M4

Energy demand reduction strategies: potential in new buildings and refurbishment
CONTENTS

1. // Introduction
   1.1. Energy consumption of the building sector
   1.2. Life cycle analysis – a holistic approach
   1.3. Embodied energy in building materials

2. // Energy in the use of buildings: legislative framework
   2.1 The European Directive 2002/91/EC
   2.2 The European Directive 2010/31/EC
   2.3 Labels and certifications

3. // Parameters to influence the building’s energy consumption in use
   3.1. Passive: Thermal inertia / Insulation / Solar control / Ventilation
   3.2. Hybrid: Free cooling / heat recovery / earth tubes
   3.3. Active: Energy efficient installations
   3.4. Building Management and Control Systems

4. // UP Measures to promote energy renovation in buildings
   4.1. The importance of energy efficient refurbishment
   4.2. Innovative urban planning by-laws
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]

Official Journal of the European Communities

Final energy consumption distribution per sector.
Total final energy consumption: 9714 ktep.
Catalonia 2007, Source: ICAEN
1. Introduction
1.1. Energy consumption in the building sector

Final energy consumption in Catalonia’s residential sector

<table>
<thead>
<tr>
<th>Domestic final energy consumption/m² of first residences 2007</th>
<th>Household energy consumption</th>
<th>heating</th>
<th>DHW / cooking</th>
<th>appliances</th>
<th>lighting</th>
<th>cooling</th>
</tr>
</thead>
<tbody>
<tr>
<td>kWh/m²</td>
<td>83.0</td>
<td>34.3</td>
<td>22.9</td>
<td>18.5</td>
<td>6.4</td>
<td>1.2</td>
</tr>
</tbody>
</table>

1. Introduction
1.1. Energy consumption in the building sector

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
1. Introduction
1.2. Life cycle analysis – a holistic approach

Objective of the cycle of resources

- Renewable energy
- Locally harvested / treated water
- Construction
- Occupancy
- Demolition
- Waste water
- Materials for recycling
- Renewable matter
- Recycled material
- Materials to be recycled
- Valorization with renewable energy
1. Introduction

1.2. Life cycle analysis – a holistic approach

Example of embodied energy / energy in use phase

<table>
<thead>
<tr>
<th>Life cycle phase</th>
<th>Energy consumption</th>
<th>CO2 Emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Reference MWh</td>
<td>Project MWh</td>
</tr>
<tr>
<td>Materials</td>
<td>16.333</td>
<td>12.589</td>
</tr>
<tr>
<td>Construction</td>
<td>167</td>
<td>289</td>
</tr>
<tr>
<td>Use phase</td>
<td>23.388</td>
<td>10.162</td>
</tr>
<tr>
<td>Deconstruction</td>
<td>251</td>
<td>194</td>
</tr>
<tr>
<td>Total</td>
<td>40.139</td>
<td>23.234</td>
</tr>
</tbody>
</table>

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 CO₂ eq.·y for a typical dwelling of 100 m² during 50 years

- Construction
- Use
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

<table>
<thead>
<tr>
<th>Insulation material</th>
<th>Primary energy (MJ/kg)</th>
<th>Emissions (kgCO$_{2eq}$/kg)</th>
<th>Cost (Euro/m$^3$)</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polystyrol, extruded</td>
<td>92,4</td>
<td>9,580</td>
<td>107</td>
<td>EMPA</td>
</tr>
<tr>
<td>Polystyrol, expanded</td>
<td>105,0</td>
<td>4,120</td>
<td>65</td>
<td>EMPA</td>
</tr>
<tr>
<td>Polyurethane PUR</td>
<td>100,0</td>
<td>4,210</td>
<td>136</td>
<td>EMPA</td>
</tr>
<tr>
<td>Glasswool</td>
<td>45,1</td>
<td>1,490</td>
<td>26</td>
<td>EMPA</td>
</tr>
<tr>
<td>Rockwool</td>
<td>21,7</td>
<td>1,480</td>
<td>115</td>
<td>EMPA</td>
</tr>
<tr>
<td>Cellular glass</td>
<td>16,5</td>
<td>0,600</td>
<td>295</td>
<td>PROVEIDOR</td>
</tr>
<tr>
<td>Sheep wool</td>
<td>14,7</td>
<td>0,045</td>
<td>108</td>
<td>PASSIVHAUS</td>
</tr>
<tr>
<td>Cork</td>
<td>25,0</td>
<td>0,021</td>
<td>402</td>
<td>EMPA</td>
</tr>
<tr>
<td>Woodfibre</td>
<td>13,7</td>
<td>-0,183</td>
<td>224</td>
<td>PROVEIDOR</td>
</tr>
<tr>
<td>Cellulose</td>
<td>7,2</td>
<td>-0,907</td>
<td>90</td>
<td>PASSIVHAUS</td>
</tr>
</tbody>
</table>
2. Energy in the building’s use: legislative framework

- **EU**
  - European Directive EPBD 2010/31/EC 05/2010
- **ES**
- **CAT**
  - Decret d’Ecoeficiència a l’Edificació (Eco efficiency decree) 08/2006
- **LOCAL**
  - Ordenança Solar Térmica (Solar Ordinance) (BCN) 07/1999
  - Ordenança Estalvi d’Aigua (Water Saving Ordinance) (Sant Cugat) 11/2002
2. Energy in the buildings: legislative framework


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

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.
“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/m²·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

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.

Study elaborated in the frame of the project b_EFIEN, promoted by Fundació b_TEC, with the participation of engineering 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
## 2. Energy in the building’s use: legislative framework
### 2.2. Quality labels and certifications

### Main areas of analysis in the certifications

<table>
<thead>
<tr>
<th>Environment</th>
<th>Urban density</th>
<th>Mobility</th>
<th>Soil protection</th>
<th>Green spaces</th>
<th>Health and comfort</th>
<th>Indoor air quality</th>
<th>Electromagnetic fields</th>
<th>Radioactive emissions</th>
<th>Thermal, visual, acoustic comfort</th>
</tr>
</thead>
<tbody>
<tr>
<td>Materials</td>
<td>Impact</td>
<td>Availability</td>
<td>Local knowledge</td>
<td>Waste</td>
<td>Socio-economic</td>
<td>Cost of improvements</td>
<td>User awareness</td>
<td>Professional training</td>
<td>Integration in networks</td>
</tr>
<tr>
<td>Energy</td>
<td>Energy demand</td>
<td>Energy distribution</td>
<td>Performance of installations</td>
<td>Renewable energies</td>
<td>Management</td>
<td>Integrated design</td>
<td>Maintenance plans</td>
<td>Audit intervals</td>
<td>Monitoring</td>
</tr>
<tr>
<td>Water</td>
<td>Water demand</td>
<td>Rain water</td>
<td>Grey water</td>
<td>Wastewater treatment</td>
<td>Others</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3. Parameters: building energy consumption in use

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

<table>
<thead>
<tr>
<th>WITHOUT CAVITY</th>
<th>HEAVY SOLID WALL</th>
<th>CAVITY WALLS</th>
<th>LIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>CONVENTIONAL</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>DOUBLE</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>EXTERIOR</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>WITH CAVITY</th>
<th>HEAVY SOLID WALL</th>
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<tr>
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<tr>
<td></td>
<td></td>
<td>DOUBLE</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>EXTERIOR</td>
<td></td>
</tr>
</tbody>
</table>
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 courtyard house based on thermal inertia.
3. Parameters: building energy consumption in use

3.1. Passive: Insulation

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

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

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.
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.

www.passive-on.org
3. Parameters: building energy consumption in use

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

Example Blood & Tissue Bank Catalonia, 2010

![Graph showing cooling and heating demand with different façade strategies.]

Demand reduction 41%!

Demanda energètica de climatització (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

- 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

Simulation: CARRIER Hourly Analysis Program v 4.12b
Annual energy demand for heating and cooling
grupoJG Enginyers
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 (8m² of solar panels – see photograph) comes up for about 1,200kWhₑ/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 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

## 4. UP Measures to promote energy renovation in buildings

### 4.1. The feasibility of energy efficient refurbishment measures

<table>
<thead>
<tr>
<th>Energy efficient renovation</th>
<th>Public subsidy</th>
<th>Final energy savings</th>
<th>Primary energy savings</th>
<th>Avoided emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M€</td>
<td>Lept</td>
<td>ktep</td>
<td>ktCO₂</td>
</tr>
<tr>
<td>Building envelope</td>
<td>111,5</td>
<td>22</td>
<td>42</td>
<td>89</td>
</tr>
<tr>
<td>Building services</td>
<td>145,5</td>
<td>61</td>
<td>116</td>
<td>244</td>
</tr>
<tr>
<td>Lighting equipment</td>
<td>22,5</td>
<td>30</td>
<td>74</td>
<td>150</td>
</tr>
<tr>
<td>Appliances</td>
<td>282,3</td>
<td>81</td>
<td>204</td>
<td>412</td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th>Energy efficient renovation</th>
<th>Estimated lifetime of measure</th>
<th>Public subsidy / primary energy saving</th>
<th>Public subsidy / avoided emissions</th>
<th>Avoided emissions / public subsidy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>a</td>
<td>€/kWh</td>
<td>€/kgCO₂</td>
<td>kgCO₂/€</td>
</tr>
<tr>
<td>Building envelope</td>
<td>30</td>
<td>0,01</td>
<td>0,04</td>
<td>23,95</td>
</tr>
<tr>
<td>Building services</td>
<td>15</td>
<td>0,01</td>
<td>0,04</td>
<td>25,15</td>
</tr>
<tr>
<td>Lighting equipment</td>
<td>6</td>
<td>0,00</td>
<td>0,03</td>
<td>40,00</td>
</tr>
<tr>
<td>Appliances</td>
<td>10</td>
<td>0,01</td>
<td>0,07</td>
<td>14,59</td>
</tr>
</tbody>
</table>
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