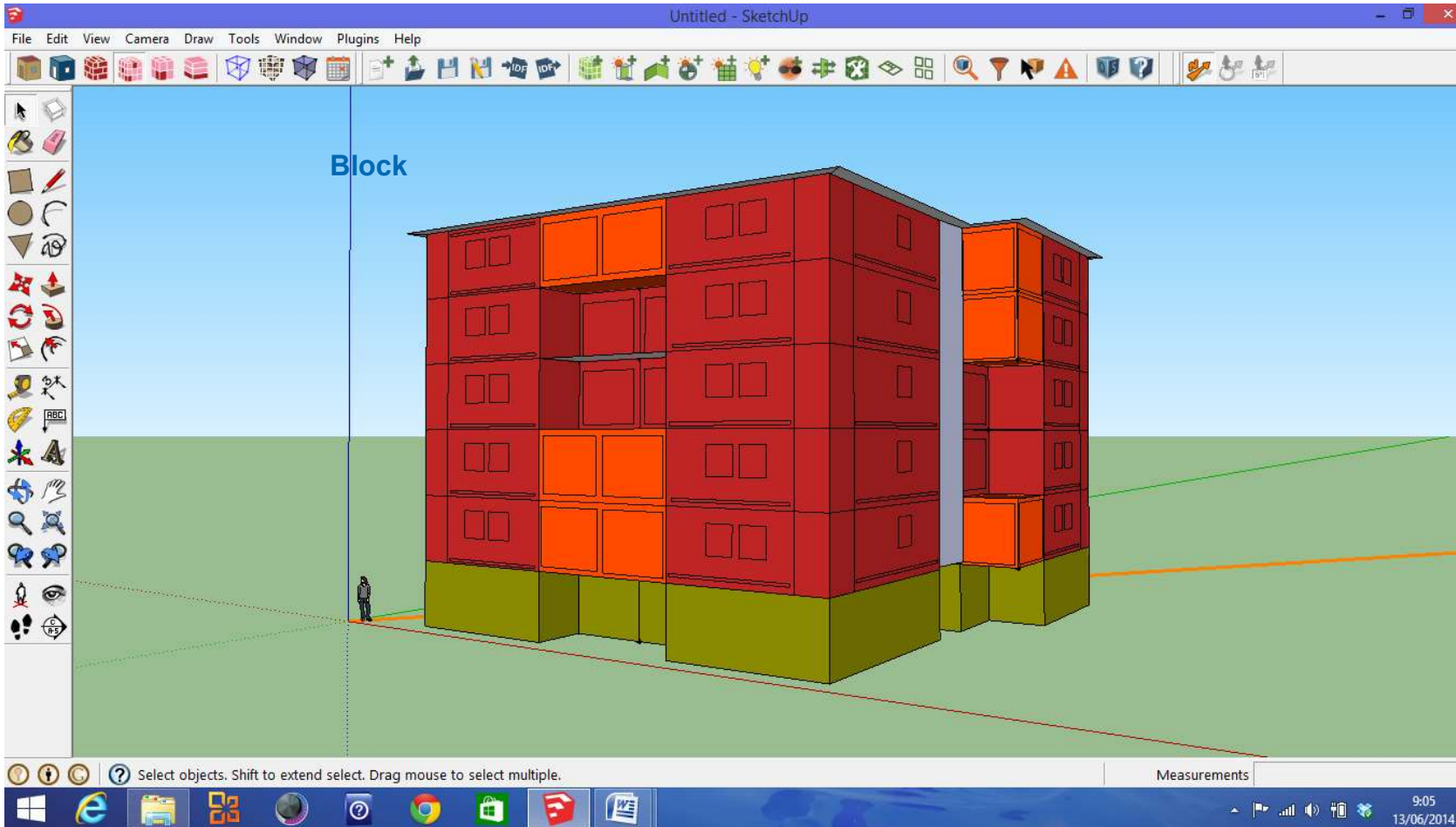


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Example 1 – thermal simulation



Type of space



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Example 1 – simulated measures



	Measure	Advantages	Disadvantages
M 1	Façade insulation from the inside	No neighborhood agreement needed	Inconveniences for users Space reduction Thermal bridges not improved
M 2	Façade insulation within the air gap	No neighborhood agreement needed Ease of implementation	Thermal bridges not improved Difficult quality control
M 3	Façade insulation from the outside	Thermal bridges solved	Neighborhood agreement needed Scaffold
M 4	Roof insulation	Easy implementation	Only for some dwellings of importance
M 5	Window substitution	Insulation and airtightness	Preferably with neighborhood agreement
C1	M 3 + 4 + 5	Deep renovation	





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Example 1 – simulation results



Bloc torre

Total edifici

Consum esp.	Consum total	Cost total	Emissions	Inversió	TIR (10a)	Estalvi 10a
Estalvi esp.	Estalvi total	Estalvi total	Reducció total	Payback	TIR (20a)	Estalvi 20a
kWh/m ² ·a	kWh/a	€/a	kgCO ₂ /a	€ - anys	%	€

Estat actual

Millores

63.3	68,920
------	--------

1.0 Aïllament de façana per l'interior

2.0 Aïllament de façana per la cambra

3.1 Aïllament de façana per l'exterior

3.2 Aïllament de façana per l'exterior +

4.0 Aïllament de la coberta

5.0 Substitució de finestres

C1 Renovació integral, façana per l'exterior

	Consum esp.	Consum total	Cost total	Emissions	Inversió	TIR (10a)	Estalvi 10a
	Estalvi esp.	Estalvi total	Estalvi total	Reducció total	Payback	TIR (20a)	Estalvi 20a
	kWh/m ² ·a	kWh/a	€/a	kgCO ₂ /a	€ - anys	%	€
	63.3	68,920					
1.0 Aïllament de façana per l'interior							
2.0 Aïllament de façana per la cambra	48.1	52,713	3,585.23	10,543	-19,404.00	-6.5%	10,976.55
	15.2	16,207	914.25	3,241	21.2	3.0%	27,224.53
3.1 Aïllament de façana per l'exterior	42.9	47,160	3,267.65	9,432	-68,040.72	#jNUM!	14,789.34
	20.4	21,760	1,231.82	4,352	55.2	-4.8%	36,681.19
3.2 Aïllament de façana per l'exterior +	37.6	41,539	2,957.52	8,308	-74,052.00	#jNUM!	18,512.88
	25.7	27,381	1,541.96	5,476	48.0	-3.8%	45,916.46
4.0 Aïllament de la coberta	59.9	65,314	4,307.48	13,063	-4,450.00	-7.7%	2,305.13
	3.4	3,606	192.00	721	23.2	2.2%	5,717.28
5.0 Substitució de finestres	44.2	48,456	3,284.86	9,691	-15,967.04	0.4%	14,582.74
	19.0	20,463	1,214.61	4,093	13.1	8.1%	36,168.76
C1 Renovació integral, façana per l'exterior	20.4	23,080	1,898.57	4,616	-125,585.12	#jNUM!	31,226.70
	42.9	45,840	2,600.90	9,168		-3.8%	77,449.86



S DEVELOPMENT PROGRAMME



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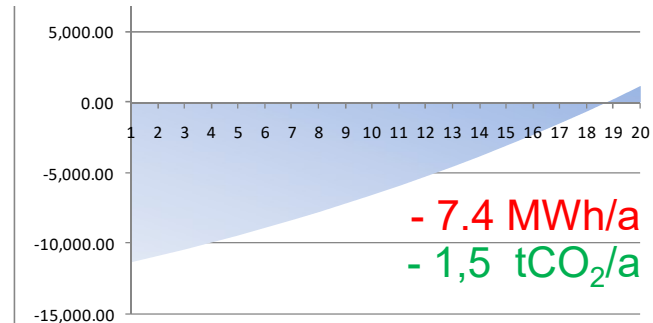


Example 1 – simulation results

M1. Interior façade insulation

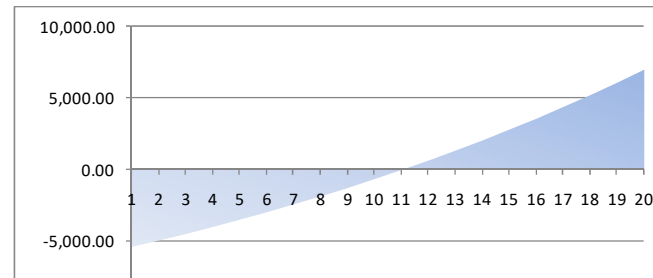
Savings: 22 %

Investment building: 11.750 €
 Investment dwelling: 1.468 €
 Pay-back: 18 years



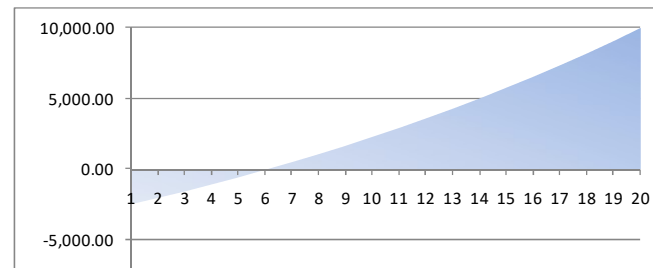
Subsidy 50%

Investment building: 5.870 €
 Investment dwelling: 734 €
 Pay-back: 11 years



Subsidy 75%

Investment building: 2.936 €
 Investment dwelling: 367 €
 Pay-back: 6 years





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Example 1 – simulation results

M2. Insulation of air gap

Savings: 16 %

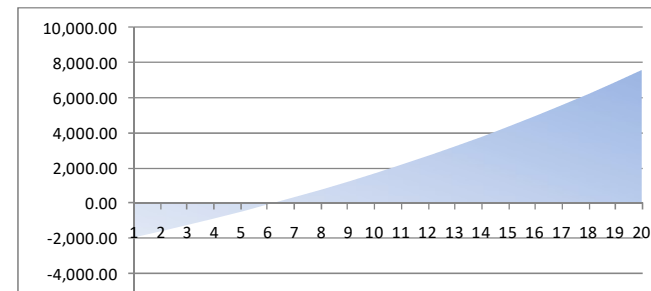
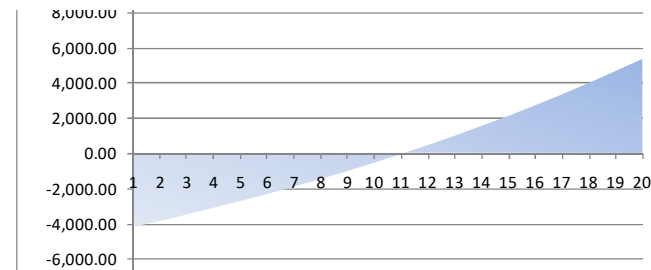
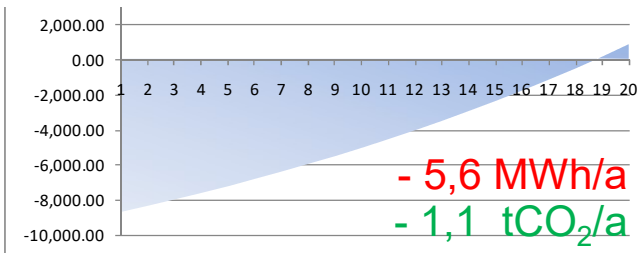
Inversió edifici: 9.000 €
 Inversió habitatge: 1.125 €
 Pay-back: 19 anys

Subvenció 50%

Inversió edifici: 4.500 €
 Inversió habitatge: 562 €
 Pay-back: 11 anys

Subvenció 75%

Inversió edifici: 2.250 €
 Inversió habitatge: 281 €
 Pay-back: 6 anys





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Example 1 – simulation results

M3.1. Exterior insulation

Savings: 25 %

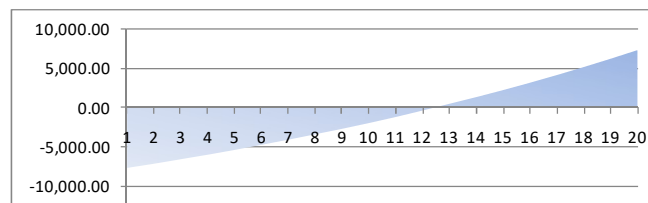
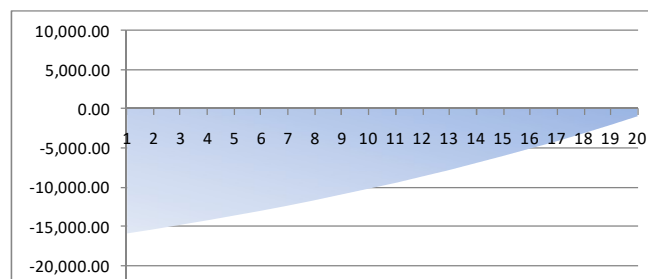
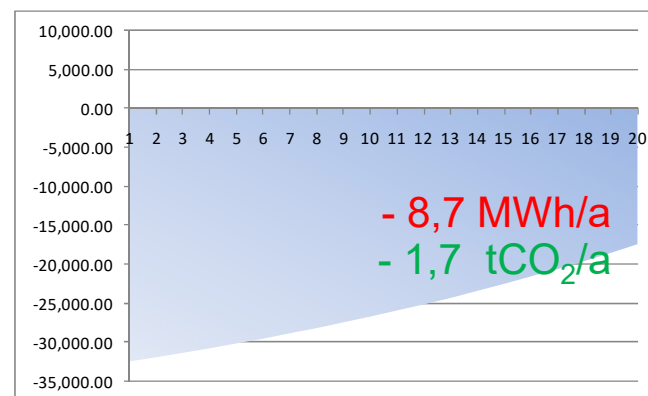
Inversió edifici:
 Inversió habitatge: 32.860 €
 Pay-back: 4.110 €
 superior a 20 anys

Subvenció 50%

Inversió edifici: 16.430 €
 Inversió habitatge: 2.055 €
 Pay-back: superior a 20 anys

Subvenció 75%

Inversió edifici: 8.215 €
 Inversió habitatge: 1.030 €
 Pay-back: 13 anys





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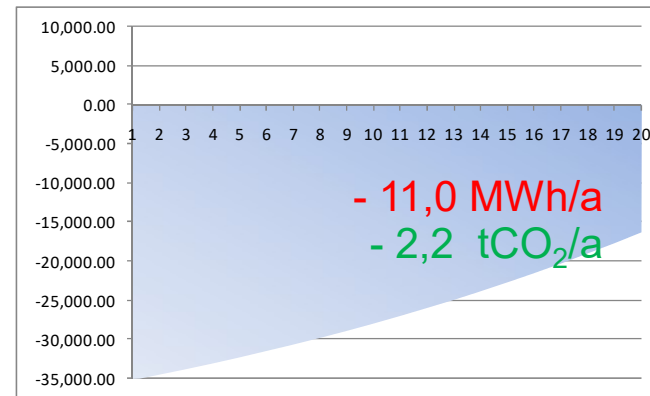


Example 1 – simulation results

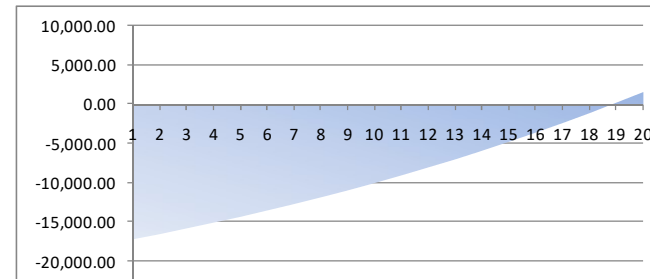
M3.2. Improved outside insulation

Savings: 32 %

Inversió edifici: 35.780 €
Inversió habitatge: 4.471 €
Pay-back: superior a 20 anys

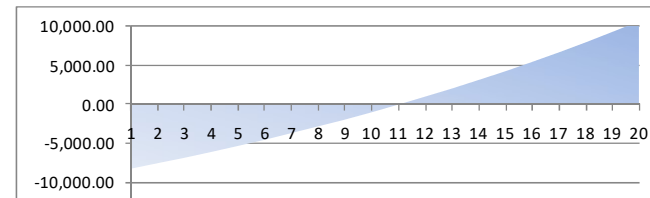


Inversió edifici: 17.880 €
Inversió habitatge: 2.235 €
Pay-back: 19 anys



Subvenció 75%

Inversió edifici: 8.942 €
Inversió habitatge: 1.118 €
Pay-back: 11 anys





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Example 1 – simulation results

M4. Roof insulation

Estalvi: 8 %

Inversió edifici: 2.350 €
 Inversió habitatge: 294 €
 Pay-back: 14 anys

Subvenció 50%

Inversió edifici: 1.177 €
 Inversió habitatge: 147 €
 Pay-back: 8 anys

Subvenció 75%

Inversió edifici: 588 €
 Inversió habitatge: 76 €
 Pay-back: 4 anys





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Example 1 – simulation results

M6. Windows substitution

Estalvi: 32 %

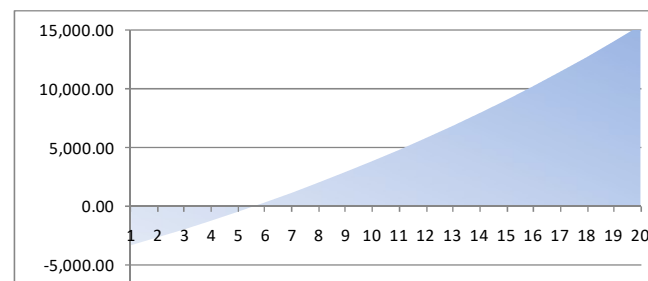
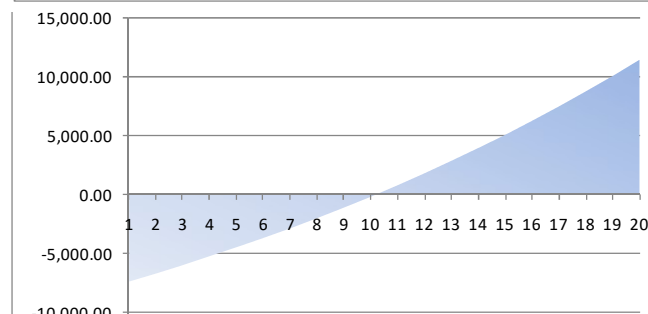
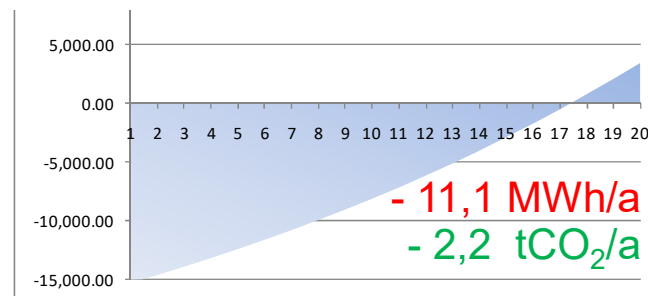
Inversió edifici: 15.970 €
 Inversió habitatge: 2.000 €
 Pay-back: 18 anys

Subvenció 50%

Inversió edifici: 7.985 €
 Inversió habitatge: 1.000 €
 Pay-back: 10 anys

Subvenció 75%

Inversió edifici: 3.992 €
 Inversió habitatge: 500 €
 Pay-back: 5 anys





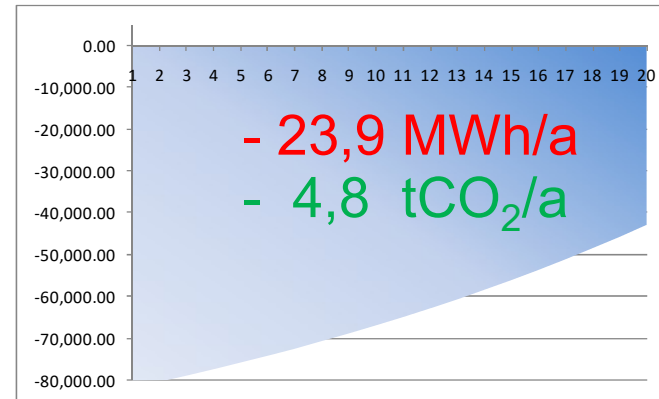
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Example 1 – simulation results

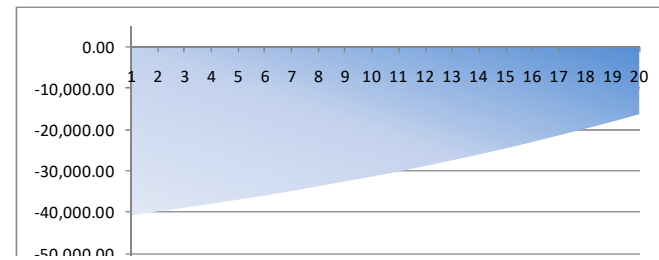
C1. Deep envelope renovation
(exterior insulation/ roof /
windows) **Savings: 70 %**

Inversió edifici: 83.000 €
Inversió habitatge: 10.374 €
Pay-back: superior a 20 anys



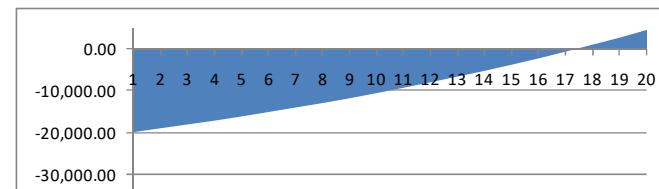
Subvenció 50%

Inversió edifici: 41.500 €
Inversió habitatge: 5.187 €
Pay-back: superior a 20 anys



Subvenció 75%

Inversió edifici: 20.750 €
Inversió habitatge: 2.594 €
Pay-back: 17 anys





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Example 2 – envelope + EE + RES



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Example 2 – envelope + EE + RES



Envelope renovation measures nZEB, Viladecans

MILLORES A L'ENVOLUPANT

comparativa estat actual i proposta de millora

		Estat actual	Estat millorat	proposta
		U (W/m2.K)	U (W/m2.K)	
Façanes				
	carrer	1,32	0,35	SATE 8cm
	pati	2,12	0,39	SATE 8cm
	mitgera vista	2,21	0,39	SATE 8cm
Cobertes				
	inclinada	1,51	0,38	8cm en cambra d'aire
	terrasses	1,35	0,51	4cm amb llosetes filtrants
	tancament atic	0,90	0,36	5cm per l'interior
Forjats				
	contacte terreny	3,92	3,92	
	entre plantes	1,70	1,70	
Obertures				
	finestres vidre senzill	5,70	1,9	marc PVC i vidre doble baix emissiu
	finestres vidre doble	4,00	1,9	marc PVC i vidre doble baix emissiu
Divisions verticals				
	entre habitatges	1,80	1,80	

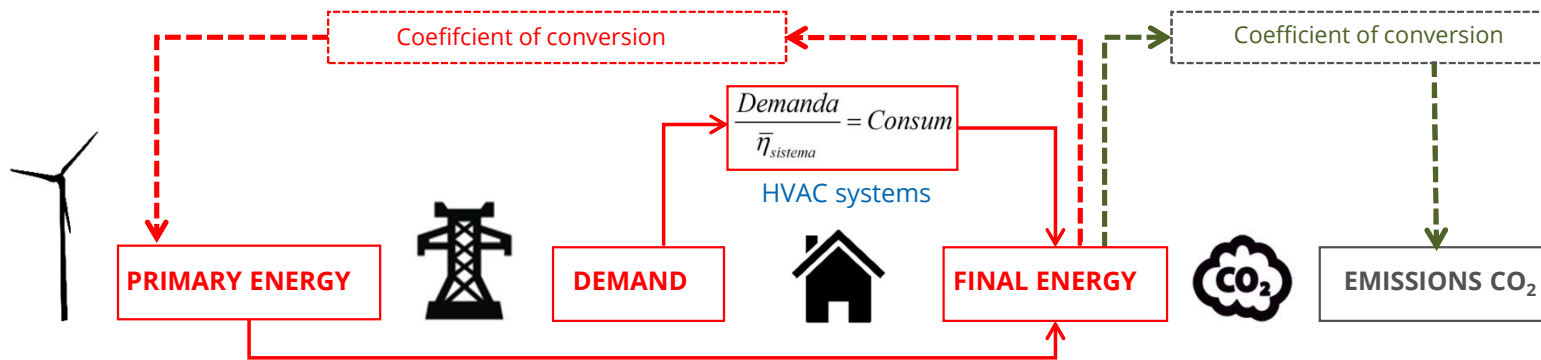


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Example 2 – envelope + EE + RES



Taula de coeficients de pas d'energia final

Tipus d'energia	Coeficients de pas a energia primària (kWh/kWh)	Coeficients de pas a emissions (kg CO2/kWh)
Carbó d'ús domèstic	1,000	0,347
GLP	1,081	0,244
Gasoil	1,081	0,287
Fueloil	1,081	0,280
Gas natural	1,011	0,204
Biomassa i biocarburants *	1,000	0,000
Electricitat peninsular	2,603	0,649
Electricitat extrapeninsular **	3,347	0,981

Font: "Condiciones de aceptación de procedimientos... Anexos 2007"



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Example 2 – envelope + EE + RES



RESULTS ENERGY QUALIFICATION – STATUS QUO

Certificación Energética de Edificios Indicador kgCO2/m ² año	Edificio Objeto		
<6,1 A			
6,1-9,9 B			
9,9-15,3 C			
15,3-23,5 D			
23,5-49,0 E	33,8 E		
49,0-57,3 F			
>57,3 G			
	Clase	kWh/m²	kWh/año
Demanda calefacción	E	90,7	95180,2
Demanda refrigeración	C	5,5	5806,1
	Clase	kWh/m²	kWh/año
Consumo energía primaria no renovable calefacción	E	136,9	143690,5
Consumo energía primaria no renovable refrigeración	C	4,6	4838,4
Consumo energía primaria no renovable ACS	G	33,5	35208,9
Consumo energía primario renovable totales	E	175,0	183737,8
	Clase	kgCO2/m² año	kgCO2/año
Emisiones CO2 calefacción	E	25,9	27231,3
Emisiones CO2 refrigeración	B	0,8	819,6
Emisiones CO2 ACS	G	7,1	7448,9
Emisiones CO2 totales	E	33,8	35499,9



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Example 2 – envelope + EE + RES



RESULTS ENERGY QUALIFICATION – IMPROVEMENT MEASURES

Certificación Energética de Edificios Indicador kgCO2/m² año	Edificio Objeto		
<p><6,1 A</p> <p>6,1-9,9 B</p> <p>9,9-15,3 C</p> <p>15,3-23,5 D</p> <p>23,5-49,0 E</p> <p>49,0-57,3 F</p> <p>>57,3 G</p>			
	<p>ADDITIONAL EMISSIONS REDUCTION DUE TO PHOTOVOLTAIC ELECTRICITY GENERATION -1.4 Kg CO2/m2</p>		
	Clase	kWh/m²	kWh/año
Demanda calefacción	B	15,0	15728,0
Demanda refrigeración	B	3,5	3699,9
	Clase	kWh/m²	kWh/año
Consumo energía primaria no renovable calefacción	B	18,1	18991,8
Consumo energía primaria no renovable refrigeración	C	5,8	6035,1
Consumo energía primaria no renovable ACS	A	3,9	4085,6
Consumo energía primario renovable totales	B	27,7	29112,5
	Clase	kgCO2/m² año	kgCO2/año
Emisiones CO2 calefacción	A	3,1	3217,1
Emisiones CO2 refrigeración	B	1,0	1022,3
Emisiones CO2 ACS	A	0,7	692,1
Emisiones CO2 totales	A	4,7	4931,5



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Example 2 – envelope + EE + RES



RENEWABLE ENERGIES

Solar thermal collectors
for domestic hot water

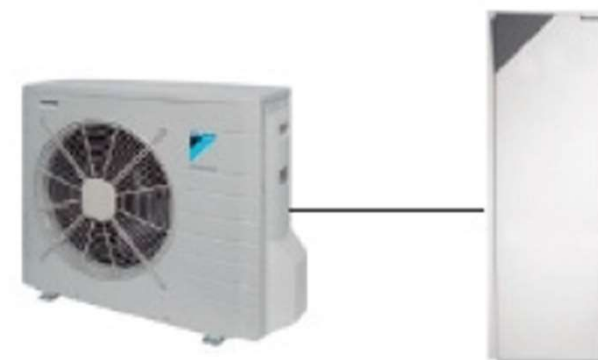


Solar photovoltaics
for electricity generation



ENERGY EFFICIENT H/C

Air-water heatpump with high energy
efficiency for space heating / cooling



tta Trama
TecnoAmbiental

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Example 2 – envelope + EE + RES



RENEWABLE ENERGIES IN URBAN ENVIRONMENT



10 solar thermal collectors

>70% DHW

14 solar fotovoltaic modules

3,5 kWp



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Example 2 – envelope + EE + RES



RENEWABLE ENERGIES IN RURAL ENVIRONMENT



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Example 2 – envelope + EE + RES



		Demanda calefacció kWh/m ² ·a	Demanda refrigeració kWh/m ² ·a	Energia primària kWh/m ² ·a	Emissions kgCO ₂ /m ² ·a
Edifici existent		90,7 E	5,5 C	175,0 E	33,8 E
NZEB Viladecans	A	7,7	2,1	26,8	6,1
	B	17,9	3,9	43,4	9,9
Millora de l'envolvent					
8cm aïllament a façana i coberta, canvi finestres, proteccions solars		15,0 B	3,5 B	63,4 C	12,7 C
Energies renovables					
Solar tèrmica per ACS (10 captadors - 70%)		90,7 E	5,5 C	151,7 E	28,9 E
Fotovoltaica (14 mòduls - 3,5 kW)		90,7 E	5,5 C	170,8 E	32,4 E
Combinacions de mesures					
Millora de l'envolvent					
Solar tèrmica per ACS (10 captadors - 70%)		15,0 B	3,5 B	40,1 B	7,7 B
Millora de l'envolvent					
Solar tèrmica per ACS (10 captadors - 70%)					
Fotovoltaica (14 mòduls - 3,5 kW)		15,0 B	3,5 B	35,9 B	6,3 B
Millora de l'envolvent					
Energies renovables i BC aerotèrmica		15,0 B	3,5 B	23,5 A	3,3 A

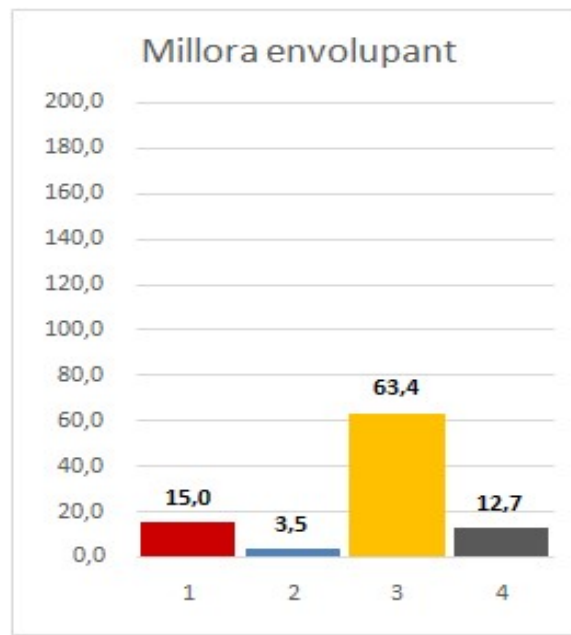
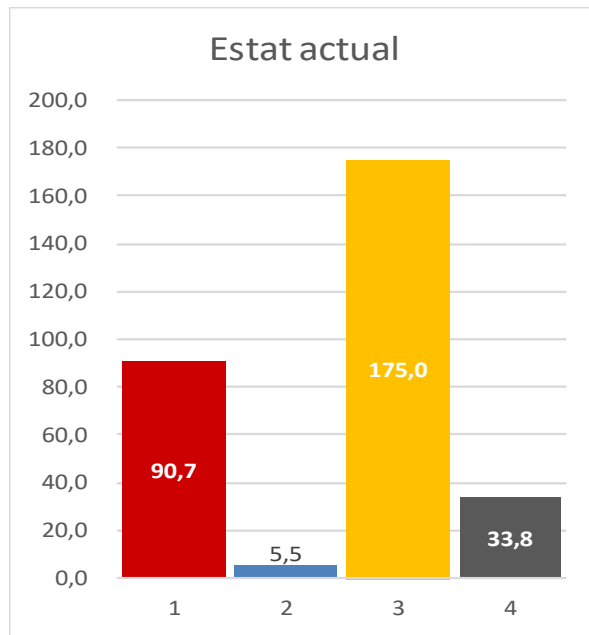


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Example 2 – envelope



- 1 – Heating demand (kWh/m²·a)
- 2 – Cooling demand (kWh/m²·a)
- 3 – Primary energy consumption (kWh/m²·a)
- 4 - CO₂ emissions (kg/m²·a)

Reduction: 83 %
 Reduction: 36 %
Reduction: 64 %
Reduction: 62 %

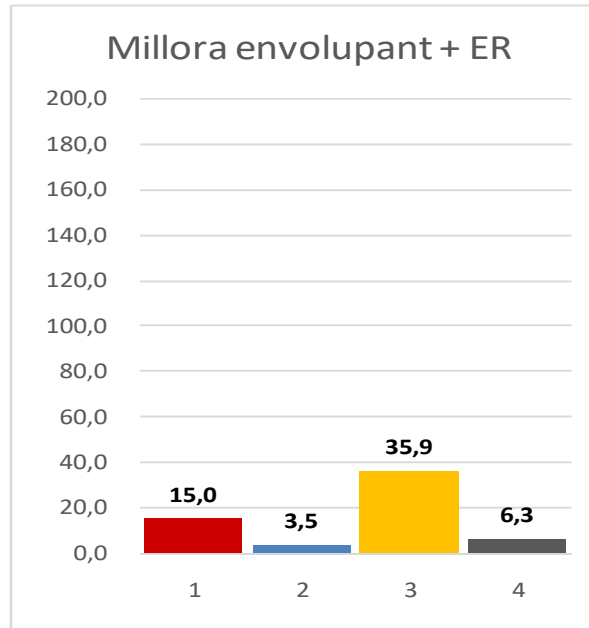
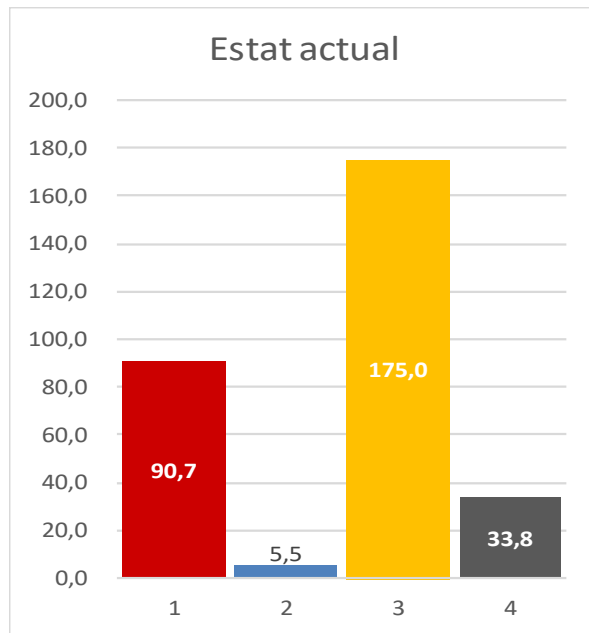
Savings (Building): 111 MWh/a
 Savings (Building): 21 tCO₂/a





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Example 2 – envelope + RES



- 1 – Heating demand (kWh/m²·a)
- 2 – Cooling demand (kWh/m²·a)
- 3 – Primary energy consumption (kWh/m²·a)
- 4 - CO₂ emissions (kg/m²·a)

Reduction: 83 %
 Reduction: 36 %
Reduction: 79 %
Reduction: 81 %

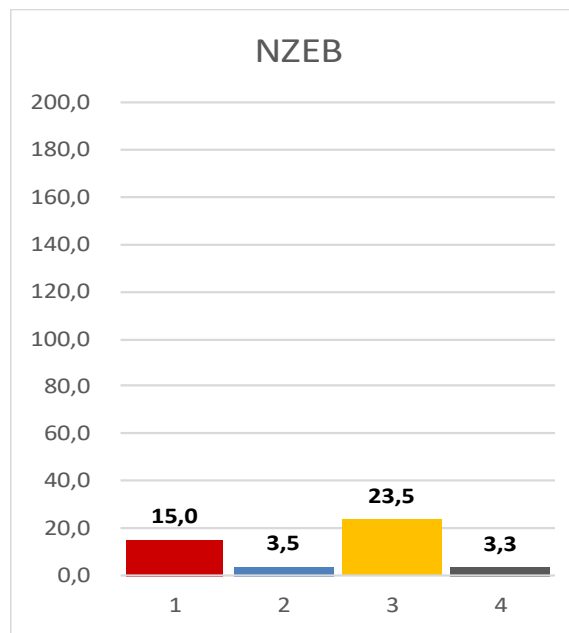
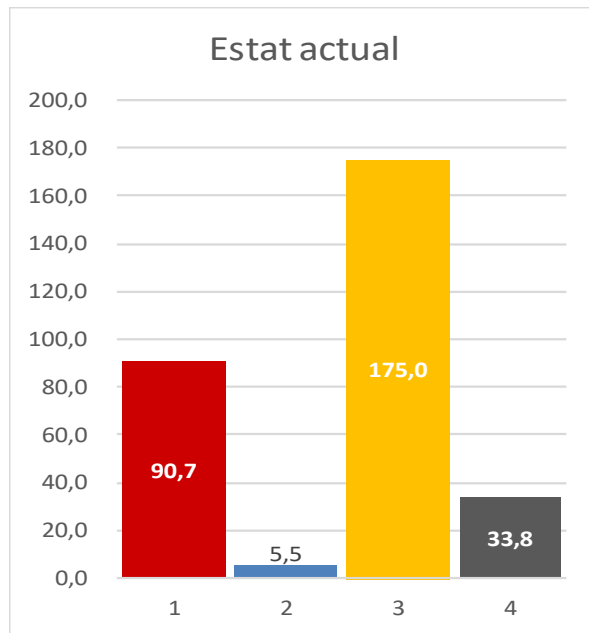
Savings (building): 139 MWh/a
 Savings (building): 27 tCO₂/a





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Example 2 – envelope + EE + RES



- 1 – Heating demand (kWh/m²·a)
- 2 – Cooling demand (kWh/m²·a)
- 3 – Primary energy consumption (kWh/m²·a)
- 4 - CO₂ emissions (kg/m²·a)

Reduction: 83 %
 Reduction: 36 %
Reduction: 87 %
Reduction: 90 %

Savings (building): 151 MWh/a
 Savings (Building): 30 tCO₂/a





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Example 3 – envelope + EE + RES



Trama
TecnoAmbiental

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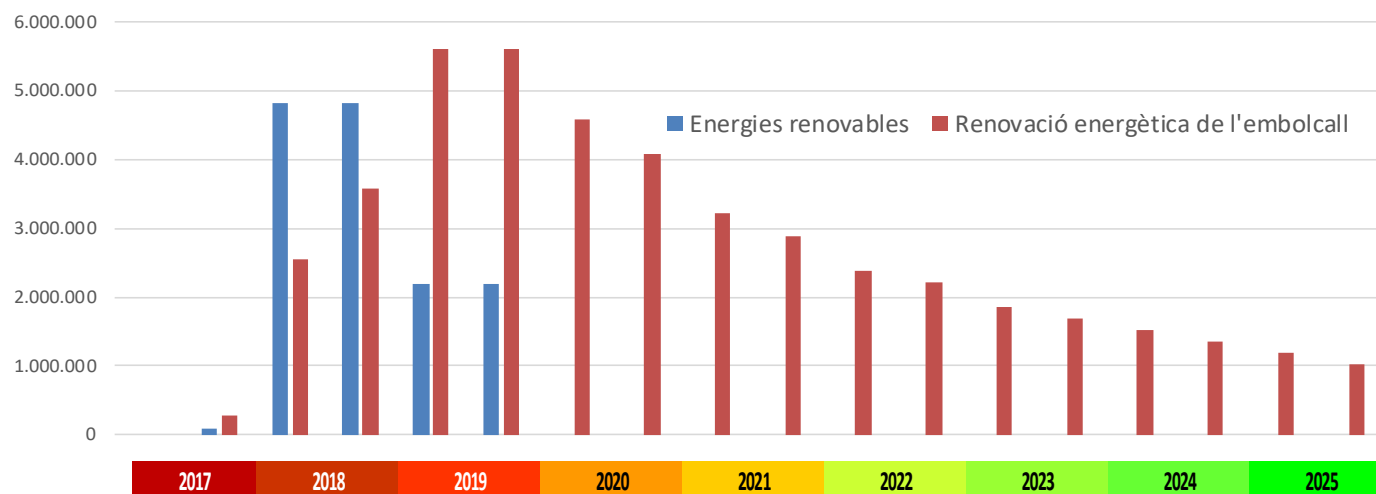


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Example 3 – envelope + RES



Inversions programades (€)



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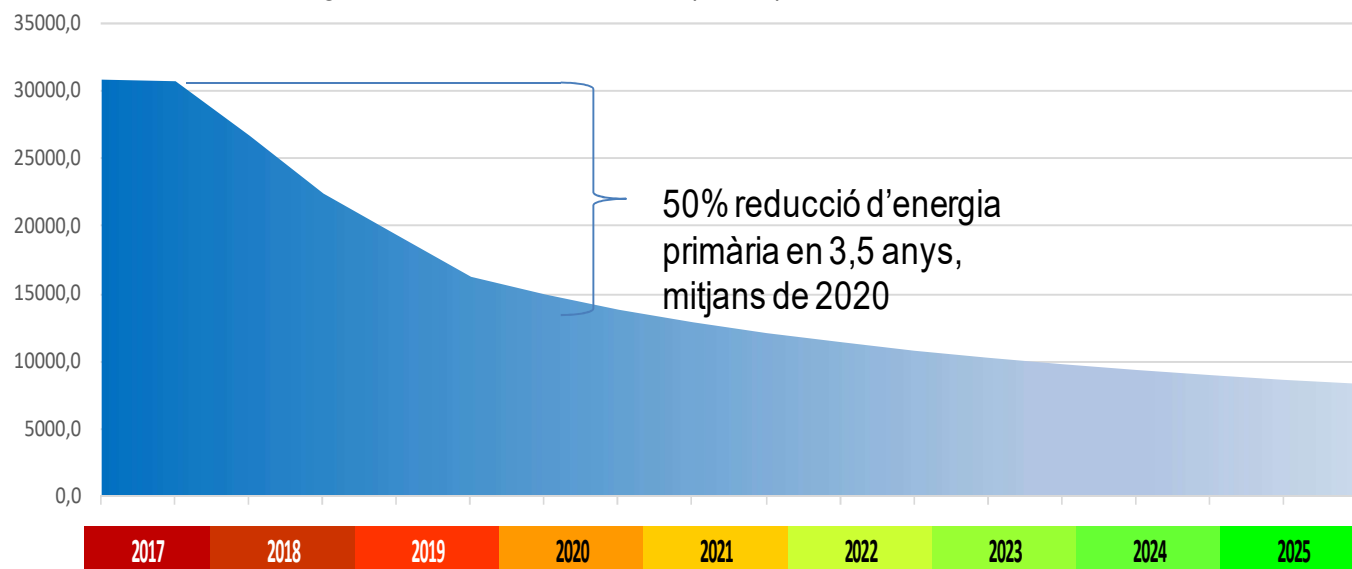


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Example 3 – envelope + RES



Consum d'energia primària no renovable (MWh)



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1. **Basic calculations and paramètres**
2. **Example 1 – only envelope retrofit**
3. **Example 2 – nZEB deep renovation**
4. **Example 3 – envelope versus RES**
5. **Conclusions**



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Conclusions



Thermal retrofit of buildings is required to achieve a drastic reduction of energy consumption and GHG emissions.

The savings are not paying off the investment costs for NZEB



THE MOTIVATIONS NEED TO BE OTHER:

- COMFORT
- REAL ESTATE INCREASE
- CLIMATE CHANGE MITIGATION



AN IMPORTANT SUBSIDY SCHEME OR OTHER FINANCING MECHANISMS ARE REQUIRED

- SUBSIDIES > 50%
- MUNICIPALITY AS INVESTOR, WITH REAL ESTATE SECURITIES



ACTIVE SYSTEMS OF RENEWABLE ENERGY GENERATION MIGHT BRING DOWN EMISSIONS AT A SHORT TERM WHILE DEEP RENOVATION MEASURES ARE GETTING IMPLEMENTED.



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Conclusions



- Not optimal part time retrofit – energy related or not - will hinder Deep renovation measures in time
 - ➔ PROMOTE OR REQUIRE INSULATION WHENEVER MAJOR MAINTENANCE MEASURES ARE IMPLEMENTED
EX. NO WATERPROOFING, NO FAÇADE IMPROVEMENT WITHOUT THERMAL INSULATION – OPPORTUNITY
- Multi-owner properties are an important challenge for the decision taking process
 - ➔ AWARENESS BUILDING AND SOCIAL MEDIATION IS REQUIRED
- There is no critical mass to reduce the costs of Deep renovation products and services
 - ➔ PROMOTION OF DEEP RENOVATION REQUIRED
- There is limited awareness at all stakeholder levels
 - ➔ AWARENESS BUILDING, TRAINING, TRAINING, TRAINING





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Conclusions



TRAINING

Project: Architects / Engineers



- Passive architecture
- Thermal bridge minimization
- Optimization of HVAC systems
- Integration of Renewable energies

Implementation.

Technicians /
Installers



- Correct implementation of critical points
- Airtightness

Users



- Set point temperatures
- Operating schedules
- Maintenance



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Thank you for your attention !