M4

Energy demand reduction strategies: potential in new buildings and refurbishment

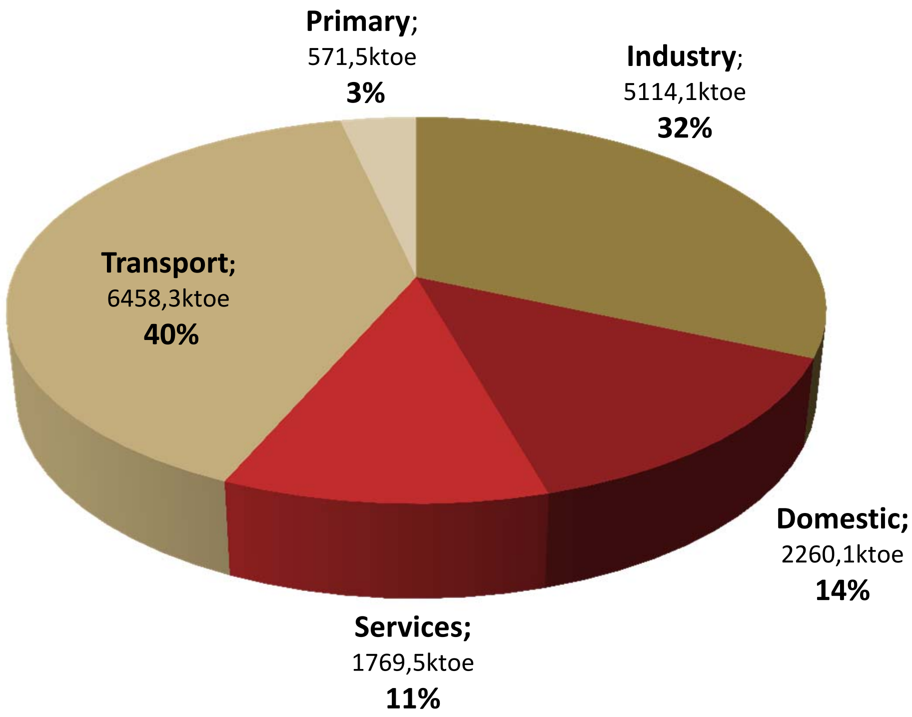
CONTENTS

1. Introduction

1.1. Energy consumption in the building sector

Contribution of the building sector to the total CO_2 emissions in Europe:

40%. [1]



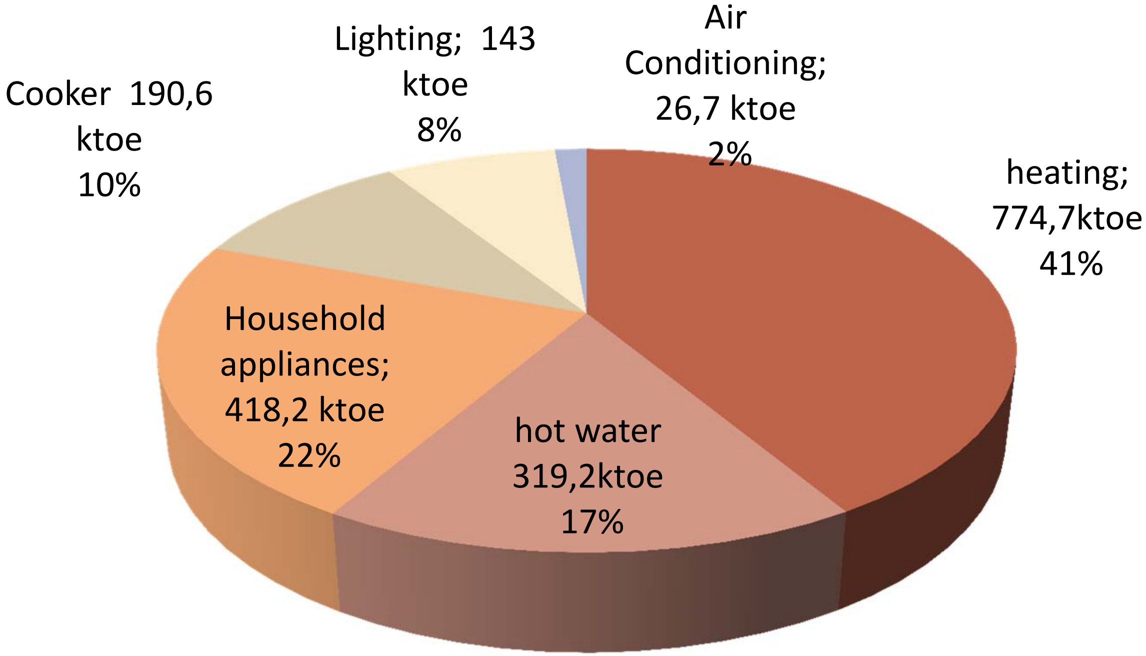
Final energy consumption distribution per sector. Total final energy consumption: 9714 ktep. Catalonia 2007, Source: ICAEN

[1] EPBD - *Energy Performance Buildings Directive* 2002/91/EC 4th of January 2003 *Official Journal of the European Communities*

1. Introduction

1.1. Energy consumption in the building sector

Final energy consumption in Catalonia's residential sector



Domestic final energy consumption/m² of first residences 2007	Household energy consumption	heating	DHW / cooking	appliances	lighting	cooling
kWh/m²	83.0	34.3	22.9	18.5	6.4	1.2

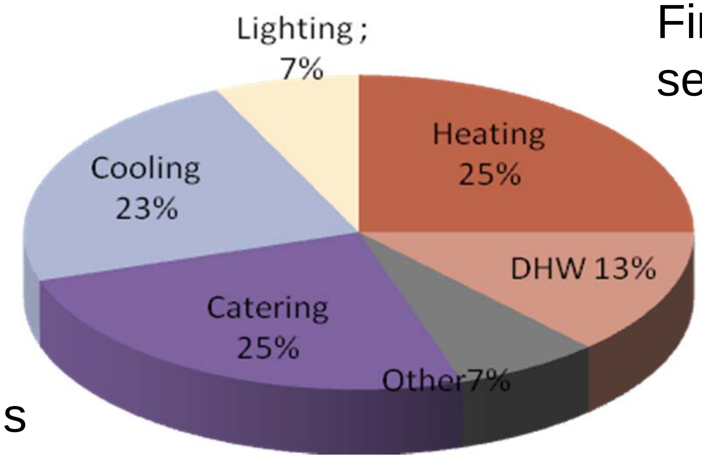
Source. Associació LIMA – Low Impact Mediterranean Architecture, "Regional Benchmark Analysis", based on data from IDESCAT and ICAEN, elaborated in the frame of the MARIE project, 9/2011

MARIE MEDITERRANEAN BUILDINGS ENERGY EFFICIENCY IMPROVEMENT

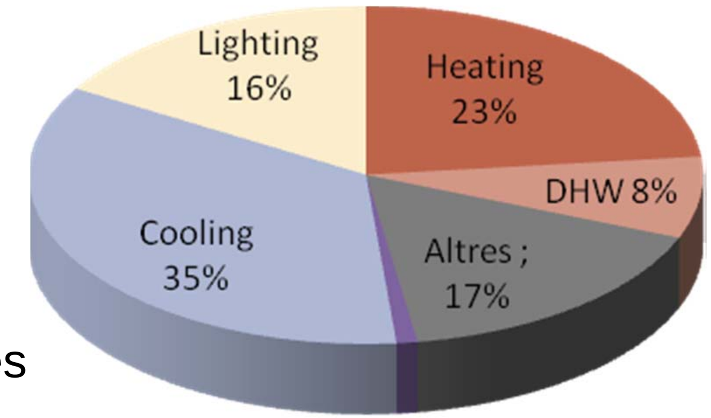
1. Introduction

1.1. Energy consumption in the building sector

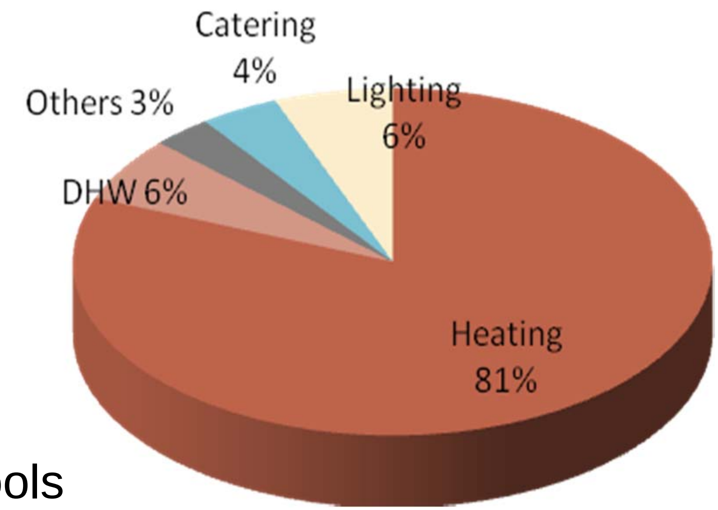
Final energy consumption in Catalonia's service sector



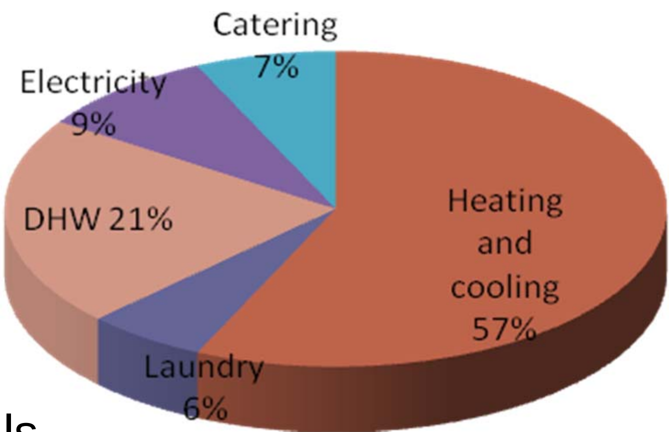
Hotels



Offices



Schools



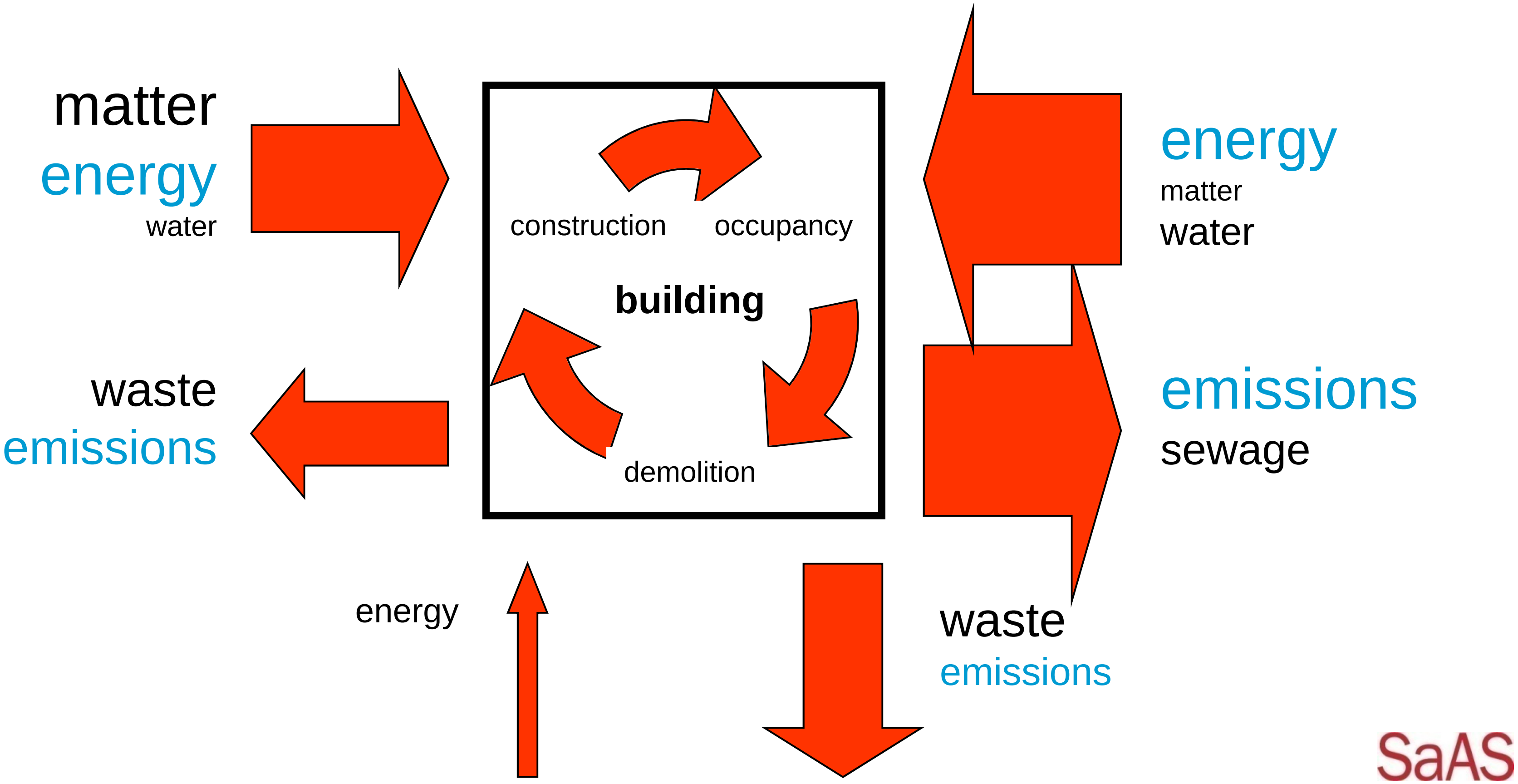
Hospitals

ICAEN (2004): Dades de consums i comportament energètic per a diferents sectors consumidors Projecte Ciutat Sostenible. Fòrum Barcelona 2.004

1. Introduction

1.2. Life cycle analysis – a holistic approach

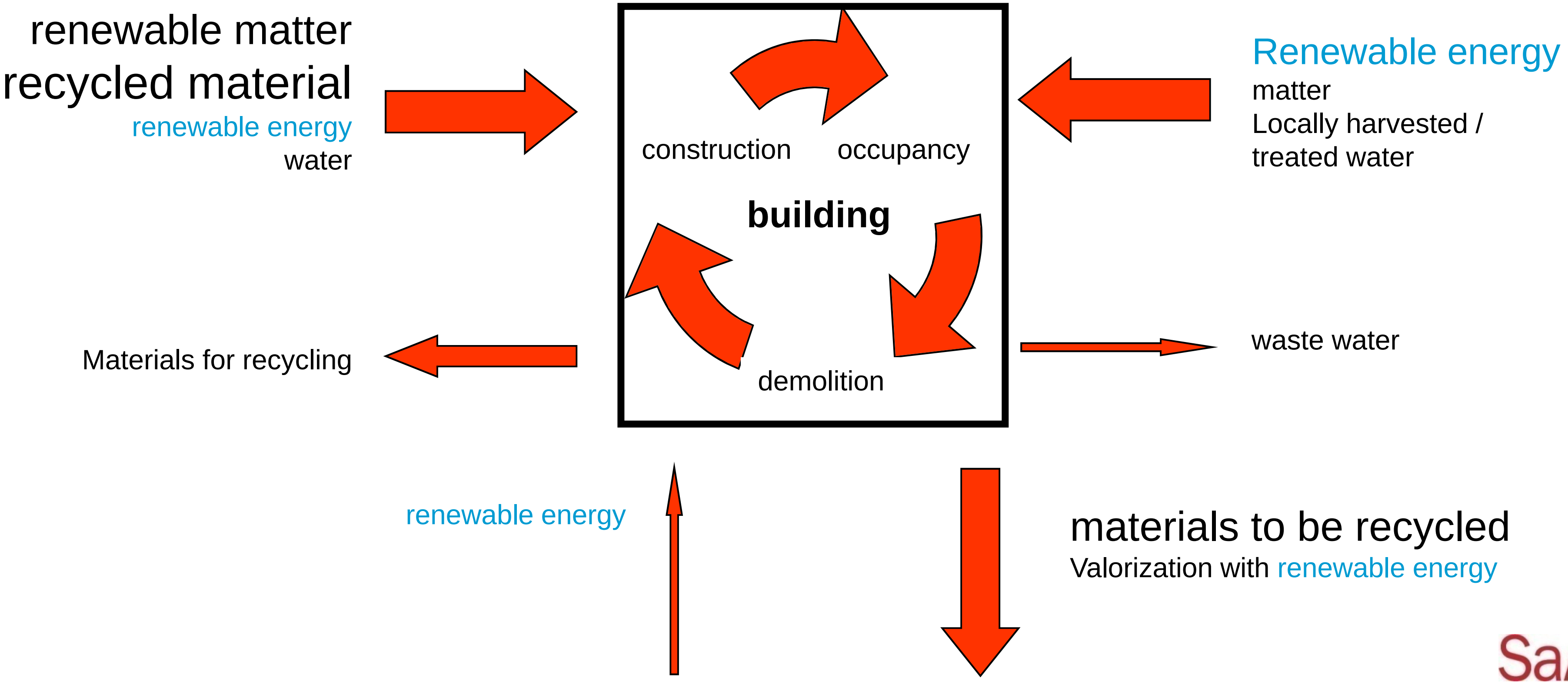
Actual model of the cycle of resources



1. Introduction

1.2. Life cycle analysis – a holistic approach

Objective of the cycle of resources



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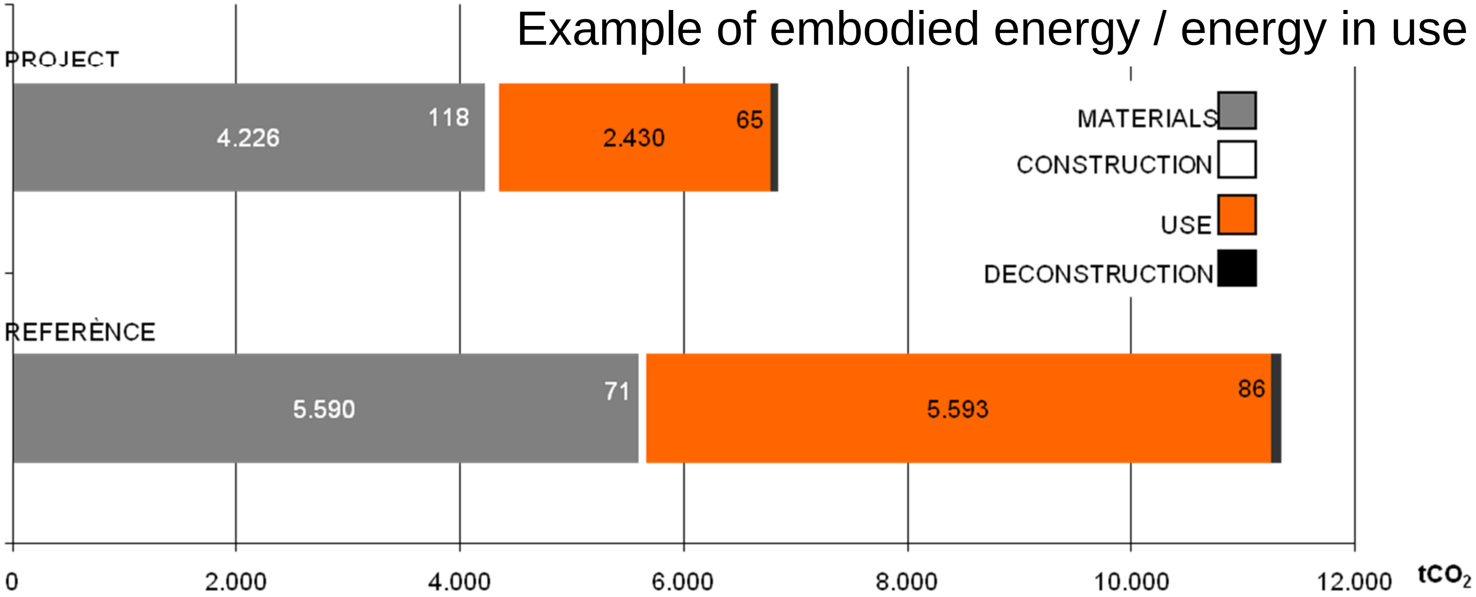
1. Introduction

1.2. Life cycle analysis – a holistic approach

Example of embodied energy / energy in use phase



Life cycle phase	Energy consumption Reference MWh	Project MWh	Reduction %	CO_2 Emissions Reference t CO_2	Project t CO_2	Reduction %
Materials	16.333	12.589	23%	5.590	4.226	24%
Construction	167	289	-73%	71	118	-66%
Use phase	23.388	10.162	57%	5.593	2.430	57%
Deconstruction	251	194	23%	86	65	24%
Total	**40.139**	**23.234**	**42%**	**11.340**	**6.839**	**40%**

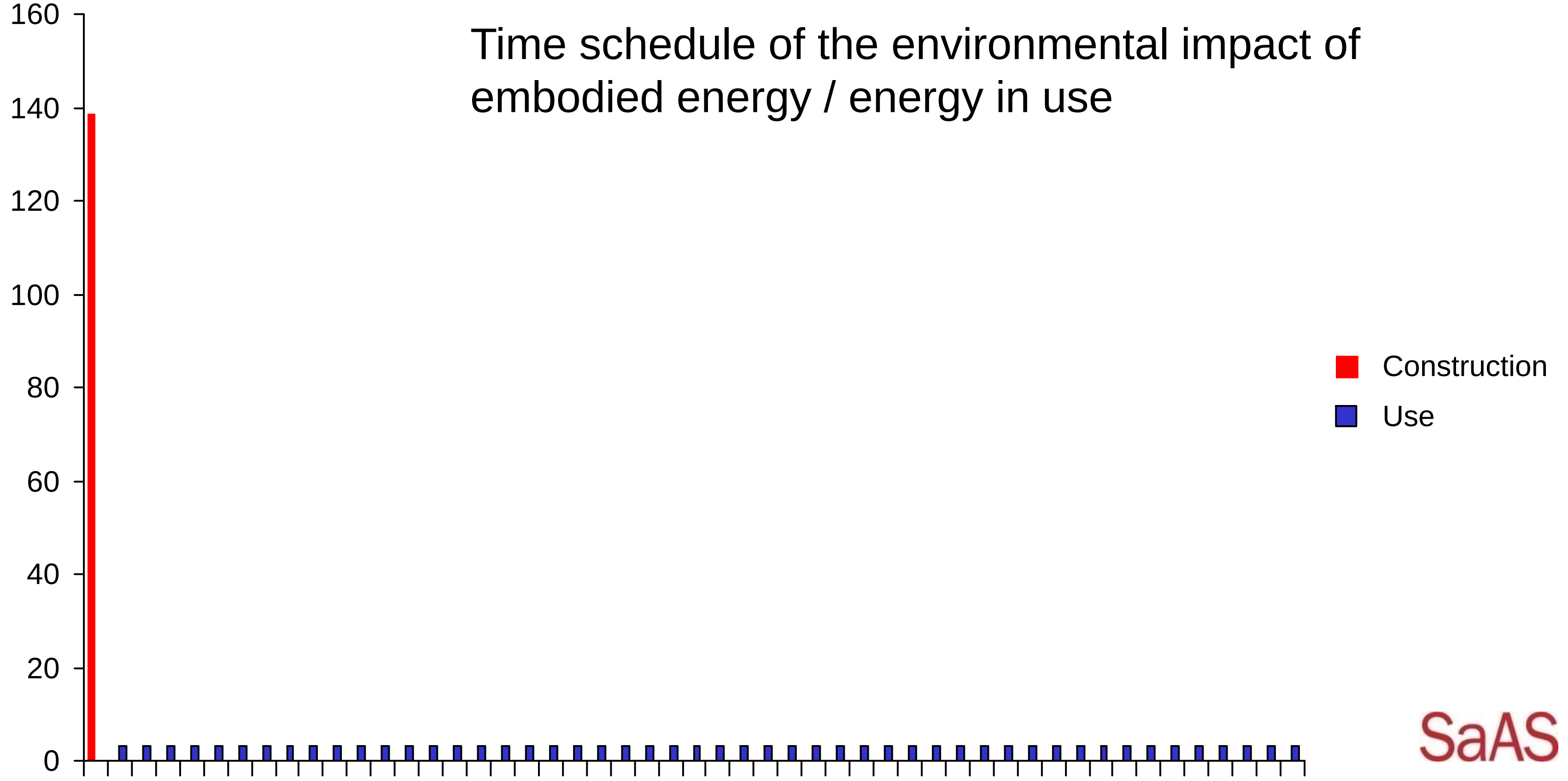
SaAS

Life cycle analysis of a 60 dwelling social housing apartment block, reference and project, SaAS 2007

1. Introduction

1.2. Life cycle analysis – a holistic approach

Time schedule of the environmental impact of embodied energy / energy in use



emissions in tones of CO_2 eq.·y for a typical dwelling of 100 m^2 during 50 years

1. Introduction

1.3. Embodied energy in building materials

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

Source: Victermofitex

Cellulose: 0,040 W/m·K (10% Borax, fireprotection and fungicide)

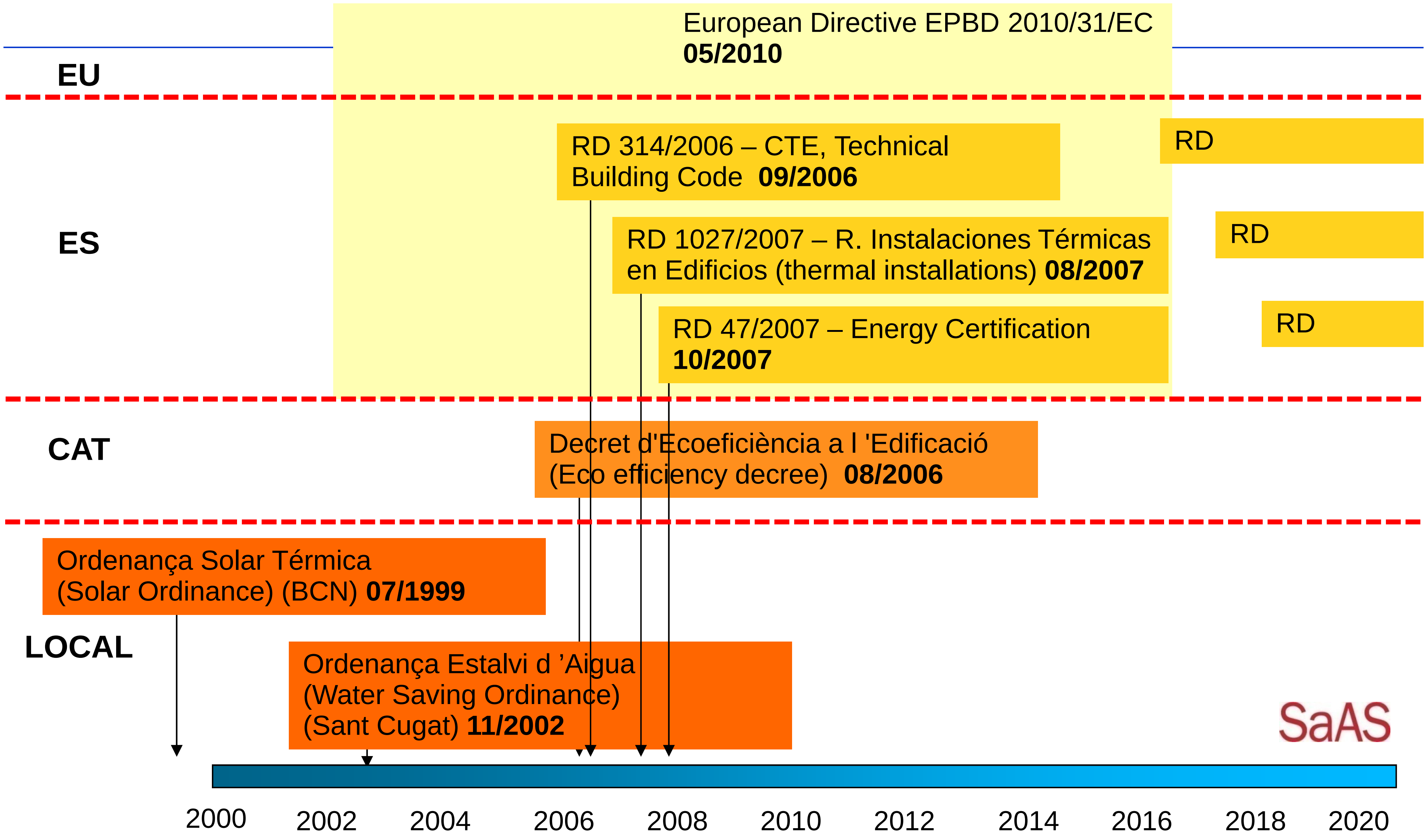
Source: CLIMACELL, Christoph Peters

1. Introduction

1.3. Embodied energy in building materials

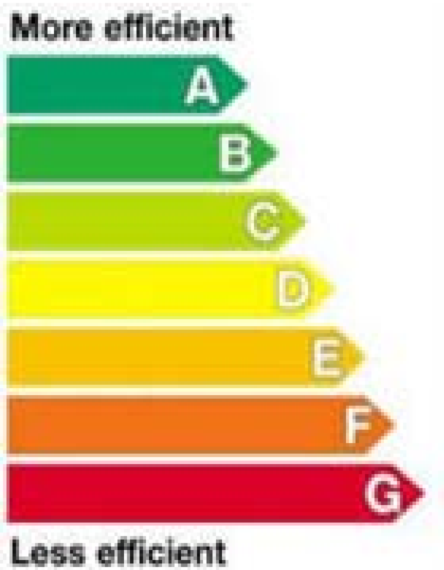
Insulation material	Primary energy (MJ/kg)	Emissions ($kgCO_{2eq}/kg$)	Cost (Euro/m³)	Source MJ - $kgCO_{2eq}$
Polystyrol, extruded	92,4	9,580	107	EMPA
Polystyrol, expanded	105,0	4,120	65	EMPA
Polyurethane PUR	100,0	4,210	136	EMPA
Glasswool	45,1	1,490	26	EMPA
Rockwool	21,7	1,480	115	EMPA
Cellular glass	16,5	0,600	295	PROVEIDOR
Sheep wool	14,7	0,045	108	PASSIVHAUS
Cork	25,0	0,021	402	EMPA
Woodfibre	13,7	-0,183	224	PROVEIDOR
Cellulose	7,2	-0,907	90	PASSIVHAUS

2. Energy in the building’s use: legislative framework



2. Energy in the buildings: legislative framework

2.1. The European Directive 2002/91/CE – EPBD



The Directive lays down requirements as regards:

- the general framework for a methodology of calculation of the integrated energy performance of buildings;
- the application of minimum requirements on the energy performance of new buildings;
- the application of minimum requirements on the energy performance of large existing buildings that are subject to major renovation;
- energy certification of buildings;
- regular inspection of boilers and of air-conditioning systems in buildings and in addition an assessment of the heating installation in which the boilers are more than 15 years old.

2. Energy in the building's use: legislative framework

2.1. The European Directive 2010/31/CE – EPBD recast

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)

Article 9
Nearly zero-energy buildings

after **31 December 2018**, new buildings occupied and owned by public authorities are nearly zero-energy buildings.

after **31 December 2020**, all new buildings are nearly zero- energy buildings

2. Energy in the building’s use: legislative framework

2.1. The European Directive 2010/31/CE – EPBD recast

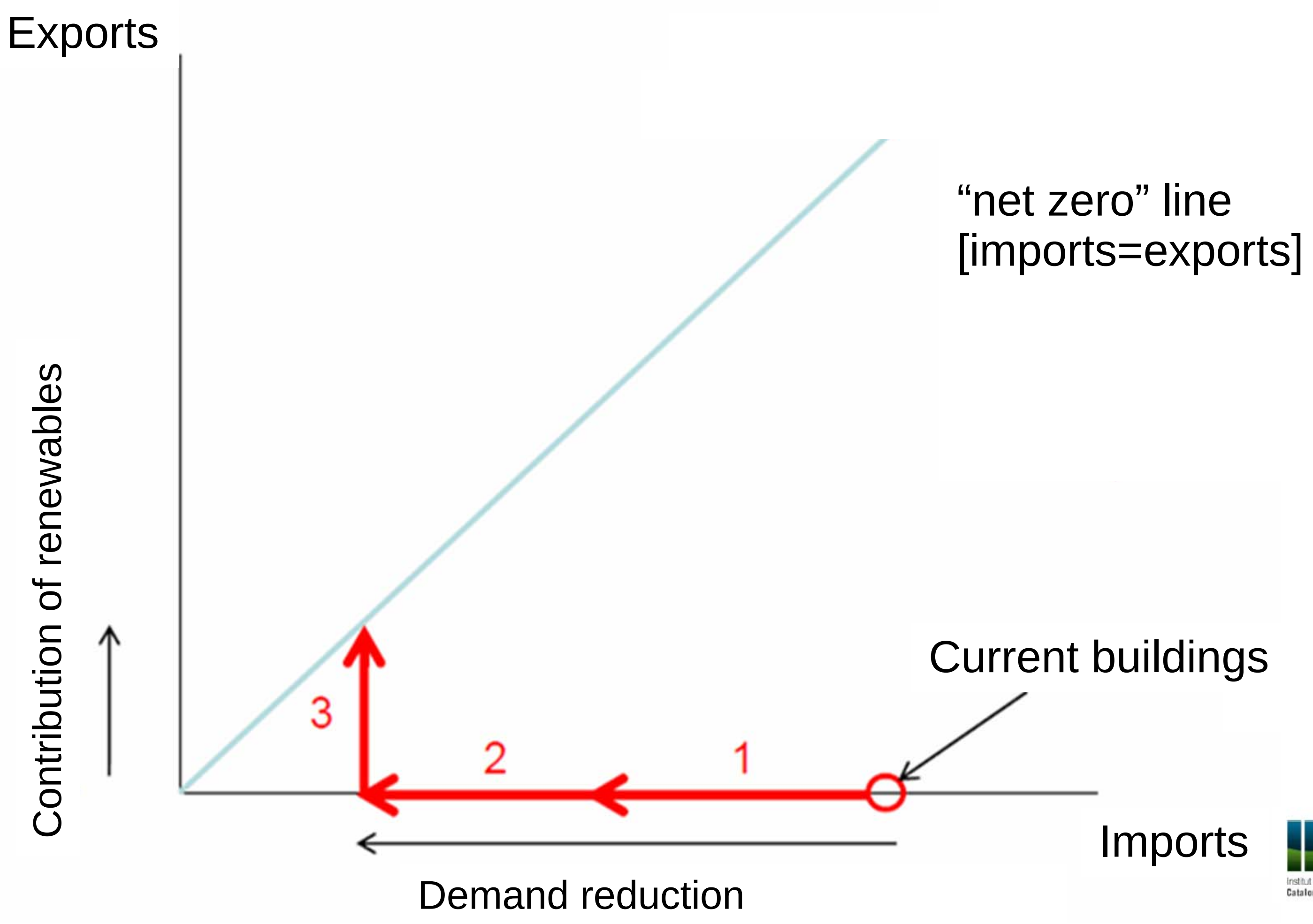
“Nearly zero-energy building” means a building that has a very high energy performance. The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby;

National plans for increasing the number of nearly zero-energy buildings:

- intermediate targets for improving the energy performance by 2015
- common numerical indicator of primary energy use expressed in kWh/m^2·a
- strengthening of energy performance certification
- energy efficiency of installations
- introduction of RES, cogeneration, DHC, heat pumps, monitoring

2. Energy in the building's use: legislative framework

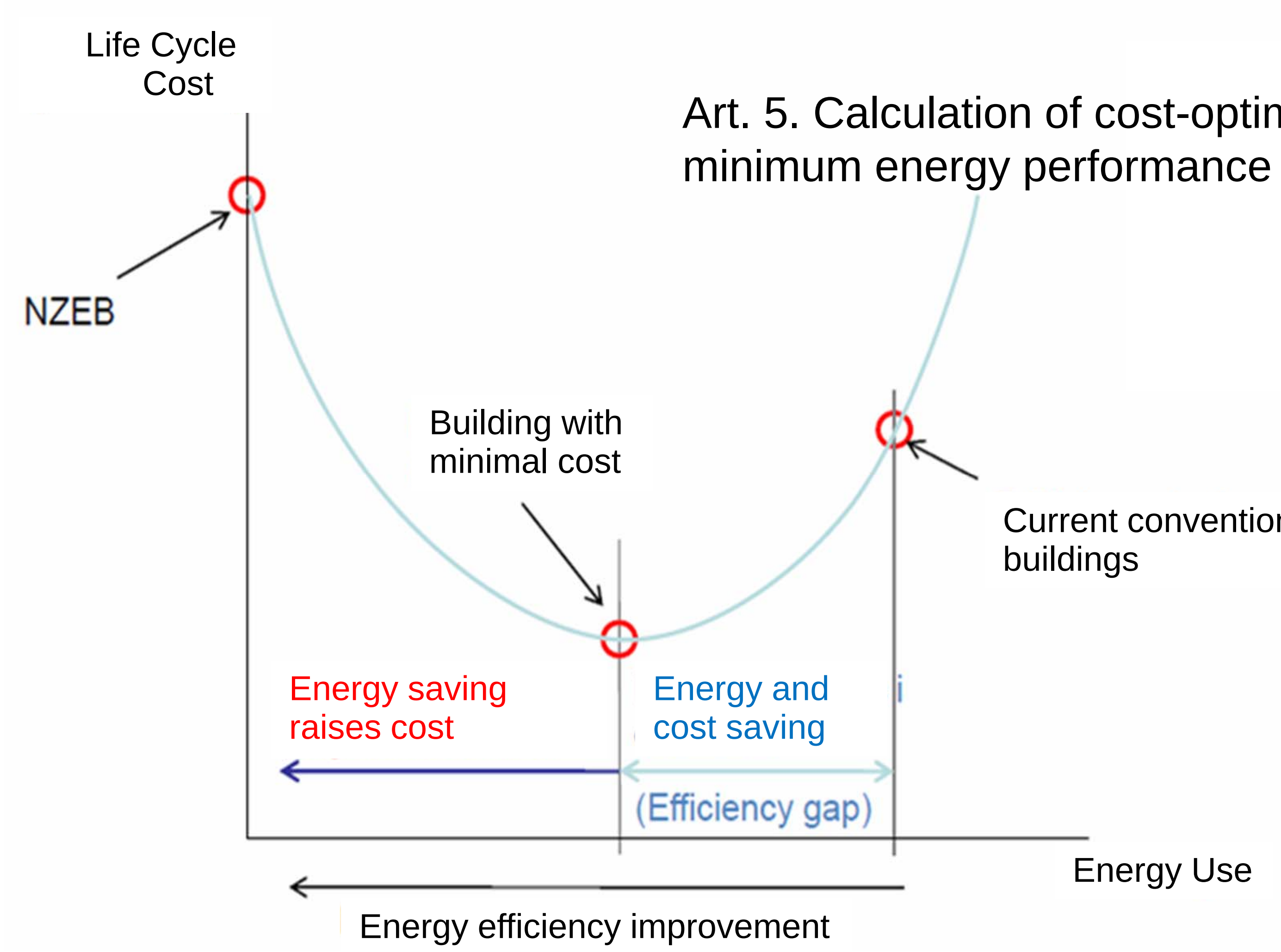
2.1. The European Directive 2010/31/CE – EPBD recast



2. Energy in the building's use: legislative framework

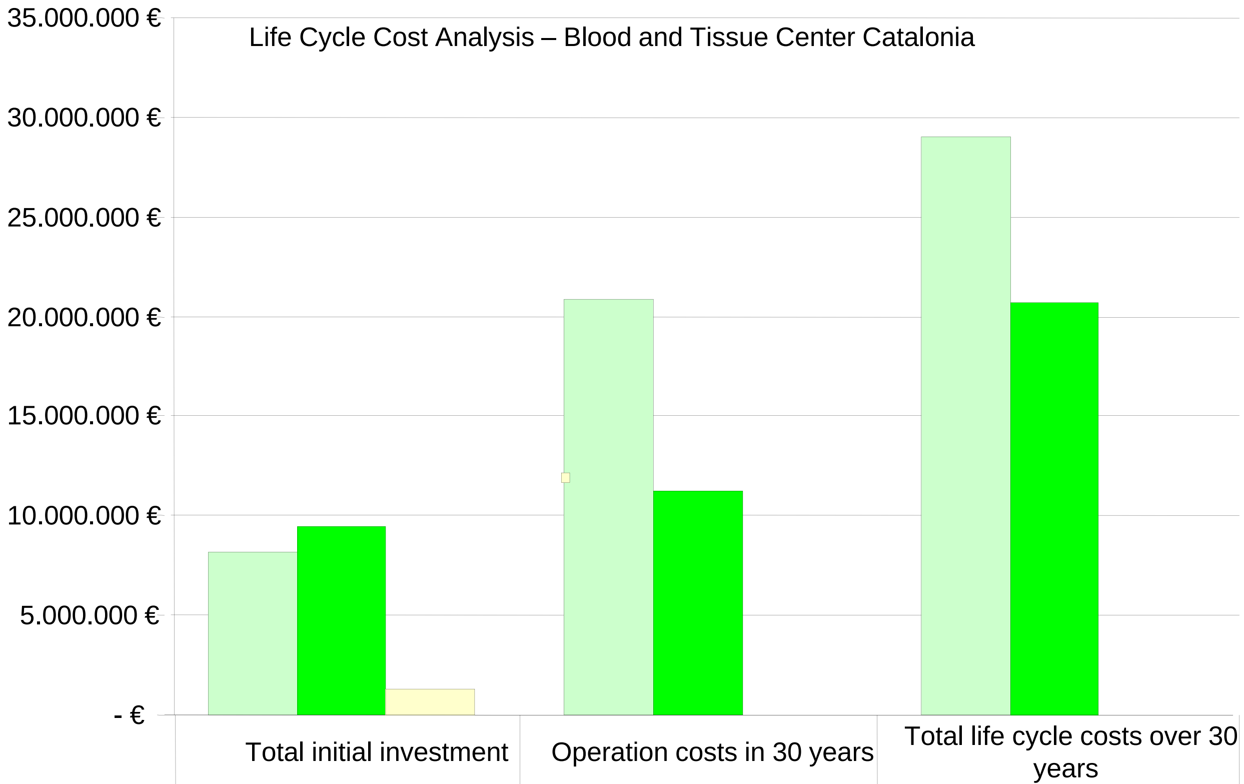
2.1. The European Directive 2010/31/CE – EPBD recast

Art. 5. Calculation of cost-optimal levels of minimum energy performance requirements



2. Energy in the building’s use: legislative framework

2.1. The European Directive 2010/31/CE – EPBD recast



	Total initial investment	Operation costs in 30 years	Total life cycle costs over 30 years
Reference	8.166.500 €	20.867.002 €	29.033.502 €
BST	9.423.754 €	11.239.677 €	20.663.431 €
Difference	1.257.254 €	-9.627.325 €	-8.370.071 €

The detailed analysis of the investment and operation costs of a building planned according to the described model gives the following results:

Difference in investment	1.2 M€
Difference in operation	9.6 M€
Total Difference (30 years)	8.4 M€

Additional benefit of investment	
Over 30 years	800%
Yearly	26%

Taking these data and the current price of money into account, the outcome are yearly returns of approximately 20%.

The return period for the investment is estimated to be 4 or 5 years.

SaAS

Study elaborated in the frame of the project b_EFIEN, promoted by Fundació b_TEC, with the participation of enginyeering and FM enterprises, SaAS, grupo JG, et.al. Barcelona 2009

2. Energy in the building's use: legislative framework

2.2. Quality labels and certifications

Código Técnico de la Edificación - CTE

Certificació energètica RD 47/2007

Decret d'Ecoeficiència en Edificació – DEE

LEED

BREEAM

VERDE

PASSIVHAUS

MINERGIE

ECO

Indicator: energy / emissions

territory / matter / water / etc.

2. Energy in the building’s use: legislative framework

2.2. Quality labels and certifications

Main arees of analysis in the certifications

Environment	Urban density Mobility Soil protection Green spaces
Materials	Impact Availability Local knowledge Waste
Energy	Energy demand Energy distribution Performance of installations Renewable energies
Water	Water demand Rain water Grey water Wastewater treatment
Health and comfort	Indoor air quality Electromagnetic fields Radioactive emissions Thermal , visual, acoustic comfort
Socio-economic	Cost of improvements User awareness Professional training Integration in networks
Management	Integrated design Maintenance plans Audit intervals Monitoring
Others	IRH med Innovative Responsible Housing for the Mediterranean

3. Parameters: building energy consumption in use

3.1. Passive: Thermal inertia / Insulation / Solar Control / Ventilation / Nat. Lighting

Thermal inertia: Heat storing capacity of a body. Main strategy in Mediterranean climates with a strong day/night temperature oscillation and mineral construction tradition.

Insulation: Control of the resistance to heat transfer from one point to another by conduction or convection through the replacement of materials or the modification of its thickness. Appearance of multilayer facades and specialist materials..

Solar control: By including barriers for solar radiation or changing the glazing characteristics, solar gains can be encouraged or prevented in order to take advantage of solar radiation in winter and to limit overheating in summer.

Ventilation: Ventilation has two effects: it favors the exchanges with the environment and facilitates the natural process of evaporative cooling. This mechanism is desirable in hot environments and buildings with low thermal mass

3. Parameters: building energy consumption in use

3.1. Façade construction typologies

HEAVY

SOLID WALL

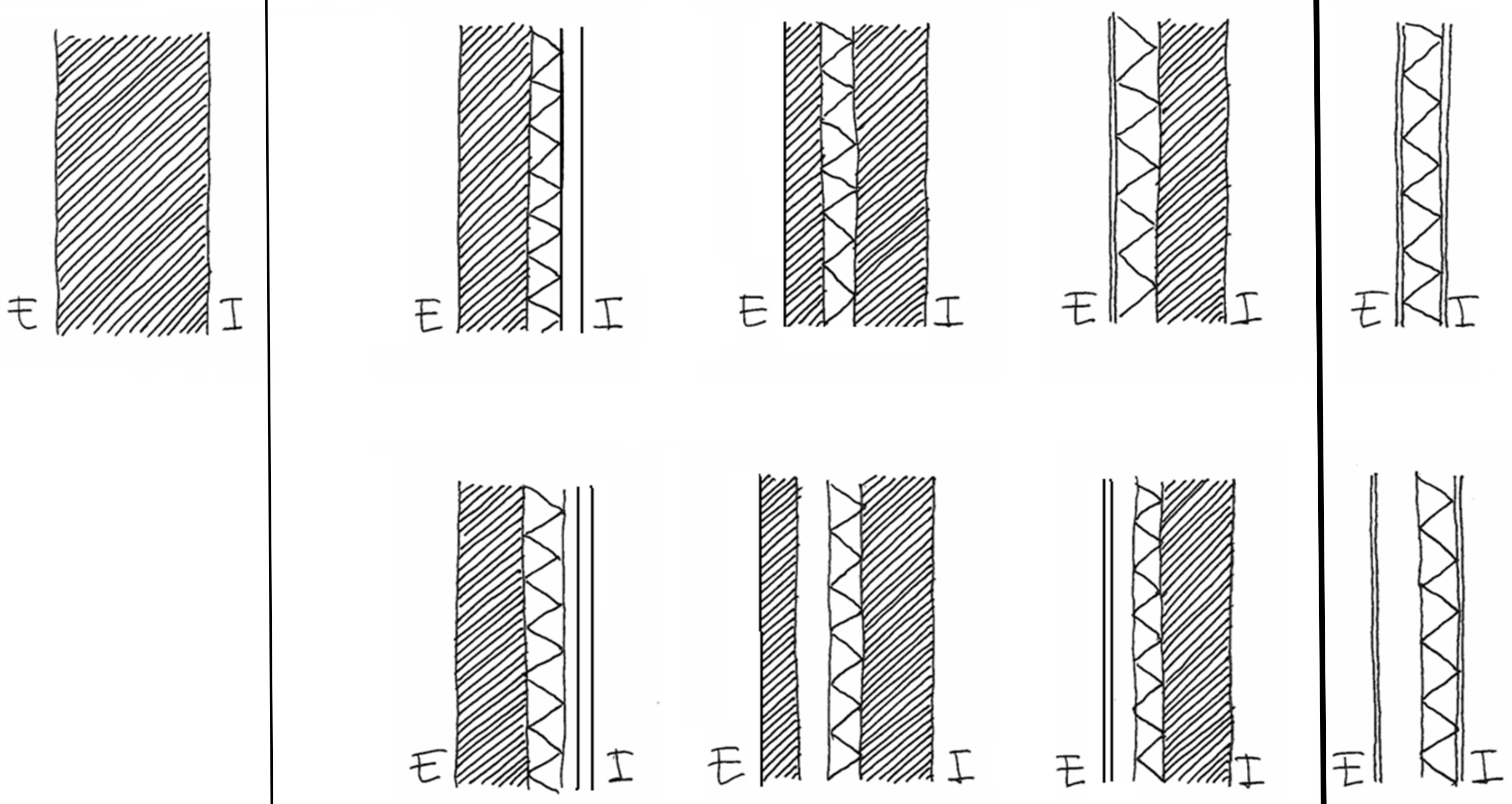
CAVITY WALLS

CONVENTIONAL **DOUBLE** **EXTERIOR**

LIGHT

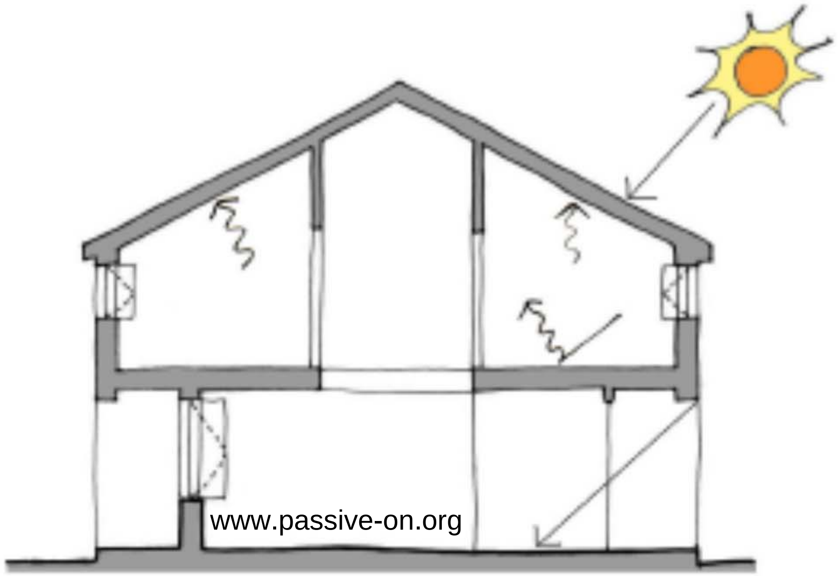
WITHOUT CAVITY

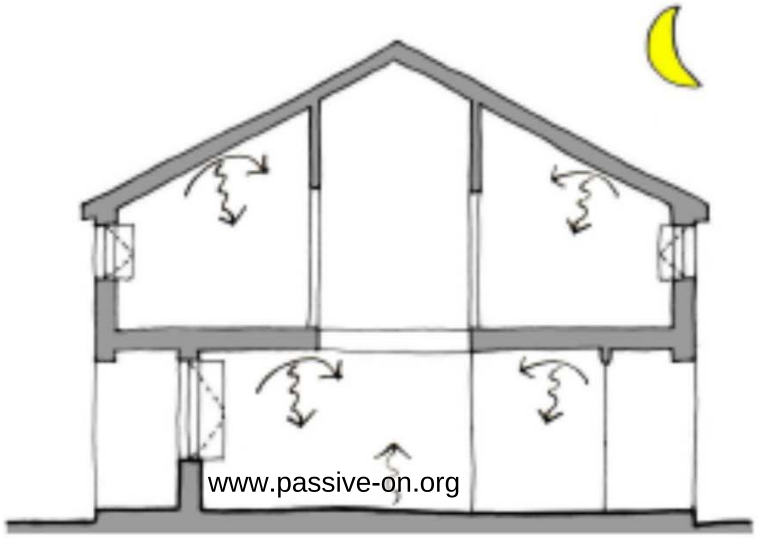
WITH CAVITY



3. Parameters: building energy consumption in use

3.1. Passive: Thermal inertia





The thermal mass stores heat during the day

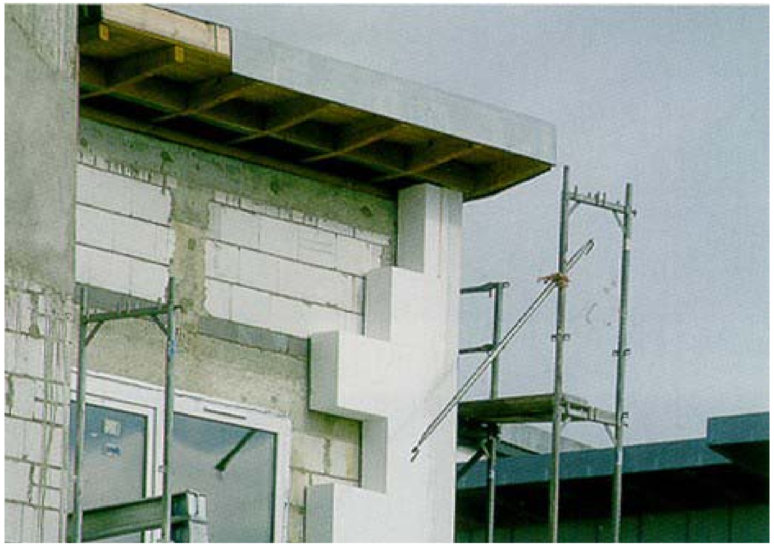
The heat stored during the day radiates back during cooler hours (night)

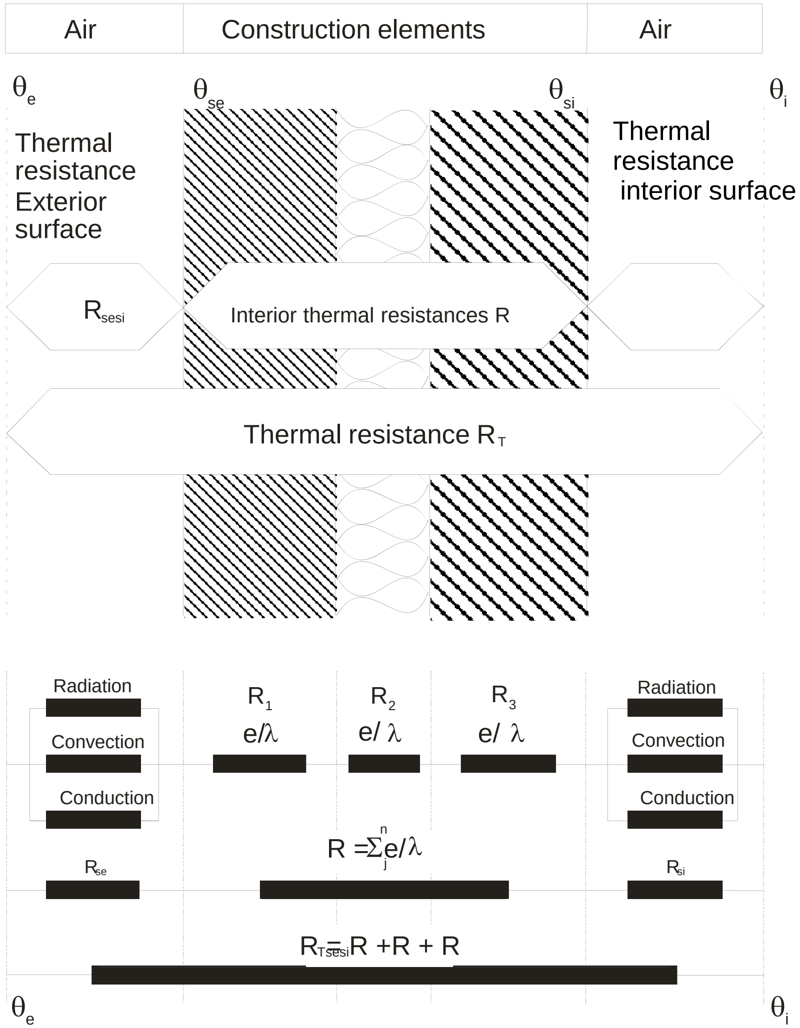
Typical Northern Mediterranean country-side house based on thermal inertia

Traditional Southern Mediterranean court-yard house based on thermal inertia

3. Parameters: building energy consumption in use

3.1. Passive: Insulation





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

$$U = \frac{1}{R_T} = \frac{\lambda}{e} \left[\frac{W}{m2 \cdot K} \right]$$

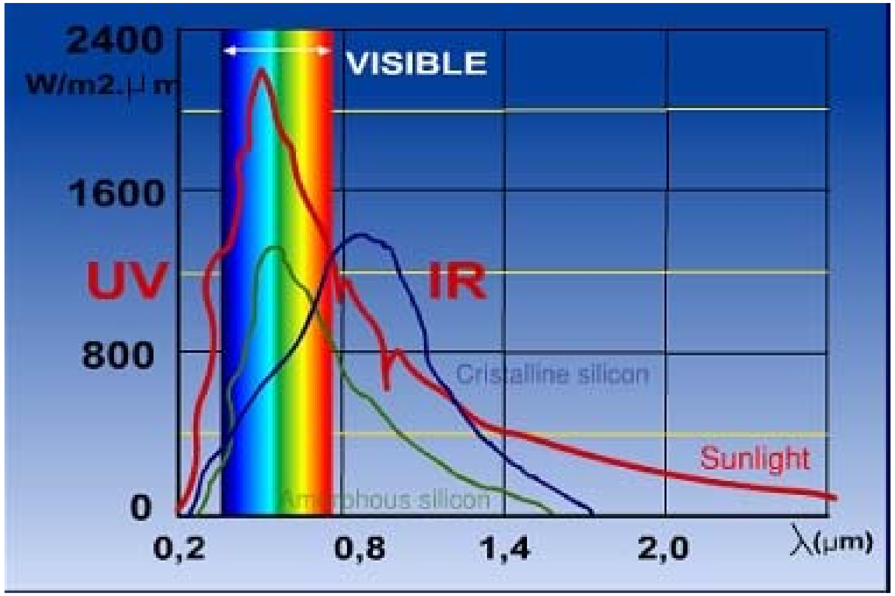
3. Parameters: building energy consumption in use

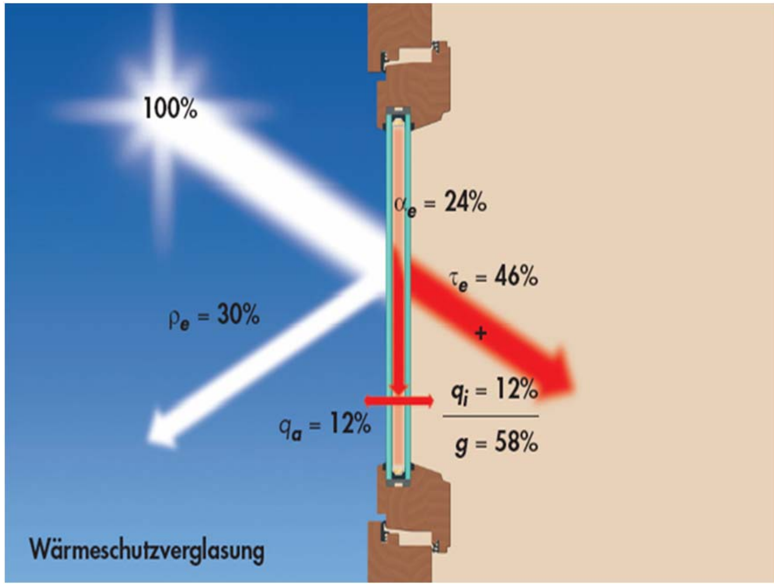
3.1. Passive: Solar control

Optimum between solar gains and solar protection according to building use, orientation, etc.

Main factors: thermal transmittance, solar factor, visible light

Shading devices, shading devices with natural light transportation

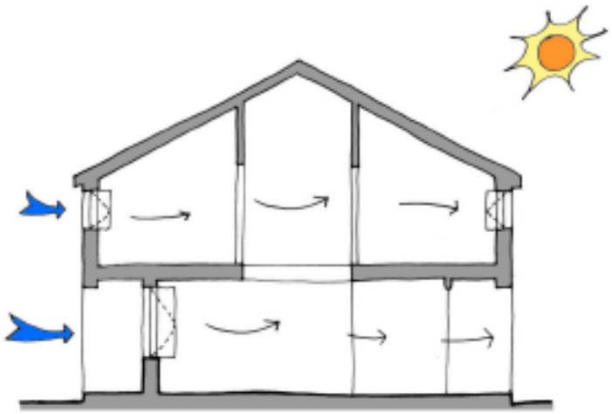




3. Parameters: building energy consumption in use

3.1. Passive: Ventilation

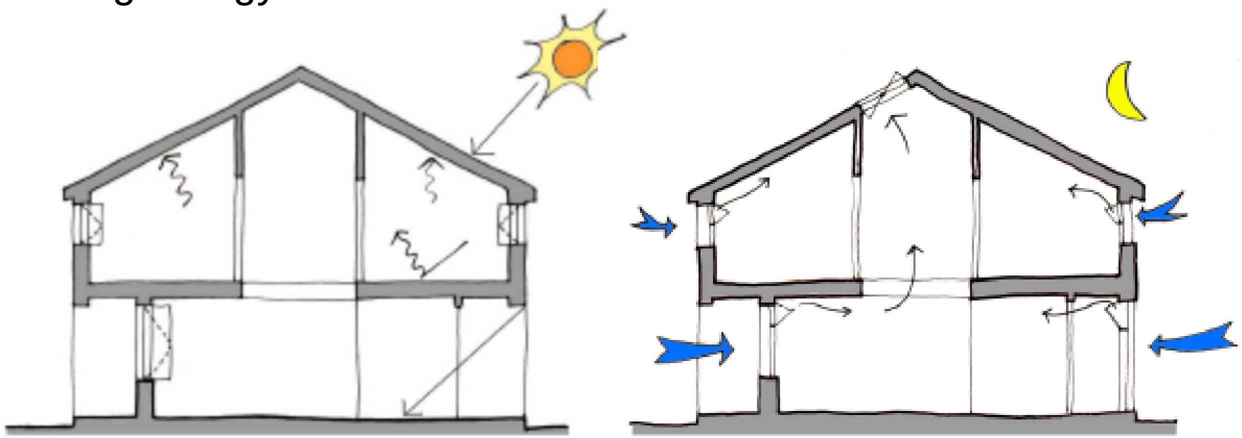
Cross ventilation: building design (distribution of apartments, for example) to allow the air flow between opposite façades to increase natural ventilation.



www.passive-on.org

Night ventilation: increase of air exchange rate during cooler summer nights to reduce the heat stored during daytime in the thermal mass of the building. Only in moderate climates will this strategy be sufficient to avoid an air conditioning system, but it will in any case reduce the cooling energy demand.

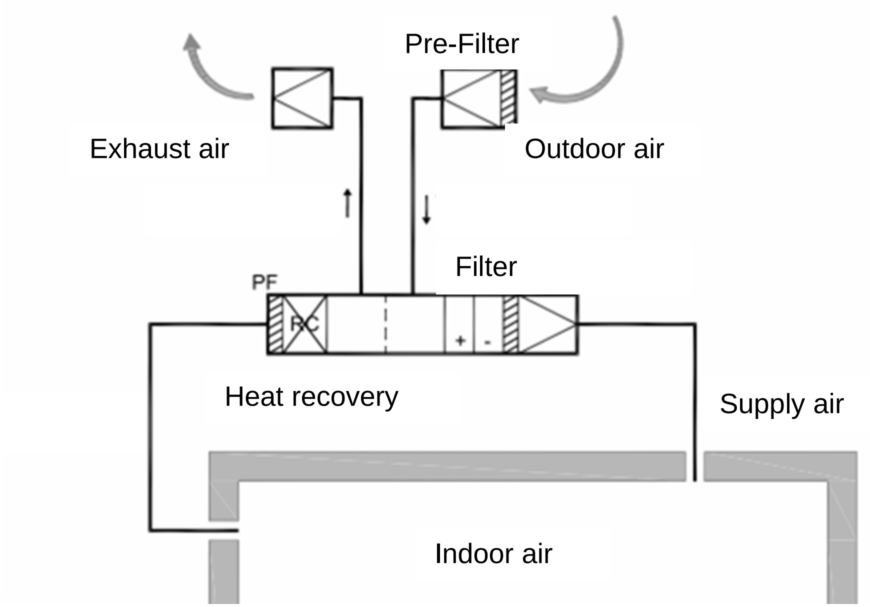
Typical night ventilation air exchange rates are 4/h, often counting on an auxiliary mechanical ventilation system to assure high energy performance ratios.

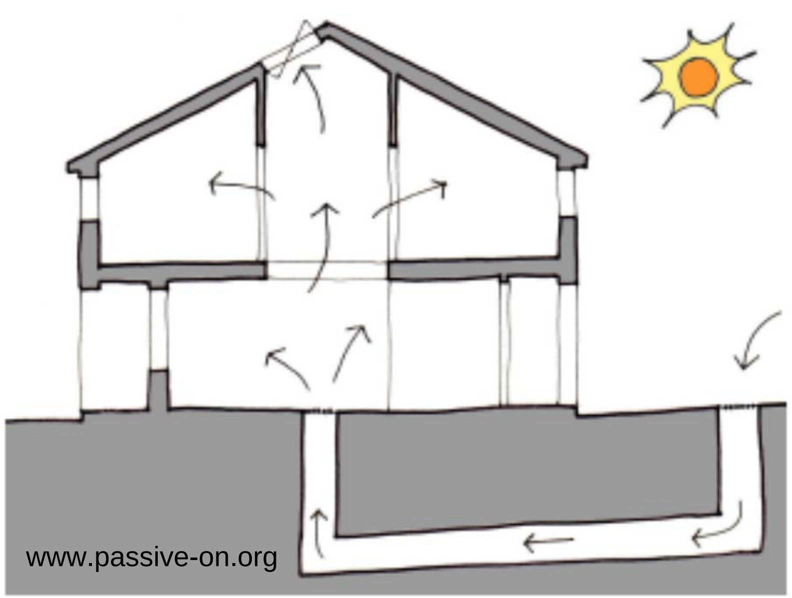


www.passive-on.org

3. Parameters: building energy consumption in use

3.2. Hybrid: Free cooling / heat recovery / earth tubes





Free cooling: use or increase of supply air flow rate whenever space cooling is required and outdoor air is cooler than indoor air.

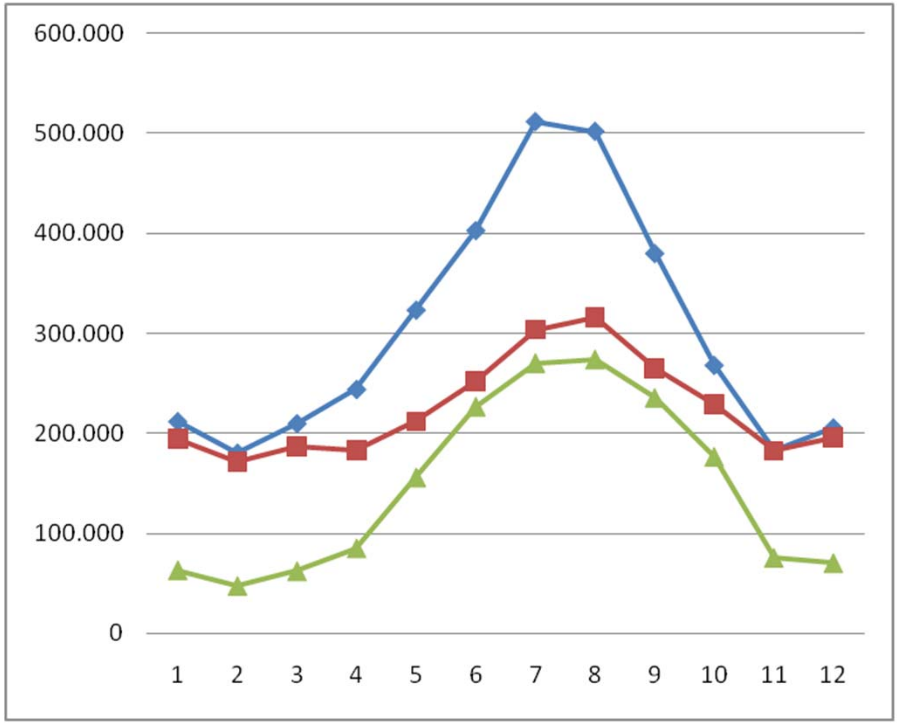
Heat recovery: pre-heating of supply air by recovering the heat from the exhaust air by means of an air-to-air heat exchanger

Earth or ground source heat exchanger: taking advantage of the moderate temperature of the ground, incoming air is conveyed through buried pipes with high thermal exchange capacity in order to get the supply air closer to comfort conditions, achieving high coefficients of performance.

3. Parameters: building energy consumption in use

3.2. Hybrid: Free cooling / heat recovery / earth tubes

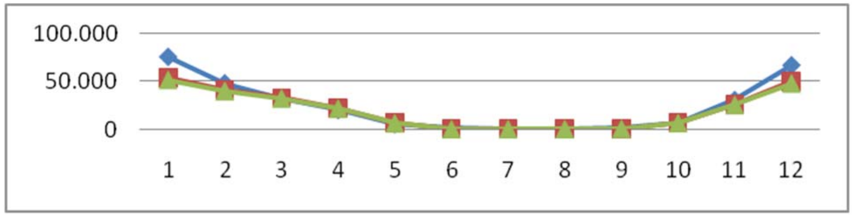
Example Blood & Tissue Bank Catalonia, 2010



100% CURTAIN WALL
HEAVY FAÇADE, WITHOUT RECOVERY
HEAVY FAÇADE, FREE COOLING AND RECOVERY

Demand reduction 41%!

SaAS



COOLING DEMAND (kWh)

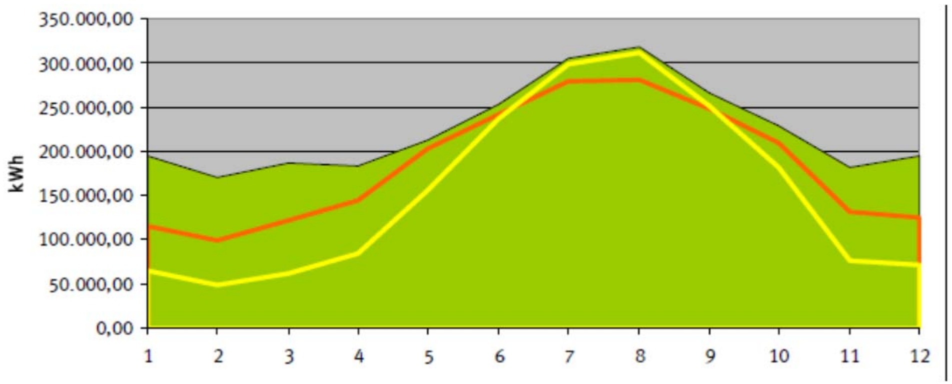
HEATING DEMAND (kWh)

Demanda energètica de climatizació (kW/h), JG Ingenieros, julio 2008 / Herramienta de cálculo: CARRIER Hourly Analysis Program v 4.12b

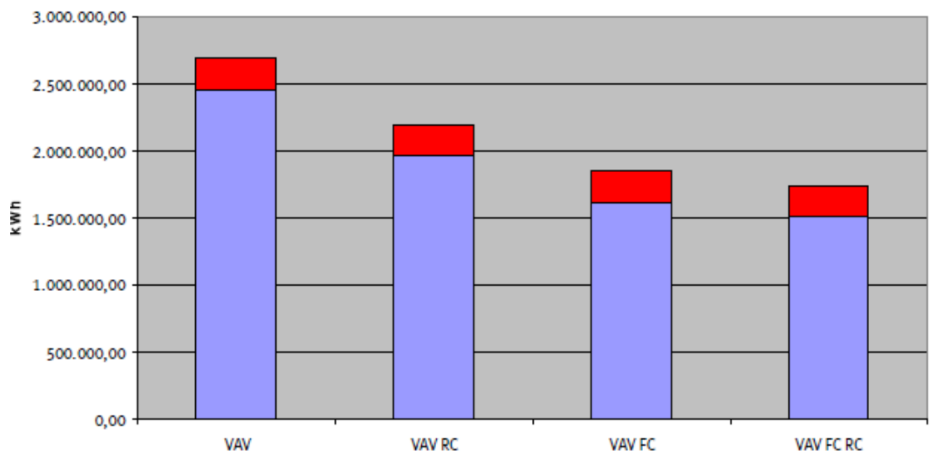
3. Parameters: building energy consumption in use

3.2. Hybrid: Free cooling / heat recovery / earth tubes

Example Blood & Tissue Bank Catalonia, 2010



Monthly heating and cooling energy demand (kW/h), grupoJG Enginyers, January 2008



- VAV air conditioners with variable air volume without heat recovery
- VAV + RC air conditioners with variable air volume with heat recovery
- VAV + FC air conditioners with variable air volume with free cooling
- VAV + FC + RC air conditioners with variable air volume with free cooling and heat recovery
- Heating demand
- Cooling demand

Simulation: CARRIER Hourly Analysis Program v 4.12b
Annual energy demand for heating and cooling
grupoJG Enginyers

SaAS

3. Parameters: building energy consumption in use

3.3. Active: Energy efficient installations

Solar thermal and solar photovoltaic modules on the roof of the LIMA - Low Impact Mediterranean Architecture prototype building, Barcelona.

In the Mediterranean climate, 1 kW installed PV power (8m^2 of solar panels – see photograph) comes up for about 1,200kWh$_e$/a, around one third of an average household's electricity demand.

3. Parameters: building energy consumption in use

3.4. Building Management and Control Systems

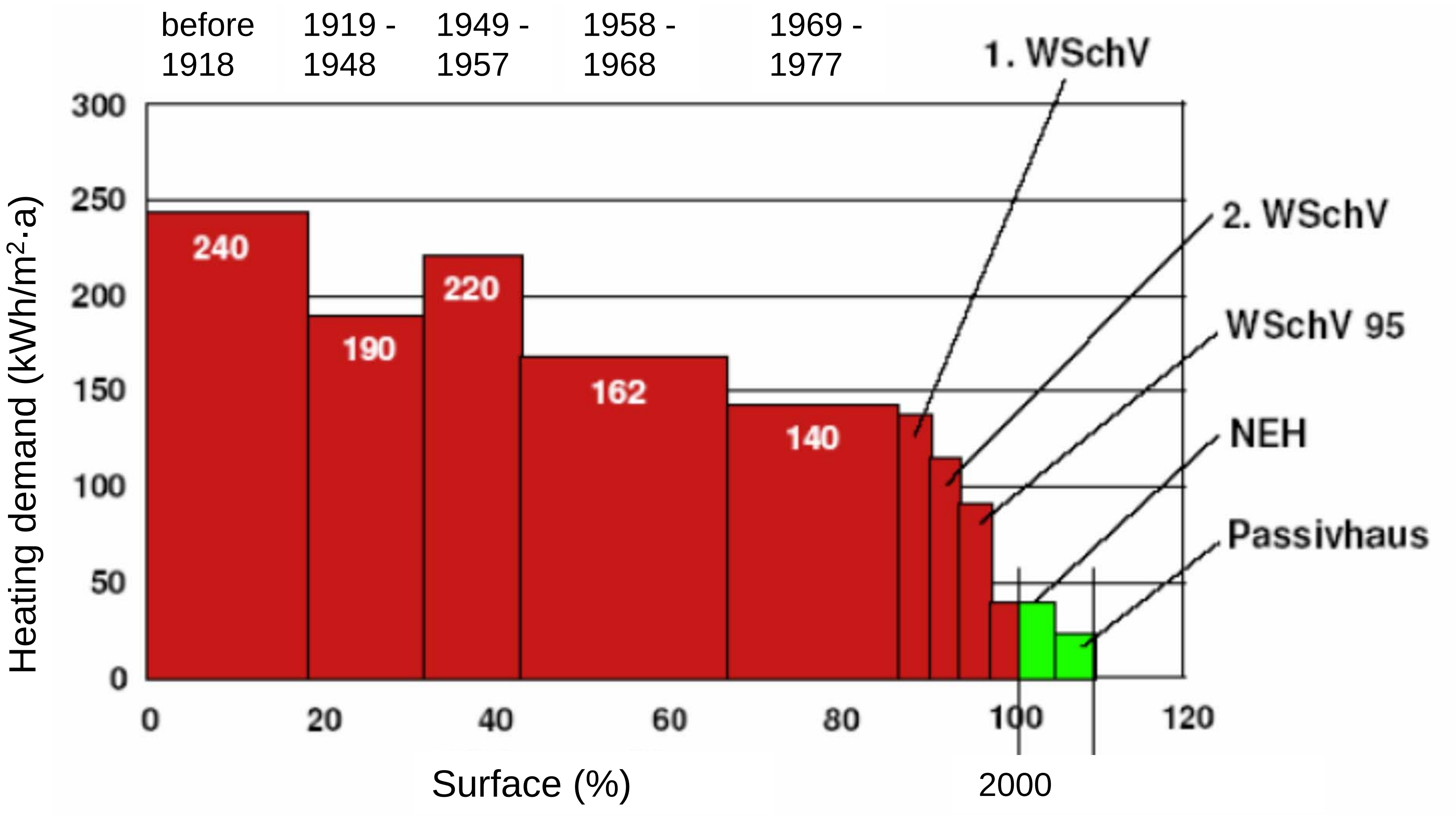
Management and control systems play an increasing role in energy consumption optimization, especially in tertiary sector buildings (offices, hotels, supermarkets).

On the basis of disaggregated metering of energy consumptions of different systems (especially heating, ventilating, air conditioning, but also lighting), specific devices regulate the relevant parameters (temperature, air renovation, luminance, etc) according to an established schedule or boundary conditions.

A centralised control via a graphical user interface permits easy access for maintenance staff to the registered data and performance control indicators, plus the detection of underperforming devices and the emission of for example alarm signals via GPRS.

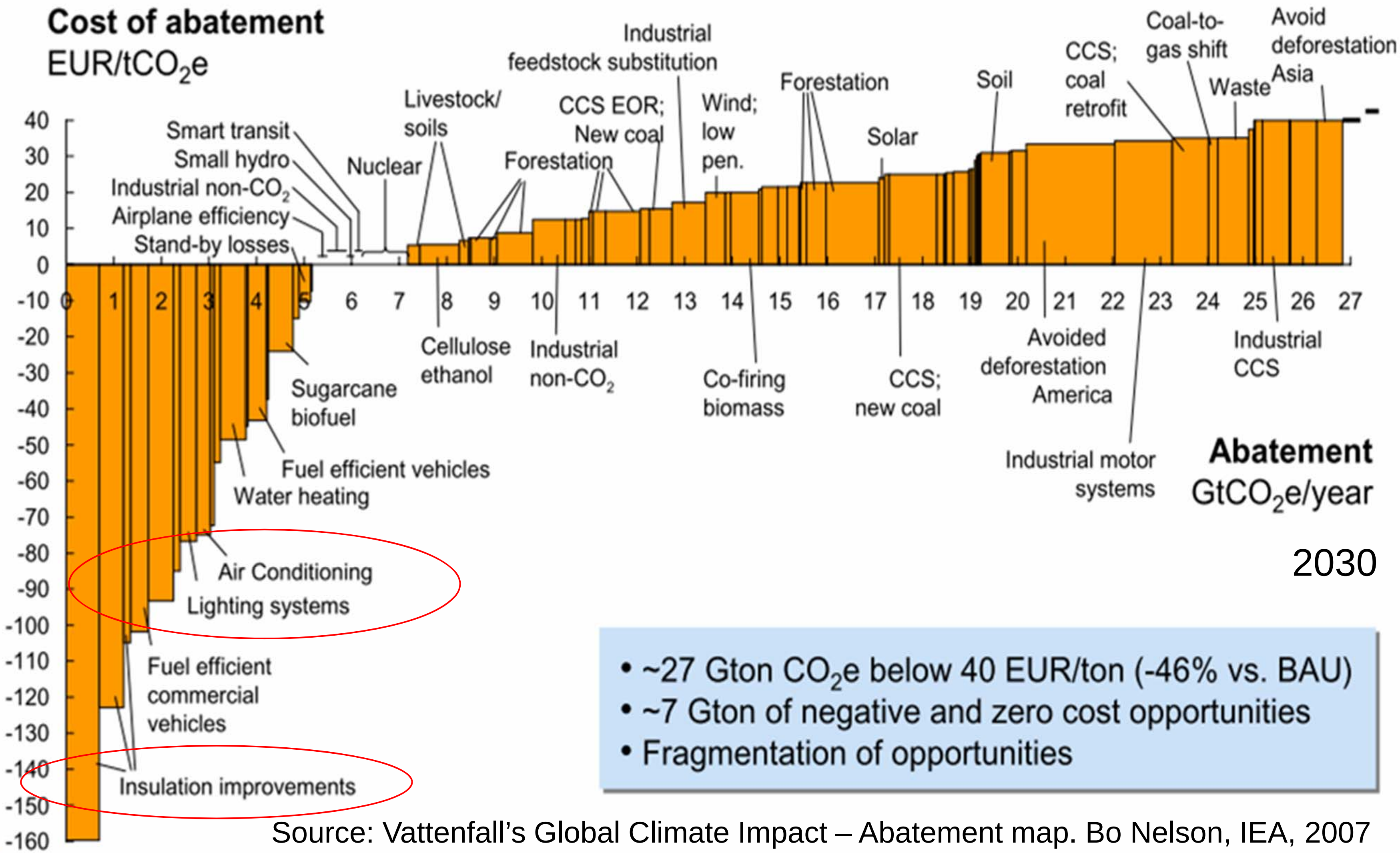
4. UP Measures to promote energy renovation in buildings

4.1. The importance of energy efficient refurbishment



4. UP Measures to promote energy renovation in buildings

4.1. The importance of energy efficient refurbishment



Source: Vattenfall's Global Climate Impact – Abatement map. Bo Nelson, IEA, 2007

4. UP Measures to promote energy renovation in buildings

4.1. The feasibility of energy efficient refurbishment measures

Energy efficient renovation	Public subsidy	Final energy savings	Primary energy savings	Avoided emissions
	M€	**ktep**	**ktep**	**ktCO₂**
Building envelope	**111,5**	**22**	**42**	**89**
Building services	**145,5**	**61**	**116**	**244**
Lighting equipment	**22,5**	**30**	**74**	**150**
Appliances	**282,3**	**81**	**204**	**412**

Source: IDAE (2011) Plan de Acción de Ahorro y Eficiencia Energética 2011-2020

Energy efficient renovation	Estimated lifetime of mesure	Public subsidy / primary energy saving	Public subsidy / avoided emissions	Avoided emissions / public subsidy
	a	**€/kWh**	**€/kgCO_2**	**kgCO_2/€**
Building envelope	**30**	**0,01**	**0,04**	**23,95**
Building services	**15**	**0,01**	**0,04**	**25,15**
Lighting equipment	**6**	**0,00**	**0,03**	**40,00**
Appliances	**10**	**0,01**	**0,07**	**14,59**

4. UP Measures to promote energy renovation in buildings

4.2. Innovative urban planning by-laws

Adapt urban by-laws to

- Ease renovation allowing an increase of constructed surface / area to insulate the building

- Define edificability according to net floor area instead of constructed area so as not to punish thicker walls.

- To promote the use of green roofs.

- To promote the incorporation of intermediate spaces for solar gains or protection (conservatory, pergolas, etc.) as well as terraces, balconies, etc..

The UP-RES Consortium

Contact institution for this module: **SaAS**

- **Finland : Aalto University School of science and technology**
  www.aalto.fi/en/school/technology/
- **Spain : SaAS Sabaté associats Arquitectura i Sostenibilitat**
  www.saas.cat
- **United Kingdom: BRE Building Research Establishment Ltd.**
  www.bre.co.uk
- **Germany :**

  AGFW - German Association for Heating, Cooling, CHP
  www.agfw.de

  UA - Universität Augsburg www.uni-augsburg.de/en

  TUM - Technische Universität München http://portal.mytum.de
- **Hungary : UD University Debrecen**

  www.unideb.hu/portal/en