DELIVERABLE **4.1**

Analysis of energy efficiency measures

Date: 28/09/2015

Prepared by: CIRCE

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DELIVERABLE FACTSHEET

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Diffusion list[1]

Approvals

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Author/s	CIRCE
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[1] To be filled just if the dissemination level is PP or RE;

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EXECUTIVE SUMMARY

The main objective of this deliverable has been to identify a set of 250 energy efficiency measures expected from the public buildings users, owners and operators aiming to maximize the potential energy savings that can be achieved both in a real and virtual worlds.

To complete successfully this objective, some rules have been established for the classification of such big quantity of measures. The economic assessment has been taken into account for the first distinction of measures between short term (those with a low or medium investment and that can be easily implemented by the users) and long term measures (those involving significant investments). Then, a new distinction has been carried out involving the different components of the building where the measure is applied. Six parts have been identified:

1. Envelope: The building envelope protects the building occupants and plays a major role in regulating the indoor environment. Consisting of the building's foundation, walls, roof, windows, and doors, the envelope controls the flow of energy between the interior and exterior of the building. A well-designed envelope allows the building to provide comfort for the occupants and respond efficiently to heating, cooling, ventilating, and natural lighting needs. Examples of envelope measures are “adding or increasing external insulation in walls”, “installation of efficient windows”, “improve insulation in thermal bridge areas”…
2. Heating, Ventilation and Air-Conditioning (HVAC) system: Usually, most HVAC equipment is not optimized. It is important to select an HVAC configuration which meets functional requirements while effectively minimizing the energy use. The design and choice of HVAC equipment also has a big impact on Indoor Environmental Quality (IEQ). A poorly designed system can have a negative impact on occupants’ health and comfort. Examples of HVAC measures are “installation of a condensing boiler”, “installation of radiant floor heating”, “use of free cooling”…
3. Domestic Hot Water (DHW): Water reduction might not seem like a way to save energy, but it takes energy to heat, pump and treat water. In seeking to reduce a water heater’s energy consumption, it makes sense to start by reducing demand. Examples of this type of measures are “installation of low-flow showerheads”, “use shower instead of bath”, “installation of taps with flow reduction”… After reducing the demand for hot water, the next potential measures seek to eliminate water heating system inefficiencies, which include how the water is heated (combustion efficiency, standby losses, etc.) and distributed. Measures of this type are “installation of a hot water return circuit”, “installation of CO_2 heat pumps”…
4. Lighting: Energy is used both to power the lights and to provide additional cooling to compensate for the added heat generated by lights. To address these issues early in the design process, it is important to determine what kinds of natural and artificial lighting will be used. In some climates the lighting load can be the building’s greatest operating expense. Examples of lighting measures are “installation of daylighting sensors”, “reduce the number of lamps”, “turn off lighting in unused rooms or zones”…

5. Electrical devices: Choosing efficient devices and making an appropriate use of them further reduce the energy use. In addition, these devices generate heat with their use, increasing the internal load and indirectly influencing in the air conditioning energy demand of the building. Examples of this type of measures are "purchase monitors with LCD screen", "purchase Energy Star label devices", "using the screensaver in a proper way"…
6. Other: The rest of measures not included in the other groups are located here. Examples of this type of measures are "wear adequate clothing", "implementation of a compressed work schedule", "installation of solar thermal panels", "installation of an ICT system"…

These two distinctions (investment and components of the building) have categorized the measures in 10 groups which have been included in a list. To complete it, the first step has been to check the main energy efficiency requirements of the real pilots already defined in *"D2.2. Virtual pilots description and game worlds' development"*. Then, an extensive and exhaustive bibliography research has been carried out trying to identify and select the most appropriate measures for which the following considerations were borne in mind:

- The environment or playable world where the measure can be implemented (residential, academic and offices).
- The real or virtual player that can carry out the measure (building user, operator, owner).
- The type of driver that is encouraging the player to carry out the measure (physical environmental, contextual, psychological, physiological, social).
- The final goal of TRIBE project.

The real or virtual player and the type of driver have been connected with numbers in case there is more than one player that could have different drivers.

Once the 250 measures haven been decided, the elaboration of a template to fulfil with basic information of the measure has been the next step. Figure 1 shows the format of the template.

Measure code: DS12i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** X Public building users (1) ☐ Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling X DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (1) (3) X Contextual (1) (3) X Psychological (1) (3) X Physiological (1) X Social (1)
Description			
Fix any leaking tap. A dripping tap can waste 5000 litres a year, while a replacement tap washer only costs a few cents.			
Benefits			
• Energy savings • Water savings			
Limitations			
• Occupant acceptance			
Economic assessment			
Mending a dripping tap washer could save over 26€ a year			
References and best practices			
- [60] Research into saving water the experiences and perceptions of customers and their households: www.ccwater.org.uk/wp-content/uploads/2013/12/Research-into-customer-water-saving.pdf			
Image gallery			

Figure 52. Fix dripping taps. Source: www.bestplumbers.com.

Figure 1. Example of a measure template. Source: Own elaboration by CIRCE.

The main parts of this template are:

- Measure code: identification of the measure with a short acronym useful for future actions in the project.
  Example: DS12i
  - The first letter means the component of the building where the measure is applied (in this case "D" regarding to DHW).
  - The second letter means if the measure is a short or long measure (in this case "S" short).
  - The number of the measure (in this case measure 12).
  - If the measure is obtained through an investment or a behaviour change (in this case "i" regarding to investment.
- Boxes to mark the main characteristics of the measure regarding to TRIBE project.
- Description: a short explanation of the measure.
- Benefits: the main advantages of the measure application mainly regarding to the energy savings that can be obtained.
- Limitations: the main disadvantages of the measure application.
- Economic assessment: a short assessment of the main economic aspects of the measure as initial investment, payback, maintenance cost…)
- References and best practices: useful links to documents where more information of the measure is available.
- Image gallery: an image to make the measure more understandable.

The acronyms before mentioned for the measure codes are the following:

- E: envelope
- H: HVAC
- D: DHW
- L (placed at second position): lighting
- ED: electrical devices
- O: other
- S: short
- L (placed at first position): long
- i: investment
- b: behaviour

The last step of this deliverable has been to establish conclusions of the analysis of the energy efficiency measures having in mind the future work to be done in TRIBE project.

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INTRODUCTION

This deliverable is the result of the works undertaken in Task 4.1 *"Selection of the energy efficiency set of measures to promote"* within WP4 *"Measures and actions for energy efficiency"*, where the 250 energy efficiency set of measures expected from the public building users, owners and operators aiming to maximize the energy savings have been identified. The results of deliverable D2.2 *"Virtual pilot description and game worlds development"* have been also useful for the measures identification.

Based on the works done under this task, this deliverable will be one of the bases for Task 4.2 *"Measures and actions effects on the players' and avatars' behaviour change"* where the impacts of every measure in the behaviour change of the public building users, owners and operators will be characterized and also for Task 4.3 *"Measures and actions effects on pilots and virtual pilots"* where the impacts in the energy performance of the buildings of every measure identified will be characterized.

All the results of WP4 connected with the rest of parallel packages (WP3, WP5 and WP6) will be useful for the energy efficiency measures to be implemented and their effects on the videogame.

1 SHORT TERM ENERGY EFFICIENCY DECISIONS AND MEASURES

1.1 Envelope measures

1.1.1 Use silicone, putty or draught excluder to reduce air infiltrations through windows and doors

Measure code: ES1i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** X Public building users (1) ☐ Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (1) (3) X Contextual (1) X Psychological (1) ☐ Physiological X Social (1) (3)
Description			
Simple and cheap means may be used as silicone, putty or draught excluder (self-adhesive strips of insulation material which are set on the edge of doors and windows to avoid the entry or exit of air) to cover the cracks and decrease air infiltrations that can be produced through the doors and windows of the building.			
Benefits			
• The energy consumption reduction potential is considered to be high (up to a 40%) • Reduce heat losses and air infiltration • Easy, fast and cheap installation (it is not necessary to dismount the window)			
Limitations			
• Durability of solution • To obtain better performance, in case of old models of windows, it is recommended to change the entire window (frame and glass) • Improve airtightness can lead to more condensation because moist air is trapped in the house			
Economic assessment			
Low investment. It depends on the particular characteristics of each building and the means used. For example, the use of draught excluder is very simple and cheap, around 0.5 €/m^2.			

References and best practices
- [1] The impact of replacement windows on air infiltration and Indoor Air Quality (IAQ) in dwellings: www.researchgate.net/profile/Tadj_Oreszczyn/publication/32886658_The_impact_of_replacement_windows_on_air_infiltration_and_indoor_air_quality_in_dwellings/links/0c9605180c12ee7a72000000.pdf - [2] Air leakage guide: www.energycodes.gov/sites/default/files/documents/BECP_Buidling%20Energy%20Code%20Resource%20Guide%20Air%20Leakage%20Guide_Sept2011_v00_lores.pdf
Image gallery

Figure 2. Adding weather stripping at leaky doors and windows. Source: www.imaginecodesignblog.com.

1.1.2 Seal air leaks located in all cavities present in the building

Measure code: ES2i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** X Public building users (1) ☐ Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (1) (3) X Contextual (1) X Psychological (1) ☐ Physiological X Social (1) (3)
Description			
Air leaks can be located in all cavities present in the building. It is not simple to find all points of air infiltration, which are not limited to doors or windows, so sometimes it can be necessary to carry out the blower door test. In general, typical infiltration points are situated in the joint of two building materials outside and/or inside. Once infiltration points are found, they should be caulked.			
Benefits			
• Reduce heat losses and air infiltration • Easy and fast installation • Improve comfort conditions			
Limitations			
• To obtain the best results, it is necessary to carry out a blower door test • Improving airtightness can lead to more condensation because moist air is trapped in the house			
Economic assessment			
Low investment. The caulking is inexpensive and easy to carry out. A typical cost of a blower door test ranges from 200€ onwards depending on the size and complexity of the structure. Over 30% in heating and cooling costs could be saved.			
References and best practices			
- [3] Save home energy by stopping air leaks: www.ianrpubs.unl.edu/live/ec479/build/ec479.pdf - [4] Air infiltration in buildings: www.osti.gov/scitech/biblio/6370839			

Image gallery

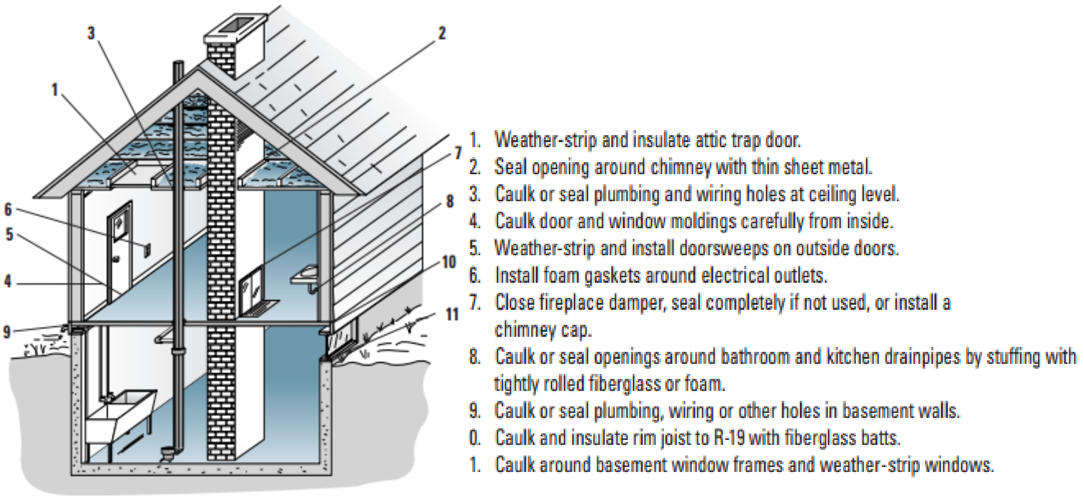


Figure 3. Easy ways to seal household air leaks. Source: www.xcelenergy.com.

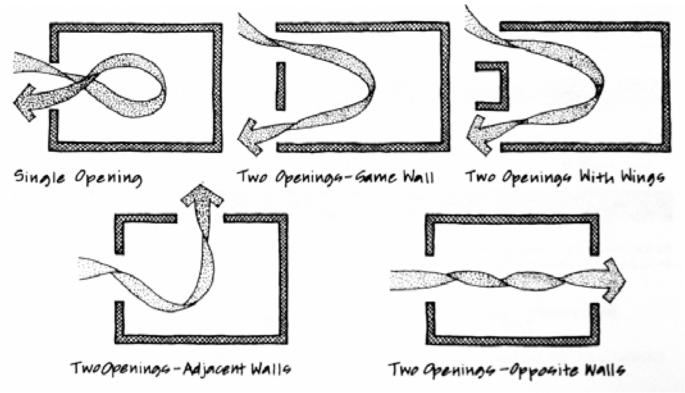
1.1.3 Close windows and doors when HVAC systems are operating

<table>
<tr><th colspan="4">Measure code: ES3b</th></tr>
<tr>
<td>Environment or playable world:
☐ Residential
☐ Academic
☐ Offices
X All</td>
<td>Carried out by:
X Public building users (1)
☐ Owners (2)
☐ Operators (3)
☐ All</td>
<td>Reduce consumption of:
X Heating
X Cooling
☐ DHW
☐ Lighting
☐ Electric devices</td>
<td>Type of driver:
X Physical environmental (1)
X Contextual (1)
X Psychological (1)
X Physiological (1)
X Social (1)</td>
</tr>
<tr><th colspan="4">Description</th></tr>
<tr><td colspan="4">Make sure windows or doors are not open unnecessarily, especially when heating, cooling or air conditioning systems are operating. To ventilate the room it is sufficient to have the window open for 10 minutes. In addition, keep it opened for longer involves losing heat from the heating system or cold from the air conditioning system. Turn off the HVAC systems during that time.</td></tr>
<tr><th colspan="4">Benefits</th></tr>
<tr><td colspan="4">• Easy application
• Saving in heating and cooling costs could be considerable, depending on unnecessary openings</td></tr>
<tr><th colspan="4">Limitations</th></tr>
<tr><td colspan="4">• Occupant acceptance</td></tr>
<tr><th colspan="4">Economic assessment</th></tr>
<tr><td colspan="4">The cost is zero, although it is convenient to train and inform properly users on these issues.</td></tr>
<tr><th colspan="4">References and best practices</th></tr>
<tr><td colspan="4">- [5] Keeping cool (or warm) sustainably at work: www.uq.edu.au/sustainability/air-conditioning-at-uq</td></tr>
<tr><th colspan="4">Image gallery</th></tr>
<tr><td colspan="4">


Figure 4. Sign to inform users. Source: www.safetysignsandnotices.co.uk.
</td></tr>
</table>

1.1.4 Manage properly the opening of windows and doors for natural ventilation

Measure code: ES4b			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** X Public building users (1) ☐ Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (1) (3) X Contextual (1) (3) X Psychological (1) (3) X Physiological (1) X Social (1)
Description			
To improve air comfort and reduce the need of HVAC systems use natural ventilation. Open windows of opposite façades to produce cross-ventilation or if the building has a space for vertical circulation or a central courtyard, open windows and/or doors at different heights to generate a vertical ventilation and expulse warm air.			
Benefits			
• Natural and healthy • It improves the quality of air • Reduce the use of cooling systems			
Limitations			
• Occupant acceptance • The quality of ventilation achieved by opening the windows will depend on the outdoor wind regime • It should be done in a controlled way so that air speed is compatible with the improvement of the comfort feeling • Outdoor air currents to properly ventilate the building are difficult to find in cities			
Economic assessment			
The initial investment is zero, although it is convenient to train and inform properly users on these issues. It reduces the costs associated to the HVAC system.			
References and best practices			
- [6] Experimental and theoretical analysis of natural ventilation by windows opening: www.sciencedirect.com/science/article/pii/S0378778802000993 - [7] Wind driven natural ventilation through multiple windows of a building - A computational approach: www.sciencedirect.com/science/article/pii/S0378778811005718			

Image gallery
 *Figure 5. Different types of natural cross-ventilation. Source: www.santacruzarchitect.wordpress.com.*

1.1.5 Periodic and suitable cleaning of windows

Measure code: ES5ib			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** X Public building users (1) ☐ Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW X Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (1) (3) X Contextual (1) (3) X Psychological (1) (3) X Physiological (1) X Social (1) (3)

Description

It is important to maintain the windows' glass clean to allow a good penetration of natural light in the building and to improve their use, avoiding the use of artificial light.

Benefits

- It improves the internal light comfort
- Reduce the use of lighting systems
- Extend the life of windows

Limitations

- It may be difficult to clean the external glass in a building with high curtain wall, in which case a specific cleaning installation is necessary

Economic assessment

Low investment. It includes the cost of water, detergent and manpower. The cost could be more elevated in case the installation of a specific cleaning system is required (up to 20€ for each window pane). It reduces the costs associated to the use of artificial lighting.

References and best practices

- [8] How the windows of skyscrapers get washed: www.citylab.com/design/2011/11/how-the-windows-of-skyscrapers-get-washed/459/

Image gallery

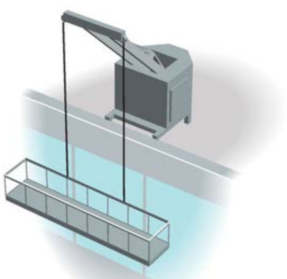


Figure 6. Boom system for the cleaning of high rise buildings. Source: www.citylab.com.

1.1.6 Correct use of external solar shading

Measure code: ES6b

Environment or playable world:	Carried out by:	Reduce consumption of:	Type of driver:
☐ Residential ☐ Academic ☐ Offices X All	X Public building users (1) ☐ Owners (2) X Operators (3) ☐ All	X Heating X Cooling ☐ DHW X Lighting ☐ Electric devices	X Physical environmental (1) (3) X Contextual (1) (3) X Psychological (1) (3) X Physiological (1) (3) X Social (1) (3)

Description

In cooling seasons users have to block direct solar radiation by closing solar shadings to avoid internal overheating. In others seasons solar shadings should be opened to take advantage of natural light and, in heating seasons also of solar radiation to increase internal thermal load.

Benefits

- Shading windows can block up to 90% of heat generated by direct sun.
- Reduce internal summer temperatures
- Improve comfort
- Reduce the use of cooling and heating systems

Limitations

- Occupant acceptance
- Design defect

Economic assessment

The initial investment is zero, although it is convenient to train and inform properly users on these issues. It reduces the costs associated to HVAC systems.

References and best practices

- [9] Impact of external shading devices on thermal and daylighting performance of offices in hot climate regions: www.sciencedirect.com/science/article/pii/S0038092X14000279

Image gallery

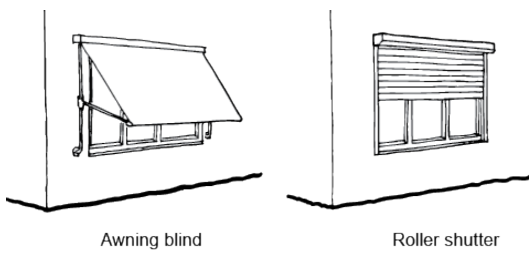


Figure 7. Adjustable shading system for eastern and western façades. Source: www.yourhome.gov.au.

1.1.7 Correct use of internal solar shading

Measure code: ES7b			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** X Public building users (1) ☐ Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling ☐ DHW X Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (1) (3) X Contextual (1) (3) X Psychological (1) (3) X Physiological (1) (3) X Social (1) (3)
Description			
Internal solar shadings allow the protection of interior space from direct radiation. The user should close the shading when direct solar radiation is entering the building in cooling seasons, while in heating seasons shadings should be opened to permit that solar radiation and natural light enter the building.			
Benefits			
• Reduce internal temperatures in cooling seasons • Increase internal thermal loads in heating seasons • Improve comfort • Reduce the use of cooling and heating systems			
Limitations			
• Occupant acceptance • Internal solar shadings are not as effective as external shadings because they allow that solar radiation enters in the interior space			
Economic assessment			
The cost is zero, although it is convenient to train and inform properly users on these issues. It reduces the costs associated to HVAC system.			
References and best practices			
- [10] An overview on solar shading systems for buildings: www.researchgate.net/publication/263745935_An_Overview_on_Solar_Shading_Systems_for_Buildings			

Image gallery

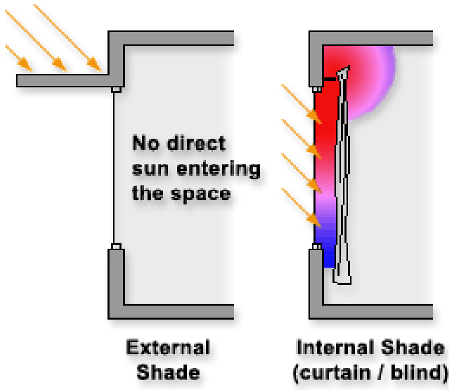



Figure 8. External vs internal shading. Source: [www.wiki.naturalfrequency.com.](www.wiki.naturalfrequency.com)

1.1.8 Improve insulation of roller shutter box

Measure code: ES8i

Environment or playable world:	**Carried out by:**	**Reduce consumption of:**	**Type of driver:**
☐ Residential ☐ Academic ☐ Offices X All	X Public building users (1) ☐ Owners (2) X Operators (3) ☐ All	X Heating X Cooling ☐ DHW ☐ Lighting ☐ Electric devices	X Physical environmental (1) (3) X Contextual (1) (3) X Psychological (1) (3) X Physiological (1) (3) X Social (3)

Description

It is important to check heat losses from the shutter box because often it is not isolated and it is a significant point of air leakage. The solution consists in installing roller shutter box insulation.

Benefits

- It allows about 5 to 10% of energy savings depending on climate conditions
- The internal space is kept, not affecting the useful surfaces
- Reduce heat losses
- The installation of insulation is a simple, fast and inexpensive intervention, where there is sufficient space (at least 2 cm)

Limitations

- The access to the roller shutter boxes may be difficult

Economic assessment

Low investment, around 9 €/m^2.

References and best practices

- [11] R+T Compass: Energy-efficient roller shutter systems: www.messe-stuttgart.de/en/r-t/visitors/press/r-t-news/r-t-news-from-16122014/r-t-compass-energy-efficient-roller-shutter-systems/

Image gallery

Figure 9. Shutter box insulation installation process. Source: [www.certificadosenergeticos.com.](www.certificadosenergeticos.com)

1.1.9 Substitution of roller tape guide

Measure code: ES9i

Environment or playable world:	**Carried out by:**	**Reduce consumption of:**	**Type of driver:**
☐ Residential ☐ Academic ☐ Offices X All	X Public building users (1) ☐ Owners (2) X Operators (3) ☐ All	X Heating X Cooling ☐ DHW ☐ Lighting ☐ Electric devices	X Physical environmental (1) (3) X Contextual (1) (3) X Psychological (1) (3) X Physiological (1) (3) X Social (3)

Description

The openings of the roller tape are considered points of air infiltrations and consequently there are thermal bridges. The measure consists in the installation of sealed roller tape guide.

Benefits

- Reduce heat losses and air infiltration and consequently heating energy is saved
- Easy and fast installation
- It is not necessary to dismount the tape

Limitations

- Depending on climate conditions, the energy savings may be not considerable

Economic assessment

Very low investment

References and best practices

- [12] Guide to home energy savings: www.xcelenergy.com/staticfiles/xe/Marketing/Files/SmartEnergyGuide.pdf

Image gallery

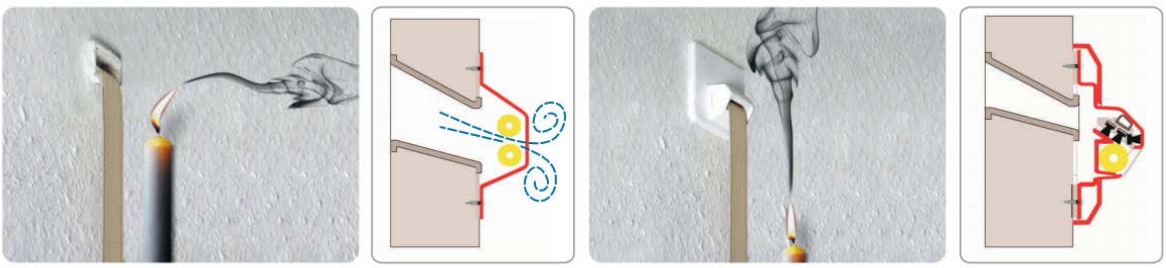


Figure 10. Difference between old and new tape guide. Source: www.beck-heun.com.

1.1.10 Maintenance of wood and aluminium windows frame

Measure code: ES10i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** X Public building users (1) ☐ Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (1) (3) X Contextual (1) (3) X Psychological (1) (3) X Physiological (1) (3) X Social (3)

Description

Inspect regularly the windows frame and repaint it if there are cracks which can expose the timber or aluminium to moisture which cause corrosion of aluminium or decomposition of the timber. Lubricate and clean hardware components to avoid a faulty closure. Badly maintained windows cause water and air infiltration.

Benefits

- Reduce air infiltration
- Heating and cooling energy are saved
- The maintenance can be home made
- Extend the lifetime of the window

Limitations

- Depending on climate conditions, it may be necessary more than one maintenance action per year

Economic assessment

Low investment. It depends on the time interval for each maintenance action.

References and best practices

- [13] Care & Maintenance of Aluminium Window & Door Frames: www.service-aluminum.com/Windows/SACI%20Care_Maintenance.pdf

Image gallery

Figure 11. Lubrication of hinges. Source: www.mansarda.it.

1.1.11 Adding a low Emissivity (E) window film

Measure code: ES11i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** X Public building users (1) ☐ Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (1) (3) X Contextual (1) (3) X Psychological (1) (3) X Physiological (1) (3) X Social (3)

Description

A low E film is an extremely thin layer of metal oxides, in the order of nanometers, which, if it is applied on the glass, provides a capacity of reinforced thermal insulation. The film reflects inward a part of the incident long-wave energy (heating), decreasing the absorption of the own glass and, therefore, the energy emitted outside.

Benefits

- Improve solar and thermal control
- Reduce summer heat gain and winter heat loss
- Decrease UV transmission such as furniture fading
- Reduce condensation in double glazing

Limitations

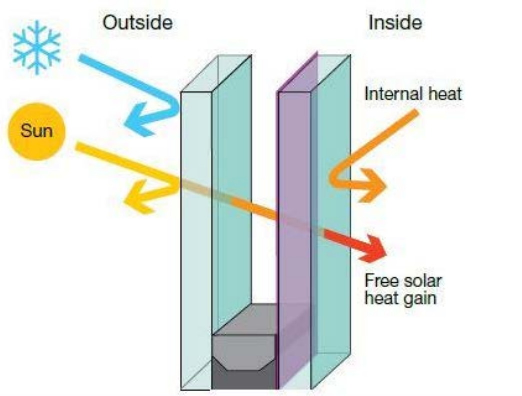
- It must be applied correctly
- It can reduce valuable solar heat gain in colder climates

Economic assessment

Low investment. The approximate cost of low emissivity layers is 20 €/m^2, although it varies for each type of layer.

References and best practices

- [14] Heat treatment and bending of low-E glass: www.sciencedirect.com/science/article/pii/S0040609099000875
- [15] Bendable silver-based low emissivity coating on glass: www.sciencedirect.com/science/article/pii/0165163389900221

Image gallery
 *Figure 12. Low E glass performance. Source: www.glassforeurope.com.*

1.1.12 Adding a solar control window film

Measure code: ES12i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) ☐ Owners (2) ☐ Operators (3) X All	**Reduce consumption of:** ☐ Heating X Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (1) (2) (3) X Contextual (1) (2) (3) X Psychological (1) (2) (3) X Physiological (1) (2) (3) X Social (3)

Description

The solar control film, easily applicable on window glasses, has the property of reflecting part of the solar radiation received, decreasing the amount of energy that passes through the glass.

Benefits

- Solar films block 99% of UV light that fades furniture
- Films add security, slowing down a break in and holding shards together if the window shatters.
- While mainly it is a retrofit product, some films can make a low-cost new window as efficient as a low-E, triple-pane unit
- Overheating is reduced as well as air conditioning needs
- Increase internal comfort

Limitations

- Some window manufacturers warn that films will void their window warranty; however, several film manufacturers offer to match it
- Certain lites, latches, and frames make installation difficult, and a bad application can leave glass looking bubbly
- Most homeowners are skeptical of the benefits, making film a hard sell that requires education
- It can block a great part of natural light, increasing lighting needs

Economic assessment

Low investment. The approximate cost of low emissivity layers is 20 €/m^2, although it varies for each type of layer. Savings of 1 to 14 €/m^2 are expected. Window films can cut utility costs by 30% to 40%. It is much cheaper than replacing windows.

References and best practices

- [16] Solar control glass for greater energy efficiency: www.glassforeurope.com/images/cont/116_6969_file.pdf
- [17] Solar control coating on glass: www.sciencedirect.com/science/article/pii/S1359028698800491

Image gallery

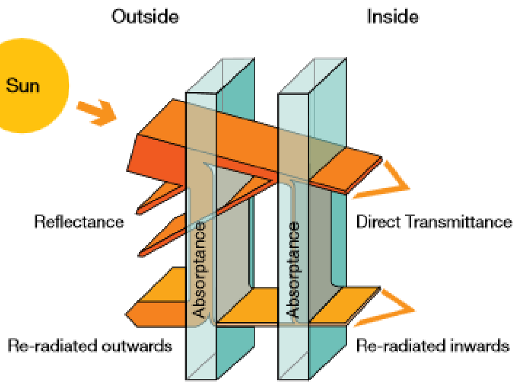


Figure 13. Glass performance with solar control film. Source: www.glassforeurope.com.

1.1.13 Put foil behind radiators to avoid heating the wall

Measure code: ES13i			
Environment or playable world: X Residential ☐ Academic ☐ Offices ☐ All	**Carried out by:** X Public building users (1) ☐ Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (1) X Contextual (1) X Psychological (1) X Physiological (1) ☐ Social
Description			
Silver foil placed in the back of a radiator will reflect heat back into a room rather than letting it uselessly escape through the walls of a house.			
Benefits			
• The energy savings will not be significant, but even a small saving is worthy • Improve comfort			
Limitations			
• Occupant acceptance			
Economic assessment			
Initial investment: low. Under 15€. Payback: low. Less than one year.			
References and best practices			
- [18] Do radiator reflectors work?: www.thegreenage.co.uk/do-radiator-reflectors-work/			
Image gallery			

Figure 14. Foil behind the radiator. Source: www. heatsave.actimedia.com.

1.1.14 Maintenance of room surfaces

Measure code: ES14ib			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** X Public building users (1) ☐ Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW X Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (1) (3) X Contextual (1) (3) X Psychological (1) (3) X Physiological (1) (3) X Social (3)
Description			
Rooms cleaned at regular intervals or painted in such a way that they have a high reflection coefficient over a long period are the basis for maintaining the high efficiency of the supplied light.			
Benefits			
• Energy savings • Improve comfort			
Limitations			
• Occupant acceptance			
Economic assessment			
Zero or low cost.			
References and best practices			
- [19] Information for maintenance: www.wila.com/en/knowledge/information-for-maintenance/			
Image gallery			
 *Figure 15. High reflection room surfaces. Source:www.lushome.com.*			

1.2 HVAC measures

1.2.1 Turning off air conditioning systems when rooms are empty

Measure code: HS1b			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** X Public building users (1) ☐ Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (1) X Contextual (1) (3) X Psychological (1) (3) X Physiological (1) X Social (1) (3)

Description

When leaving the room, even if it is for a short time, the air conditioning should be turned off. If possible, turn off the air conditioning 20 minutes before leaving, the air will stay cool during this time and there will be sufficient thermal comfort.

Benefits

- The saving potential is medium, depending on the type of equipment and their use
- Energy savings achieved can be between 10 and 20% with proper user training

Limitations

- Occupant acceptance

Economic assessment

The cost is zero, although it is convenient to train and inform properly users on these issues.

References and best practices

- [20] Estimating the energy consumption and power demand of small power equipment in office buildings: www.sciencedirect.com/science/article/pii/S0378778814001224
- [21] Energy efficiency of office equipment in commercial buildings - the case of Thailand: www.ac.els-cdn.com/S036054429700162X/1-s2.0-S036054429700162X-main.pdf?_tid=4dc21bf8-fa4b-11e4-a263-00000aab0f6c&acdnat=1431616386_0221f399ad78b4129e2c3c70991f28be

Image gallery

Figure 16. Turning off air conditioning. Source: www.overstock.com.

1.2.2 Upgrade and maintain the filters of the HVAC system

Measure code: HS2i			
Environment or playable world: ☐ Residential X Academic X Offices ☐ All	**Carried out by:** ☐ Public building users (1) ☐ Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (3) X Contextual (3) X Psychological (3) ☐ Physiological ☐ Social
Description			
Air filters are used to reduce the amount of dust that reaches the wet coils, keeping the HVAC system clean. Dust can make mold to grow on the wet coils and ducts and can reduce the efficiency of the coils. Clogged filters reduce the air flow and can cause uneven air flow as well as higher energy bills. By choosing the right air filter and replacing it at regular maintenance intervals, the HVAC system motor will have less resistance to deliver the air to the ventilation system.			
Benefits			
• The energy consumption reduction potential is considered low to medium. With this measure, a reduction in ventilation losses of over 50% can be obtained on a building in which the ventilation is turned on all day • Provide better air quality for the building occupants (especially against some type of allergy) • Reduce HVAC operating costs			
Limitations			
• Operation and Maintenance (O&M) staff size, skill level, and budget need to be considered			
Economic assessment			
The cost is low or even zero, since most of the actions are for the improvement of the maintenance of HVAC systems, although it will depend in each case on the type and age of the HVAC system.			
References and best practices			
- [22] Indoor air quality guide - Best practices for design, construction, and commissioning: www.cms.ashrae.biz/iaqguide/pdf/IAQGuide.pdf?bcsi_scan_C17DAEAF2505A29E=0&bcsi_scan_filename=IAQGuide.pdf			

Image gallery
 *Figure 17. Filters cleaning Source: www.greenbuildingservices.com.*

1.2.3 Adjust the temperature of the thermostat properly

Measure code: HS3b			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** X Public building users (1) ☐ Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (1) X Contextual (1) (3) X Psychological (1) (3) X Physiological (1) X Social (1) (3)

Description

Each degree the thermostat is raised above 21° (recommended set point for winter) implies an unnecessary waste of energy of up to 6-8%. While in summer, each degree below 25° (recommended set point for summer) implies an overconsumption of around 6-8%.

Benefits

- 6-20% percent of energy savings

Limitations

- Occupant acceptance
- Difficulty in setting an agreement between different users of room

Economic assessment

No costs.

References and best practices

- [23] Optimized monthly-fixed thermostat-setting scheme for maximum energy-savings and thermal comfort in air-conditioned spaces: www.sciencedirect.com/science/article/pii/S0306261907001201
- [24] Testing the effect of defaults on the thermostat settings of OECD employees: www.sciencedirect.com/science/article/pii/S0140988313000753

Image gallery

Figure 18. Adjusting the temperature of the thermostat. Source: www.nathansheatandair.com.

1.2.4 Adding or repairing HVAC distribution system insulation

Measure code: HS4i			
Environment or playable world: ☐ Residential X Academic X Offices ☐ All	**Carried out by:** ☐ Public building users (1) ☐ Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (3) X Contextual (3) X Psychological (3) ☐ Physiological ☐ Social

Description

A correct thermal insulation of HVAC distribution ducts and pipes (including corners) reduces energy losses in distribution and improves the performance of the systems since the equipment works with fluids at temperatures close to the design temperature.

Benefits

- The energy savings potential is medium, but it depends on the actual condition of the installation. A reduction of up to 70% of energy losses with respect to non-isolated distribution systems is obtained

Limitations

- Just applicable for buildings with centralized HVAC system

Economic assessment

Initial investment: low, but it depends on each installation, it can be very simple and cheap (e.g. the average price of an insulating aluminum adhesive tape is 0.6€/meter).

References and best practices

- [25] Duct sealing: www.energystar.gov/ia/products/heat_cool/ducts/DuctSealingBrochure04.pdf?893a-5295
- [26] Measure guideline - Sealing and insulating ducts in existing homes: www.nrel.gov/docs/fy12osti/53494.pdf

Image gallery

Figure 19. Air duct and pipe insulation. Sources: www.savewithces.com and www.francobelli.com.

1.2.5 Verify the appropriate operation of timers of the ventilation system

Measure code: HS5b			
Environment or playable world: ☐ Residential X Academic X Offices ☐ All	**Carried out by:** ☐ Public building users (1) ☐ Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (3) X Contextual (3) X Psychological (3) ☐ Physiological ☐ Social

Description

Verify the correct operation of timers in terms of control system depending on the level of occupation of the building. For example: stop during evenings and holidays, change the mode of operation depending on the occupation level and change the programming between winter and summer.

Benefits

- The energy consumption reduction potential is considered from low to medium. With this measure, a reduction in ventilation losses over 50% can be obtained on a building in which the ventilation is turned on all day
- Provide better air quality for the building occupants
- Reduce HVAC operating costs

Limitations

- Operation and Maintenance (O&M) staff size, skill level, and budget need to be considered

Economic assessment

The cost is low or even zero, since most of the actions are for the improvement of the control of ventilation systems, although it will depend in each case on the type and age of the ventilation system.

References and best practices

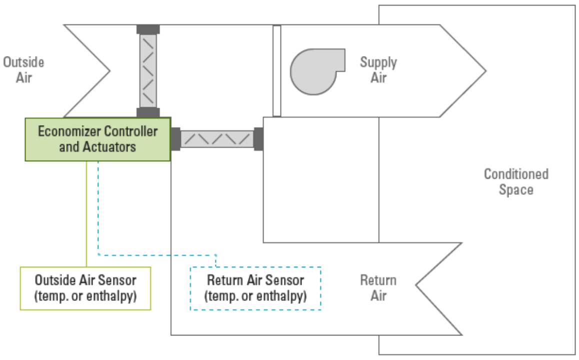
- [27] Guide to best practice Maintenance & Operation of HVAC systems for energy efficiency: www.airah.org.au/imis15_prod/Content_Files/UsefulDocuments/DCCEE_HVAC_HESS_GuideToBestPractice2012.PDF

Image gallery

Figure 20. Ventilation system timer. Source: www.maico-fans.com.

1.2.6 Use of free-cooling

Measure code: HS6b			
Environment or playable world: ☐ Residential X Academic X Offices ☐ All	**Carried out by:** ☐ Public building users (1) ☐ Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating X Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (3) X Contextual (3) X Psychological (3) ☐ Physiological ☐ Social
Description			
Free cooling consists in using the outside air cooling capacity to renew and cool the inside air of a room, reducing the energy consumption of the cooling equipment. As consequence, the system only switches on extraction and air conditioning fans, avoiding starting up the compressor of the cooling equipment.			
Benefits			
• The energy consumption reduction potential is medium. With this measure, it is estimated that the achieved savings in the total energy consumption can be up to 18%			
Limitations			
• Reduction in energy dissipation • Effectiveness linked to environmental conditions (the determination of the dissipation depends entirely on environmental characteristics)			
Economic assessment			
Initial investment: low. In some cases the cost of this measure will be zero, if a ventilation system coupled to the installation of air conditioning is already available.			
References and best practices			
- [28] Potential for free-cooling by ventilation: www.sciencedirect.com/science/article/pii/S0038092X05002677 - [29] Free-running temperature and potential for free cooling by ventilation - A case study: www.sciencedirect.com/science/article/pii/S0378778811002660			

Image gallery
 *Figure 21. Free cooling diagram. Source: [www.caasupport.com.](http://www.caasupport.com)*

1.2.7 Analysis of the combustion and maintenance of heating boilers

Measure code: HS7i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) ☐ Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** X Heating ☐ Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (3) X Contextual (3) X Psychological (3) ☐ Physiological ☐ Social
Description			
The efficiency of the combustion of a heating boiler is defined by the air-fuel ratio. This ratio is fitted in the regular maintenance of boilers through the adjustment and cleaning of the burners. It is necessary to perform fume analysis periodically to verify that the combustion parameters are within the recommended values.			
Benefits			
• Obtain the maximum performance of boilers • Optimal combustion • It is estimated that the energy saving potential is low (around 10%), depending on how the maintenance was done previously			
Limitations			
• Operation and Maintenance (O&M) staff size, skill level, and budget need to be considered • Occupant acceptance			
Economic assessment			
This measure has no associated cost, unless a company for the maintenance of the system is hired (from 200€ a year).			
References and best practices			
- [27] Guide to best practice Maintenance & Operation of HVAC systems for energy efficiency: www.airah.org.au/imis15_prod/Content_Files/UsefulDocuments/DCCEE_HVAC_HESS_GuideToBestPractice2012.PDF			
Image gallery			
 *Figure 22. Gas boiler combustion analysis. Source: www.coastalhvac.squarespace.com.*			

1.2.8 Replacement of the refrigerants fluids in heating and cooling equipment

Measure code: HS8i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) ☐ Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (3) X Contextual (3) X Psychological (3) ☐ Physiological ☐ Social

Description

Refrigerants are fluids used for exchanges of energy in refrigeration systems. This measure consists in the replacement of the current refrigerant of the air conditioning equipment by a new refrigerant based on HydroCarbons (HCs) which is manufactured based on natural compounds.

Benefits

- No damage of the ozone layer: refrigerants with low Ozone Depletion Potential (ODP) and Global Warming Potential (GWP)
- It is not required to perform any substitution on the equipment parts
- It takes less refrigerant for the same charge

Limitations

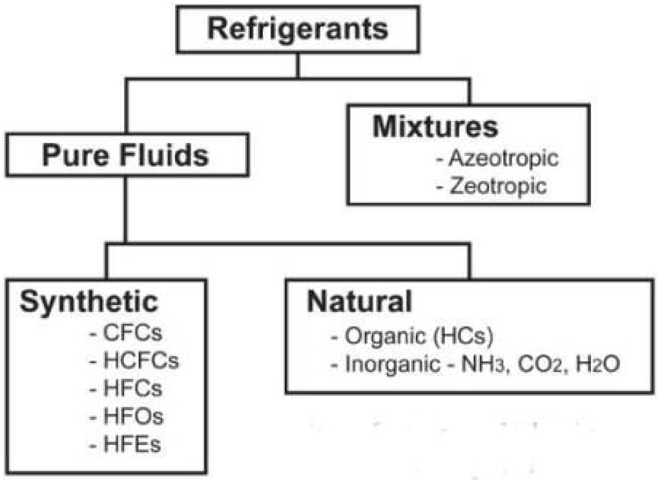
- HCs do not perform as well as HydroChloroFluoroCarbons (HCFCs)

Economic assessment

Initial investment: high. Estimated payback: 14 years.

References and best practices

- [30] HVAC refrigerants: a balanced approach: www.trane.com/commercial/uploads/pdf/11612/related_literature/refrigerant/hvac_refrigerants.pdf

Image gallery
 *Figure 23. Classification of fluids used as refrigerants. Source: www.ec.gc.ca.*

1.2.9 Adding or repairing boilers insulation

Measure code: HS9i

Environment or playable world:	**Carried out by:**	**Reduce consumption of:**	**Type of driver:**
☐ Residential ☐ Academic ☐ Offices X All	☐ Public building users (1) ☐ Owners (2) X Operators (3) ☐ All	X Heating ☐ Cooling ☐ DHW ☐ Lighting ☐ Electric devices	X Physical environmental (3) X Contextual (3) X Psychological (3) ☐ Physiological ☐ Social

Description

Insulation of boilers is necessary to protect people against contact with hot surfaces and to ensure an acceptable working temperature in the boiler room. Insulation of boilers is a very efficient way to keep water hotter for longer, especially if the equipment is exposed to cold conditions in winter.

Benefits

- It is an improvement for very old boilers that cannot be substituted for technical and economic reasons
- Avoid heat loss and optimize the efficiency of the boiler
- Lower water temperature setting

Limitations

- It must go with other measures to achieve significant energy savings

Economic assessment

Initial investment: low. 1-3% economic saving. Payback in 1.5 years.

References and best practices

- [31] Boilers: www.betterbricks.com/sites/default/files/operations/om_of_boilers_final.pdf

Image gallery

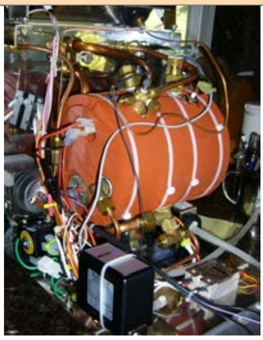


Figure 24. Boiler insulation. Source: www.ielogical.com.

1.2.10 Proper operation of the regulatory systems of the temperature of the heating and cooling equipment

Measure code: HS10i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) ☐ Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (3) X Contextual (3) X Psychological (3) ☐ Physiological ☐ Social

Description

A control system is a device or set of devices aimed at maintaining a variable at a certain value, or between certain limits set previously. This measure consists in the proper operation of one of these variables (the temperature) in the heating and cooling equipment.

Benefits

- Obtain the maximum performance of heating and cooling equipment
- It is estimated that the energy saving potential is low (around 10%)

Limitations

- Operation and Maintenance (O&M) staff size, skill level, and budget need to be considered

Economic assessment

This measure has no associated cost, unless a company for the maintenance of the system is hired (from 200€ a year).

References and best practices

- [32] Fundamentals of HVAC controls: www.cs.berkeley.edu/~culler/cs294-f09/m197content.pdf

Image gallery

Figure 25. Boiler thermostat. Source: www.euroair.es.

1.2.11 Cleaning the radiator surfaces

Measure code: HS11ib			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** X Public building users (1) ☐ Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** X Heating ☐ Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (1) (3) X Contextual (1) (3) X Psychological (1) (3) X Physiological (1) X Social (1)

Description

When the radiator heats up, it causes the air around it to rise as it is heated, and this draws up dusty air from the floors. As the dust sticks on the radiators, it acts like a layer of insulation, which reduces the heat transfer efficiency of the radiators. This measure consists in cleaning this dust of the radiators.

Benefits

- Obtain the maximum heat transfer efficiency of radiators
- Simple process of cleaning

Limitations

- Occupant acceptance
- Operation and Maintenance (O&M) staff size, skill level, and budget need to be considered

Economic assessment

This measure has no associated cost, unless a company for the maintenance of the system is hired (from 200€ a year).

References and best practices

- [33] Stainless steel maintenance: www.theradiatorcentre.com/tech-sheets/9/The-Radiator-Centre_stainless-steel-maintenance_archos.pdf

Image gallery

Figure 26. Cleaning the radiator surface. Source: www.pendock.co.uk.

1.2.12 Place the condenser unit in a ventilated area without solar radiation

Measure code: HS12i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** X Public building users (1) ☐ Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating X Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (1) (3) X Contextual (1) (3) X Psychological (1) (3) X Physiological (1) X Social (1)

Description

If possible locate the condenser unit in an area of the building with shade, that it is not blocked by fences, shrubs and other buildings, or any other obstruction around about 50 cm from the unit. The unit will be more efficient in the shade, but it also needs to be in a place with good ventilation.

Benefits

- Obtain the maximum efficiency of the unit

Limitations

- If not considered during the installation, a new location has to be chosen
- Not always possible to choose a shadow area

Economic assessment

This measure has no associated cost. 1-3% of electricity cost savings.

References and best practices

- [34] Optimum placement of condensing units of split-type air-conditioners by numerical simulation: www.sciencedirect.com/science/article/pii/S0378778807002691
- [35] Placement of condensing units of split-type air-conditioners at low-rise residences: www.sciencedirect.com/science/article/pii/S1359431102000686

Image gallery

Figure 27. Condenser units placed at shadow. Source: www.madridvertical.eu.

1.2.13 Installation of a programmable thermostat

Measure code: HS13i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** X Public building users (1) ☐ Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (1) (3) X Contextual (1) (3) X Psychological (1) (3) X Physiological (1) X Social (1)

Description

A programmable thermostat offers pre-programmed settings to regulate the building's temperature. Programmable thermostats can store multiple daily settings (six or more temperature settings a day) that can be manually overridden without affecting the rest of the daily or weekly program.

Benefits

- Establish a program that automatically reduces heating and cooling consumption
- Pre-programmed settings are intended to deliver energy savings without sacrificing comfort depending on the occupant's schedule

Limitations

- It requires properly installation
- It requires properly set and use

Economic assessment

Initial investment: low. 10-30% cost savings

References and best practices

- [36] Energy efficiency and the misuse of programmable thermostats: The effectiveness of crowdsourcing for understanding household behaviour: www.sciencedirect.com/science/article/pii/S2214629615000730

Image gallery

Figure 28. Programmable thermostat. Source: www.dispositivoseficientes.blogia.com.

1.2.14 Purge radiators at the beginning of the heating season

<table>
<tr><th colspan="4">Measure code: HS14i</th></tr>
<tr>
<td>Environment or playable world:
☐ Residential
☐ Academic
☐ Offices
X All</td>
<td>Carried out by:
X Public building users (1)
☐ Owners (2)
X Operators (3)
☐ All</td>
<td>Reduce consumption of:
X Heating
☐ Cooling
☐ DHW
☐ Lighting
☐ Electric devices</td>
<td>Type of driver:
X Physical environmental (1) (3)
X Contextual (1) (3)
X Psychological (1) (3)
X Physiological (1)
X Social (1)</td>
</tr>
<tr><th colspan="4">Description</th></tr>
<tr><td colspan="4">One of the most common causes of poor performance of a hot water radiator is air trapped in the system. Over time, the repeated heating and then cooling back down of the water in the system causes air to be released from the water. And since air does not conduct heat as well as water, this trapped air reduces the energy efficiency of the radiator system. To eliminate the air, it should be purged out of the radiators at the beginning of the heating season, and then whenever they seem to not be heated as much as normal.</td></tr>
<tr><th colspan="4">Benefits</th></tr>
<tr><td colspan="4">• Easy to implement
• Depending on what type of radiator, it may be possible to automate the process of bleeding the radiators by using an auto vent
• Obtain the maximum efficiency of the unit</td></tr>
<tr><th colspan="4">Limitations</th></tr>
<tr><td colspan="4">• Occupant acceptance
• Operation and Maintenance (O&M) staff size, skill level, and budget need to be considered</td></tr>
<tr><th colspan="4">Economic assessment</th></tr>
<tr><td colspan="4">Zero or low investment. 5% cost savings.</td></tr>
<tr><th colspan="4">References and best practices</th></tr>
<tr><td colspan="4">- [36] Energy efficiency and the misuse of programmable thermostats: The effectiveness of crowdsourcing for understanding household behaviour: www.sciencedirect.com/science/article/pii/S2214629615000730</td></tr>
<tr><th colspan="4">Image gallery</th></tr>
<tr><td colspan="4">
Figure 29. Bleeding a radiator. Source: www.tratojusto.es.</td></tr>
</table>

1.2.15 Use ceiling fans instead of air conditioning when possible

Measure code: HS15b			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** X Public building users (1) ☐ Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating X Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (1) (3) X Contextual (1) (3) X Psychological (1) (3) X Physiological (1) X Social (1)

Description

Fans can make feel 3 to 8 degrees cooler, allowing dialling the AC to a higher temperature with no reduction in comfort. In temperate climates, or during moderately hot weather, ceiling fans may allow to avoid using the air conditioner altogether.

Benefits

- Easy installation
- Low maintenance
- Adaptability
- Filter odors quickly
- High energy savings

Limitations

- Occupant acceptance
- Aesthetic
- Poor installation can affect the fan's noise level

Economic assessment

Initial investment: low. Central AC costs seventy times more to run than a fan.

References and best practices

- [37] Cooling your home with fans and ventilation: www.nrel.gov/docs/fy01osti/29513.pdf

Image gallery

Figure 30. Ceiling fan. Source: www.thisoldhouse.com.

1.2.16 Relocate thermostats to appropriate areas

Measure code: HS16i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** X Public building users (1) ☐ Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (1) (3) X Contextual (1) (3) X Psychological (1) (3) X Physiological (1) X Social (1)

Description

To operate properly, a thermostat must be located on an interior wall away from direct sunlight, drafts, doorways, skylights, and windows. It should be located where natural room air currents (warm air rising, cool air sinking) occur. Furniture will block natural air movement, so do not place pieces in front of or below the thermostat. Also make sure the thermostat is conveniently located for programming.

Benefits

- Better performance and efficiency of the thermostats
- Easy installation
- Prevent "ghost readings" or unnecessary furnace or air conditioner cycling
- A variation in the temperature of 1°C saves around 7% of the HVAC energy consumption

Limitations

- Occupant knowledge

Economic assessment

The investment is zero.

References and best practices

- [38] How people use thermostats in homes: A review: www.eec.ucdavis.edu/files/How_people_use_thermostats_in_homes.pdf

Image gallery

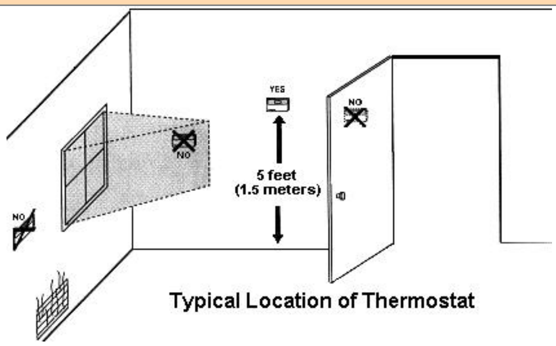


Figure 31. Appropriate location of a thermostat. Source: www.longviewweb.com.

1.2.17 Avoid using personal heaters in air-conditioned spaces

Measure code: HS17i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** X Public building users (1) ☐ Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** X Heating ☐ Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (1) X Contextual (1) X Psychological (1) X Physiological (1) X Social (1)
Description			
Generally, these types of heaters are inefficient, ineffective, and in some cases, unsafe. If occupants are in an air conditioned space (or one that is centrally heated) and find conditions a little chilly, they should not resort to personal heaters. The air-conditioning system will only work against the personal heater by drawing the warm air away.			
Benefits			
• Better performance and efficiency of the thermostats • Easy installation • Prevent "ghost readings" or unnecessary furnace or air conditioner cycling • A variation in the temperature of 1°C saves around 7% of the HVAC energy consumption			
Limitations			
• Occupant acceptance • Facility heating system modifications should be made where possible to avoid the use of space heaters			
Economic assessment			
The investment is zero.			
References and best practices			
- [39] Portable electric space heaters: www.mge.com/images/PDF/Brochures/residential/PortableElectricSpaceHeaters.pdf			

Image gallery

Figure 32. Personal heater in an office. Source: www.facilities.unsw.edu.au.

1.2.18 Turn off kitchen and bath fans immediately after use

Measure code: HS18b			
Environment or playable world: X Residential ☐ Academic ☐ Offices ☐ All	**Carried out by:** X Public building users (1) ☐ Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW ☐ Lighting X Electric devices	**Type of driver:** X Physical environmental (1) X Contextual (1) X Psychological (1) ☐ Physiological X Social (1)
Description			
This measure consists in turning off fans of the bathroom and the kitchen approximately 10 minutes once they have cooled the room to avoid that they expel fresh air outside the house. Although this does not seem like a huge change, a lot of energy is used if these are left on all day.			
Benefits			
• Energy savings			
Limitations			
• Occupant acceptance			
Economic assessment			
No costs.			
References and best practices			
- [40] Residential Fan Efficiency: www.energycodes.gov/sites/default/files/documents/cn_residential_fan_efficiency.pdf			
Image gallery			

Figure 33. Kitchen hood. Source: www.furniturefashion.com.

1.2.19 Cleaning heat exchangers of chillers

Measure code: HS19i			
Environment or playable world:	**Carried out by:**	**Reduce consumption of:**	**Type of driver:**
☐ Residential	☐ Public building users (1)	☐ Heating	X Physical environmental (3)
X Academic	☐ Owners (2)	X Cooling	X Contextual (3)
X Offices	X Operators (3)	☐ DHW	X Psychological (3)
☐ All	☐ All	☐ Lighting	☐ Physiological
		☐ Electric devices	☐ Social

Description

HVAC heat exchangers are critical to resident's comfort in the building. Regularly scheduled heater exchanger cleanings will maintain clean waterside surfaces and ensure superb operation and efficiency.

Benefits

- Energy savings
- Decrease operating and maintenance costs
- Optimum performance

Limitations

- Operation and Maintenance (O&M) staff size, skill level, and budget need to be considered

Economic assessment

This measure has no associated cost, unless a company for the maintenance of the system is hired (from 200€ a year). Decrease the energy cost in around 30%.

References and best practices

- [41] Heat exchanger cleaning procedures: www.multistack.com/Portals/0/PDF/Heat_Exchanger_Cleaning.984fadde-8a66-435d-866a-b659cc70cfc7.pdf

Image gallery

Figure 34. Cleaning a chiller. Source: www.tcwilson.com.

1.2.20 Installation of dampers on flue gas ducts

Measure code: HS20i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) ☐ Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** X Heating ☐ Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (3) X Contextual (3) X Psychological (3) ☐ Physiological ☐ Social
Description			
A flue damper is a cast iron plate with a spindle fitted inside the first piece of flue pipe that connects to the cast iron multifuel or woodburning stove. It works as a butterfly valve. The loss of energy due to room air spillage via the chimney to the outside can be avoided with flue dampers.			
Benefits			
• It can save more than 4000 kWh per year depending on the combustion heating appliance and the outside conditions • Reduce losses when combustion heating appliance is switched off • Prevent heated room air from escaping via the chimney • Prevent loss of heat stored in the stove • Prevent flue-gas back-flow • Reduce fuel consumption			
Limitations			
• High leakage • Blade flutter • Tendency of the blade to warp • Large clearance needs for the open blade			
Economic assessment			
The costs of the installation can be quickly recouped by the energy and fuel savings produced. The payback periods which are calculated according to the flue damper, location and chimney diameter are between 1.5-3 years.			
References and best practices			
- [42] Boiler draft and flue gas equipment: www.tssa.org/CorpLibrary/ArticleFile.asp?Instance=136&ID=C7B50BA36090493F8336C67379E42DA8			

Image gallery
 *Figure 35. Flue collar damper. Source: [www.vogelzang.com.](http://www.vogelzang.com)*

1.2.21 Installation of motion sensors for HVAC systems

Measure code: HS21i			
Environment or playable world: ☐ Residential X Academic X Offices ☐ All	**Carried out by:** ☐ Public building users (1) X Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) (3) X Contextual (2) (3) X Psychological (2) (3) ☐ Physiological ☐ Social

Description

As part of a HVAC energy management system, occupancy sensors enable facility managers to automatically control HVAC operation based on room occupancy. If the room is physically occupied, then the system will allow occupants to control the climate. Once a room is vacant, the system will automatically set back the HVAC equipment to reduce energy consumption and equipment wear.

Benefits

- No energy is spent to climate control an empty room
- Easy-to-implement

Limitations

- Integrating motion sensors is still somewhat limited in terms of dynamic in the field solutions
- Primarily used in commercial buildings

Economic assessment

Initial investment: low.

References and best practices

- [43] Observe: Occupancy-based system for efficient reduction of HVAC energy: www.vs.inf.ethz.ch/edu/HS2011/CPS/papers/erickson11_observe.pdf

Image gallery

Figure 36. Wireless occupancy sensors. Source: www.buildingcontrols.honeywell.com.

1.2.22 Installation of humidity sensors

Measure code: HS22i			
Environment or playable world: ☐ Residential X Academic X Offices ☐ All	**Carried out by:** ☐ Public building users (1) X Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating X Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) (3) X Contextual (2) (3) X Psychological (2) (3) ☐ Physiological ☐ Social
Description			
A humidity sensor and fan control detects excess humidity in a room and automatically activates the ventilation fan to reduce excess condensation. The device features an easily adjustable setting for sensor sensitivity, humidity level and automatic time out which can be set to meet the specific ventilation needs of a room.			
Benefits			
• Reduce the appearance of mold and mildew • Provide a more comfortable environment • Reduce energy usage by automatically operating the fan only when needed, reducing continuous or unnecessary use			
Limitations			
• Only applicable in buildings with mechanical ventilation			
Economic assessment			
Initial investment: low.			
References and best practices			
- [44] Moisture control and ventilation: www.ncbi.nlm.nih.gov/books/NBK143947			
Image gallery			

Figure 37. Humidity sensor. Source: www.sensovant.com.

1.2.23 Installation of an efficient destratification fan system

Measure code: HS23i			
Environment or playable world: ☐ Residential X Academic X Offices ☐ All	**Carried out by:** ☐ Public building users (1) X Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW ☐ Lighting X Electric devices	**Type of driver:** X Physical environmental (2) (3) X Contextual (2) (3) X Psychological (2) (3) ☐ Physiological ☐ Social

Description

Thermal stratification is caused by hot air rising up to the ceiling or roof space because it is lighter than the surrounding cooler air. The same applies to cool air falling to the floor as it is heavier than the surrounding warmer air. This means that HVAC systems have to constantly cycle on in order to maintain the overall building interior at a settled temperature. HVAC systems are typically over delivering either heating or cooling to compensate for this stratification phenomenon. To avoid this issue the air can be moved by an efficient destratification fan.

Benefits

- Extremely simple to retrofit and/or install
- The amount of HVAC equipment required for a building or space is reduced
- Complement the HVAC system in any building as efficient air movement is the key to make sure an HVAC system operates at its maximum potential without wasting energy

Limitations

- Spaces which are not tall enough to become highly stratified

Economic assessment

Affordable purchase and install price. Payback: Three months. Energy savings on heating and cooling costs by up to 50%.

References and best practices

- [45] Technology evaluation of thermal destratifiers and other ventilation technologies: www.aiha.org/aihce06/handouts/d1hughes.pdf
- [46] Case Study: Lush Retail Ltd - Hatch Pond Road, Poole: www.airius.co.uk/sites/default/files/Lush%20Retail%20Ltd%20-%20Hatchpond%20Road%20Case%20Study%202.pdf

Image gallery

Figure 38. Helicentrifugal destratification fan. Source: www.puravent.co.uk.

1.2.24 Installation of thermostatic radiator valves

<table>
<tr><th colspan="4">Measure code: HS24i</th></tr>
<tr>
<td>Environment or playable world:
☐ Residential
☐ Academic
☐ Offices
X All</td>
<td>Carried out by:
☐ Public building users (1)
☐ Owners (2)
☐ Operators (3)
X All</td>
<td>Reduce consumption of:
X Heating
☐ Cooling
☐ DHW
☐ Lighting
☐ Electric devices</td>
<td>Type of driver:
X Physical environmental (1) (2) (3)
X Contextual (1) (2) (3)
X Psychological (1) (2) (3)
☐ Physiological
☐ Social</td>
</tr>
<tr><th colspan="4">Description</th></tr>
<tr><td colspan="4">These elements open and close automatically the flow of hot water in radiators and fancoils, depending on the temperature selected by the user. To install thermostatic valves, the heating circuit should be leaked out and the shut-off valve should be replaced by a thermostatic valve.</td></tr>
<tr><th colspan="4">Benefits</th></tr>
<tr><td colspan="4">• High energy saving depending on the building and the zoning of the distribution loops (between 5-7% of the heating generation energy)
• Adjustment room by room, according to their characteristics of temperature, insolation and use
• In buildings where only some areas are used after normal schedule, the installation of remote control thermostatic valves allows heating out of the schedule only the required areas</td></tr>
<tr><th colspan="4">Limitations</th></tr>
<tr><td colspan="4">• Incorrect handling by users
• Occupant acceptance</td></tr>
<tr><th colspan="4">Economic assessment</th></tr>
<tr><td colspan="4">Initial investment: low. Measure of easy implementation (20€/valve).
Payback: Between 1 and 2 years.</td></tr>
<tr><th colspan="4">References and best practices</th></tr>
<tr><td colspan="4">- [47] Impact of low investment strategies for space heating control: Application of thermostatic radiators valves to an old residential building: www.sciencedirect.com/science/article/pii/S0378778815000043
- [48] Thermostatic radiator valve (TRV) demonstration project: www.osti.gov/scitech/servlets/purl/119941</td></tr>
</table>

Image gallery
   *Figure 39. Thermostatic valve for radiator. Source: [www.radiatorx.blogspot.com.](http://www.radiatorx.blogspot.com)*

1.2.25 Installation of a radiator booster

Measure code: HS25i			
Environment or playable world: X Residential ☐ Academic ☐ Offices ☐ All	**Carried out by:** X Public building users (1) ☐ Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** X Heating ☐ Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (1) X Contextual (1) X Psychological (1) ☐ Physiological ☐ Social

Description

A radiator booster is a white telescopic tube that sits on top of a radiator. A small thermostatic fan draws the heat trapped behind the radiator and distributes it more evenly around the room, which could help to reduce the thermostat setting.

Benefits

- Heat up the room a 15% more quickly
- It can raise the temperature of a room by 3C
- Heating consumption savings of 10%

Limitations

- Occupant acceptance
- Small noise of the fan
- Appearance

Economic assessment

Initial investment: low. Around 35€.
Payback: very low. Around eight weeks.

References and best practices

- [49] The radiator booster : www.radiatorbooster.com

Image gallery

Figure 40. Radiator booster. Source: www.theguardian.com.

1.3 DHW measures

1.3.1 Lower the DHW temperature set-point

Measure code: DS1b			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** X Public building users (1) ☐ Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling X DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (1) X Contextual (1) (3) X Psychological (1) (3) X Physiological (1) X Social (1) (3)
Description			
Water should not be overheated more than necessary (each 10°C rise in DHW temperature increases the energy consumption by around 15%). To save energy, it is recommended to adjust the thermostat of DHW at 60°C (this temperature should not be reduced to avoid problems of formation of legionella).			
Benefits			
• The savings potential depends on the building's water consumption. Savings of up to 30% of the electricity consumption dedicated to heat the water can be obtained			
Limitations			
• Occupant acceptance • Operation and Maintenance (O&M) staff size, skill level, and budget need to be considered			
Economic assessment			
No cost.			
References and best practices			
- [50] Best practices for efficient hot water distribution in multifamily buildings: www.aceee.org/files/proceedings/2012/data/papers/0193-000030.pdf			
Image gallery			

Figure 41. Lower the DHW temperature setpoint Source: lifehacker.com.

1.3.2 Adding or repairing tank insulation

Measure code: DS2i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** X Public building users (1) ☐ Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling X DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (1) (3) X Contextual (1) (3) X Psychological (1) (3) X Physiological (1) ☐ Social
Description			
It is recommended to properly insulate DHW storage tanks to limit heat losses. Insulating the hot water tank is an easy and inexpensive way to improve energy efficiency and save money. For an electric water heater, it also might be considered insulating underneath the tank as well.			
Benefits			
• Reduce standby heat losses by 25%–45%			
Limitations			
• Be sure that the water heater is not leaking. If the tank leaks, a new water heater is needed			
Economic assessment			
Initial investment: pre-cut jackets or blankets available from around 20 €. Some utilities even install these at a low or no cost. Payback: about 1 year Save about 4%–9% in water heating costs			
References and best practices			
- [51] Optimal insulation of solar hot water tanks: www.sciencedirect.com/science/article/pii/0306261985900418			
Image gallery			

Figure 42. Adding insulation to the hot water tank. Source: www.energy.gov.

1.3.3 Adding or repairing DHW distribution systems

Measure code: DS3i

Environment or playable world:	**Carried out by:**	**Reduce consumption of:**	**Type of driver:**
☐ Residential	☐ Public building users (1)	☐ Heating	X Physical environmental (3)
☐ Academic	☐ Owners (2)	☐ Cooling	X Contextual (3)
☐ Offices	X Operators (3)	X DHW	X Psychological (3)
X All	☐ All	☐ Lighting	☐ Physiological
		☐ Electric devices	☐ Social

Description

It is recommended to properly insulate pipes to limit heat losses, as well as to install the boiler/accumulator as close as possible to the consumption end points to limit the losses that occur through the walls of the pipes. The insulation normally used for pipes where the water circulates are moulds of elastomeric foam and rock wool, and should be installed both on supply and return pipes.

Benefits

- A good insulation of the pipes reduces the thermal losses in around 50%

Limitations

- Operation and Maintenance (O&M) staff size, skill level, and budget need to be considered
- Just applicable for buildings with centralized HVAC system

Economic assessment

Initial investment: low, but it depends on each installation

References and best practices

- [52] Heat losses from an insulated pipe: www.sciencedirect.com/science/article/pii/0022247X80902759
- [53] Effectiveness of PVC coatings as thermal insulation for domestic hot-water piping: www.sciencedirect.com/science/article/pii/0306261994900663

Image gallery

Figure 43. Insulation of hot water pipes. Source: www.consumerreports.org.

1.3.4 Maintenance and inspection of DHW pumps

Measure code: DS4i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) ☐ Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling X DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (3) X Contextual (3) X Psychological (3) ☐ Physiological ☐ Social
Description			
The water needs to be boosted by electric pumps to get to the different end points of consumption of a building. The resulting electric consumption can become an important part, especially in high buildings; therefore it is necessary for the installation to be dimensioned correctly. It is recommended to perform a correct maintenance and cleaning of the water pumps on a regular basis to avoid unnecessary energy consumption.			
Benefits			
• The saving potential is low; it depends on the water consumption of the building. Savings of up to 30% of the electric consumption of the pumps can be obtained			
Limitations			
• Operation and Maintenance (O&M) staff size, skill level, and budget need to be considered • Just applicable for buildings with centralized HVAC system			
Economic assessment			
Initial investment: zero-low. It is one of the measures of maintenance, which in general do not have associated costs.			
References and best practices			
- [54] Pumps 101: Operation, maintenance and monitoring basics: www.gouldspumps.com/ittgp/medialibrary/goulds/website/Literature/White%20Papers/ITT_white_paper_Pumps_101_Operation_Maintenance_and_Monitoring_Basics.pdf?ext=.pdf - [55] Deterioration and inspection of water distribution systems: www.fcm.ca/Documents/reports/Infraguide/Deterioration_and_Inspection_of_Water_Distribution_Systems_EN.pdf			

Image gallery
 *Figure 44. Maintenance and inspection of water pumps. Source:www.electrobombasmanogil.com.*

1.3.5 Installation of a timer for the DHW recirculation pump

Measure code: DS5i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling X DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) (3) X Contextual (2) (3) X Psychological (2) (3) X Physiological (2) ☐ Social
Description			
It is recommended to install a timer that disconnects the recirculation pump during the hours in which there is no demand of DHW in the building.			
Benefits			
• In addition to saving energy, the lifespan of the pump is extended			
Limitations			
• There must be a hot water return circuit installed in the distribution network			
Economic assessment			
Initial investment: low. A timer integrated in the recirculating pump costs about 200€.			
References and best practices			
- [56] Energy efficient controls for multifamily domestic hot water: www.energy.gov/sites/prod/files/2015/01/f19/ba_webinar_dentz_ansanelli_1-21-15_0.pdf - [57] Domestic hot water systems: www.aspe.org/sites/default/files/webfm/ContinuingEd/CEU_221_Mar15.pdf			
Image gallery			

Figure 45. Hot Water Re-Circulating Pump with Timer. Source: www.homedepot.com.

1.3.6 Installation of a timer for the DHW boiler

Measure code: DS6i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling X DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) (3) X Contextual (2) (3) X Psychological (2) (3) X Physiological (2) ☐ Social

Description

The measure consists in installing a timer (digital or analogic) which turns off the boiler when there is no demand of DHW (e.g. in residential buildings during the night there is no relevant demand of DHW).

Benefits

- Energy savings
- Schedule different patterns of use

Limitations

- It must be kept in mind the time that it normally takes the water to be heated before scheduling

Economic assessment

Initial investment: low. The cost starts from 5€ for the analog timers and from 40€ for the digitals ones which have possibility of remote control.

References and best practices

- [56] Energy efficient controls for multifamily domestic hot water: www.energy.gov/sites/prod/files/2015/01/f19/ba_webinar_dentz_ansanelli_1-21-15_0.pdf
- [57] Domestic hot water systems: www.aspe.org/sites/default/files/webfm/ContinuingEd/CEU_221_Mar15.pdf

Image gallery

Figure 46. Analog timer Source: www.directindustry.com/.

1.3.7 Installation of mixing valves in the outlet of the DHW tank

Measure code: DS7i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling X DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) (3) X Contextual (2) (3) X Psychological (2) (3) X Physiological (2) ☐ Social
Description			
A thermostatic mixing valve mixes cold and hot water, generally with a temperature differential of at least 7°C, in order to obtain mixed water at a stabilized temperature, avoiding in this way losses of hot water while adjusting the temperature with the tap.			
Benefits			
• Increase the hot water storage capacity • Perfect for thermal or photovoltaic solar hot water heating because of increase in storage capacity • A mixing valve can make tap temperatures safe even when running a water heater at maximum temperatures • Mixing valves may be better regulation of the temperature of the hot water at the tap compared to thermostats that turn water heating on and off			
Limitations			
• Running water heater at increased water temperatures may cause increased amount of calcification to precipitate out of the water requiring more frequent cleaning and shorter element life • Increase water temperature in tank will mean more stand-by loss • Increase installation space			
Economic assessment			
The retail cost of the valves at some of the larger retail chains is just under 100 €. A plumber may charge 100-200 € to install it.			
References and best practices			
- [56] Energy efficient controls for multifamily domestic hot water: www.energy.gov/sites/prod/files/2015/01/f19/ba_webinar_dentz_ansanelli_1-21-15_0.pdf - [57] Domestic hot water systems: www.aspe.org/sites/default/files/webfm/ContinuingEd/CEU_221_Mar15.pdf			

Image gallery
 *Figure 47. Mixing valve. Source: [www.waterheatertimer.org.](http://www.waterheatertimer.org)*

1.3.8 Installation of taps with flow reduction (faucet aerator)

Measure code: DS8i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** X Public building users (1) ☐ Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling X DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (1) (3) X Contextual (1) (3) X Psychological (1) (3) X Physiological (1) ☐ Social

Description

One of the solutions to save water and energy consists of the placement of an aerator at the exit of the water taps. These devices are screwed into the output of the faucet, reducing the flow of water and they are compatible with most faucets since they are available in different sizes and different types of thread.

Benefits

- Easy to install
- Energy saving due to pumping (around 50%) and the derivative of the water heating (around 30%)
- Anti-calcareous and do not become clogged
- The use of aerators allows 50% of water savings

Limitations

- Occupant acceptance
- Operation and Maintenance (O&M) staff size, skill level, and budget need to be considered

Economic assessment

Initial investment: low. 4 € per aerator
Payback: low. Less than 1 year

References and best practices

- [58] Hydraulic performance of faucet aerator as water saving device and suggestions for its improvements: www.esatjournals.org/Volumes/IJRET/2014V03/I07/IJRET20140307041.pdf

Image gallery

Figure 48. Tap aerator. Source: www.cleanenergyresourceteams.org.

1.3.9 Adding or repairing water heaters insulation

Measure code: DS9i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) ☐ Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling X DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (3) X Contextual (3) X Psychological (3) ☐ Physiological ☐ Social

Description

Insulation of water heaters is necessary to protect against contact with hot surfaces and to ensure an acceptable working temperature in the water heater house. Insulation of water heaters is a very efficient way to keep your water hotter for longer, especially if the equipment is exposed to cold conditions in winter.

Benefits

- It is an improvement for very old water heaters that cannot be substituted for technical and economic reasons
- Avoid heat loss and optimize the efficiency of the water heater
- Lower water temperature setting

Limitations

- It must go with other measures to achieve significant energy savings

Economic assessment

Initial investment: low. 1-3% economic saving. Payback in 1.5 years.

References and best practices

- [31] Boilers: www.betterbricks.com/sites/default/files/operations/om_of_boilers_final.pdf

Image gallery

Figure 49. Insulation of a water heater. Source: www.ecofoil.com.

1.3.10 Installation of low-flow showerheads

Measure code: DS10i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** X Public building users (1) ☐ Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling X DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (1) (3) X Contextual (1) (3) X Psychological (1) (3) X Physiological (1) X Social (1)
Description			
One of the solutions to save water and energy consists of the placement of an aerator at the exit of the showerheads. These devices are screwed into the output of the showerhead, reducing the flow of water and they are compatible with most showerheads since they are available in different sizes and different types of thread.			
Benefits			
• Easy to install • Energy saving due to pumping (around 50%) and the derivative of the water heating (around 30%) • Anti-calcareous and do not become clogged • The use of low-flow showerheads allows 50% of water savings			
Limitations			
• Occupant acceptance • Operation and Maintenance (O&M) staff size, skill level, and budget need to be considered			
Economic assessment			
Initial investment: low. 4 € per low-flow showerhead Payback: low. Less than 1 year			
References and best practices			
- [58] Hydraulic performance of faucet aerator as water saving device and suggestions for its improvements: www.esatjournals.org/Volumes/IJRET/2014V03/I07/IJRET20140307041.pdf			

Image gallery
 *Figure 50. Low-flow showerhead. Source: [www.energy.gov.](http://www.energy.gov)*

1.3.11 Use shower instead of bath

Measure code: DS11b			
Environment or playable world: X Residential ☐ Academic ☐ Offices ☐ All	**Carried out by:** X Public building users (1) ☐ Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling X DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (1) X Contextual (1) X Psychological (1) X Physiological (1) X Social (1)
Description			
Take a shower instead of a bath. A full bath (140-180 litres) wastes about three times the energy and water compared to a five minutes shower			
Benefits			
• Energy savings • Water savings			
Limitations			
• Occupant acceptance			
Economic assessment			
Cost saving: Around 360€/years			
References and best practices			
- [59] Going with the flow: challenging students to make assumptions: www.129.81.170.14/~cortez/Prints/FeltonAnhaltCortez2015.pdf			
Image gallery			

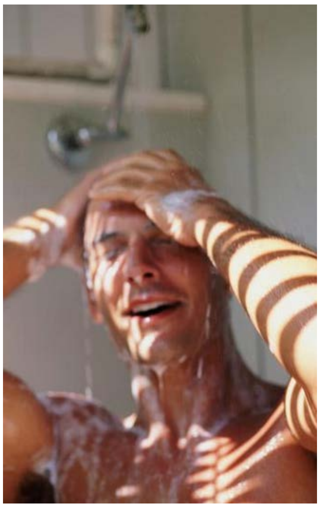


Figure 51. Take a shower instead of a bath. Source: www.budgeting.thenest.com.

1.3.12 Fix dripping taps

Measure code: DS12i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** X Public building users (1) ☐ Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling X DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (1) (3) X Contextual (1) (3) X Psychological (1) (3) X Physiological (1) X Social (1)
Description			
Fix any leaking tap. A dripping tap can waste 5000 litres a year, while a replacement tap washer only costs a few cents.			
Benefits			
• Energy savings • Water savings			
Limitations			
• Occupant acceptance			
Economic assessment			
Mending a dripping tap washer could save over 26€ a year			
References and best practices			
- [60] Research into saving water the experiences and perceptions of customers and their households: www.ccwater.org.uk/wp-content/uploads/2013/12/Research-into-customer-water-saving.pdf			
Image gallery			

Figure 52. Fix dripping taps. Source: www.bestplumbers.com.

1.3.13 Installation of thermostatic taps

Measure code: DS13i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** X Public building users (1) ☐ Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling X DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (1) (3) X Contextual (1) (3) X Psychological (1) (3) X Physiological (1) X Social (1)

Description

Thermostatic taps are taps able to mix the water to a desired temperature, and it can keep it constant for a greater comfort of the user.

Benefits

- Comfort
- Energy and water saving (up to 10-15%)
- High security
- Calibration accuracy and reliability

Limitations

- Occupant acceptance
- The mechanism of mixture (more complex) can give loss of pressure in the flow of water
- They are more sensitive to the dirt that can come through the pipes, so it is advisable to clean them regularly
- It is necessary certain pressure of hot water. For that reason, low power heaters of less than 6 litres are not advisable

Economic assessment

Initial investment: medium. Payback: between 1 and 5.2 years.

References and best practices

- [61] MEErP preparatory study on taps and showers: www.susproc.jrc.ec.europa.eu/taps_and_showers/docs/Task4_2ndTWG_v2.4.pdf

Image gallery

Figure 53. Thermostatic tap. Source: www.luvbathrooms.co.uk.

1.3.14 Installation of motion sensor faucets

Measure code: DS14i			
Environment or playable world: ☐ Residential X Academic X Offices ☐ All	**Carried out by:** ☐ Public building users (1) ☐ Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling X DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (3) X Contextual (3) X Psychological (3) ☐ Physiological ☐ Social
Description			
A motion sensor faucet is a faucet equipped with a proximity sensor and mechanism that opens its valve to allow water to flow in response to the presence of a hand or hands in close proximity.			
Benefits			
• Easy to operate • Stop the spread of germs and bacteria • Prevent water overflow • Prevent scalding injury • Improvements to sensor-controlled fixtures and to low-and no-flow toilets and urinals			
Limitations			
• Most touchless faucets operate on battery or A/C power and require sensors to work. This can be costly and inconvenient when the batteries run out and need to be replaced • It is often inconvenient to have a touchless faucet in a sink where different temperatures of water are needed • The installation process can be complex			
Economic assessment			
On average, the return on investment for sensor devices is about 30%. The higher the water costs, the higher the return. The lower the water costs, the lower the return. The payback period is about 3-6 months.			
References and best practices			
- [62] Sensor-operated plumbing fixtures do they save water?: www.energy.ca.gov/appliances/2013rulemaking/documents/responses/Water_Appliances_12-AAER-2C/Sensor-Operated_Fixtures_Final_Report_March_2010_2013-06-03_TN-71101.pdf			

Image gallery
 *Figure 54. Motion sensor faucet. Source: www.chinazhanying.com.*

1.3.15 Limit shower length to 5–7 minutes

Measure code: DS15b			
Environment or playable world: X Residential ☐ Academic ☐ Offices ☐ All	**Carried out by:** X Public building users (1) ☐ Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling X DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (1) X Contextual (1) X Psychological (1) X Physiological (1) X Social (1)

Description

Using an average number of 8 litres per minute from a typical shower head, by reducing your shower length by 4 minutes per day would save 14000 litres per year. In addition to save water, you also save the energy required to heat water to the shower temperature.

Benefits

- Energy and water savings

Limitations

- Occupant acceptance

Economic assessment

Spending one minute less in the shower each day will save 15€ off the energy bills each year, per person.

References and best practices

- [60] Research into saving water the experiences and perceptions of customers and their households: www.ccwater.org.uk/wp-content/uploads/2013/12/Research-into-customer-water-saving.pdf

Image gallery

Figure 55. Reduce shower length. Source: www.choice.com.au.

1.3.16 Cleaning the DHW tank to avoid sediments

Measure code: DS16i			
Environment or playable world: X Residential ☐ Academic ☐ Offices ☐ All	**Carried out by:** X Public building users (1) ☐ Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling X DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (1) X Contextual (1) X Psychological (1) X Physiological (1) X Social (1)

Description

DHW tank efficiency is vulnerable to sediment and it makes rumbling sounds when sediment builds up. The sediment grows depending on the hardness of water and other factors. The efficiency drops as heat transfer surfaces are covered with sediment. Flushing water heater every six months prevents sediment.

Benefits

- If the tank is clean, the thermostat reads the correct temperature and the heat transfer surface and heat exchanger maximize efficiency

Limitations

- Occupant acceptance
- Water softener prevents sediment but costs money and it also shortens the life of the tank

Economic assessment

Savings around 2€ per month/extend life

References and best practices

- [63] Final report study on benefits of removal of water hardness (calcium and magnesium ions) from a water supply: www.waterheatertimer.org/pdf/Battelle_Water-softening-research.pdf

Image gallery

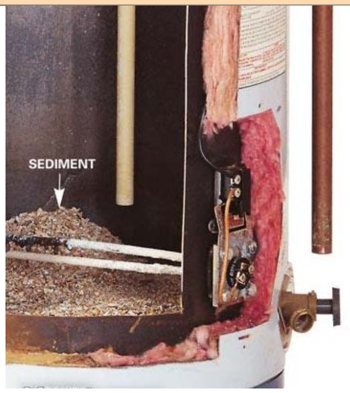


Figure 56. Sediment in a hot water tank. Source: www.familyhandyman.com.

1.3.17 Disconnect the DHW tank in case it is not working for more than three days

Measure code: DS17b			
Environment or playable world: X Residential ☐ Academic ☐ Offices ☐ All	**Carried out by:** X Public building users (1) ☐ Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling X DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (1) X Contextual (1) X Psychological (1) ☐ Physiological X Social (1)
Description			
It is recommended to disconnect the DHW tank in case it is not going be used for more than three days.			
Benefits			
• Energy savings			
Limitations			
• Occupant acceptance			
Economic assessment			
Zero investment.			
References and best practices			
- [64] Water heaters: Turn off or leave on?: www.fplblog.com/ask-the-expert/water-heaters-turn-off-or-leave-on/			
Image gallery			

Figure 57. Domestic hot water tank. Source: www. hollowayvhte.centerblog.net.

1.3.18 Wash hands with cold water instead of warm water

Measure code: DS18b			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** X Public building users (1) ☐ Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling X DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (1) X Contextual (1) X Psychological (1) X Physiological (1) X Social (1)

Description

Although the perception that hot water is more hygienic is based in some factual evidence, there are few, if any hygienic benefits, of using warm or hot water to wash one's hands. It is true that heat kills bacteria; however, the level of the heat required to neutralize pathogens is beyond what is considered safe for prolonged human contact.

Benefits

- Energy savings to heat the water
- Avoid wasting water while waiting for the running faucet to heat up

Limitations

- Occupant acceptance

Economic assessment

Zero investment.

References and best practices

- [65] Water temperature as a factor in handwashing efficacy: www.onlinelibrary.wiley.com/doi/10.1046/j.1471-5740.2002.00043.x/abstract

Image gallery

Figure 58. Washing hands with cold water. Source: www.info.debgroup.com.

1.4 Lighting measures

1.4.1 Change to task lighting method when required

Measure code: LS1i			
Environment or playable world: ☐ Residential X Academic X Offices ☐ All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW X Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) ☐ Physiological X Social (2)
Description			
The measure proposes the installation of task lighting to give the possibility of concentrating light only in working areas or, in general, where and when it is needed through the combination with general lighting.			
Benefits			
• In offices, energy savings of around 22% compared to fixed general lighting solution can be achieved, by using combination of general and task lighting. • It influences positively in the productivity of workers • Individual workers can control their lighting • Increase indoor environmental quality			
Limitations			
• Possibility of glare if there is difference of luminosity between zones • Risk of visual fatigue increases • User acceptance			
Economic assessment			
Initial investment: medium. The total cost could include the costs of: installation, wiring, lamps and luminaire. It could be convenient to reduce the power of ambient lights to adapt them to the new configuration.			
References and best practices			
- [66] Energy saving potential and strategies for electric lighting in future North European, low energy office buildings: A literature review: www.sciencedirect.com/science/article/pii/S0378778811002933# - [67] Light fixtures and layout: www.sustainabilityworkshop.autodesk.com/buildings/light-fixtures-and-layout			

Image gallery

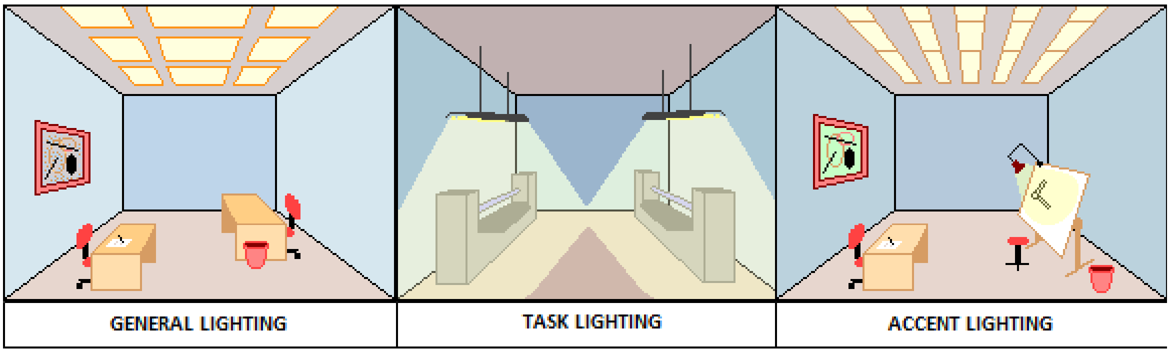
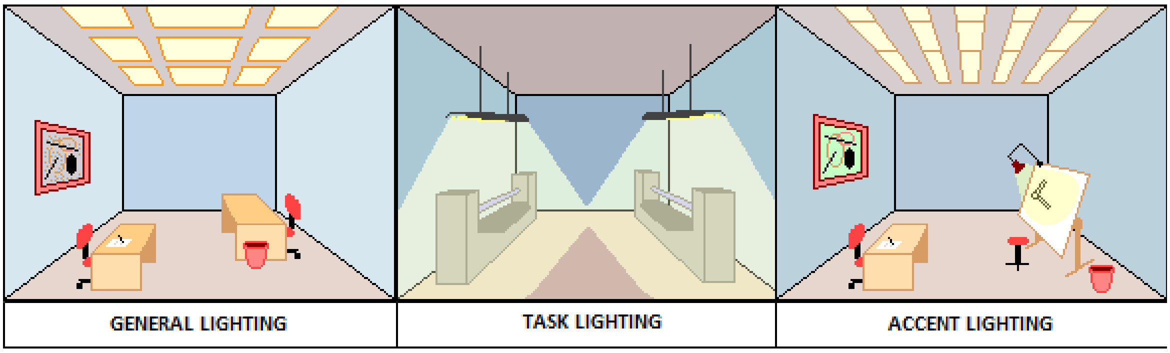


Figure 59. Methods of lighting. Source: www.recursos.citcea.upc.edu.

1.4.2 Change to accent lighting when required

Measure code: LS2i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** X Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW X Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (1) (2) X Contextual (1) (2) X Psychological (1) (2) X Physiological (1) X Social (1) (2)
Description			
The measure proposes the installation of accent lighting to provide concentrated light on areas with specific requirements of luminosity.			
Benefits			
• Important energy savings can be achieved since the light is just concentrated where and when is needed • Increase indoor environmental comfort • Users are free to regulate the illuminance level of their working areas without affecting others colleagues			
Limitations			
• Risk of visual fatigue increases. • Desktop lamps should not be used for prolonged periods of time, and never as the sole light source			
Economic assessment			
Initial investment: low. The cost is the necessary to buy desk lamps (starting from 15€).			
References and best practices			
- [66] Energy saving potential and strategies for electric lighting in future North European, low energy office buildings: A literature review: www.sciencedirect.com/science/article/pii/S0378778811002933# - [67] Light fixtures and layout: www.sustainabilityworkshop.autodesk.com/buildings/light-fixtures-and-layout			

Image gallery
 *Figure 60. Methods of lighting. Source: www.recursos.citcea.upc.edu.*

1.4.3 Cleaning and maintenance of lamps and luminaires regularly

Measure code: LS3ib			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** X Public building users (1) ☐ Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW X Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (1) (3) X Contextual (1) (3) X Psychological (1) (3) X Physiological (1) X Social (1)
Description			
The measure consists in cleaning lamps and luminaires every year with soft moist cotton cloth, soft-bristled anti-static brush, or low-power vacuum cleaner as well as replacing bulb lamp at the end of its lifespan or lenses if they appear yellow.			
Benefits			
• Energy savings in electricity can be up to 50% of electrical consumption in lighting • Increase visual comfort of users • Avoid light losses due to the inefficiency of lamps and luminaires			
Limitations			
• The energy potential of this measure depends on the previous conditions of the systems • In the case of LED luminaires, risk of damage to the LEDs should be considered • It is recommended to remove diffusers/covers and reflectors as well as lamps during the cleaning process to clean them separately			
Economic assessment			
Initial investment: low. The total cost depends on the quantity of luminaires and lamps which must be cleaned and the quantity of bulb lamps which need to be replaced. It reduces costs associated to lighting energy.			
References and best practices			
- [68] Guide on the maintenance of indoor electric lighting system: www.sdsn.org.cn/1_12_sdsn_zmdqbz/admin/bztx/UploadFiles/CIE%2097%EF%BC%9A2005.pdf - [69] EUP: implementation of Regulation 245/2009. Luminaire documentation: maintenance and disassembly: www.zumtobel.com/PDB/teaser/EN/Maintenance.pdf			

Image gallery

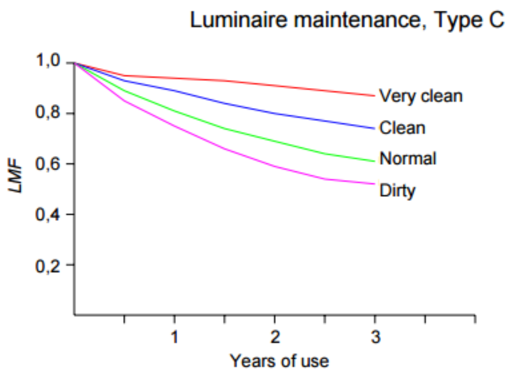



Figure 61. Luminaire's Maintenance Factor for type C luminaires (Closed tip housing unventilated). Source: CIE 97:2005.

1.4.4 Reduce the number of lamps

Measure code: LS4i

Environment or playable world:	**Carried out by:**	**Reduce consumption of:**	**Type of driver:**
☐ Residential	X Public building users (1)	☐ Heating	X Physical environmental (1) (3)
☐ Academic	☐ Owners (2)	☐ Cooling	X Contextual (1) (3)
☐ Offices	X Operators (3)	☐ DHW	X Psychological (1) (3)
X All	☐ All	X Lighting	X Physiological (1)
		☐ Electric devices	X Social (1)

Description

The measure proposes to remove from each fixture a certain number of lamps depending on the light levels previously measured with a light meter. Lamps will be removed where light levels are higher than the acceptable working levels.

Benefits

- The reduced number of lamps reduces also the energy consumption
- Improve visual comfort
- Less maintenance will be required

Limitations

- De-lamping may require some minimal wiring changes or the installation of phantom tubes
- A preliminary daylight study may be necessary

Economic assessment

Initial investment: low. The cost is zero if the measure is self-made installed. Other costs may appear if wiring should be changed or if a maintenance company is contracted.

References and best practices

- [70] Workplace De-lamping: www.publicpolicycenter.hawaii.edu/projects-programs/ sustainable-saunders/brief004.pdf
- [71] Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings: www.eur-lex.europa.eu/legal-content/EN/TXT/?uri=URISERV:en0021

Image gallery

Figure 62. Light meter. Source: www.ecutool.com.

1.4.5 Reduce the number of luminaires

Measure code: LS5i

Environment or playable world:	Carried out by:	Reduce consumption of:	Type of driver:
☐ Residential	☐ Public building users (1)	☐ Heating	X Physical environmental (2) (3)
X Academic	X Owners (2)	☐ Cooling	X Contextual (2) (3)
X Offices	X Operators (3)	☐ DHW	X Psychological (2) (3)
☐ All	☐ All	X Lighting	☐ Physiological
		☐ Electric devices	X Social (2)

Description

The measure consists in removing luminaires in spaces where the light levels are higher than the acceptable working lighting level and the entire luminaire could be removed.

Benefits

- The number of luminaires can be reduced and thus their associated energy consumption
- The visual comfort will increase

Limitations

- In existing installations, the rearrangement can lead to considerable investment costs.
- A preliminary daylight study could be necessary

Economic assessment

Initial investment: low. The cost depends mainly on how difficult removing the luminaires and rearrange the lighting installation will be. It reduces maintenance costs.

References and best practices

- [72] Offices. A guide to energy efficient and cost effective lighting: www.seai.ie/Publications/Your_Business_Publications/Technology_Guides/Office_Lighting_Guide_FNL.pdf

Image gallery

Offices	
Interior type, task or activity	**E_m**
Performance of work, copying, etc.	300
Writing, typing and reading, data processing on a PC	500
Technical drawing	750
CAD workstations	500
Conference and meeting rooms	500
Reception desks	300
Archives	200

Figure 63. Minimum required average illuminance values per task in office. Source: www.etaplighting.com

1.4.6 Turn off lighting in unused rooms or zones

Measure code: LS6b			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** X Public building users (1) ☐ Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW X Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (1) (3) X Contextual (1) (3) X Psychological (1) (3) X Physiological (1) X Social (1)

Description

If there are not presence detectors, the light should be turned off when a room is not used. This measure has to be specially considered in those spaces usually closed during weekends by assuring that any unnecessary light is switched on.

Benefits

- It is a free-of-charge measure that involves relevant savings (up to 20%)

Limitations

- This measure is narrowly related to the collaboration from the occupants or users, so providing education and training measures should be considered

Economic assessment

The cost is zero. Signals which could be placed to educate the users, have trifling costs. It reduces electricity costs.

References and best practices

- [73] Lighting at work: www.qub.ac.uk/safety-reps/sr_webpages/safety_downloads/HSG38Lightingatwork.pdf

Image gallery

Figure 64. Signal about the lights switch off. Source: www.geneva.il.us.

1.4.7 Appropriate orientation of the work place

Measure code: LS7i

Environment or playable world:	Carried out by:	Reduce consumption of:	Type of driver:
☐ Residential	X Public building users (1)	☐ Heating	X Physical environmental (1) (3)
X Academic	☐ Owners (2)	☐ Cooling	X Contextual (1) (3)
X Offices	X Operators (3)	☐ DHW	X Psychological (1) (3)
☐ All	☐ All	X Lighting	X Physiological (1)
		☐ Electric devices	X Social (1)

Description

This measure consists in orienting the workplace to maximize the use of natural light and ensuring that no glare occurs. The most suitable option is by letting the light arrive sideway to the workplace.

Benefits

- It is possible to get a more pleasant working environment
- If glare is avoided, the closing of curtains, blinds or other items which block out the sunlight is consequently avoided
- There will not be need of using artificial light

Limitations

- It is closely related to the location of windows, skylights and other natural light entrance, thus its potential is limited by the initial design of the building

Economic assessment

The cost is zero.

References and best practices

- [74] Lighting control strategy for energy efficient office lighting system design: www.sciencedirect.com/science/article/pii/S0378778813004301
- [73] Lighting at work: www.qub.ac.uk/safety-reps/sr_webpages/safety_downloads/HSG38Lightingatwork.pdf

Image gallery

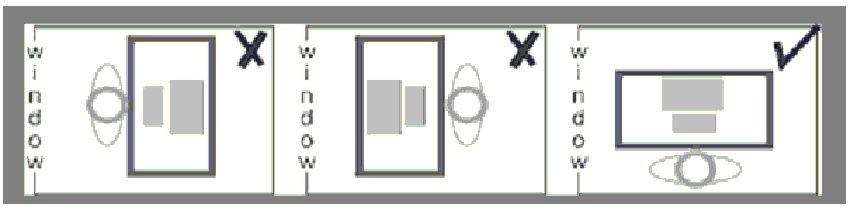


Figure 65. Workstation set up. Source: www3.imperial.ac.uk.

1.4.8 Lighting zoning through manual switches

Measure code: LS8i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** X Public building users (1) ☐ Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW X Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (1) (3) X Contextual (1) (3) X Psychological (1) (3) X Physiological (1) X Social (1)

Description

This measure consists in creating lighting zones (group of luminaires) which can be controlled independently. This way, switch on/off the lights only in the desired zone will be possible. Usually the zones are divided considering the type of activities or the penetration of natural light.

Benefits

- Increase visual comfort

Limitations

- Manual switches depend on users behaviour, so in some cases the installation of presence sensor or dimmers could be the best solution

Economic assessment

Initial investment: low. The main cost of the measure is the rearrangement of electrical system and the installation of additional switches when necessary. It reduces electricity costs.

References and best practices

- [75] The control zone: www.ecmag.com/section/lighting/control-zone

Image gallery

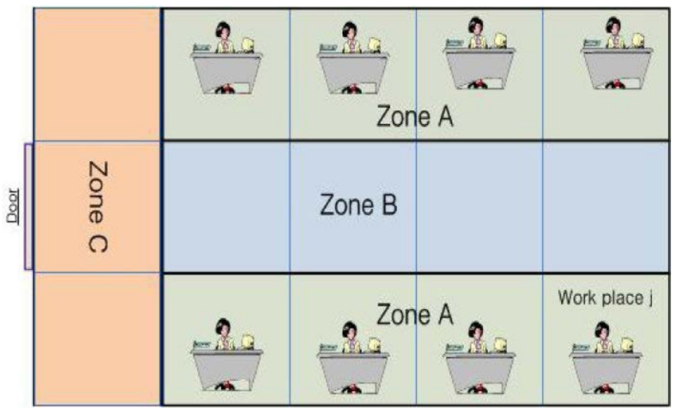


Figure 66. Zoning strategy for a typical share office. Source: www.elsevier.es.

1.4.9 Programming different scenarios for the same place

Measure code: LS9i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW X Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) (3) X Contextual (2) (3) X Psychological (2) (3) ☐ Physiological X Social (2) (3)

Description

If different activities (e.g. screening, meeting) with different required lighting levels are developed in the same space (e.g. in a conference room, classroom), it shall be given the possibility of adapting easily the illuminance levels to the activity through switches or touchpad controls which activate predetermined scenarios. The regulation of each scenario could be changed also after the installation.

Benefits

- Increase visual comfort
- Give the user the freedom of creating different lighting atmosphere in a simple way

Limitations

- A rearrangement of wiring may be necessary
- If users do not use lighting controls properly, reaching significant energy savings will be difficult

Economic assessment

Initial investment: medium. The cost of the measure includes the installation of control switches and the rearrangement of wiring. The cost may be higher depending on the type of selected control, e.g. a touchpad control will be more expensive than a normal switch. It reduces electricity costs.

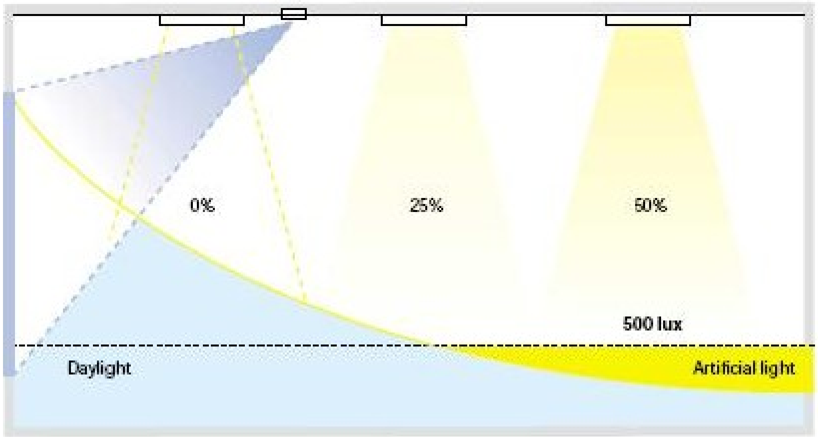
References and best practices

- [76] Dynamic light: www.etaplighting.com/uploadedFiles/Downloadable_documentation/documentatie/Dynamisch_licht_EN_p175-176-brochure.pdf

Image gallery
 *Figure 67. Touchpad control. Source: www2.advantech.com.*

1.4.10 Turn off the luminaires close to windows when there is enough daylighting

Measure code: LS10b			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** X Public building users (1) ☐ Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW X Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (1) X Contextual (1) X Psychological (1) X Physiological (1) X Social (1)
Description			
This measure is based on the collaboration of users who have to switch off lights when natural sunlight provides sufficient amount of daylight. It is important to eliminate the habit of turning on the light whenever one enters in a room.			
Benefits			
• This measure helps to optimize the use of natural light, which as a whole (luminosity sensors, dimmable systems, orientation of the workplace, blinds) can lead to a reduction in the lighting consumption of up to 30% • Increase indoor environmental quality and consequently the productivity of workers			
Limitations			
• Education, training and signposting on the potential energy savings which depend on users may be necessary to obtain significant energy savings • Its saving potential heavily depends on the actual use of natural lighting as well as the particular characteristics of the building (presence of awnings or other protective solar shadings, building orientation, possibilities and ease of improvements, etc.) • In several cases the availability of lighting zoning will be necessary			
Economic assessment			
The cost is zero, although it is convenient to train and inform properly users on these issues.			
References and best practices			
- [77] A literature review of the effects of natural light on building occupants: www.nrel.gov/docs/fy02osti/30769.pdf			

Image gallery
 *Figure 68. Variable light levels based on daylight availability. Source: www.automatedbuildings.com.*

1.4.11 Optimized interior security lighting

Measure code: LS11i			
Environment or playable world: ☐ Residential X Academic X Offices ☐ All	**Carried out by:** ☐ Public building users (1) X Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW X Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) (3) X Contextual (2) (3) X Psychological (2) (3) ☐ Physiological X Social (2) (3)

Description

The interior security lighting system can be optimized:

- reducing the illuminance performance (and consequently wattage power) to have a maximum of 54 lux
- avoiding the use of security light during the day
- using emergency lights with low capacity backup batteries
- replacing emergency exit lights by luminous tritium power free exit signs

Benefits

- Reduce the energy consumption
- Increase the lifespan of lamps
- Easy application
- Tritium lights are powered-free and do not require: external power sources, electrical connection or ambient lighting to function

Limitations

- If motion and photo sensors are installed in combination with security lights, energy savings will be more relevant

Economic assessment

Initial investment: low. The cost includes the substitution of lamps when necessary as well as a timer control to program the on/off of the lights.

References and best practices

- [78] Lighting design considerations: www.iar.unicamp.br/lab/luz/ld/Arquitetural/diversos/Lighting%20design%20considerations.pdf

Image gallery
 *Figure 69. Luminous tritium exit signs. Source: www.militarysystems-tech.com.*

1.4.12 Place floor lamps and hanging lamps in corners

Measure code: LS12i			
Environment or playable world: X Residential ☐ Academic ☐ Offices ☐ All	**Carried out by:** X Public building users (1) ☐ Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW X Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (1) X Contextual (1) X Psychological (1) X Physiological (1) X Social (1)

Description

This measure consists in rearranging the floor and hanging lamps in the corners of a room in order to increase their performance through the reflection of the light into the walls.

Benefits

- Reduce lighting consumption
- Easy application

Limitations

- Occupant acceptance
- Displacing lamps is not possible in several cases due to space restrictions

Economic assessment

Initial investment: zero.

References and best practices

- [78] Lighting design considerations: www.iar.unicamp.br/lab/luz/ld/Arquitetural/diversos/Lighting%20design%20considerations.pdf

Image gallery

Figure 70. Corner lamp. Source: www.pinterest.com.

1.5 Electrical devices measures

1.5.1 Use of multiple power strips with switch and/or programmable plugs

Measure code: EDS1i			
Environment or playable world: ☐ Residential X Academic X Offices ☐ All	**Carried out by:** X Public building users (1) ☐ Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW ☐ Lighting X Electric devices	**Type of driver:** X Physical environmental (1) (3) X Contextual (1) (3) X Psychological (1) (3) X Physiological (1) X Social (1) (3)
Description			
The use of a power strip is recommendable especially in office buildings where many devices as computers, printers, monitors, etc… are usually left in standby mode, spending unnecessary energy during the night-time, holidays and weekends. Power strips could switch all electrical equipment of a working area simultaneously. Alternatively, programmable outlets can be used to allow automatic on and off based on schedules selected by users.			
Benefits			
• The energy consumption reduction potential is up to 15% of the consumption under normal operation conditions • Easy and cheap installation • Avoid internal heat gains			
Limitations			
• Occupant acceptance • Power strips may create a parasitic load, which must be included in the analysis of total costs savings potential			
Economic assessment			
Initial investment: low. The price varies depending on the type of equipment that is purchased, being for the power strips and conventional programmable plugs between 5 and 20 euros.			
References and best practices			
- [79] Reducing office plug loads through simple and inexpensive advanced power strips: www.nrel.gov/docs/fy13osti/57730.pdf			

Image gallery
   *Figure 71. Multiple power-strip with switch. Source: www.pccomponentes.com.*

1.5.2 Set the energy saving mode of the electrical equipment

Measure code: EDS2b			
Environment or playable world: ☐ Residential ☐ Academic X Offices ☐ All	**Carried out by:** X Public building users (1) ☐ Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW ☐ Lighting X Electric devices	**Type of driver:** X Physical environmental (1) (3) X Contextual (1) (3) X Psychological (1) (3) X Physiological (1) X Social (1) (3)

Description

It is recommended to properly set the energy saving mode of computers, printers, photocopiers and other office equipment, with which it can be saved up to 50% of the equipment's energy consumption.

Benefits

- Simple, energy savings between 10 and 20% can be achieved with proper training
- Easy application
- Extend the lifespan of equipment

Limitations

- Occupant acceptance

Economic assessment

The cost is zero, although it is convenient to train and inform properly users on these issues.

References and best practices

- [20] Estimating the energy consumption and power demand of small power equipment in office buildings: www.sciencedirect.com/science/article/pii/S0378778814001224
- [21] Energy efficiency of office equipment in commercial buildings - the case of Thailand: www.ac.els-cdn.com/S036054429700162X/1-s2.0-S036054429700162X-main.pdf?_tid=4dc21bf8-fa4b-11e4-a263-00000aab0f6c&acdnat=1431616386_0221f399ad78b4129e2c3c70991f28be

Image gallery

Figure 72. Energy saving mode. Source: www.computeralliance.com.au.

1.5.3 Turning off the screen of the monitor

Measure code: EDS3b			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** X Public building users (1) ☐ Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW ☐ Lighting X Electric devices	**Type of driver:** X Physical environmental (1) (3) X Contextual (1) (3) X Psychological (1) (3) X Physiological (1) X Social (1) (3)

Description

When making short stops, of about 10 minutes, turn off the monitor screen, because it is the part of the computer that consumes more energy (between 70-80%). For stops of more than one hour it is recommended to turn off completely the computer.

Benefits

- Energy savings between 10 and 20% can be achieved with proper training
- Avoid internal heat gains
- Extend the lifespan of the monitor

Limitations

- Occupant acceptance

Economic assessment

The cost is zero, although it is convenient to train and inform properly to the users on these issues.

References and best practices

- [80] A case study on the individual energy use of personal computers in an office setting and assessment of various feedback types towards energy savings: www.sciencedirect.com/science/article/pii/S0378778815301237

Image gallery

Figure 73. Turn off your computer. Source: hyunjink.blogspot.com.es.

1.5.4 Adjusting the brightness of the TV or monitor screen to a medium level

Measure code: EDS4b			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** X Public building users (1) ☐ Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW ☐ Lighting X Electric devices	**Type of driver:** X Physical environmental (1) (3) X Contextual (1) (3) X Psychological (1) (3) X Physiological (1) X Social (1) (3)

Description

By adjusting the brightness of the screen to a medium level, between 15-20% of energy can be saved. With a low level brightness, which is fixed in many laptops by default when they work with the battery, energy savings up to 40% can be achieved.

Benefits

- Simple, energy savings between 10 and 20% can be achieved with proper training
- Easy application
- The benefits are not only in terms of energy savings, but also in vision health. A low brightness avoids eyes stressing

Limitations

- Occupant acceptance

Economic assessment

The cost is zero, although it is convenient to train and inform properly employees and users on these issues.

References and best practices

- [81] Power Consumption by Computer Monitors at Different Contrast/Brightness Levels and its Impact on the Carbon Footprint: www.academia.edu/6229033/Power_Consumption_by_Computer_Monitors_at_Different_Contrast_Brightness_Levels_and_its

Image gallery

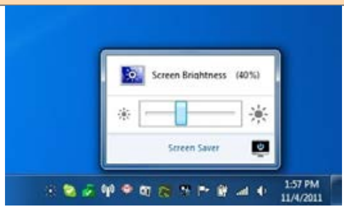


Figure 74. Adjust brightness of PC. Source: www.schoolsrugbyacademy.com.

1.5.5 Using the desktop screen in a proper way

Measure code: EDS5b			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** X Public building users (1) ☐ Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW ☐ Lighting X Electric devices	**Type of driver:** X Physical environmental (1) (3) X Contextual (1) (3) X Psychological (1) (3) X Physiological (1) X Social (1) (3)

Description

Choose dark colours for the background images of the desktop screen. On average, a white page needs 74 W to display, while a dark one needs only 59 W (25% less energy).

Benefits

- Energy savings of 20% can be achieved with proper training
- Easy application
- The benefits are not only in terms of energy savings, but also in vision health

Limitations

- Occupant acceptance

Economic assessment

The cost is zero, although it is convenient to train and inform properly employees and users on these issues.

References and best practices

- [82] Blackle vs. Google Monitor Power Consumption Tested: www.pcstats.com/articleview.cfm?articleID=2649

Image gallery

*Figure 75. Black Google. Source: **www.dailyapps.net.***

1.5.6 Using the screensaver in a proper way

Measure code: EDS6b			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** X Public building users (1) ☐ Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW ☐ Lighting X Electric devices	**Type of driver:** X Physical environmental (1) (3) X Contextual (1) (3) X Psychological (1) (3) X Physiological (1) X Social (1) (3)
Description			
The screensaver that consumes less energy is the black one, saving on average 7.5 Wh, value lower than for any animated screensaver. It is recommended to configure that it is activated after 10 minutes of inactivity.			
Benefits			
• Energy savings between 10% and 20% can be achieved with proper training • Easy application			
Limitations			
• Occupant acceptance • The energy saving is less relevant in LCD monitors			
Economic assessment			
The cost is zero, although it is convenient to train and inform properly employees and users on these issues.			
References and best practices			
- [83] HTG Explains: Why Screen Savers Are No Longer Necessary: www.howtogeek.com/128644/htg-explains-why-screen-savers-are-no-longer-necessary/ - [84] Energy consumption of workstations and external devices in school of business and information technology: www.theseus.fi/bitstream/handle/10024/47095/Koret_Jere.pdf?sequence=1			

Image gallery

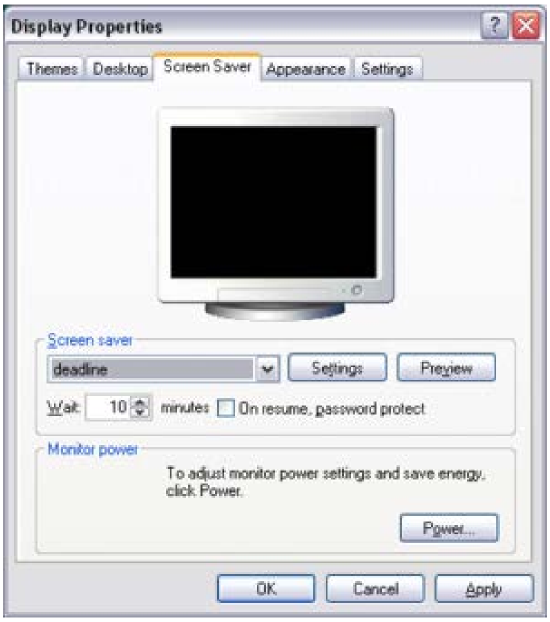


Figure 76. Black screen saver. Source: www.docs.thinkboxsoftware.com.

1.5.7 Use and manage properly the energy consumption of printers and photocopiers

Measure code: EDS7b			
Environment or playable world: ☐ Residential ☐ Academic X Offices ☐ All	**Carried out by:** X Public building users (1) ☐ Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW ☐ Lighting X Electric devices	**Type of driver:** X Physical environmental (1) X Contextual (1) X Psychological (1) X Physiological (1) X Social (1)
Description			
When printing or photocopying documents, it is convenient to carry out printing works at double-side and in draft quality mode.			
Benefits			
• Simple, energy savings between 10% and 20% can be achieved with proper training • Paper, toner and water are also saved • Avoid internal heat gains			
Limitations			
• Occupant acceptance • Sometimes it is necessary to print in normal or best mode and to use only one side of the paper			
Economic assessment			
The cost is zero, although it is convenient to train and inform properly employees on these issues.			
References and best practices			
- [85] Power consumption the hidden costs of copiers and printers: www.risolatin.com/site/PDFs/Info_Resources/White_Paper_The_Hidden_Costs.pdf			

Image gallery

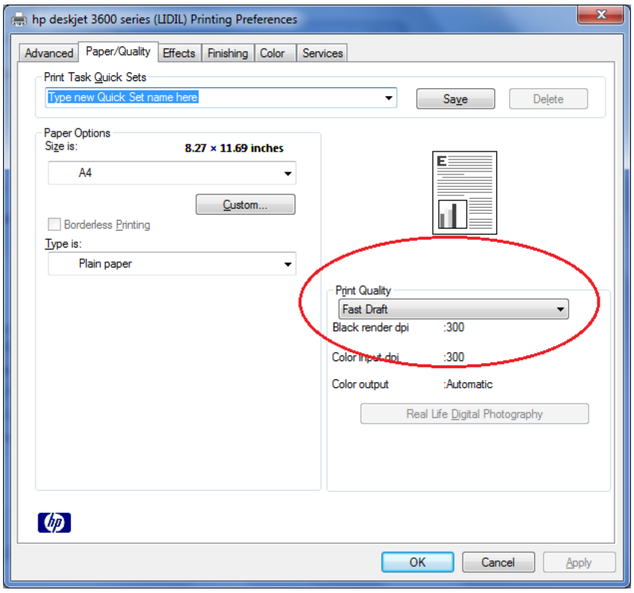


Figure 77. Select draft quality. Source: www3.hp.com.

1.5.8 Turning off the TV

Measure code: EDS8b			
Environment or playable world: X Residential ☐ Academic ☐ Offices ☐ All	**Carried out by:** X Public building users (1) ☐ Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW ☐ Lighting X Electric devices	**Type of driver:** X Physical environmental (1) X Contextual (1) X Psychological (1) ☐ Physiological X Social (1)

Description

Turning off the TV, radio, computers or other appliances if no one use them.

Benefits

- Energy savings between 10% and 20% can be achieved with proper training

Limitations

- Occupant acceptance

Economic assessment

The cost is zero, although it is convenient to train and inform properly users on these issues.

References and best practices

- [86] Household energy consumption and consumer electronics: The case of television: www.sciencedirect.com/science/article/pii/S0301421508000785

Image gallery

Figure 78. Turn Off TV When Not In Use Sign. Source: www.mydoorsign.com.

1.5.9 Set the economic program of the washing machine

Measure code: EDS9b			
Environment or playable world: X Residential ☐ Academic ☐ Offices ☐ All	**Carried out by:** X Public building users (1) ☐ Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW ☐ Lighting X Electric devices	**Type of driver:** X Physical environmental (1) X Contextual (1) X Psychological (1) ☐ Physiological X Social (1)

Description
Select the washing machine economic program.
Benefits
• Energy savings between 10 and 20% can be achieved with proper training • Clothes will be cleaned as good as with other programs
Limitations
• Occupant acceptance • The length of the program is larger than a normal program
Economic assessment
The cost is zero, although it is convenient to train and inform people on these issues.
References and best practices
- [87] A simplified model for the electrical energy consumption of washing machines: www.sciencedirect.com/science/article/pii/S2352710215000200
Image gallery

Figure 79. Select economy program. Source: www.dreamstime.com.

1.5.10 Set the economic program of the dishwasher

Measure code: EDS10b			
Environment or playable world: X Residential ☐ Academic ☐ Offices ☐ All	**Carried out by:** X Public building users (1) ☐ Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW ☐ Lighting X Electric devices	**Type of driver:** X Physical environmental (1) X Contextual (1) X Psychological (1) ☐ Physiological X Social (1)
Description			
Select the dishwasher economic program.			
Benefits			
• Energy savings between 10% and 20% can be achieved with proper training • Dishes will be cleaned as good as with other programs			
Limitations			
• Occupant acceptance • The length of the program is larger than a normal program			
Economic assessment			
The cost is zero, although it is convenient to train and inform people on these issues.			
References and best practices			
- [88] Demand side management of a domestic dishwasher: Wind energy gains, financial savings and peak-time load reduction: www.sciencedirect.com/science/article/pii/S0306261912005156			
Image gallery			

Figure 80. Select economy program. Source: www.dreamstime.com.

1.5.11 Set the economic program of the oven

Measure code: EDS11b			
Environment or playable world: X Residential ☐ Academic ☐ Offices ☐ All	**Carried out by:** X Public building users (1) ☐ Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW ☐ Lighting X Electric devices	**Type of driver:** X Physical environmental (1) X Contextual (1) X Psychological (1) ☐ Physiological X Social (1)
Description			
Select the oven economic program.			
Benefits			
• Energy savings between 10 and 20%can be achieved with proper training			
Limitations			
• Occupant acceptance • The length of the program is larger than a normal program			
Economic assessment			
The cost is zero, although it is convenient to train and inform people on these issues.			
References and best practices			
- [89] Energy conservation standards standby mode and off mode microwave ovens; petition for reconsideration: www.mercatus.org/publication/energy-conservation-standards-standby-mode-and-mode-microwave-ovens-petition			
Image gallery			

Figure 81. Oven economy program. Source: www.siemens-home.de.

1.5.12 Set the appropriate temperatures of refrigerator and freezer

Measure code: EDS12b

Environment or playable world:	Carried out by:	Reduce consumption of:	Type of driver:
X Residential ☐ Academic X Offices ☐ All	X Public building users (1) ☐ Owners (2) ☐ Operators (3) ☐ All	☐ Heating ☐ Cooling ☐ DHW ☐ Lighting X Electric devices	X Physical environmental (1) X Contextual (1) X Psychological (1) ☐ Physiological X Social (1)

Description

The measure consists in setting the appropriate temperature for freezers and refrigerators. The optimal temperature for a refrigerator is 5°C while for a freezer is -18°C. The temperature setting depends also on climate conditions.

Benefits

- Simple, energy savings between 10 and 20% can be achieved with proper training

Limitations

- Occupant acceptance

Economic assessment

The cost is zero, although it is convenient to train and inform properly users on these issues.

References and best practices

- [90] Implementation of energy efficiency standards of household refrigerator/freezer in China: Potential environmental and economic impacts: www.sciencedirect.com/science/article/pii/S0306261910004782

Image gallery

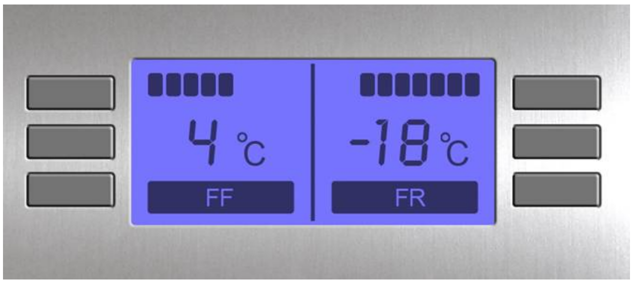


Figure 82. Energy saving mode. Source: www.dalllac.com.

1.5.13 Unplug battery chargers when their use is not necessary

Measure code: EDS13b			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** X Public building users (1) ☐ Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW ☐ Lighting X Electric devices	**Type of driver:** X Physical environmental (1) X Contextual (1) X Psychological (1) ☐ Physiological X Social (1)

Description

Mobile phones, laptops, tablets and other devices are usually left plugged to their battery charger though they are already fully charged or they are in sleep mode. This generates phantom consumption which can be easily avoided.

Benefits

- Energy savings up to 5% can be achieved
- The battery life will be preserved

Limitations

- Occupant acceptance
- The energy savings potential depends on the efficiency and number of chargers, on the devices plugged and on the use made of them

Economic assessment

The cost is zero, although it is convenient to train and inform properly users on these issues.

References and best practices

- [91] Is there phantom power usage in your home? www.cleanenergyresourceteams.org/blog/there-phantom-power-usage-your-home

Image gallery

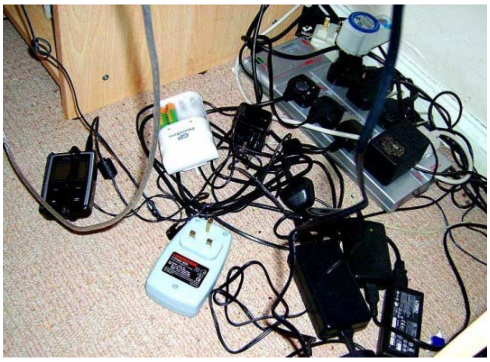


Figure 83. High energy saving potential if there are many connected devices. Source: www.inhabitat.com.

1.5.14 Use of networking printers

Measure code: EDS14i			
Environment or playable world: ☐ Residential X Academic X Offices ☐ All	**Carried out by:** X Public building users (1) ☐ Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW ☐ Lighting X Electric devices	**Type of driver:** X Physical environmental (1) X Contextual (1) X Psychological (1) ☐ Physiological X Social (1)

Description

The measure proposes to reduce the number of personal printers and replace them with a common networking one, saving significant a amount of energy.

Benefits

- Energy savings
- Reduce maintenance costs
- Discourage paper wasting

Limitations

- The responsibility of turning off the printer during the night and weekend shall be assigned to one of the users to avoid energy waste

Economic assessment

The measure is economically viable if the printers which have to be replaced are inefficient and need to be changed.

References and best practices

- [92] Guide to Reducing Energy Use in Office Equipment: www.greenshorenstein.info/pdf/19.%20Guide%20to%20Reducing%20Energy%20Use%20in%20Office%20Equipment%20-%20U.C.%20Berkeley%20-%203-20-1999.pdf

Image gallery

Figure 84. Network printer configuration. Source: www.utilizewindows.com.

1.5.15 Use pressure cookers

Measure code: EDS15i			
Environment or playable world: X Residential ☐ Academic ☐ Offices ☐ All	**Carried out by:** X Public building users (1) ☐ Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW ☐ Lighting X Electric devices	**Type of driver:** X Physical environmental (1) X Contextual (1) X Psychological (1) ☐ Physiological X Social (1)

Description

The use of pressure cookers reduces times of cooking compared with traditional methods.

Benefits

- Energy savings could be up to 50%
- Less time of cooking reduces the energy consumption
- In summer less heat is generated due to shorter time of cooking
- Less water consumption, because pressure cookers need less water to cook compared with traditional pots
- Foods cooked with pressure cookers retain most of their nutrients and are tastier

Limitations

- User acceptance
- Cooking with pressure cookers may result more difficult compared with traditional pots

Economic assessment

Initial investment: low. Prices vary depending on types. A new generation pressure cooker costs approximately 130€.

References and best practices

- [93] Energy consumption in microwave cooking of rice and its comparison with other domestic appliances: www.sciencedirect.com/science/article/pii/S0260877405007612

Image gallery

Figure 85. Electric pressure cooker. Source: www.instantpot.com.

1.5.16 Use a toaster oven or microwave instead of the oven

Measure code: EDS16b			
Environment or playable world: X Residential ☐ Academic ☐ Offices ☐ All	**Carried out by:** X Public building users (1) ☐ Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW ☐ Lighting X Electric devices	**Type of driver:** X Physical environmental (1) X Contextual (1) X Psychological (1) ☐ Physiological X Social (1)

Description

The measure proposes using a microwave or a toaster oven instead of a traditional oven to save energy considering that the formers are more efficient in daily cooking.

Benefits

- Microwave and toaster oven reduce the time of cooking reducing, consequently, the energy consumption
- In summer, toaster oven and microwave generate less heat due to shorter time of cooking, but also to reduced dimension of both
- Comparing one hour in the oven versus fifteen minutes in the microwave, you're saving about 1 to 1.5 kW by using the microwave

Limitations

- User acceptance
- Sometimes it is necessary to use a traditional oven due to the quantity of food which will be cocked or due to the cooking technique

Economic assessment

The cost is zero if you possess a microwave or toaster oven, otherwise you can buy a microwave for 50€ and a toaster oven for 30€.

References and best practices

- [93] Energy consumption in microwave cooking of rice and its comparison with other domestic appliances: www.sciencedirect.com/science/article/pii/S0260877405007612

Image gallery

Figure 86. Microwave and toaster oven. Sources: www.avartawellness.com ; www.amazon.com.

1.5.17 Turning off communal equipment at the end of the day

Measure code: EDS17b			
Environment or playable world: X Residential ☐ Academic X Offices ☐ All	**Carried out by:** X Public building users (1) ☐ Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW ☐ Lighting X Electric devices	**Type of driver:** X Physical environmental (1) (3) X Contextual (1) (3) X Psychological (1) (3) ☐ Physiological X Social (1) (3)
Description			
The measure proposes to switch off completely all the electronic devices which normally, in an office or in residential buildings are left on stand-by or functioning in the night and at weekends, although they are not used. Electronic devices could be: coffee makers, water cooling devices, printers, copiers, microwaves, displays, etc…			
Benefits			
• Reduce electricity consumption • Extend the lifespan of electronic devices			
Limitations			
• User acceptance • In office buildings it is necessary to put in charge someone who has to switch off all the electronic devices			
Economic assessment			
The cost is zero.			
References and best practices			
- [94] Occupant behaviour and schedule modelling for building energy simulation through office appliance power consumption data mining: www.sciencedirect.com/science/article/pii/S0378778814005714			

Image gallery

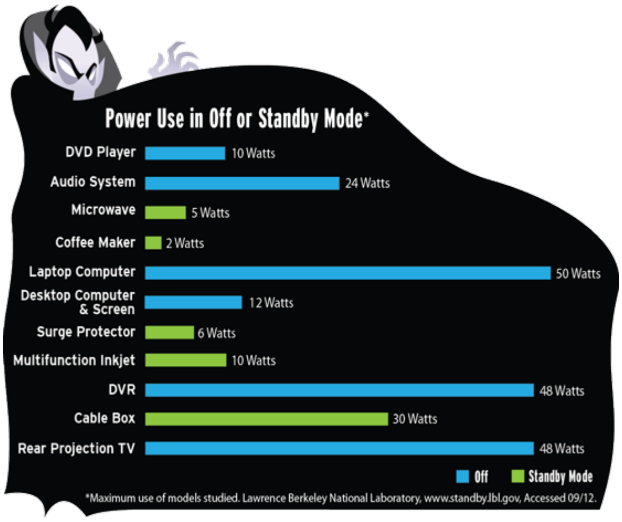


Figure 87. Vampire energy loss. Source: www.wwcccs.com.

1.5.18 Air dry dishes instead of using the dishwasher's drying cycle

Measure code: EDS18b			
Environment or playable world: X Residential ☐ Academic ☐ Offices ☐ All	**Carried out by:** X Public building users (1) ☐ Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW ☐ Lighting X Electric devices	**Type of driver:** X Physical environmental (1) X Contextual (1) X Psychological (1) ☐ Physiological X Social (1)
Description			
The measure proposes avoiding the use of dishwasher to dry dishes and leave that air dries them.			
Benefits			
• Reduce electricity consumption • Almost no effort is required			
Limitations			
• User acceptance • The time of air drying is longer than a dishwasher's drying cycle			
Economic assessment			
The cost is zero.			
References and best practices			
- [95] How Energy Efficient Are Modern Dishwashers?: www.aceee.org/files/proceedings/2008/data/papers/1_123.pdf			
Image gallery			

Figure 88. Air dry dishes. Source: www.examiner.com.

1.5.19 Wash only full loads of dishes and clothes

Measure code: EDS19b			
Environment or playable world: X Residential ☐ Academic ☐ Offices ☐ All	**Carried out by:** X Public building users (1) ☐ Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW ☐ Lighting X Electric devices	**Type of driver:** X Physical environmental (1) X Contextual (1) X Psychological (1) ☐ Physiological X Social (1)

Description

The measure consists in using the washing machine and dishwasher only when there are full loads because in this way it is more efficient.

Benefits

- Reduce electricity consumption
- Reduce water consumption
- Almost no effort is required

Limitations

- User acceptance
- Sometimes if washing machines or dishwashers are excessively full, the cleaning will not be effective

Economic assessment

The cost is zero.

References and best practices

- [96] Washing machines: policy recommendations: www.topten.eu/uploads/File/130904_Topten_recommendations_Washing_machines.pdf

Image gallery

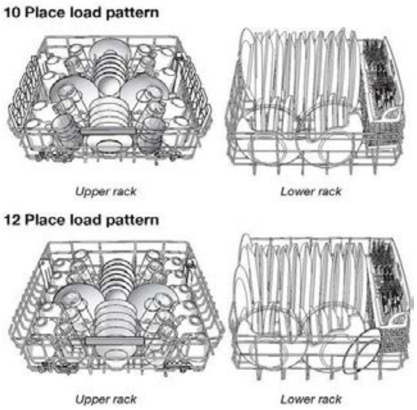


Figure 89. The correct way to load dishes. Source: www.thekitchn.com.

1.5.20 Turn off the oven or the electric cooker before finishing

Measure code: EDS20b			
Environment or playable world: X Residential ☐ Academic ☐ Offices ☐ All	**Carried out by:** X Public building users (1) ☐ Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW ☐ Lighting X Electric devices	**Type of driver:** X Physical environmental (1) X Contextual (1) X Psychological (1) ☐ Physiological X Social (1)

Description

The measure consists in turning off the oven or the electrical cooker before finishing the cook of a meal. In this way, the period of time which an oven or a glass ceramic plate needs to cool down is used, taking advantage of the residual heat to finish cooking the dish.

Benefits

- Reduce consumption in electricity or gas
- Almost no effort is required
- Reduce heat gains in summer

Limitations

- User acceptance

Economic assessment

The cost is zero.

References and best practices

- [97] Electricity usage of an Oven: www.energyusecalculator.com/electricity_oven.htm

Image gallery

Figure 90. Surface hot indicators for electric cooker. Source: www.fisherpaykel.com.

1.5.21 Air dry clothes

Measure code: EDS21b			
Environment or playable world: X Residential ☐ Academic ☐ Offices ☐ All	**Carried out by:** X Public building users (1) ☐ Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW ☐ Lighting X Electric devices	**Type of driver:** X Physical environmental (1) X Contextual (1) X Psychological (1) X Physiological (1) X Social (1)

Description

The energy consumption of a dryer machine can be avoided if the clothes are air dried.

Benefits

- Reduce electricity consumption
- Clothes will last longer
- Reduce heat gain in summer
- If air dry method is used, no money will be spent to buy a dryer

Limitations

- User acceptance
- If there is no space to hang the clothes or the weather is not appropriate, the user will prefer the use of dryer

Economic assessment

The cost is zero. Clothes air dry is free.

References and best practices

- [98] Clothes dryers discussion paper: www.ausgrid.com.au/~/media/Files/About%20Us/Newsroom/Discussions/Clothes%20Dryers%20Discussion%20Paper.pdf

Image gallery

Figure 91. Clothes air drying. Source: www.ecns.cn.

1.5.22 Regularly defrost manual defrost refrigerators and freezers

Measure code: EDS22b			
Environment or playable world: X Residential ☐ Academic ☐ Offices ☐ All	**Carried out by:** X Public building users (1) ☐ Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW ☐ Lighting X Electric devices	**Type of driver:** X Physical environmental (1) X Contextual (1) X Psychological (1) ☐ Physiological X Social (1)

Description

To improve their efficiency, it is necessary, amongst other things, to defrost refrigerators and freezers manually minimum once a year, to avoid the grown of ice which is an insulator and prevents an efficient use.

Benefits

- Reduce electricity consumption
- Extend the lifespan of refrigerators and freezers
- Obtain better performance from refrigerators and freezers, especially if they are old
- The defrosting operation is simple and fast to realize

Limitations

- Before defrosting, it will be necessary to empty refrigerators and freezers
- User acceptance

Economic assessment

The cost is zero.

References and best practices

- [99] When to defrost a refrigerator, and when to remove the scale from the heat exchanger of a power plant: www.sciencedirect.com/science/article/pii/0017931094900876

Image gallery

Figure 92. Defrost with defroster spray. Source: www.homecareessentials.co.uk/.

1.5.23 Cover liquids and wrap foods stored in the refrigerator

Measure code: EDS23b			
Environment or playable world: ☐ Residential X Academic X Offices ☐ All	**Carried out by:** X Public building users (1) ☐ Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW ☐ Lighting X Electric devices	**Type of driver:** X Physical environmental (1) X Contextual (1) X Psychological (1) ☐ Physiological X Social (1)

Description

Uncovered liquids or foods putted in the refrigerator release vapours that add to the compressor workload.

Benefits

- Reduce electricity consumption
- Extend the lifespan of the refrigerator
- Food is better preserved

Limitations

- User acceptance

Economic assessment

The cost is zero.

References and best practices

- [100] Refrigerator tips for saving energy & food safety: www.home-wizard.com/how-to-guide/appliances/refrigerator/articles-videos/refrigerator-operating-tips.aspx

Image gallery

Figure 93. How to store food properly in the freezer and fridge. Source: www.lifehacker.com/.

1.5.24 Repair refrigerator door seals

Measure code: EDS24i			
Environment or playable world: X Residential ☐ Academic ☐ Offices ☐ All	**Carried out by:** X Public building users (1) ☐ Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW ☐ Lighting X Electric devices	**Type of driver:** X Physical environmental (1) (3) X Contextual (1) (3) X Psychological (1) (3) ☐ Physiological X Social (1) (3)

Description

If the door of the refrigerator is not sealed properly, cold air will escape and warm air will enter into the cabinet, rising the temperature inside the fridge.

Benefits

- Reduce electricity consumption because the fridge's cabinet does not let escape cool from inside
- Extend the lifespan of refrigerator
- The seal can be installed easily

Limitations

- It could be difficult to find the gasket which properly fits with the refrigerator

Economic assessment

The cost of the seal is approximately 50€ and its installation can be self-made.

References and best practices

- [101] How to Replace a Refrigerator Door Seal: www.wikihow.com/Replace-a-Refrigerator-Door-Seal

Image gallery

Figure 94. How to replace a refrigerator door gasket. Source: www.familyhandyman.com/.

1.5.25 Match the size of the pan to the heating element

Measure code: EDS25b			
Environment or playable world: X Residential ☐ Academic ☐ Offices ☐ All	**Carried out by:** X Public building users (1) ☐ Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW ☐ Lighting X Electric devices	**Type of driver:** X Physical environmental (1) X Contextual (1) X Psychological (1) ☐ Physiological X Social (1)
Description			
When cooking, use the heating element that matches as much as possible the pan to avoid heat losses.			
Benefits			
• Reduce consumption in electricity or gas, depending on the type of heating element • Extend the lifespan of the pans because excessive heat can damage them • Easy application			
Limitations			
• User acceptance			
Economic assessment			
The cost is zero.			
References and best practices			
- [102] Analytical modeling of pan and oil heating on an electric coil cooktop: www.nfpa.org/~/media/files/research/research-foundation/research-foundation-reports/other-research-topics/rfanalyticalmodelingofpanandoilheatingonanelectriccoilcooktop.pdf?la=en.			
Image gallery			

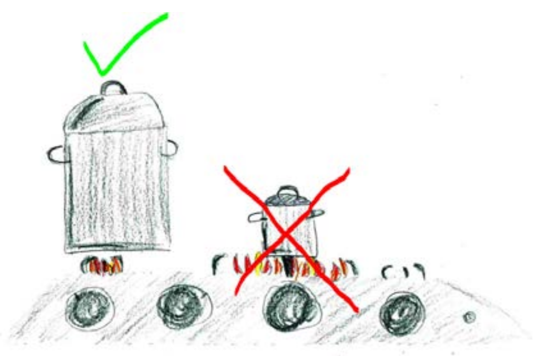


Figure 95. Match the size of the pot with the size of the stove. Source: www.comune.trento.it

1.5.26 Use a covered kettle or pan or electric kettle to boil water

Measure code: EDS26ib			
Environment or playable world: X Residential ☐ Academic ☐ Offices ☐ All	**Carried out by:** X Public building users (1) ☐ Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW ☐ Lighting X Electric devices	**Type of driver:** X Physical environmental (1) X Contextual (1) X Psychological (1) ☐ Physiological X Social (1)

Description

To save energy it is recommended to use a covered kettle, a pan or an electric kettle to boil water.

Benefits

- Reduce electricity consumption because these appliances are more efficient than boil water on electric or gas cooker
- The water will boil faster
- Reduce heat gains

Limitations

- A kettle, electric kettle or pan is necessary

Economic assessment

The cost of an electric kettle or a kettle is approximately 30€.

References and best practices

- [103] The best way to boil water: nitty-gritty: www.alumni.stanford.edu/get/page/magazine/article/?article_id=29243

Image gallery

Figure 96. Electric kettle. Source: www.reddit.com.

1.5.27 Use the washing machine with cold water

Measure code: EDS27b			
Environment or playable world: X Residential ☐ Academic ☐ Offices ☐ All	**Carried out by:** X Public building users (1) ☐ Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW ☐ Lighting X Electric devices	**Type of driver:** X Physical environmental (1) X Contextual (1) X Psychological (1) X Physiological (1) X Social (1)
Description			
Wash clothes on a cold wash cycle whenever possible, considering that 90% of the washing machine energy consumption is used to heat water.			
Benefits			
• Reduce electricity consumption • The manufacturing cost of cold fill washing machine is lower			
Limitations			
• Users consider that only with warm water clothes get really clean • To wash with cold water a cold-water detergent is necessary			
Economic assessment			
The cost is zero and it reduces the energy cost			
References and best practices			
- [104] Cold or hot wash: technological choices, cultural change, and their impact on clothes-washing energy use in China: www.sciencedirect.com/science/article/pii/S0301421506004241			

Image gallery

Wash cycle	Loading Type	Star Rating	Annual Energy Cost*	
			Cold only connect or peak electric water heater	*Dual hot & cold connect, gas water heater*
5 kg capacity – small				
Warm	Top	★	$169.30	$63.70
Cold	Top	★	$20.20	-
Warm	Front	★★½	$102.00	$48.40
Cold	Front	★★½	$26.30	-
7 kg capacity – medium				
Warm	Top	★½	$203.00	$71.20
Cold	Top	★½	$16.90	-
Warm	Front	★★★★	$74.20	$38.10
Cold	Front	★★★★	$23.30	-
8.5 kg capacity – large				
Warm	Top	★½	$243.40	$90.30
Cold	Top	★½	$27.30	-
Warm	Front	★★★★	$94.10	$52.60
Cold	Front	★★★★	$35.50	-

Figure 97. Annual energy cost based on using washing machine 7 times per week, electricity tariff 28 c/kWh & gas tariff 1.7 c/MJ. Source: www.sustainability.vic.gov.au.

1.5.28 Cleaning of the backside of the fridge

Measure code: EDS28b			
Environment or playable world: X Residential ☐ Academic ☐ Offices ☐ All	**Carried out by:** X Public building users (1) ☐ Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW ☐ Lighting X Electric devices	**Type of driver:** X Physical environmental (1) X Contextual (1) X Psychological (1) ☐ Physiological X Social (1)

Description

It is necessary to clean the backside of the fridge once a year because a lot of dust is accumulated behind the fridge on the condenser coil, causing inefficiently operation.

Benefits

- Reduce electricity consumption
- Extend the lifespan of the fridge
- It is easy and rapid to realize

Limitations

- It is necessary to keep care of the coil during the cleaning to avoid damage it
- The fridge shall be unplugged

Economic assessment

The cost is zero and it reduces energy cost.

References and best practices

- [105] How to clean your refrigerators condenser coils or fan: www.greenlivingideas.com/2014/07/22/clean-refrigerators-condenser-coils/

Image gallery

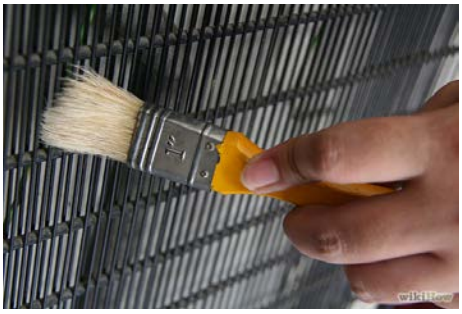


Figure 98. Narrow paint brush to remove stubborn dirt and dust. Source: www.wikihow.com.

1.5.29 When cooking on the range, use pot lids to help food cook faster

Measure code: EDS29b			
Environment or playable world: X Residential ☐ Academic ☐ Offices ☐ All	**Carried out by:** X Public building users (1) ☐ Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW ☐ Lighting X Electric devices	**Type of driver:** X Physical environmental (1) X Contextual (1) X Psychological (1) ☐ Physiological X Social (1)
Description			
To accelerate the cooking of meals and save energy, it is recommended to use pot lids.			
Benefits			
• Reduce consumption in electricity or gas • Reduce cooking time			
Limitations			
• User acceptance			
Economic assessment			
The cost is zero and it reduces energy cost			
References and best practices			
- [106] Does water boil faster in a covered or uncovered pot?: www.mindyourdecisions.com/blog/2012/06/21/does-water-boil-faster-in-a-covered-or-uncovered-pot/#.VbiQjfntlBc			
Image gallery			

Figure 99. Use pot lids. Source: www.comune.trento.it/.

1.5.30 Promote the use of solar chargers

Measure code: EDS30i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** X Public building users (1) ☐ Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW ☐ Lighting X Electric devices	**Type of driver:** X Physical environmental (1) X Contextual (1) X Psychological (1) ☐ Physiological X Social (1)

Description

Encourage the use of solar charger to charge mobile phones or other portable devices.

Benefits

- Reduce electricity consumption
- It is a portable power storage

Limitations

- The solar charger need a lot of hours of sunlight to recharge itself
- If the solar charger is not made of recycled materials, the ecological footprint associated with solar cells is high

Economic assessment

A portable solar charger could cost approximately 25€.

References and best practices

- [107] Solar battery charger for portable devices application: www.greenlivingideas.com/2014/07/22/clean-refrigerators-condenser-coils/www.siliconreef.com.br/site/assets/public/files/whitepapers/3500ac808019af98523befe5dfa302c1.pdf

Image gallery

Figure 100. Portable solar charger. Source: www.busysale.com/.

1.5.31 Using hand cleaners instead of electrical ones

Measure code: EDS31ib			
Environment or playable world: ☐ Residential X Academic X Offices ☐ All	**Carried out by:** X Public building users (1) ☐ Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW ☐ Lighting X Electric devices	**Type of driver:** X Physical environmental (1) X Contextual (1) X Psychological (1) ☐ Physiological X Social (1)
Description			
The use of paper towels to dry hands instead of electric dryer saves energy.			
Benefits			
• Reduce electricity consumption • Noise generated by electrical hand dryers is avoided • Avoid the spread of airborne bacteria			
Limitations			
• Paper towels generate more waste than electric hand dryers • From the point of view of life cycle, electric hand dryers could be more sustainable especially if get a lot of usage			
Economic assessment			
A towel dispenser could cost approximately 40€. Depending on the frequency and period of use could be more convenient the use of an efficient electric hand dryer. The cost of installation of a paper dispenser is lower than the cost of electric hand dryer			
References and best practices			
- [108] A comparative life cycle assessment of conventional hand dryer and roll paper towel as hand drying methods: www.sciencedirect.com/science/article/pii/S0048969715001424			

Image gallery
 *Figure 101. Spread of bacteria after hand drying. Source: www.twosides.info/.*

1.5.32 Try to optimize the delivery of print jobs or photocopies

Measure code: EDS32b			
Environment or playable world: ☐ Residential X Academic X Offices ☐ All	**Carried out by:** X Public building users (1) ☐ Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW ☐ Lighting X Electric devices	**Type of driver:** X Physical environmental (1) X Contextual (1) X Psychological (1) ☐ Physiological X Social (1)
Description			
The measure suggests organizing print jobs or photocopies to print them all together using printers intensively (the action of switching on and off these equipment is when more energy is consumed).			
Benefits			
• Reduce electricity consumption because printers are more efficient if used continuously instead of turning them on from standby mode many times • Extend the lifespan of printer and photocopiers			
Limitations			
• User acceptance			
Economic assessment			
The cost is zero.			
References and best practices			
- [109] Office equipment Introducing energy saving opportunities for business: www.carbontrust.com/media/13113/ctv005_office_equipment.pdf			
Image gallery			

Figure 102. Print conductor. Source: www.prweb.com.

1.5.33 Remove refrigerators from places next to heat sources

Measure code: EDS33b			
Environment or playable world: X Residential ☐ Academic ☐ Offices ☐ All	**Carried out by:** X Public building users (1) ☐ Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW ☐ Lighting X Electric devices	**Type of driver:** X Physical environmental (1) X Contextual (1) X Psychological (1) X Physiological (1) X Social (1)

Description

The refrigerator shall be positioned away from other appliances or any other heat sources which can transfer heat to the refrigerator.

Benefits

- Reduce the electricity consumption of the refrigerator
- Extend the lifespan of the refrigerator

Limitations

- Sometimes the position where the refrigerator could be placed is mandatory and the closeness to heat sources cannot be avoided

Economic assessment

The cost is zero.

References and best practices

- [110] Role of ambient temperature, door opening, thermostat setting position and their combined effect on refrigerator-freezer energy consumption: www.sciencedirect.com/science/article/pii/S0196890401000693

Image gallery

Figure 103. Refrigerator placement. Source: wonderfulengineering.com/.

1.5.34 Print only necessary documents

Measure code: EDS34b

Environment or playable world:	Carried out by:	Reduce consumption of:	Type of driver:
☐ Residential X Academic X Offices ☐ All	X Public building users (1) ☐ Owners (2) ☐ Operators (3) ☐ All	☐ Heating ☐ Cooling ☐ DHW ☐ Lighting X Electric devices	X Physical environmental (1) X Contextual (1) X Psychological (1) ☐ Physiological X Social (1)

Description

Avoid printing unnecessary documents which could be used in digital form or pages with little information which could be transcript manually instead of printing it.

Benefits

- Reduce the electricity consumption
- Avoid paper, ink and toner wasting

Limitations

- User acceptance

Economic assessment

The cost is zero.

References and best practices

- [111] Save trees, save paper: www.thinkbeforeprinting.org/

Image gallery

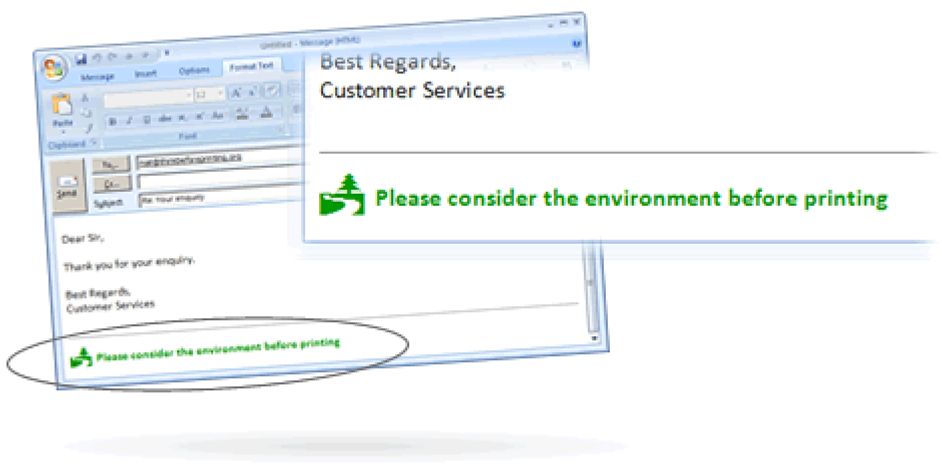


Figure 104. Email signature. Source: thinkbeforeprinting.org/.

1.5.35 Decalcify home appliances

Measure code: EDS35b			
Environment or playable world: X Residential ☐ Academic ☐ Offices ☐ All	**Carried out by:** X Public building users (1) ☐ Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW ☐ Lighting X Electric devices	**Type of driver:** X Physical environmental (1) X Contextual (1) X Psychological (1) ☐ Physiological X Social (1)

Description

Public water usually has minerals and others substances which can damage appliances which use water. The calcification generated affects the efficiency of electric resistance which could also crack. Use an acidic product (e.g. vinegar or citric acid cleaner) to maintain dishwasher, washing machine and other home appliances which use water.

Benefits

- Reduce the electricity consumption
- Extend the lifespan of appliances
- The maintenance can be carried out by users

Limitations

- User acceptance

Economic assessment

Initial investment: low. The total cost includes the price of a decalcifier product, 10€ approximately.

References and best practices

- [112] Descaling Appliances: Which Acid is Best?: www.scottiestech.info/2009/04/22/descaling-appliances-which-acid-is-best/

Image gallery

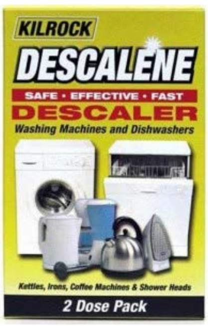
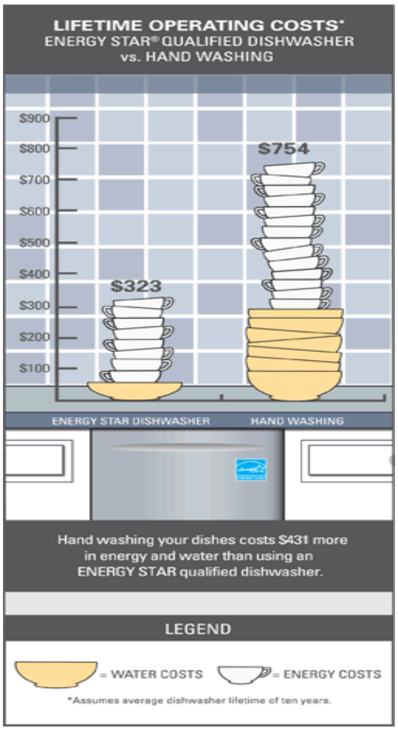


Figure 105. Descaler product. Source: www.amazon.co.uk.

1.5.36 Use dishwasher instead of hand-washing dishes

Measure code: EDS36b			
Environment or playable world: X Residential ☐ Academic ☐ Offices ☐ All	**Carried out by:** X Public building users (1) ☐ Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling X DHW ☐ Lighting X Electric devices	**Type of driver:** X Physical environmental (1) X Contextual (1) X Psychological (1) ☐ Physiological X Social (1)
Description			
The measure proposes the use of a dishwasher instead of washing dishes by hand.			
Benefits			
• Reduce the electricity consumption if the domestic hot water system is electric • Reduce the consumption of water • Reduce the time spent to wash dishes • The dishwasher eliminate more bacteria than hand wash			
Limitations			
• Not always it is possible to install dishwasher due to space restrictions • More maintenance cost • The detergent of dishwasher is more expensive than of hand washing			
Economic assessment			
The cost is zero if an efficient dishwasher is installed, otherwise the cost will be high, from 350€ to 1500€.			
References and best practices			
- [113] Residential dishwasher introduction: www.allianceforwaterefficiency.org/Residential_Dishwasher_Introduction.aspx			

Image gallery
 *Figure 106. Dishwasher vs handwash. Source: www.energystar.gov.*

1.5.37 Install coffee machines with thermal jug

<table>
<tr><th colspan="4">Measure code: EDS37i</th></tr>
<tr>
<td>Environment or playable world:
X Residential
☐ Academic
☐ Offices
☐ All</td>
<td>Carried out by:
X Public building users (1)
☐ Owners (2)
☐ Operators (3)
☐ All</td>
<td>Reduce consumption of:
☐ Heating
☐ Cooling
☐ DHW
☐ Lighting
X Electric devices</td>
<td>Type of driver:
X Physical environmental (1)
X Contextual (1)
X Psychological (1)
☐ Physiological
X Social (1)</td>
</tr>
<tr><th colspan="4">Description</th></tr>
<tr><td colspan="4">The measure consists in installing coffee machines with thermal jugs with vacuum insulation to keep the coffee at a right temperature for a long period avoiding heat losses.</td></tr>
<tr><th colspan="4">Benefits</th></tr>
<tr><td colspan="4">• 25% of electrical consumption for each brewing is saved compared with coffee machines with plastic transparent jug or heating elements
• The “burnt flavor” in coffee that may occur due to overheating a glass pot on a heating element is avoided</td></tr>
<tr><th colspan="4">Limitations</th></tr>
<tr><td colspan="4">• Some users prefer using an heating plate to keep the coffee warming for longer periods
• Users could prefer a transparent jug</td></tr>
<tr><th colspan="4">Economic assessment</th></tr>
<tr><td colspan="4">Initial investment: medium. The average cost of a coffee machine with thermal jug is 125€, meanwhile a coffee machine with a transparent jug could cost approximately 60€. It reduces energy costs</td></tr>
<tr><th colspan="4">References and best practices</th></tr>
<tr><td colspan="4">- [114] Super-efficient coffee machines – Best available technology (BAT) and market transformation: www.topten.info/uploads/File/038_Barbara_Josephy_final_Coffee.pdf
- [115] ENERGY STAR Market & industry scoping report coffee makers: www.energystar.gov/ia/products/downloads/ENERGY_STAR_Scoping_Report_Coffee_Makers.pdf</td></tr>
</table>

Image gallery
 *Figure 107. Coffee maker with thermal jug. Source: www.amazon.com.*

1.5.38 Ironing efficiently

Measure code: EDS38b			
Environment or playable world: X Residential ☐ Academic ☐ Offices ☐ All	**Carried out by:** X Public building users (1) ☐ Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW ☐ Lighting X Electric devices	**Type of driver:** X Physical environmental (1) X Contextual (1) X Psychological (1) ☐ Physiological X Social (1)

Description

To iron in an efficient way, first the activity should be planned. Accumulate large batches of clothes and start with those which need cooler temperatures, then iron clothes which need higher temperatures and finally turn off the iron and use the stored heat energy to complete the ironing. Remember to turn off the iron if ironing is stopped.

Benefits

- Energy savings because warm up times are reduced and the iron is used efficiently
- Ironing large batches of clothes at once avoids the iron preheating

Limitations

- User acceptance
- Difficult to accumulate large batches of clothes

Economic assessment

The cost is zero and it reduces electricity bills

References and best practices

- [116] Shopping guide to Electric Irons: www.ethicalconsumer.org/buyersguides/appliances/electricirons.aspx
- [117] Electricity usage of an Iron: www.energyusecalculator.com/electricity_iron.htm

Image gallery

Figure 108. Iron. Source: www.applianceretailer.com.au.

1.5.39 Defrost food naturally instead of using the microwave

Measure code: EDS39b			
Environment or playable world: X Residential ☐ Academic ☐ Offices ☐ All	**Carried out by:** X Public building users (1) ☐ Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW ☐ Lighting X Electric devices	**Type of driver:** X Physical environmental (1) X Contextual (1) X Psychological (1) ☐ Physiological X Social (1)
Description			
To obtain maximum savings by defrosting food in the fridge during the night instead of using the microwave.			
Benefits			
• By avoiding the use of the microwave significant savings in electricity can be reached • The frosted food placed in the fridge it's advantageous for the fridge because the food temperature is lower than that of the fridge and so its workload is reduced			
Limitations			
• User acceptance • Natural defrost requires larger times of defrosting than microwave			
Economic assessment			
The cost is zero.			
References and best practices			
- [118] Thawing Foods: www.extension.psu.edu/food/preservation/news/2012/thawing-foods			
Image gallery			

Figure 109. Defrost food in the fridge. Source: www.lifehacker.com/.

1.5.40 Disconnect the fridge in case it is not working for long times

Measure code: EDS40b			
Environment or playable world: X Residential ☐ Academic ☐ Offices ☐ All	**Carried out by:** X Public building users (1) ☐ Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW ☐ Lighting X Electric devices	**Type of driver:** X Physical environmental (1) X Contextual (1) X Psychological (1) ☐ Physiological X Social (1)

Description

Disconnect the fridge if it is not going to be used for long periods, e.g. during holiday.

Benefits

- Significant electricity savings during the period of switching off
- Reduction of electricity bills
- The performance of the fridge after the shutting down will be improved

Limitations

- User acceptance
- It will be necessary to defrost the fridge before turning it off

Economic assessment

The cost is zero.

References and best practices

- [119] Should you unplug a refrigerator for a long vacation?: www.traveltips.usatoday.com/should-unplug-refrigerator-long-vacation-107063.html

Image gallery

Figure 110. Disconnected fridge during holiday. Source: www.samsung.com.

1.5.41 Dry hair naturally

Measure code: EDS41b			
Environment or playable world: X Residential ☐ Academic ☐ Offices ☐ All	**Carried out by:** X Public building users (1) ☐ Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW ☐ Lighting X Electric devices	**Type of driver:** X Physical environmental (1) X Contextual (1) X Psychological (1) X Physiological (1) X Social (1)
Description			
Let dry your hair naturally or with a towel instead of using hair dryer			
Benefits			
• Reduce electricity consumption • Reduce hair damages			
Limitations			
• User acceptance • In winter and for people with long hair, avoiding the use of hair dryer may be difficult			
Economic assessment			
The cost is zero. It reduces electricity bills.			
References and best practices			
- [120] Why buy an energy efficient hair dryer?: www.texasishot.org/texas-energy-efficiency-2/hair-dryer-electric-usage/			
Image gallery			

Figure 111. Dying hair with a towel. Source: www.itsevalicious.com.

1.6 Other measures

1.6.1 Pressing one button to call the lift in case there are several ones

Measure code: OS1b			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** X Public building users (1) ☐ Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW ☐ Lighting X Electric devices	**Type of driver:** X Physical environmental (1) X Contextual (1) X Psychological (1) ☐ Physiological X Social (1)
Description			
If there are several elevators with more than one button to call, it is enough with pressing one of them to prevent unnecessary rides of the elevators.			
Benefits			
• The energy saving potential is medium-low. Savings up to 20% of the energy consumed in the lift can be obtained, but it depends on the size of the building and the use of it			
Limitations			
• Occupant acceptance			
Economic assessment			
No cost.			
References and best practices			
- [121] Energy efficiency in lifts: www.lift-report.de/index.php/news/407/56/Energy-efficiency-in-lifts			
Image gallery			

Figure 112. Calling the lift. Source: www.letramedia.cl.

1.6.2 Use stairs instead of lifts

Measure code: OS2b			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** X Public building users (1) ☐ Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW ☐ Lighting X Electric devices	**Type of driver:** X Physical environmental (1) X Contextual (1) X Psychological (1) X Physiological (1) X Social (1)

Description

For heights below the third floor, it is healthier, more economic and ecological to take the stairs up and down than to use the lift, and below the fifth floor, go walking down the stairs to the street.

Benefits

- The energy savings potential is medium-low. savings up to 20% of the energy consumed in the lift can be obtained, but it depends on the size of the building and the use of it

Limitations

- Occupant acceptance

Economic assessment

No cost.

References and best practices

- [121] Energy efficiency in lifts: www.lift-report.de/index.php/news/407/56/Energy-efficiency-in-lifts

Image gallery

Figure 113. Poster advising the use of stairs. Source: www.transformer.blogs.quo.es.

1.6.3 Inspection and maintenance of lifts

Measure code: OS3i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) ☐ Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW ☐ Lighting X Electric devices	**Type of driver:** X Physical environmental (3) X Contextual (3) X Psychological (3) ☐ Physiological ☐ Social
Description			
Ensure regular maintenance and inspection of the lifts system, in order to foresee possible breakdowns and the wear and malfunction of the equipment which would end up in an increase in the energy consumption of the system.			
Benefits			
• The energy savings potential is medium-low. savings up to 20% of the energy consumed in the lift can be obtained, but it depends on the size of the building and the use of it			
Limitations			
• Operation and Maintenance (O&M) staff size, skill level, and budget need to be considered			
Economic assessment			
Medium-high cost, but it depends on the type of lift and the use of it.			
References and best practices			
- [121] Energy efficiency in lifts: www.lift-report.de/index.php/news/407/56/Energy-efficiency-in-lifts			
Image gallery			

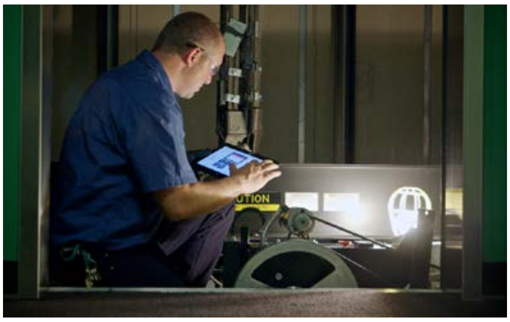


Figure 114. Maintenance of a lift. Source: www.blogs.microsoft.com.

1.6.4 Sensitizing of occupants through workshops

Measure code: OS4i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** X Public building users (1) ☐ Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling X DHW X Lighting X Electric devices	**Type of driver:** ☐ Physical environmental X Contextual (1) X Psychological (1) ☐ Physiological X Social (1)
Description			
Information, education and awareness of the occupants of the building will be a tool of vital importance to ensure the operability of any energy management improvement plan of the building.			
Benefits			
• The savings potential is between 10-20%			
Limitations			
• Occupant acceptance			
Economic assessment			
Zero or low cost.			
References and best practices			
- [122] Energy savings by user interaction and visualisation: www.pure.ltu.se/portal/files/41424721/paper_34.pdf - [123] Creativity workshops as learning arena for energy efficient user behavior?: www.ioe.ac.uk/newsEvents/documents/News_and_Events_Events/Compes_and_Dahmen.pdf			
Image gallery			
 *Figure 115. Energy efficiency workshops for building occupants. Source: www.araucanianoticias.cl.*			

1.6.5 Wear adequate clothing

Measure code: OS5b			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** X Public building users (1) ☐ Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (1) X Contextual (1) X Psychological (1) X Physiological (1) X Social (1)

Description

Building occupants can contribute to their own comfort by wearing seasonally appropriate clothing.

Benefits

- Energy saving (6-20%)
- Improving comfort

Limitations

- Occupant acceptance

Economic assessment

No cost.

References and best practices

- [124] Policy manual: operating policies and procedures: www.hr.usu.edu/files/policies/525.pdf

Image gallery

Figure 116. Wear appropriate clothing. Source: www.climalit.es.

1.6.6 Optimization of the conditions of the electric bill

Measure code: OS6i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** X Public building users (1) ☐ Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (1) X Contextual (1) X Psychological (1) X Physiological (1) X Social (1)

Description

Perform continuous monitoring of electrical bills and their suitability for consumption and market conditions. Although it does not save energy, it is very important from the economic point of view.

Benefits

- Less expensive electricity rates
- Proper power contracting
- Contracts updated according to new charges that are added or deleted
- There are not reactive power values which penalise the invoice

Limitations

- Occupant acceptance

Economic assessment

Initial investment: low. The contracting price of a company that performs electrical bill monitoring is not high, and the savings that can be achieved are important.
Payback: low.

References and best practices

- [125] Concurrent optimization of consumer's electrical energy bill and producer's power generation cost under a dynamic pricing model: www.citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.408.2700&rep=rep1&type=pdf

Image gallery

Figure 117. Optimization of the electric bill. Source: www.greentechmedia.com.

1.6.7 Create reminders and promotional materials to raise awareness

Measure code: OS7i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** X Public building users (1) ☐ Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling X DHW X Lighting X Electric devices	**Type of driver:** X Physical environmental (1) X Contextual (1) X Psychological (1) ☐ Physiological X Social (1)

Description

Successful marketing campaigns are vital to raise awareness. Gentle reminders in the form of emails will reinforce the request to comply with energy efficiency practices, as well as weekly or monthly newsletters that offer advice and reward for participation.

Benefits

- Energy savings
- Improve knowledge in energy efficiency in buildings

Limitations

- Occupant acceptance

Economic assessment

Initial investment: low.
Payback: low.

References and best practices

- [125] Concurrent optimization of consumer's electrical energy bill and producer's power generation cost under a dynamic pricing model: www.citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.408.2700&rep=rep1&type=pdf

Image gallery

Figure 118. Example of a reminder. Source: www.dvgbc.org.

1.6.8 Move the furniture or objects that block the natural light

Measure code: OS8b			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** X Public building users (1) ☐ Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW X Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (1) X Contextual (1) X Psychological (1) X Physiological (1) X Social (1)
Description			
Inadvertently blocking windows when arranging your furniture can cut into a room's natural light. Rearrange the space to keep natural light sources free and unobstructed. Keep larger pieces toward the center of the room. Even knick-knacks on a windowsill block a surprising amount of light.			
Benefits			
• Reduce energy consumption • Easy application • Avoid the damage of furniture			
Limitations			
• Occupant acceptance • Displacing furniture is not possible in several cases due to space restrictions			
Economic assessment			
Zero investment.			
References and best practices			
- [126] How room arrangements affect energy efficiency of your home: www.extension.org/pages/25642/how-room-arrangements-affect-energy-efficiency-of-your-home#.VbIg9_lXSPU			
Image gallery			

Figure 119. Arranged furniture without blocking the natural light. Source: www.decorpad.com.

1.6.9 Remove furniture from the front of HVAC terminal units

Measure code: OS9b			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** X Public building users (1) ☐ Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (1) X Contextual (1) X Psychological (1) X Physiological (1) X Social (1)

Description

This measure consists in rearranging furniture that is blocking the HVAC terminal units in order to increase their performance.

Benefits

- Reduce energy consumption
- Increase the heating/cooling moving around the room
- Easy application
- Avoid the damage of furniture

Limitations

- Occupant acceptance
- Displacing furniture is not possible in several cases due to space restrictions

Economic assessment

Zero investment.

References and best practices

- [126] How room arrangements affect energy efficiency of your home: www.extension.org/pages/25642/how-room-arrangements-affect-energy-efficiency-of-your-home#.Vblg9_lXSPU

Image gallery

Figure 120. Radiator blocked by furniture. Source: www.espaciohogar.com.

1.6.10 Implementation of a compressed work schedule

Measure code: OS10ib			
Environment or playable world: ☐ Residential ☐ Academic X Offices ☐ All	**Carried out by:** X Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling X DHW X Lighting X Electric devices	**Type of driver:** X Physical environmental (1) (2) X Contextual (1) (2) X Psychological (1) (2) X Physiological (1) X Social (1) (2)

Description
A compressed work schedule allows an employee to work a traditional 35-40 hour workweek in less than the traditional number of workdays.
Benefits
• Reduce energy consumption • Employee's ability to better manage their personal responsibilities • Employee´s transport energy savings • Additional day off for employees while preserving their full-time income
Limitations
• Occupant acceptance (both employers and employees) • Not possible in all type of jobs
Economic assessment
Zero investment.
References and best practices
- [127] Energy Savings: A Potential Benefit of a Compressed Work Week: http://members.questline.com/Article.aspx?articleID=23698&accountID=1877&nl=13261
Image gallery

Figure 121. Compressed work weeks. Source: www.mobility.tamu.edu.

1.6.11 Allow employees to work from home on alternate days

Measure code: OS11ib			
Environment or playable world: ☐ Residential ☐ Academic X Offices ☐ All	**Carried out by:** X Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling X DHW X Lighting X Electric devices	**Type of driver:** X Physical environmental (1) (2) X Contextual (1) (2) X Psychological (1) (2) X Physiological (1) X Social (1) (2)

Description

Give the employees an option to work from home on alternate days. With Virtual Private Network (VPN) technology, an employee can connect to office network safely and securely.

Benefits

- With fewer employees in office, less lighting and HVAC would be required
- Technology gives employees advantage of flexible work arrangements
- Employee´s transport energy savings

Limitations

- Occupant acceptance (both employers and employees)
- It is not possible in all type of jobs

Economic assessment

Zero investment.

References and best practices

- [128] Background document: a literature review of aspects of teleworking research: http://www.eci.ox.ac.uk/research/energy/downloads/40house/background_doc_n.pdf

Image gallery

Figure 122. Teleworking. Source: www.recruiterbox.com.

2 LONG TERM ENERGY EFFICIENCY DECISIONS AND MEASURES

2.1 Envelope measures

2.1.1 Adding or increasing external insulation in walls

Measure code: EL1i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) ☐ Physiological ☐ Social
Description			
External Thermal Insulation Composite Systems (ETICS) in retrofitting projects consist in adding a surface layer of thermal insulation (EPS, XPS, glass wool, cork…) externally attached (stuck, plastic pins and profiles) to the façades and visible party walls, to then protect the insulation using a new outside finish, usually based on mortar.			
Benefits			
• The added load to the structure and foundation is minimal • The internal space is respected, not affecting the useful surfaces • The work can be performed from the outside, without bothering the occupants of the building			
Limitations			
• It should not be used in buildings that are going to receive repeated and severe impacts • It should be studied the exposure to strong winds and not recommended in hurricane zones. For this reason, there should not be used either in high-rise buildings where the force of the wind is usually subject to special engineering solutions to ensure stability to long term • It is not recommended when the façade of the building to retrofit is not noticeably flat and vertical			
Economic assessment			
Initial investment: between 53 and 98 €/m^2 depending on whether the installation is in situ or through prefabricated panels. This difference in initial price can be justified by long-term maintenance savings in repairs. Maintenance and replacement cost must be realistic for the building owner. Light systems based on EPS insulation are less expensive than heavy systems, insulated with XPS.			

References and best practices
- [129] Thermal performance of a building envelope incorporating ETICS with vacuum insulation panels and EPS: www.sciencedirect.com/science/article/pii/S0378778814005477 - [130] Inspection and diagnosis system of ETICS on walls: www.sciencedirect.com/science/article/pii/S0950061813005424
Image gallery

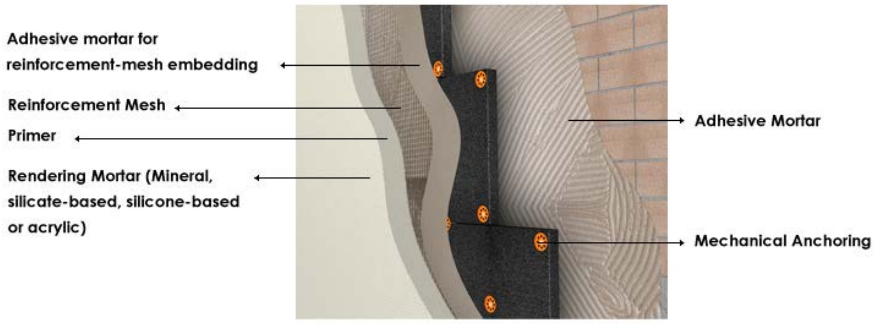


Figure 123. Layers of ETICS. Source: www.thermocal.es.

2.1.2 Adding or increasing internal insulation in walls

Measure code: EL2i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) ☐ Physiological X Social (2)

Description

The internal insulation system is based on the placement of thermal insulation in the internal layers of facades and party walls to coat after with a new internal finish, usually of plasterboard panel, or cladding finish of hollow brick. This system leaves out of the envelope the thermal mass of the wall, and therefore it allows a rapid warming of the habitable areas. In return the closures will not radiate the stored heat during the day to the inside.

Benefits

- Ease and speed of execution without the need of install auxiliary means
- Suitable for buildings that need heating with an intermittent use
- The outside finish is not conditioned
- This system is a good choice where there is impossibility of acting from outside or where the building façades are classified or protected

Limitations

- Risk of condensation. It can be necessary a vapour barrier, especially in humid areas
- Lost useful surface
- Costly treatment of thermal bridges
- Do not use in areas of the building with humidity pathologies

Economic assessment

Between 17 and 39 €/m^2 depending of the installation method (plasterboard panel or hollow brick internal finish)

References and best practices

- [131] Interior insulation retrofit of a historical brick wall using vacuum insulation panels - hygrothermal numerical simulations and laboratory investigations: www.sciencedirect.com/science/article/pii/S0360132314001103
- [132] Measure guideline - Internal insulation of masonry walls: www.nrel.gov/docs/fy12osti/54163.pdf

Image gallery

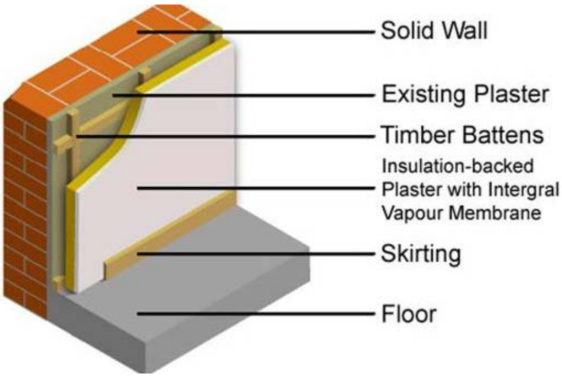


Figure 124. Example of internal insulation by layers. Source: www.greendealprotection.co.uk.

2.1.3 Adding insulation in air chambers of walls through injection

Measure code: EL3i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) ☐ Physiological ☐ Social

Description

In the case of the existence of air chambers in the thermal envelope of the building to retrofit, it is possible to fill these chambers with thermal insulation. The most common methods are the injection of polyurethane (PUR) foam and cellulose.

Benefits

- Ease of execution without scaffolding
- Conservation of the outside appearance of the façade
- Preservation of the useful surface of the housing
- Minimum replacement of the original works
- This solution can be used when other possibilities of insulation implementation are discarded

Limitations

- Inability to effectively control foam expansion due to the frequency with which the cameras have interruptions
- It cannot be used when the camera has as an end wall ventilation
- The degree of control over the end result efficiency is low (auxiliary means needed: thermographic camera)
- The application of these solutions involves the creation of numerous thermal bridges
- Require special attention, both for the assessment of their suitability as for execution
- Waterproofing of the enclosure cannot be guaranteed in any case with this system.

Economic assessment

Initial investment: low around 7 €/m^2

References and best practices

- [133] First things first - insulating wall cavities: www.homeenergy.org/show/article/id/1772
- [134] Investigation into the performance of urea formaldehyde foam insulation: http://www.branz.co.nz/cms_show_download.php?id=476263817f61338944a0fa6e5453960d79f8a7a3

Image gallery

Figure 125. Injection insulation Source: www.generadordeprecios.info.

2.1.4 Installation of a ventilated façade

Measure code: EL4i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) ☐ Physiological ☐ Social
Description			
It is a double façade system provided with an external coating fastened with metal profiles to the internal part of the enclosure. Between both, there is an air chamber partially filled in with thermal insulation. The ventilation is raised through top and bottom openings or through the design of the envelope seals.			
Benefits			
• Protection of the internal enclosure and of the insulation against the action of the wind, the rain and solar radiation. • Elimination of thermal bridges • Decrease of the solar contribution in summer conditions • Thermal inertia • Ease of assembly • Easy maintenance • Valid solution for retrofitting of buildings without discomfort for occupants and without affecting its useful surfaces.			
Limitations			
• More complex installation than other systems • Bad fire resistance			
Economic assessment			
Initial investment: high. About 164 €/m^2. Higher costs than the other interventions of facade insulation and the maintenance and cost replacement must be realistic and amortizable for the ownership of the building			
References and best practices			
- [135] Ventilated facades energy performance in summer cooling of buildings: www.sciencedirect.com/science/article/pii/S0038092X03003396 - [136] Energy performance of an open-joint ventilated façade compared with a conventional sealed cavity façade: www.sciencedirect.com/science/article/pii/S0038092X11001484			

Image gallery

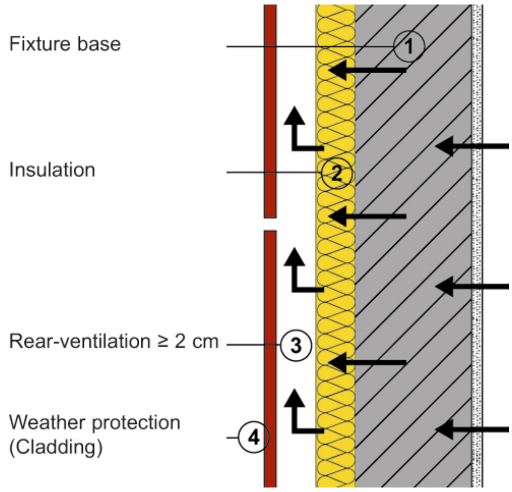


Figure 126. Rear-ventilated facade system. Source: www.fvhf.de.

2.1.5 Adding or increasing external insulation in roofs

Measure code: EL5i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) ☐ Physiological ☐ Social
Description			
This measure consists in adding a layer of insulation to the exterior face of the roofs with the object of reducing their thermal transmittance. The measure is of great interest for 1 or 2-storey buildings. It should be initially rejected for high-rise buildings roofs or for which have a thermal buffer space, as lumbers or no conditioned spaces.			
Benefits			
• Minimum interference to the users of the building • The height of the rooms on the top floor is not reduced • Surface temperature higher than the dew point of the indoor environment, sufficient to avoid condensation • All the thermal inertia is used • In sloping roofs, the external insulation enables the recovery as habitable of the under roof spaces, increasing the useful surface of the building • In flat roofs the insulation is useful to protect the waterproofing sheet, so the durability of waterproofing increases considerably.			
Limitations			
• Normally, executing the intervention through the outside, it will affect all of the building not just a flat in particular. Therefore it will be required, prior to the intervention, the express agreement of the community of neighbours.			
Economic assessment			
Initial investment: around 15 €/m^2 Payback: around 2 years			
References and best practices			
- [137] Determination of optimum insulation thicknesses of the external walls and roof (ceiling) for Turkey's different degree-day regions: www.sciencedirect.com/science/article/pii/S0301421507001826 - [138] Tips for roof insulation: www.energyquarter.com/energy-saving/insulation/tips-for-roof-insulation/			

Image gallery
 Figure 127. Sloping roof external insulation. Source: www.pachecoam.com.

2.1.6 Adding or increasing internal insulation in roofs

Measure code: EL6i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) ☐ Physiological ☐ Social

Description

The insulation from the inside is achieved by insulating the roof of the building or the ceiling of the upper housing in case it is a multi-family building. It is a simple execution and it allows the use of thermal insulation materials of lower quality and lower cost than in the external insulation.

Benefits

- Prevent the lifting of the external roof (tiles or pavement), waterproofing, etc.
- It enables the retrofitting from the aesthetic point of view of the inside of the building
- Especially suitable when it is not necessary to carry out works of waterproofing or modification of the external roof of the building
- It is especially suitable to insulate on the inside when the buildings are not of permanent occupation. It is the typical case of a weekend house
- In the case of buildings with a degree of protection as part of the historical and artistic heritage, working on the inside will be the only option to execute the work of retrofitting.

Limitations

- The thermal insulation is out of the building envelope corresponding to the roof
- There is no elimination of thermal bridges
- Interstitial and superficial condensation of each construction should be checked individually and decide, case by case, the installation of a vapour barrier

Economic assessment

Initial investment: around 15 €/m^2
Payback: around 2 years

References and best practices

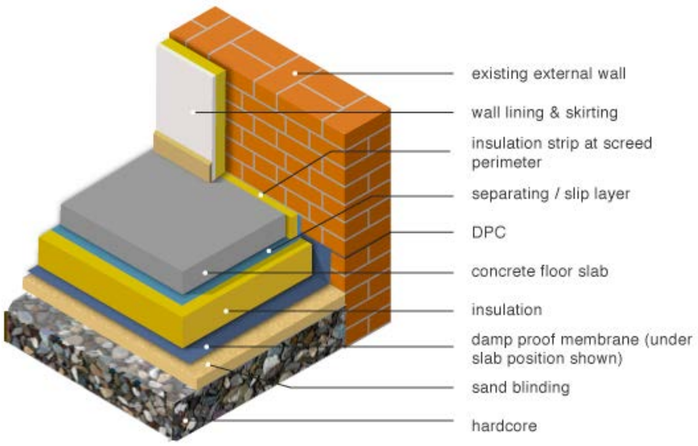
- [139] Dwelling renovation and spatial quality - The impact of the dwelling renovation on spatial quality determinants: www.sciencedirect.com/science/article/pii/S2212609015000023
- [140] Rigid foam polyurethane (PU) derived from castor oil (Ricinus communis) for thermal insulation in roof systems: www.sciencedirect.com/science/article/pii/S2095263512000696

Image gallery

Figure 128. Installation of internal insulation. Source:www.isover.es.

2.1.7 Adding or increasing external insulation in floors

Measure code: EL7i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) X Physiological (2) ☐ Social
Description			
This measure consists in adding a layer of thermal insulation to floors with the goal of reducing the thermal transmittance. This measure is of interest for 1 or 2-storey buildings for enclosures that are in contact with permanent occupied spaces.			
Benefits			
• Provide thermal mass, particularly useful in southward facing rooms and it helps to maintain steady temperatures • Thickness of insulation is less restricted than for an above-slab condition • Avoid lack of comfort due to "cold radiation" and risk of superficial condensation caused by low surface temperature of the floor • Using closed pore insulation, the thermal performance will not be lost even if the insulation is wet			
Limitations			
• Rooms are slower to heat in comparison with an above-slab condition • The external thermal insulation can be made only when there is a space with sufficient height to work with comfort to install the insulation system			
Economic assessment			
Initial investment: between 8 and 11 €/m^2			
References and best practices			
- [141] Insulating raised floors in hot, humid climates: www.lsuagcenter.com/NR/rdonlyres/D33F711D-DC4B-4E4C-9ED6-A97DCE9DB026/79805/pub3187insulatingraisedfloorsLOWRES.pdf - [142] Thermal insulation of floors: www.designforhomes.org/wp-content/uploads/2012/03/ThermalInsulation.pdf			

Image gallery
 *Figure 129. External insulation layer by layer. Source: [www.greenspec.co.uk.](http://www.greenspec.co.uk)*

2.1.8 Adding or increasing internal insulation in floors

Measure code: EL8i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) X Physiological (2) ☐ Social
Description			
This measure consists in adding a layer of thermal insulation to the internal face of the floors with the goal of reducing the thermal transmittance. This measure is of interest for 1 or 2-storey buildings. It is a simple implementation work and it is interesting when it is necessary to replace the floor in the conditioned lower floor.			
Benefits			
• Insulation above the slab increases the heating response time • Temperatures will increase more quickly when the heating system is switched on in comparison with below slab insulation • In the case of a radiant floor heating installation, the insulation including the system tends to be sufficient			
Limitations			
• The effect of temperature regulation by thermal mass is unavailable • Point loading requires careful specification of the floor finish where it bears on a smaller area of insulation beneath • When in conjunction with timber-based flooring it is not advisable for use in 'wet' rooms such as kitchens and bathrooms • The internal insulation will necessarily produce a rise in the level of the floor in about 7 to 10 cm, which must be taken into account especially for accessibility to the building.			
Economic assessment			
Initial investment: around 10 €/m^2			
References and best practices			
- [142] Thermal insulation of floors: www.designforhomes.org/wp-content/uploads/2012/03/ThermalInsulation.pdf			

Image gallery
 *Figure 130. Installation of internal insulation. Source: www.foamglas.es.*

2.1.9 Installation of efficient windows (double glazing with aluminium frames with thermal break)

Measure code: EL9i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) ☐ Physiological X Social (2)

Description

This measure consists in the replacement of inefficient windows (e.g. aluminium frame without thermal brake and single glazing) for an efficient one with double glazing and aluminium frames with thermal brake. A typical transmittance of this type of windows is between U=2.2 W/m^{2}K and U=3.5 W/m^{2}K compared to the transmittance of inefficient windows which typical is higher than 4 W/m^{2}K

Benefits

- Airtightness improved
- Limited condensation
- Sound insulation
- Safety
- Reduce heat losses
- Easy cleaning
- The aluminum frame is available in various colors
- Aluminum is a strong and rigid material, its properties do not change with the weather and its rigidity is ensured at high and low temperatures

Limitations

- The energy consumption for aluminium manufacturing is high.
- Double glazing cannot be repaired
- During the summer months, trapping heat inside glass panes can lead to a stuffy and uncomfortable room
- The most common complaint of this frame is that in winter the aluminum sweat
- It is a cooler material than the wood and PVC
- Over time, the aluminum can become corroded

Economic assessment
Initial investment: high. It can be estimated an average cost of about 1500€ for each window, but this price vary greatly, depending on the size of the window and manufacturers. Energy costs are reduced.
References and best practices
- [143] Thermal convection in double glazed windows with structured gap: www.sciencedirect.com/science/article/pii/S0378778811001551 - [144] Low heat loss double-glazed windows: www.sciencedirect.com/science/article/pii/0360544287900429
Image gallery

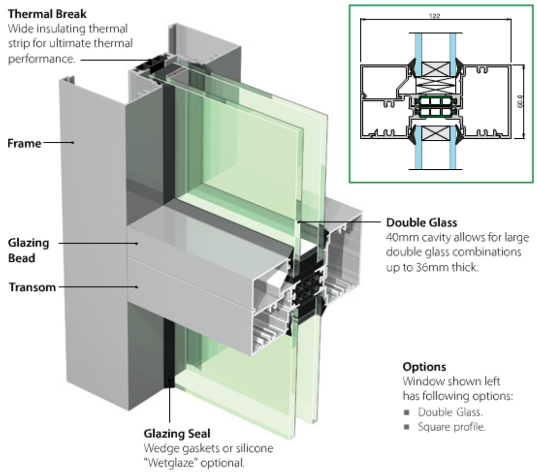


Figure 131. Aluminium frame with thermal break. Source: www.arborcrest.com.au.

2.1.10 Installation of efficient windows (double glazing with wood frames)

Measure code: EL10i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) ☐ Physiological X Social (2)

Description

This measure consists in the replacement of inefficient windows (e.g. aluminium frame without thermal brake and single glazing) for an efficient one with double glazing and wood frames. A typical transmittance of this type of windows is between U=1.9 W/m^{2}K and U=3 W/m^{2}K, better performance than inefficient windows which have a typical transmittance higher than 4 W/m^{2}K.

Benefits

- Airtightness improved
- Limited condensation
- Sound insulation
- Safety
- Reduce heat losses
- Wood is the most natural material and allows that the walls sweat from the inside to the outside. The same properties of wood regulate humidity naturally inside of the building.
- It allows the installation of any security system for preventing theft, which applies both in the enclosures (mechanical systems in doors and windows) and those who are connected to a central.
- The majority of woods used are suitably treated against fire, ensuring a greater resistance than other non-combustible materials

Limitations

- Double glazing cannot be repaired
- During the summer months, trapping heat inside glass panes can lead to a suffocating and uncomfortable room
- Wood is the material that more maintenance requires. It is recommended to varnish the external side every two years.
- It is not advisable the use of wood window frames in buildings located in areas with strong wind and rain. These climatic conditions cause heavy wear on the material, hence increase the need to be repaired.
- Other enemies of wood, such as solar radiation and the emergence of organisms (fungi and insects), can be treated with components such as resin or insecticides. It should be paid

special attention to the moth. There are many chemicals against the emergence of the woodworm.

Economic assessment

The price is usually high. Energy costs are reduced.

Table 1. Cost savings of wood frames. Source: Elaborated by CIRCE.

Type of frame	Total cost (10 m^2 of windows and 6 months)	% saving
Aluminium without thermal break	1.27 €/day 410€	-
Wood	0.87 €/day 158€	62%

References and best practices

- [143] Thermal convection in double glazed windows with structured gap: www.sciencedirect.com/science/article/pii/S0378778811001551
- [144] Low heat loss double-glazed windows: www.sciencedirect.com/science/article/pii/0360544287900429
- [145] Carbon footprint versus performance of aluminum, plastic, and wood window frames from cradle to gate: www.mdpi.com/2075-5309/2/4/542/pdf

Image gallery

Figure 132. Wood frame. Source: www.getdomainvids.com.

2.1.11 Installation of efficient windows (double glazing with PVC frames)

Measure code: EL11i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) ☐ Physiological X Social (2)
Description			
This measure consists in the replacement of inefficient windows (e.g. aluminium frame without thermal brake and single glazing) for an efficient one with double glazing and PVC frames. A typical transmittance of this type of windows is between U=1.7 W/m^{2}K and U=2.9 W/m^{2}K, better performance than inefficient windows which have a typical transmittance higher than 4 W/m^{2}K.			
Benefits			
• Airtightness improved • Limited condensation • Reduce heat losses • It allows a perfect soundproofing and it reduces noise pollution • It is a durable and resistant to cold and air material, very suitable for cold areas • It does not need any special treatment for its conservation, just wash it with soap and water without risk of rot or damage to the material • There is a wide range of colors, although white is the most widely used color, there are imitation wood, without a too high price			
Limitations			
• Double glazing cannot be repaired • During the summer months, trapping heat inside glass panes can lead to a suffocating and uncomfortable room • PVC frame is more expensive than the rest • PVC with high temperatures can be deformed • PVC is a polluting material			

Economic assessment

Energy costs are reduced.

Table 2. Cost savings of PVC frames. Source: Elaborated by CIRCE.

Type of frame	Total cost (10 m^2 of windows and 6 months)	% saving
Aluminium without thermal break	1.27 €/day 410€	-
PVC	1.07 €/day 195€	52%

References and best practices

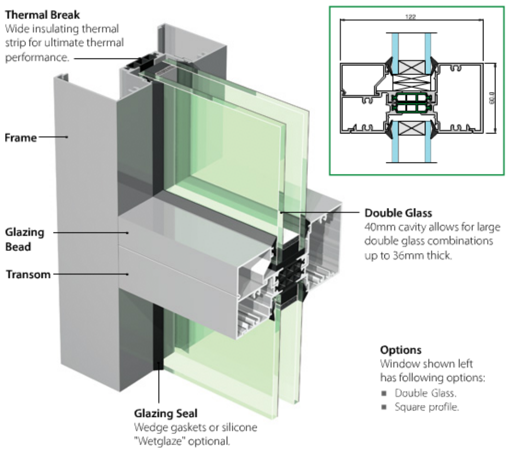
- [143] Thermal convection in double glazed windows with structured gap: www.sciencedirect.com/science/article/pii/S0378778811001551
- [144] Low heat loss double-glazed windows: www.sciencedirect.com/science/article/pii/0360544287900429
- [145] Carbon footprint versus performance of aluminum, plastic, and wood window frames from cradle to gate: www.mdpi.com/2075-5309/2/4/542/pdf

Image gallery

Figure 133. PVC frames. Source: www.doubleglazingprices.org.uk.

2.1.12 Installation of efficient windows (low-E double glazing with aluminium frames with thermal break)

Measure code: EL12i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) ☐ Physiological X Social (2)
Description			
This measure consists in the replacement of inefficient windows (e.g. aluminium frame without thermal brake and single glazing) for an efficient one with Low-E double glazing and aluminium frames with thermal brake. Low emissivity glasses are equipped with an invisible metallic coating that reflects inward part of the incident long-wave energy (heating), decreasing the absorption of the own glass and, therefore, the energy that emits to the outside. A typical transmittance of this type of windows is U=1.8 W/m^2K.			
Benefits			
• Airtightness improved • Sound insulation • Safety • Easy cleaning • The aluminum frame is available in various colors • Aluminum is a strong and rigid material, its properties do not change with the weather and its rigidity is ensured at high and low temperatures • Improve solar and thermal control • Reduce summer heat gain and winter heat loss • Decrease UV transmission such as furniture fading • Reduce condensation in double glazing			

Limitations
• The energy consumption for aluminium manufacturing is high. • Double glazing cannot be repaired • During the summer months, trapping heat inside glass panes can lead to a suffocating and uncomfortable room • The most common complaint of this frame is that in winter the aluminum sweat • It is a cooler material than the wood and PVC • Over time, the aluminum can become corroded • Valuable solar heat gain in colder climates can be reduced
Economic assessment
Initial investment: high. It can be estimated an average cost of about 1600€ for each window, but this price vary greatly, depending on the size of the window and manufacturers. Energy costs are reduced.
References and best practices
- [143] Thermal convection in double glazed windows with structured gap: www.sciencedirect.com/science/article/pii/S0378778811001551 - [144] Low heat loss double-glazed windows: www.sciencedirect.com/science/article/pii/0360544287900429 - [14] Heat treatment and bending of low-E glass: www.sciencedirect.com/science/article/pii/S0040609099000875
Image gallery
 *Figure 134. Aluminium frame with thermal break. Source: www.arborcrest.com.au.*

2.1.13 Installation of efficient windows (low-E double glazing with wood frames)

Measure code: EL13i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) ☐ Physiological X Social (2)

Description

This measure consists in the replacement of inefficient windows (e.g. aluminium frame without thermal brake and single glazing) for an efficient one with Low-E double glazing and wood frames. Low emissivity glasses are equipped with an invisible metallic coating that reflects inward part of the incident long-wave energy (heating), decreasing the absorption of the own glass and, therefore, the energy that emits to the outside. A typical transmittance of this type of windows is U=1.5 W/m^2K.

Benefits

- Airtightness improved
- Energy costs reduced
- Sound insulation
- Wood is the most natural material and allows that the walls sweat from the inside to the outside. The same properties of wood regulate humidity naturally inside of the building
- It allows the installation of any security system for preventing theft, which applies both in the enclosures (mechanical systems in doors and windows) and those who are connected to a central
- The majority of woods used are suitably treated against fire, ensuring a greater resistance than other non-combustible materials
- Improve solar and thermal control
- Reduce summer heat gain and winter heat loss
- Decrease UV transmission such as furniture fading
- Reduce condensation in double glazing

Limitations

- Double glazing cannot be repaired
- During the summer months, trapping heat inside glass panes can lead to a stale and uncomfortable room

- Wood is the material that more maintenance requires. It is recommended to varnish the external side every two years
- It is not advisable the use of wood window frames in buildings located in areas with strong wind and rain. These climatic conditions cause heavy wear on the material, hence increase the need to be repaired
- Other enemies of wood, such as solar radiation and the emergence of organisms (fungi and insects), can be treated with components such as resin or insecticides. It should be paid special attention to the moth. There are many chemicals against the emergence of the woodworm
- Valuable solar heat gain in colder climates can be reduced

Economic assessment

The price is usually high.

Table 3. Cost savings of wood frames. Source: Elaborated by CIRCE.

Type of frame	Total cost (10 m^2 of windows and 6 months)	% saving
Aluminium without thermal break	1.27 €/day 410€	-
Wood	0.87 €/day 158€	62%

References and best practices

- [143] Thermal convection in double glazed windows with structured gap: www.sciencedirect.com/science/article/pii/S0378778811001551
- [144] Low heat loss double-glazed windows: www.sciencedirect.com/science/article/pii/0360544287900429
- [145] Carbon footprint versus performance of aluminum, plastic, and wood window frames from cradle to gate: www.mdpi.com/2075-5309/2/4/542/pdf

Image gallery

Figure 135. Wood frame. Source: www.getdomainvids.com.

2.1.14 Installation of efficient windows (low-E double glazing with PVC frames)

Measure code: EL14i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) ☐ Physiological X Social (2)

Description

This measure consists in the replacement of inefficient windows (e.g. aluminium frame without thermal brake and single glazing) for an efficient one with Low-E double glazing and PVC frames. Low emissivity glasses are equipped with an invisible metallic coating that reflects inward part of the incident long-wave energy (heating), decreasing the absorption of the own glass and, therefore, the energy that emits to the outside. A typical transmittance of this type of windows is U=1.3 W/m^{2}K

Benefits

- Airtightness improved
- Energy costs reduced
- It allows a perfect soundproofing and it reduces noise pollution
- It does not need any special treatment for its conservation, just wash it with soap and water without risk of rot or damage to the material
- There is a wide range of colors, although white is the most widely used color, there are imitation wood, without a too high price
- Improve solar and thermal control
- Reduce summer heat gain and winter heat loss
- Decrease UV transmission such as furniture fading
- Reduce condensation in double glazing

Limitations

- Double glazing cannot be repaired
- During the summer months, trapping heat inside glass panes can lead to a stale and uncomfortable room
- PVC frame is more expensive than the rest
- PVC with high temperatures can be deformed
- PVC is a polluting material
- Valuable solar heat gain in colder climates can be reduced

Economic assessment

Energy costs are reduced.

Table 4. Cost savings of PVC frames. Source: Elaborated by CIRCE.

Type of frame	Total cost (10 m^2 of windows and 6 months)	% saving
Aluminium without thermal break	1.27 €/day 410€	-
PVC	1.07 €/day 195€	52%

References and best practices

- [143] Thermal convection in double glazed windows with structured gap: www.sciencedirect.com/science/article/pii/S0378778811001551
- [144] Low heat loss double-glazed windows: www.sciencedirect.com/science/article/pii/0360544287900429
- [145] Carbon footprint versus performance of aluminum, plastic, and wood window frames from cradle to gate: www.mdpi.com/2075-5309/2/4/542/pdf

Image gallery

Figure 136. PVC frames. Source: www.doubleglazingprices.org.uk.

2.1.15 Installation of efficient windows (solar control double glazing with aluminium frames with thermal break)

Measure code: EL15i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) ☐ Physiological X Social (2)
Description			
This measure consists in the replacement of inefficient windows (e.g. aluminium frame without thermal brake and single glazing) for an efficient one with solar control double glazing and aluminium frames with thermal brake. Solar control glasses have the property of reflecting part of the energy of the received solar radiation, decreasing the amount of energy that passes through the glass. A typical transmittance of this type of windows is U=1.8 W/m^2K.			
Benefits			
• Airtightness improved • Sound insulation • Safety • Easy cleaning • The aluminum frame is available in various colors • Aluminum is a strong and rigid material, its properties do not change with the weather and its rigidity is ensured at high and low temperatures • Solar control glasses cut utility costs by 30% to 40% • Solar control glasses can block 99% of UV light that fades furniture			
Limitations			
• The energy consumption for aluminium manufacturing is high. • Double glazing cannot be repaired • During the summer months, trapping heat inside glass panes can lead to a stale and uncomfortable room • The most common complaint of this frame is that in winter the aluminum sweat • It is a cooler material than wood and PVC • Over time, the aluminum can become corroded • Can reduce valuable solar heat gain in colder climates			

Economic assessment
Initial investment: high. The price varies greatly, depending on the size of the window and manufacturers. Energy costs are reduced.
References and best practices
- [16] Solar control glass for greater energy efficiency: www.glassforeurope.com/images/cont/116_6969_file.pdf - [17] Solar control coating on glass: www.sciencedirect.com/science/article/pii/S1359028698800491
Image gallery

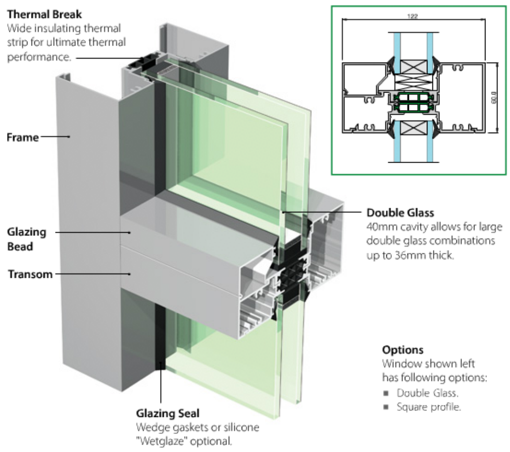



Figure 137. Aluminium frame with thermal break. Source: www.arborcrest.com.au.

2.1.16 Installation of efficient windows (solar control double glazing with wood frames)

Measure code: EL16i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) ☐ Physiological X Social (2)

Description

This measure consists in the replacement of inefficient windows (e.g. aluminium frame without thermal brake and single glazing) for an efficient one with solar control double glazing and wood frames. Solar control glasses have the property of reflecting part of the energy of the received solar radiation, decreasing the amount of energy that passes through the glass. A typical transmittance of this type of windows is U=1.5 W/m^2K

Benefits

- Airtightness improved
- Sound insulation
- Wood is the most natural material and allows that the walls sweat from the inside to the outside. The same properties of wood regulate humidity naturally inside of the building
- It allows the installation of any security system for preventing theft, which applies both in the enclosures (mechanical systems in doors and windows) and those who are connected to a central
- The majority of woods used are suitably treated against fire, ensuring a greater resistance than other non-combustible materials
- Solar control glasses cut utility costs by 30% to 40%
- Solar control glasses can block 99% of UV light that fades furniture.

Limitations

- Double glazing cannot be repaired
- During the summer months, trapping heat inside glass panes can lead to a stale and uncomfortable room
- Wood is the material that more maintenance requires. It is recommended to varnish the external side every two years
- It is not advisable the use of wood window frames in buildings located in areas with strong wind and rain. These climatic conditions cause heavy wear on the material, hence increase the need to be repaired

- Other enemies of wood, such as solar radiation and the emergence of organisms (fungi and insects), can be treated with components such as resin or insecticides. It should be paid special attention to the moth. There are many chemicals against the emergence of the woodworm
- Valuable solar heat gain in colder climates can be reduced

Economic assessment

The price is usually high.

Table 5. Cost savings of wood frames. Source: Elaborated by CIRCE.

Type of frame	Total cost (10 m^2 of windows and 6 months)	% saving
Aluminium without thermal break	1.27 €/day 410€	-
Wood	0.87 €/day 158€	62%

References and best practices

- [143] Thermal convection in double glazed windows with structured gap: www.sciencedirect.com/science/article/pii/S0378778811001551
- [144] Low heat loss double-glazed windows: www.sciencedirect.com/science/article/pii/0360544287900429
- [145] Carbon footprint versus performance of aluminum, plastic, and wood window frames from cradle to gate: www.mdpi.com/2075-5309/2/4/542/pdf

Image gallery

Figure 138. Wood frame. Source: www.getdomainvids.com.

2.1.17 Installation of efficient windows (solar control double glazing with PVC frames)

Measure code: EL17i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) ☐ Physiological X Social (2)

Description

This measure consists in the replacement of inefficient windows (e.g. aluminium frame without thermal brake and single glazing) for an efficient one with solar control double glazing and PVC frames. Solar control glasses have the property of reflecting part of the energy of the received solar radiation, decreasing the amount of energy that passes through the glass. A typical transmittance of this type of windows is U=1.3 W/m^2K.

Benefits

- Airtightness improved
- It allows a perfect soundproofing and it reduces noise pollution
- It is a durable and resistant to cold and air material, very suitable for cold areas
- It does not need any special treatment for its conservation, just wash it with soap and water without risk of rot or damage to the material
- There is a wide range of colors, although white is the most widely used color, there are imitation wood, without a too high price
- Solar control glasses cut utility costs by 30% to 40%
- Solar control glasses can block 99% of UV light that fades furniture

Limitations

- Double glazing cannot be repaired
- During the summer months, trapping heat inside glass panes can lead to a stale and uncomfortable room
- PVC frame is more expensive than the rest
- PVC with high temperatures can be deformed
- PVC is a polluting material
- Valuable solar heat gain in colder climates can be reduced

Economic assessment

Energy costs are reduced.

Table 6. Cost savings of PVC frames. Source: Elaborated by CIRCE.

Type of frame	Total cost (10 m^2 of windows and 6 months)	% saving
Aluminium without thermal break	1.27 €/day 410€	-
PVC	1.07 €/day 195€	52%

References and best practices

- [143] Thermal convection in double glazed windows with structured gap: www.sciencedirect.com/science/article/pii/S0378778811001551
- [144] Low heat loss double-glazed windows: www.sciencedirect.com/science/article/pii/0360544287900429
- [145] Carbon footprint versus performance of aluminum, plastic, and wood window frames from cradle to gate: www.mdpi.com/2075-5309/2/4/542/pdf

Image gallery

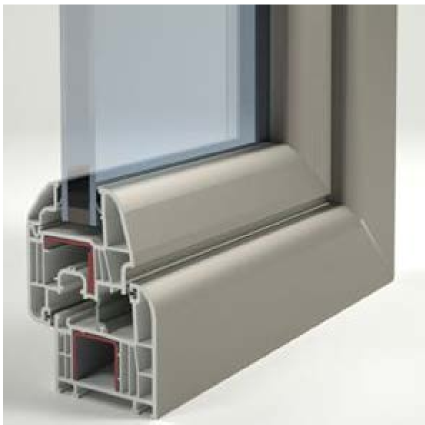


Figure 139. PVC frames. Source: www.doubleglazingprices.org.uk.

2.1.18 Installation of efficient windows (triple glazing with aluminium frames with thermal break)

Measure code: EL18i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) ☐ Physiological X Social (2)

Description

This measure consists in the replacement of inefficient windows (e.g. aluminium frame without thermal brake and single glazing) for an efficient one with triple glazing and aluminium frames with thermal brake. A typical transmittance of this type of windows is between U=0.8 W/m^{2}K and U=1.1 W/m^{2}K compared to the transmittance of inefficient windows which is typically higher than 4 W/m^{2}K.

Benefits

- Airtightness improved
- Limited condensation
- Sound insulation
- Safety
- Reduce heat losses
- Easy cleaning
- The aluminum frame is available in various colors
- Aluminum is a strong and rigid material, its properties do not change with the weather and its rigidity is ensured at high and low temperatures
- It can achieve up to 20% energy savings on top of double pane

Limitations

- The energy consumption for aluminium manufacturing is high
- During the summer months, trapping heat inside glass panes can lead to a stale and uncomfortable room
- The most common complaint of this frame is that in winter the aluminum sweat.
- It is a cooler material than the wood and PVC.
- Over time, the aluminum can become corroded.
- Triple glass is much heavier than double pane windows
- A flipside drawback to the insulating strengths of triple-pane windows is that a lot of condensation can form on the exterior of the windows on cold mornings.

• The extra-cost of the third glass is justifiable in very cold climates.
Economic assessment
Initial investment: high. It can cost about 25-30% more than a comparable double-pane windows. Energy costs are reduced.
References and best practices
- [146] Novel hybrid vacuum/triple glazing units with pressure equalisation design: www.sciencedirect.com/science/article/pii/S0950061814011532   - [147] Flow and heat transfer in double, triple and quadruple pane windows: www.sciencedirect.com/science/article/pii/S0378778814008883
Image gallery
   *Figure 140. Aluminium frame with thermal break. Source: www.archiexpo.com.*

2.1.19 Installation of efficient windows (triple glazing with wood frames)

Measure code: EL19i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) ☐ Physiological X Social (2)

Description

This measure consists in the replacement of inefficient windows (e.g. aluminium frame without thermal brake and single glazing) for an efficient one with triple glazing and wood frames. A typical transmittance of this type of windows is approximately U=0.9 W/m^2K compared with a transmittance of inefficient windows which is generally higher than U=4 W/m^2K.

Benefits

- Airtightness improved
- Limited condensation
- Sound insulation
- Safety
- Reduce heat losses
- Wood is the most natural material and allows that the walls sweat from the inside to the outside. The same properties of wood regulate humidity naturally inside of the building
- The majority of woods used are suitably treated against fire, ensuring a greater resistance than other non-combustible materials
- It can achieve up to 20% energy savings on top of double pane

Limitations

- During the summer months, trapping heat inside glass panes can lead to a stale and uncomfortable room
- Wood is the material that more maintenance requires. It is recommended to varnish the external side every two years
- It is not advisable the use of wood window frames in buildings located in areas with strong wind and rain. These climatic conditions cause heavy wear on the material, hence increase the need to be repaired
- Other enemies of wood, such as solar radiation and the emergence of organisms (fungi and insects), can be treated with components such as resin or insecticides. It should be paid special attention to the moth. There are many chemicals against the emergence of the woodworm
- Triple glass is much heavier than double pane windows

- A flipside drawback to the insulating strengths of triple-pane windows is that a lot of condensation can form on the exterior of the windows on cold mornings
- The extra-cost of the third glass is justifiable in very cold climates

Economic assessment

Initial investment: high. A triple glass can cost from 25-30% more than comparable double-pane windows. Energy costs are reduced.

Table 7. Cost savings of wood frames. Source: Elaborated by CIRCE.

Type of frame	Total cost (10 m^2 of windows and 6 months)	% saving
Aluminium without thermal break	1.27 €/day 410€	-
Wood	0.87 €/day 158€	62%

References and best practices

- [143] Thermal convection in double glazed windows with structured gap: www.sciencedirect.com/science/article/pii/S0378778811001551
- [144] Low heat loss double-glazed windows: www.sciencedirect.com/science/article/pii/0360544287900429
- [145] Carbon footprint versus performance of aluminum, plastic, and wood window frames from cradle to gate: www.mdpi.com/2075-5309/2/4/542/pdf

Image gallery

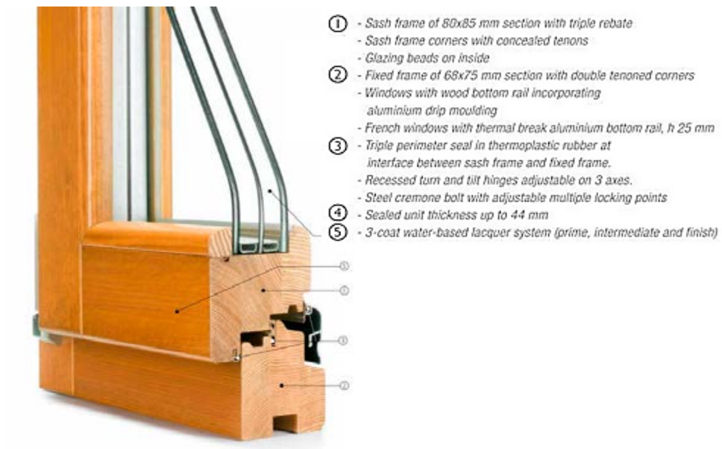


Figure 141. Wood frame. Source: www.pdf.archiexpo.com.

2.1.20 Installation of efficient windows (triple glazing with PVC frames)

Measure code: EL20i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) ☐ Physiological X Social (2)

Description

This measure consists in the replacement of inefficient windows (e.g. aluminium frame without thermal brake and single glazing) for an efficient one with triple glazing and PVC frames. A typical transmittance of this type of windows is between U=0.7 W/m^{2}K and U=1 W/m^{2}K more performant than inefficient windows which has a typical transmittance higher than 4 W/m^{2}K.

Benefits

- Airtightness improved
- Limited condensation
- Reduce heat losses
- It allows a perfect soundproofing and it reduces noise pollution.
- It is a durable and resistant to cold and air material, very suitable for cold areas.
- It does not need any special treatment for its conservation, just wash it with soap and water without risk of rot or damage to the material.
- There is a wide range of colors, although white is the most widely used color, there are imitation wood, without a too high price
- It can achieve up to 20% energy savings on top of double pane

Limitations

- During the summer months, trapping heat inside glass panes can lead to a stale and uncomfortable room
- PVC frame is more expensive than the rest.
- PVC with high temperatures can be deformed.
- PVC is a polluting material.
- Triple glass is much heavier than double pane windows
- A flipside drawback to the insulating strengths of triple-pane windows is that a lot of condensation can form on the exterior of the windows on cold mornings.
- The extra-cost of the third glass is justifiable in very cold climates

Economic assessment

Initial investment: high. A triple glass can cost from 25-30% more than comparable double-pane windows. Energy costs are reduced.

Table 8. Cost savings of PVC frames. Source: Elaborated by CIRCE.

Type of frame	Total cost (10 m^2 of windows and 6 months)	% saving
Aluminium without thermal break	1.27 €/day 410€	-
PVC	1.07 €/day 195€	52%

References and best practices

- [146] Novel hybrid vacuum/triple glazing units with pressure equalisation design: www.sciencedirect.com/science/article/pii/S0950061814011532
- [147] Flow and heat transfer in double, triple and quadruple pane windows: www.sciencedirect.com/science/article/pii/S0378778814008883

Image gallery

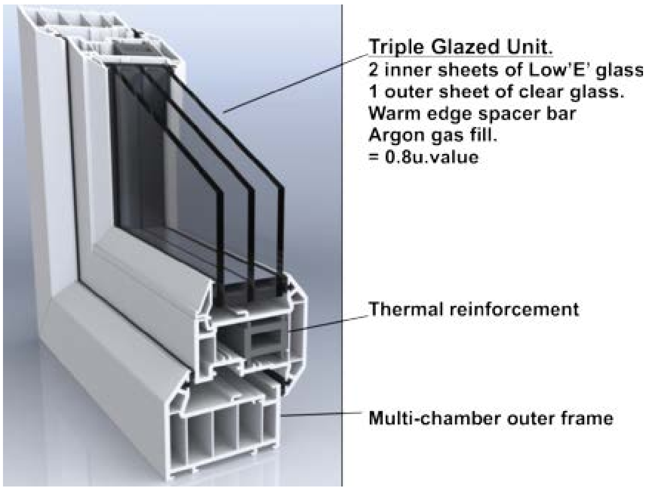


Figure 142. PVC triple glazing window. Source: www.diypvcwindows.com.

2.1.21 Installation of double windows

Measure code: EL21i			
Environment or playable world: X Residential ☐ Academic ☐ Offices ☐ All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) ☐ Physiological X Social (2)
Description			
It is a solution to be considered in cold areas, traditionally used in high mountain areas. The installation of another window offers a double protection from the cold climate, creating also an air chamber which works like a greenhouse, forming a layer of warm air and improves the thermal resistance.			
Benefits			
• Better thermal and acoustic insulation by adding the insulating properties of both windows. • The air chamber created between the two windows provides thermal resistance to the combination, decreasing the transmittance.			
Limitations			
• Occasional discomfort of the occupants of the building if the placement is inside • Cleaning of glasses is complicated • The openings of each window must be studied. It usually works properly with sliding windows • It should be checked that the thickness of the façade is sufficient to support the installation of a second window • It is important the sealing of both windows to prevent infiltrations which can finish with the thermal resistance of the chamber			
Economic assessment			
Initial investment: high. Expenditure on the acquisition of new windows and in their placement which needs masonry work and finishes. Reduce energy costs.			
References and best practices			
- [148] Modelling and simulation of a ventilated double window: www.sciencedirect.com/science/article/pii/S1359431110003492 - [149] Evaluation of the performance indices of a ventilated double window through experimental and analytical procedures - SHGC-values: www.sciencedirect.com/science/article/pii/S037877881400927X			

Image gallery
 Figure 143. Sliding double window. Source: [www.lashome.com.](http://www.lashome.com)

2.1.22 Convert balconies into galleries

Measure code: EL22i			
Environment or playable world: X Residential ☐ Academic ☐ Offices ☐ All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** X Heating ☐ Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) ☐ Physiological X Social (2)

Description

The system consists in the installation of glazing to close balconies and create, in winter, a closed buffer space which accumulate heat and avoid the contact of external wall surface with cold air. It will work as a greenhouse, so in summer it has to be left open to avoid overheating.

Benefits

- It protects external walls from atmospheric agents extending the life of external coating
- Expand living spaces
- Reduce air infiltrations
- Savings of up to 11% and, on average, around 6% in the residential building's heating energy consumption
- Best results are obtained if balconies are oriented to South side

Limitations

- In summer, depending on the use it can cause discomfort situations.
- To prevent overheating in summer conditions, it is important to completely open the glazing system.
- In non-residential building, the use of the galleries should be automatized to avoid incorrect use
- The cleaning of glazing could be difficult

Economic assessment

Initial investment: medium. The more transparent glass to solar radiation it is, the simpler it becomes, and that is also the most suitable for this purpose. To the cost of the window with simple glass, it must be added the cost of installation and the cost of some kind of protection to avoid the heat to escape at night in winter conditions.

References and best practices

- [150] A new research confirms: balcony glazing saves energy: www.issuu.com/oriongroup.india/docs/orion_newsletter_october_-_december_2011
- [151] Energy saving effects of the balcony glazing: www.dspace.cc.tut.fi/dpub/bitstream/handle/123456789/6765/hilliaho.pdf?sequence=3

Image gallery
 *Figure 144. Balcony glazing with sliding glass. Source: [www.archiexpo.com.](http://www.archiexpo.com)*

2.1.23 Build a greenhouse

Measure code: EL23i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** X Heating ☐ Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) ☐ Physiological X Social (2)

Description

The greenhouse is an element of solar energy collection which consists of large glazed surfaces in the Southern façade which not allow escaping the emitted radiations which have a long wavelength. In large buildings, the greenhouse must be complemented with a ventilation system that properly spreads out the hot air currents.

Benefits

- The solar energy entering the greenhouse is stored by the thermal mass of the walls and floors which release it during the night
- Through a ventilation system, heat can be distributed through the rooms

Limitations

- In summer, depending on the weather, the protection against overheating is very delicate, and it can cause discomfort situations. The interspace between the collector area and the accumulator element do not have comfortable thermal conditions. It is therefore a space of difficult use
- To prevent overheating in summer conditions, it is important to complete the system with solar protections (awnings, etc.) and with large openings for the evacuation of the overheating
- When the greenhouse is for many users, the system of openings, solar protection and ventilation, should be monitored for correct management

Economic assessment

The more transparent glass to solar radiation it is, the simpler it becomes, and that is the most suitable for the construction the greenhouses. To the cost of the window with simple glass, it must be added the cost of solar protection or the opening mechanisms for summer conditions, and, optionally, some kind of protection to avoid the heat to escape at night in winter conditions.

References and best practices

- [152] Structural analysis of greenhouses - A case study in Turkey: www.sciencedirect.com/science/article/pii/S0360132305001551
- [153] Energy performance of greenhouse for energy saving in buildings: www.sciencedirect.com/science/article/pii/S1876610212016529

Image gallery
 Figure 145. CIRCE´s building greenhouse. Source: Elaborated by CIRCE.

2.1.24 Installation of a green roof

Measure code: EL24i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) ☐ Physiological ☐ Social
Description			
The vegetation acts as a solar radiation protection in summer, preventing overheating and the fluctuation of the temperature inside the buildings. In winter it would run as an organic insulation that prevents internal energy losses. It is mainly used in flat and slightly sloping roofs.			
Benefits			
• It increases the environmental humidity and decreases the air temperature, due to the evapotranspiration process performed by the plants. • It works in the improvement of their quality providing O_2 and absorbing CO_2 • It works over pollution, because both in the substrate as in the leaves, particles and heavy metals suspended in the air are fixed • It reduces the transmittance, thus increases the thermal insulation • In roofs, it protects the waterproof coating against solar radiation, sudden changes in temperature and mechanical stress • It improves the visual impact from nearby higher buildings • The perennial species protect the wall of heat losses, and the insulating effect might be of 30%, according to the vigour of the plant and its development • In some cases, the incident radiation can be reduced from 50% to 90% • It is advisable in combination with photovoltaic panels: vegetation beneath them, cools by evapotranspiration avoiding inadvisable overheating for photovoltaic panels			
Limitations			
• Vegetation requires some maintenance • The thermal properties of the vegetation and the substrate may not be employed in energy certification			
Economic assessment			
Annual savings around 8% are achieved in extreme cool/hot climates. In warm/temperate climates up to 10% and in cold climates 5%. The cost of a green roof is between 40 €/m^2 and 160 €/m^2 depending of the type of roof.			

References and best practices
- [154] A comprehensive study of green roof performance from environmental perspective: www.sciencedirect.com/science/article/pii/S2212609014000211 - [155] The retrofit of existing buildings through the exploitation of the green roofs – A simulation study: www.sciencedirect.com/science/article/pii/S1876610214033979
Image gallery

Figure 146. CIRCE´s building green roof. Source: Elaborated by CIRCE.

2.1.25 Use of appropriate materials to increase the thermal inertia of the exposed surfaces to solar radiation

Measure code: EL25i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) ☐ Physiological ☐ Social
Description			
The thermal inertia is the resistance that a body offers to change its temperature. The envelopes and rooms with significant inertia accumulate a lot of energy. To make a component to contribute with its mass to the thermal stability of the room, it is necessary that this component is inside the room or that its mass is in direct contact with the inside (uninsulated envelope or insulated on the outside).			
Benefits			
• The energy accumulation allows distributing the thermal inertia properly in the periods of consumption due to the gap that suffers the thermal wave, and it will prevent the thermal effect that is produced at the moment of capture. • In rooms of permanent use, the thermal inertia is desirable and the insulation should be external • It is suitable the combination with night ventilation when overheating is produced • In climates where the thermal oscillation during the day is large with respect to the outside, thermal inertia is also favourable			
Limitations			
• In general, it is necessary to use large thickness and heavy materials in order to have thermal inertia in the envelope. • Heating of buildings with great inertia is slow. • Materials such as adobe, that have a high accumulation capacity and which provide great thermal stability to the building, have the disadvantage that, given that there is no demand, there is no specialized labour and in addition it requires protection and maintenance			
Economic assessment			
The cost depends on the type of construction. To take advantage of the thermal mass of the conventional constructive solutions, it is enough with placing the insulation on the outside.			

References and best practices
- [156] Thermal mass and sustainable building - improving energy performance and occupant comfort: www.irishconcrete.ie/downloads/Thermal_Mass_and_Sustainable_Building.pdf - [157] Energy analysis of buildings employing thermal mass in Cyprus: www.sciencedirect.com/science/article/pii/S0960148102000071
Image gallery

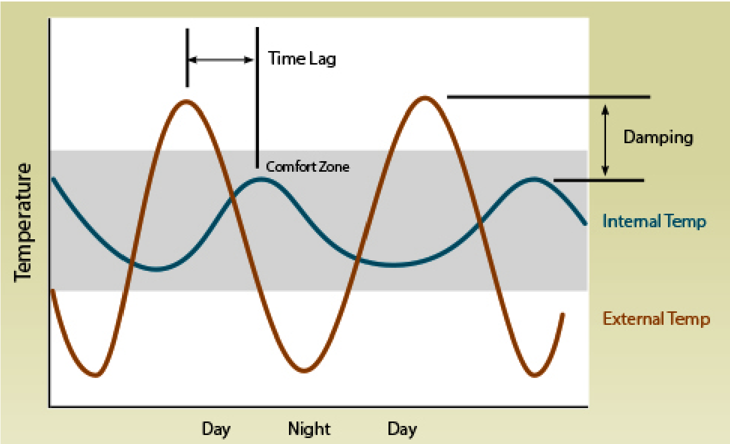


Figure 147. Damping and time lag due to thermal mass. Source: www.precast.org.

2.1.26 Improve insulation in thermal bridge areas

Measure code: EL26i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) ☐ Physiological X Social (2)

Description

The thermal bridge is a localised area of the building envelope where the heat-flow is different (usually higher) in comparison with adjacent areas. Usually thermal bridges are located at the end of the windows frame, in the pillars meetings, in the meetings between pillars and floors and where a radiator is placed for heating, inserted in a niche which leaves the enclosure thinner and thermally unprotected.
The measure consists in the application of thermal insulation preferably on the exterior face of thermal bridge.

Benefits

- The added load to the structure and foundation is minimal
- The internal space is respected, not affecting their useful surfaces
- The work can be performed from the outside, without bothering to the occupants of the building
- Reduce heat losses and consequently heating energy is saved
- Applicable to numerous construction systems

Limitations

- Increased thickness of wall may cause junction problems with neighbouring properties if the house is part of a terrace or semidetached house. This is especially challengingly if the property is set directly against a public footpath.
- A completely thermal bridge free implementation is not possible with justifiable effort in some cases (e.g. basement plinth, projecting balcony slabs, etc.)
- Maintenance and replacement cost must be realistic for the building owner.

Economic assessment

Initial investment: medium. Depending on the type and number of thermal bridges, the installation of insulation could be done by not specialised workers.

References and best practices
- [158] The impact of thermal bridges on the energy demand of buildings with double brick wall constructions: www.sciencedirect.com/science/article/pii/S0378778808001321 - [159] A quantitative methodology to evaluate thermal bridges in buildings: www.sciencedirect.com/science/article/pii/S0306261911008506
Image gallery

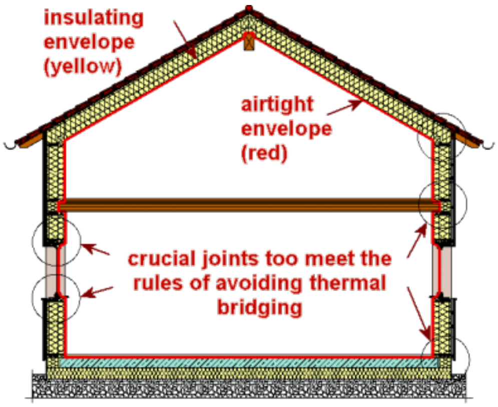


Figure 148. Typical localization of thermal bridges. Source: [www.passipedia.passiv.de.](www.passipedia.passiv.de)

2.1.27 Installation of false ceiling to reduce internal height

Measure code: EL27i

Environment or playable world:	Carried out by:	Reduce consumption of:	Type of driver:
☐ Residential	☐ Public building users (1)	X Heating	X Physical environmental (2)
X Academic	X Owners (2)	X Cooling	X Contextual (2)
X Offices	☐ Operators (3)	☐ DHW	X Psychological (2)
☐ All	☐ All	☐ Lighting	☐ Physiological
		☐ Electric devices	☐ Social

Description

The installation of suspended ceiling reduces the volume which has to be heated or cooled helping to lower heating or cooling bills. A reduction of 0.50 metres of internal room height obtained by the installation of false ceiling allows around 1-2% of energy savings in air conditioning.

Benefits

- Less energy demand
- The installation is easy and fast
- Allow to hide cables and pipes
- It could be combined with the insulation of the roof
- It could be combined with radiant cooling system

Limitations

- The installation of suspended ceiling depends of the height of the room
- It can imply a reconfiguration of light system or other equipment.
- Less thermal mass exposed

Economic assessment

Initial investment: medium. Between 14 and 25 €/m^2

References and best practices

- [160] Suspended ceiling or open plenum?: www.armstrong.co.uk/content2/commclgeu/files/74818.pdf

Image gallery

Figure 149. Drop ceiling. Source: www.eomelectricalcontractors.co.uk.

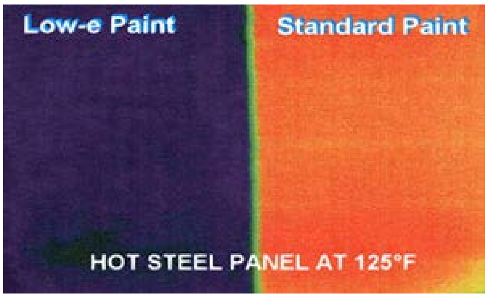
2.1.28 Application of an appropriate solar reflectance coating for the roof

Measure code: EL28i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating X Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) (3) X Contextual (2) (3) X Psychological (2) (3) ☐ Physiological X Social (2)
Description			
Dark colours absorb the solar radiation more than clear ones which are reflective. The measure consists in the use of dark or clear coatings for the roof depending on the climate conditions. In cold climate to increase heat absorption dark coloured coatings will be used, meanwhile in hot climate clear coatings will be used to reduce heat gains.			
Benefits			
• The measure is adaptable to all climate conditions • Easy to install • No professional workers required depending on the construction type			
Limitations			
• Freedom of aesthetic choice is limited for users and architects • Compatibility of the reflective roofing material with the existing roof • Regular maintenance could be necessary • Dust could reduce the properties of reflectively or absorption			
Economic assessment			
Initial investment: medium. The cost of coating will be approximated of 5 €/m^2 at which the cost of application will be added. It reduces energy costs in cooling or heating.			
References and best practices			
- [161] Demonstration of cooling savings of light coloured roof surfacing in Florida Commercial buildings: retail strip mall: www.fsec.ucf.edu/en/publications/pdf/FSEC-CR-964-97.pdf - [162] Demonstration of Energy Savings of Cool Roofs: www.escholarship.org/uc/item/4p14n8hw#page-11			

Image gallery
 *Figure 150. Roof whitening. Source: www.fsec.ucf.edu.*

2.1.29 Application of an appropriate solar reflectance coating for the external walls

Measure code: EL29i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating X Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) (3) X Contextual (2) (3) X Psychological (2) (3) ☐ Physiological X Social (2)
Description			
Dark colours absorb the solar radiation more than clear ones which are reflective. The measure consists in the use of dark or clear coatings for the external wall depending on the climate conditions. In cold climate to increase heat absorption dark coloured coatings will be used, meanwhile in hot climate clear coatings will be used to reduce heat gains.			
Benefits			
• The measure is adaptable to all climate conditions • Easy to install • No professional workers required depending on the construction type • Darker exterior wall paint would prevent the growth of algae as it keeps the surface warmer			
Limitations			
• Freedom of aesthetic choice is limited for users and architects • Compatibility of the reflective material with the existing wall • Regular maintenance could be necessary • Dust could reduce the properties of reflectively or absorption • It is not as important as roof coating			
Economic assessment			
Initial investment: medium. The cost of coating will be approximated of 5 €/m^2 at which the cost of application will be added. It reduces energy costs in cooling or heating.			
References and best practices			
- [163] Energy Savings for Stucco Walls Coated with Cool Colours: web.ornl.gov/sci/roofs+walls/staff/papers/20.pdf - [164] Estimating thermal performance of cool coloured paints: www.sciencedirect.com/science/article/pii/S0378778809001546			

Image gallery
 *Figure 151. Thermal image of a hot steel plate. Source: www.ips-innovations.com.*

2.1.30 Application of an appropriate solar reflectance coating for the internal walls

Measure code: EL30i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling ☐ DHW X Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) (3) X Contextual (2) (3) X Psychological (2) (3) ☐ Physiological X Social (2)

Description

The measure consists in painting internal walls with low-e wall paint, which reflects the heat inside before it is lost through the wall. Otherwise in cooling seasons, the heat is coming through the roof and the walls from the outside and low-e wall paint will block part of the heat and not release it into the room.

Benefits

- The measure is adaptable to all climate conditions
- No professional workers required depending on the construction type

Limitations

- Freedom of aesthetic choice is limited for users and architects
- Dust could reduce the properties of reflectivity.
- It is as not important as roof coating.

Economic assessment

Initial investment: medium. It is needed to consider the cost of the coating and its application. It reduces energy costs in cooling or heating.

References and best practices

- [165]Low Emissive Paints: www.ips-innovations.com/low_emissive_paints.htm

Image gallery

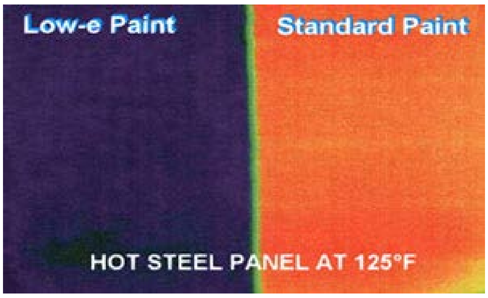
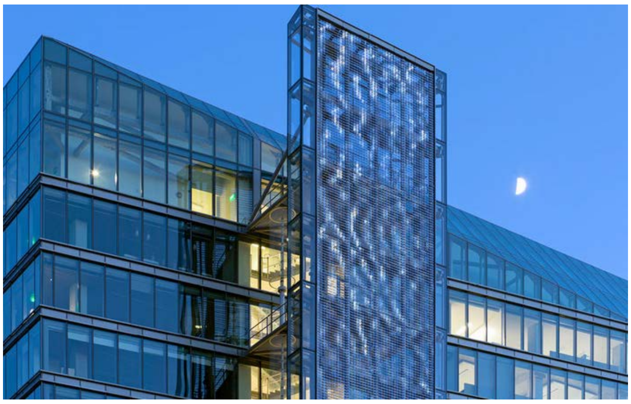


Figure 152. Thermal image of a hot steel plate. Source: www.ips-innovations.com.

2.1.31 Improvement of the percentage of transparent envelope

Measure code: EL31i			
Environment or playable world: ☐ Residential X Academic X Offices ☐ All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** X Heating ☐ Cooling ☐ DHW X Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) X Physiological (2) X Social (2)
Description			
The measure consists in creating new windows in the external walls to gain more light and/or solar contribution. In temperate/warm climate, the new transparent surfaces should be located, if more natural light is necessary, at north side to avoid direct solar radiation in cooling seasons. In cold climate, new openings could be located at south façade to take advantage of solar radiation to heat the building in addition to improve natural daylighting.			
Benefits			
• Increase thermal and visual comfort • Improve the quality of interior spaces, offering new views to the users • Increase air volume for the natural ventilation			
Limitations			
• Reduce thermal mass of the building • Increase the transmittance of the envelope, due to the lower thermal resistance of the windows • This measure requires a previous study of incident solar radiation on façades and an energy balance • The maintenance of windows may be more expensive than the maintenance of external walls • Reduce sound insulation			
Economic assessment			
Initial investment: high. Economically convenient only in heavy refurbishment. It reduces costs in heating and lighting.			
References and best practices			
- [166] Low-energy office buildings using existing technology: simulations with low internal heat gains: www.journal-ijeee.com/content/3/1/19			

Image gallery
 *Figure 153. Transparent envelope. Source: www.buildingdata.energy.gov.*

2.1.32 Substitution of transparent for opaque insulated envelope

Measure code: EL32i			
Environment or playable world: ☐ Residential X Academic X Offices ☐ All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) X Physiological (2) X Social (2)

Description

The measure consists in replacing windows with opaque insulated panels to reduce energy losses and air infiltrations through transparent enclosures. The opaque panels provide shading to the building, reducing solar radiation and avoiding overheating in hot climates.

Benefits

- Increase thermal comfort
- Reduce the transmittance of the envelope, due to the higher thermal resistance of the panels
- Reduce air infiltrations and energy losses
- Increase thermal mass of the building
- The maintenance of opaque panels is cheaper than the maintenance of windows
- Increase sound insulation

Limitations

- This measure requires a previous study of incident solar radiation on façades and an energy balance
- Reduce visual comfort
- Reduce daylighting contribution
- Reduce air volume for the natural ventilation

Economic assessment

Initial investment: high. Economically convenient only in heavy refurbishment. It reduces costs in heating and cooling.

References and best practices

- [166] Low-energy office buildings using existing technology: simulations with low internal heat gains: www.journal-ijeee.com/content/3/1/19

Image gallery
 Figure 154. Substitution of transparent envelope for opaque insulated envelope. Source: www.quoteimg.com.

2.1.33 Installation of solar tubes

Measure code: EL33i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW X Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) ☐ Physiological X Social (2)
Description			
The installation of a solar tube allows capturing natural light from the roof and transports it downward in the rooms through a tube with a highly reflective interior surface channel.			
Benefits			
• Increase visual comfort • Provide natural light in spaces without windows to the exterior • Easy and cheap to install • The intensity of natural light can be controlled			
Limitations			
• It could cause air or water infiltrations if is not properly sealed • Increase thermal transmittance			
Economic assessment			
Initial investment: low. The solar tube costs approximately 250€. The installation can be homemade with average skills. It reduces costs in lighting.			
References and best practices			
- [167]Hollow light guide efficiency and illuminance distribution on the light-tube base under overcast and clear sky conditions: www.sciencedirect.com/science/article/pii/S0030402612008650 - [168] Computational analysis on the enhancement of daylight penetration into dimly lit spaces: Light tube vs. fiber optic dish concentrator: www.sciencedirect.com/science/article/pii/S0360132312002272			

Image gallery

Figure 155. Solar tube application in office space. Source: www.skylightsolutions.com.

2.1.34 Build a Trombe wall

Measure code: EL34i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** X Heating ☐ Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) ☐ Physiological ☐ Social

Description

The Trombe wall consists of a black painted wall built behind a window. Both of them have two vents positioned one at the top and the other at the bottom. Between the window and the wall there is an air chamber. The Trombe wall functions differently depending on the season and on the hour of the day. It uses its thermal mass to transfer the heat accumulated during the day to the night. During heating seasons the window's vents are closed to accumulate heat in the air chamber, meanwhile wall's vents are opened and create a chimney effect which contribute to heat indoor air. In cooling seasons the window's vents are opened to avoid the accumulation of the heat, meanwhile the wall vents are closed to protect the interior space from warm air and to use the entire wall as thermal mass.

Benefits

- Increase thermal comfort
- The optimal use is in climates with high temperature differences between day and night or summer and winter.
- It can be used in all climates
- Better performance could be reached, installing an overhang over the windows to protect it from direct solar radiation in summer.
- Improve sound insulation

Limitations

- The windows should have low emission glazing and high performance
- Unless it is insulated it can lost heat during the night
- Reduce daylight and visual comfort

Economic assessment

Initial investment: high. It requires the installation of a window with a big surface, a very thick wall and operating louvers or dampers to close the vents. It reduces costs in heating and cooling.

References and best practices
- [169] An Experimental Investigation of a Novel Trombe Wall with Venetian Blind Structure: www.sciencedirect.com/science/article/pii/S1876610215002994 - Empirical investigation of the cooling performance of a new designed Trombe wall in combination with solar chimney and water spraying system: www.sciencedirect.com/science/article/pii/S0378778815003734 - [170] Experimental study of the heating performance of a Trombe wall with a new design: www.sciencedirect.com/science/article/pii/S0038092X15003047
Image gallery

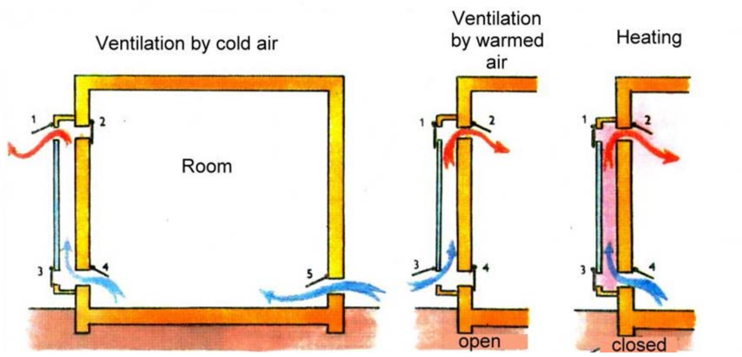


Figure 156. Trombe wall functioning. Source: www.web2.mendelu.cz.

2.1.35 Installation of basement windows

Measure code: EL35i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW X Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) ☐ Physiological X Social (2)
Description			
The measure consists in the installation of windows in the basement floor to take advantage of natural light and natural ventilation.			
Benefits			
• Increase visual and thermal comfort • Allow natural ventilation of basement floors • It can be used in all climates			
Limitations			
• Reduce sound insulation • Reduce thermal resistance • Natural ventilation is not always allowed • It could generate water infiltration if the installation is not properly executed			
Economic assessment			
Initial investment: high. The cost is approximately 2500€. It requires excavation to install the windows as well as works to create the opening in the basement wall. It is economically convenient only if the basement floor is regularly used. It reduces costs in lighting.			
References and best practices			
- [171] How to install basement windows and satisfy egress codes: www.familyhandyman.com/basement/how-to-install-basement-windows-and-satisfy-egress-codes/view-all - [169] An experimental investigation of a novel trombe wall with venetian blind structure: www.sciencedirect.com/science/article/pii/S1876610215002994			

Image gallery

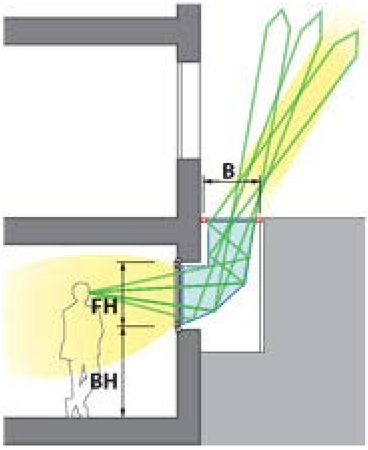


Figure 157. Vertical section of a basement window. Source: [www.heliobus.com.](http://www.heliobus.com)

2.1.36 Installation of revolving doors

Measure code: EL36i			
Environment or playable world: ☐ Residential X Academic X Offices ☐ All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) ☐ Physiological X Social (2)
Description			
The measure consists in replacing standard swinging door with revolving doors to reduce the amount of unconditioned air entering the building by a factor of eight.			
Benefits			
• Reduce the energy required for heating and cooling loads • Increase thermal comfort			
Limitations			
• The replacement is not always feasible • The evacuation of the building through revolving door is problematic. Additionally swinging doors are necessary • There may be anxiety about getting limbs caught			
Economic assessment			
Initial investment: high. The price of revolving doors starts from 2500€ depending on its size and architectural features. It reduces energy costs.			
References and best practices			
- [172] Modifying habits towards sustainability: a study of revolving door usage on the MIT campus: www.web.mit.edu/~slanou/www/shared_documents/366_06_REVOLVING_DOOR.pdf			

Image gallery
 *Figure 158. Intelligent sign on hotel's revolving door. Source: www.danpink.com.*

2.1.37 Create entrance vestibule with two doors

Measure code: EL37i			
Environment or playable world: ☐ Residential X Academic X Offices ☐ All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) ☐ Physiological X Social (2)
Description			
The measure consists in replacing single door entrance with two doors entrance vestibule to reduce the amount of unconditioned air entering the building.			
Benefits			
• Reduce the energy required for heating and cooling loads • Increase thermal comfort • Offer a better control over the entrance			
Limitations			
• The replacement is not always feasible • When the flow of people through the vestibule increases, the chance of having one door closed decreases			
Economic assessment			
Initial investment: medium. It reduces energy costs.			
References and best practices			
- [173] Air infiltration through building entrances: www.publications.lib.chalmers.se/records/fulltext/184752/184752.pdf - [174] Energy saving impact of ASHRAE 90.1 vestibule requirements: modelling of air infiltration through door openings: www.pnl.gov/main/publications/external/technical_reports/PNNL-20026.pdf			

Image gallery

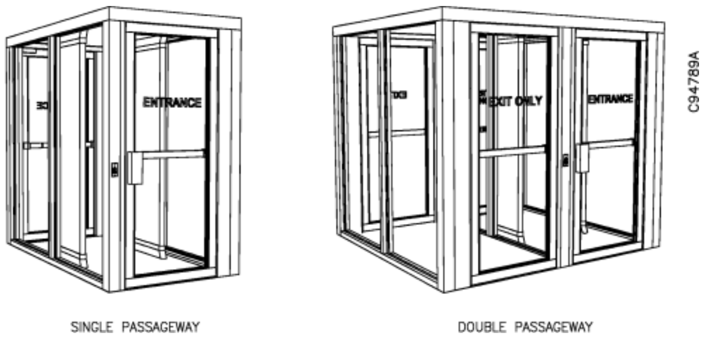


Figure 159. Security vestibule. Source: [www2.diebold.com.](www2.diebold.com)

2.1.38 Installation of an air-barrier system

Measure code: EL38i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) ☐ Physiological X Social (2)

Description

Air barriers are systems of materials designed and constructed to control airflow between a conditioned space and an unconditioned space. The air barrier system is the primary air enclosure boundary that separates indoor (conditioned) air and outdoor (unconditioned) air.

Benefits

- Eliminate uncontrolled air leakage while offering many other benefits
- Improve building performance by reducing heating and cooling costs by as much as 36%
- Control over temperature, humidity, moisture and air quality throughout the building and in all types of weather

Limitations

- Subject to temperature changes
- Materials selected for the air barrier system must be accessible for periodic maintenance

Economic assessment

Initial investment: less than 1-2% of the cost of the building.

References and best practices

- [175] Air barrier systems in buildings: www.wbdg.org/resources/airbarriers.php
- [176] Understanding air barriers: www.buildingscience.com/documents/digests/bsd-104-understanding-air-barriers

Image gallery

Figure 160. Installation of an air barrier. Source: www.constructionspecifier.com.

2.1.39 Adding a electrochromic window film

Measure code: EL39i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling ☐ DHW X Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) (3) X Contextual (2) (3) X Psychological (2) (3) X Physiological (2) (3) X Social (2) (3)
Description			
An electrochromic window film is able to change the transparency or the colour of the glass where it is applied thanks to an electrical voltage which passes across it. The passage from one state to another can be done manually, with n ON/OFF switch or could be automatic, if it is associated to a sunlight sensor.			
Benefits			
• Reduce cooling and heating loads • Increase visual and thermal comfort • Power is needed only to change from one state to the other • Increase internal privacy and security			
Limitations			
• The durability has not been tested yet			
Economic assessment			
Initial investment: high. Approximately 200€/m^2. It reduces energy costs			
References and best practices			
- [177] Electrochromic glasses prepared by the sol–gel method: www.sciencedirect.com/science/article/pii/S0927024898000610 - [178] Properties, performance and current status of the laminated electrochromic glass of Gesimat: www.sciencedirect.com/science/article/pii/S0927024809001809			

Image gallery

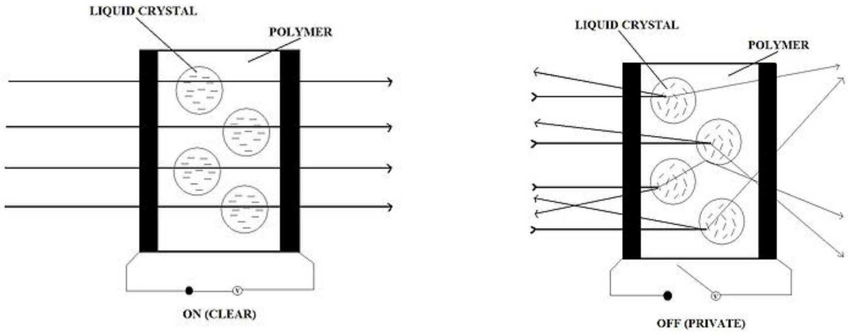


Figure 161. Technology of electrochromic film. Source: [www.invisishade.com.](www.invisishade.com)

2.1.40 Installation of fixed external systems for solar shading (louvres)

Measure code: EL40i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling ☐ DHW X Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) X Physiological (2) X Social (2)

Description

The measure consists in installing louvres as external solar shading system. The inclination of louvres will be selected depending of latitude and climate. The goal is to protect windows from solar radiation in summer, but allowing entering that solar radiation in winter. On south façade louvres should be installed horizontally, meanwhile on East and West façade vertically.

Benefits

- Reduce the energy required for cooling loads
- Increase thermal comfort
- Reduce glare problems caused by daylight
- They are available in a lot of architectural solutions and materials
- Weather protection

Limitations

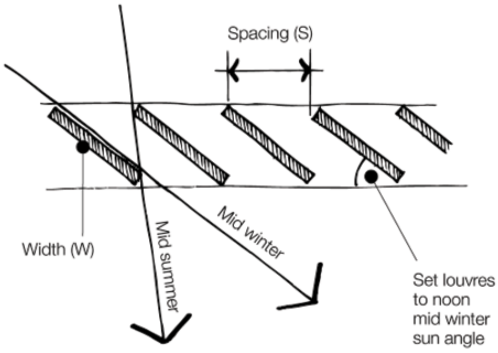
- Reduce the contribution of natural light to the building
- Limit the contact with the exterior environment
- The inclination of louvres cannot be regulated to adapt them to light conditions
- The cleaning of louvres is not simple

Economic assessment

Initial investment: high. It reduces energy costs

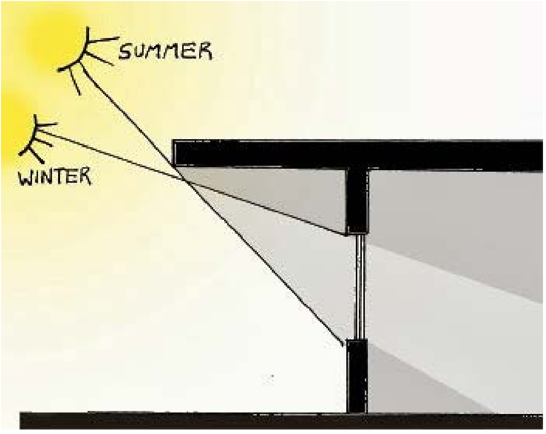
References and best practices

- [179] Reprint of "Assessment of approaches for modelling louver shading devices in building energy simulation programs": www.sciencedirect.com/science/article/pii/S0378778813007287
- [180] Evaluation of a solar thermal system using building louvre shading devices www.sciencedirect.com/science/article/pii/S0038092X05001428

Image gallery
 *Figure 162. Louvres position on West façade. Source: www.yourhome.gov.au.*

2.1.41 Installation of fixed external systems for solar shading (overhangs)

Measure code: EL41i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling ☐ DHW X Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) X Physiological (2) X Social (2)
Description			
The measure consists in installing overhangs above windows to avoid direct solar radiations in summer. The depth of overhangs will be calculated depending of latitude and climate. The selected depth should allow the crossing of solar radiation in winter to contribute at heat gains.			
Benefits			
• Reduce the energy required for cooling loads • Increase thermal comfort • They are available in a lot of architectural solutions and materials			
Limitations			
• Reduce the contribution of natural light to the building • It is not adjustable			
Economic assessment			
Initial investment: medium. It is the simplest and least expensive shading method. It reduces energy costs.			
References and best practices			
- [181] Energy and carbon emission payback analysis for energy-efficient retrofitting in buildings—Overhang shading option: www.sciencedirect.com/science/article/pii/S0378778811004725 - [182] Effects of overhang shading of windows having arbitrary azimuth: www.sciencedirect.com/science/article/pii/0038092X80904880			

Image gallery
 Figure 163. Overhang shading in winter and summer. Source: www.architecturerevived.blogspot.com.es

2.1.42 Installation of mobile external systems for solar shading (louvres)

Measure code: EL42i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling ☐ DHW X Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) X Physiological (2) X Social (2)

Description

The measure consists in installing Louvres as external solar shading system with an inclination which could be adjustable depending of latitude and climate. The setting will be made manually or by an automatic control device. On south façade louvres should be installed horizontally, meanwhile on East and West façade vertically.

Benefits

- It reduces the energy required for cooling and heating loads
- Increase thermal comfort
- Reduce glare problems caused by daylight
- They are available in a lot of architectural solutions and materials
- Manual or automatic setting of inclination give full control of thermal and light conditions
- Weather protection
- It allows control of privacy

Limitations

- The cleaning of louvres is not simple
- Limit the contact with the exterior environment
- The easiness of installation depends on the type of façade
- The optimal operating of the measure depends on users behaviour

Economic assessment

Initial investment: high. It reduces energy costs.

References and best practices

- [183] The energy savings potential of using dynamic external louvers in an office building: www.sciencedirect.com/science/article/pii/S0378778810001866
- [180] Evaluation of a solar thermal system using building louvre shading devices: www.sciencedirect.com/science/article/pii/S0038092X05001428

Image gallery

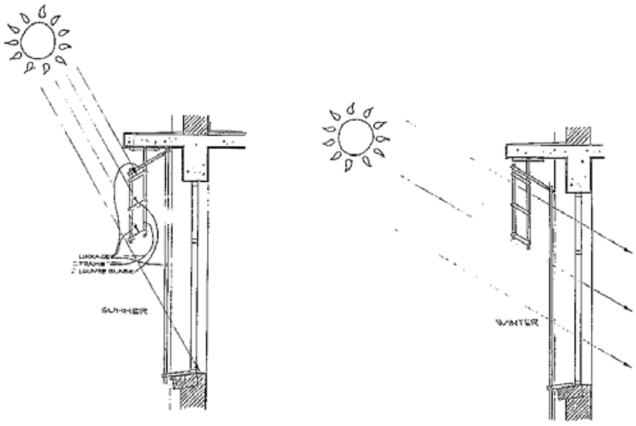


Figure 164. Summer and winter louvres position. Source: [www.collections.infocollections.org.](http://www.collections.infocollections.org)

2.1.43 Installation of mobile external systems for solar shading (shutters)

Measure code: EL43i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling ☐ DHW X Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) X Physiological (2) X Social (2)

Description

The measure consists in installing shutters as external solar shading system on south, east and west façade.

Benefits

- Reduce the energy required for cooling and heating loads
- Increase thermal comfort
- Reduce glare problems caused by daylight
- They are available in a lot of architectural solutions and materials
- Allow varied control of privacy and light transmission
- Weather protection
- Light can be diffused, depending on the direction the vanes are tilted

Limitations

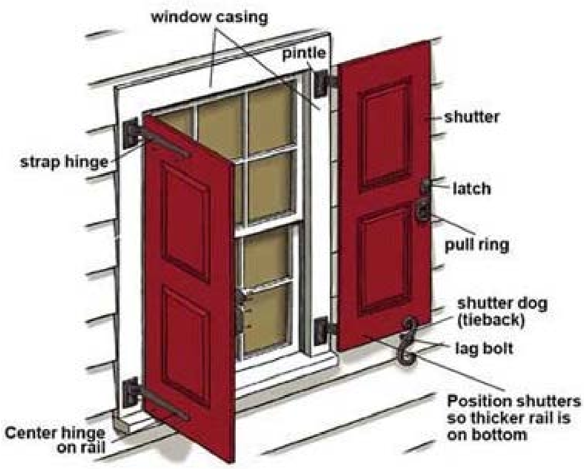
- The cleaning of shutters is not simple
- Shutters can warp if used in a too-damp environment
- Shutters can discolour due to sun exposition depending on the material used
- A large wall area is required to lay the open shutters against the wall
- The optimal effectivity of the measure depends on users behaviour

Economic assessment

Initial investment: high. Shutter installation cost is roughly 25€ to 100€ per pair, depending on the installation site. Shutter cost depends mainly on the material and the type of shutter, so the cost start from 50€ per pair and raise to 5000€ per pair. It reduces energy costs.

References and best practices

- [184] Performance of a window shutter with phase change material under summer Mediterranean climate conditions: www.sciencedirect.com/science/article/pii/S1359431115002835
- [185] Development of a window shutter with phase change materials: Full scale outdoor experimental approach: www.sciencedirect.com/science/article/pii/S0378778814010093

Image gallery
 *Figure 165. Exterior shutter parts. Source: www.thisoldhouse.com.*

2.1.44 Installation of flexible external systems for solar shading (awnings and blinds)

Measure code: EL44i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling ☐ DHW X Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) X Physiological (2) X Social (2)
Description			
The measure consists in installing awnings and/or blinds externally, to protect interior spaces from direct solar radiation, avoiding overheating in summer.			
Benefits			
• Reduce the energy required for cooling • Increase thermal comfort • Reduce glare problems caused by daylight • Allow control of privacy and light transmission			
Limitations			
• The cleaning is not simple and dirt could cause molds, mildew and fungal growth • Weather direct exposure reduces the lifetime of the systems • Awnings and fabric blinds should be rolled up during heavy storms to avoid damage • The optimal effectivity of the measure depends on users behaviour			
Economic assessment			
Initial investment: high. It reduces energy costs.			
References and best practices			
- [186] Simplified architectural method for the solar control optimization of awnings and external walls in houses in hot and dry climates: www.sciencedirect.com/science/article/pii/S0960148102000149 - [187] A new design of configurable solar awning for managing cooling and heating loads: www.sciencedirect.com/science/article/pii/S0378778809001856			

Image gallery

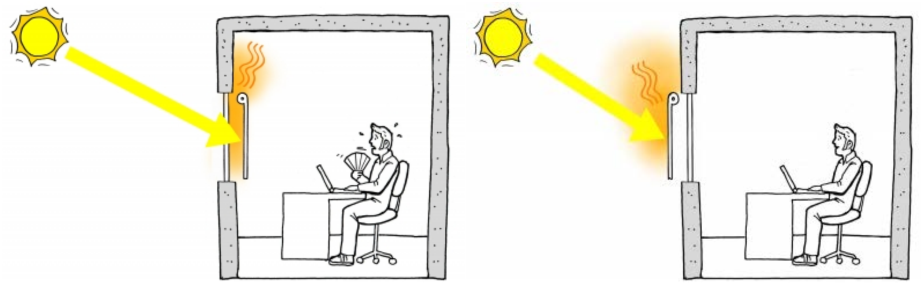



Figure 166. External blinds block heat more the interior than internal ones. Source: [www.sustainabilityworkshop.autodesk.com.](www.sustainabilityworkshop.autodesk.com)

2.1.45 Installation of internal solar shading (curtains and blinds)

Measure code: EL45i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** X Public building users (1) ☐ Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling ☐ DHW X Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (1) (3) X Contextual (1) (3) X Psychological (1) (3) X Physiological (1) X Social (1)

Description

The measure consists in installing curtains or blinds as internal solar shading system to protect interior spaces from solar direct radiation avoiding overheating and glare.

Benefits

- Reduce the energy required for cooling
- Increase thermal comfort
- Reduce glare problems caused by daylight
- There are curtains and blinds available in a lot of architectural solutions and materials
- Allow control of privacy and light transmission
- Easy and cheap to install

Limitations

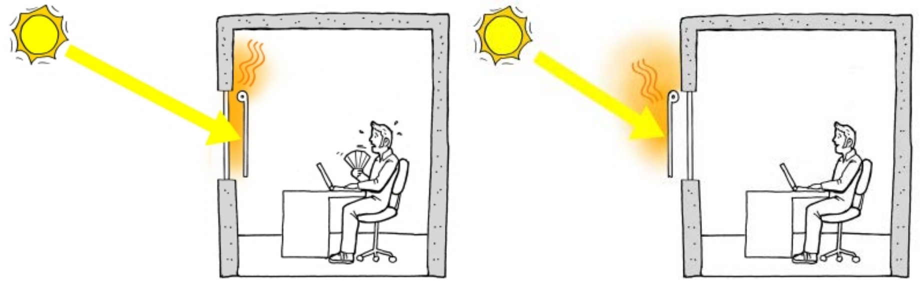
- Curtain and blinds can discolour due to sun exposition depending on the material used
- The protection from overheating is not very efficient because curtains or blinds allow direct solar radiation to pass through the window
- The optimal effectivity of the measure depends on users behaviour

Economic assessment

Initial investment: low. The installation is very simple and it could be done by non-professional users. It reduces energy costs.

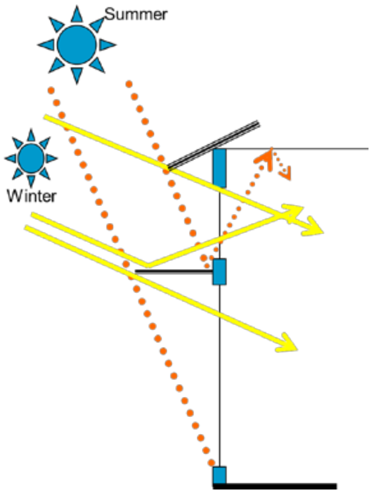
References and best practices

- [188] An empirical validation of modelling solar gain through a glazing unit with external and internal shading screens: www.sciencedirect.com/science/article/pii/S135943110600233X

Image gallery
 *Figure 167. External blinds block heat more the interior than internal ones. Source: www.sustainabilityworkshop.autodesk.com.*

2.1.46 Installation of solar shelf

Measure code: EL46i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW X Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) X Physiological (2) X Social (2)
Description			
The solar shelf is a solar shading system which in addition to protect the building from direct solar radiation, it reflects natural light with its upper surface (painted with a flat finish) on the ceiling of interior spaces.			
Benefits			
• Reduce the energy required for cooling and lighting • Increase thermal comfort • Reduce glare problems caused by daylight • Improve light penetration			
Limitations			
• Solar shelfs are efficient only if installed on south façades • The design and installation of solar shelfs should be done in a proper way to obtain maximum performance and to avoid glare • Exterior shelves must be weather resistant • If it is desirable to darken the room this may be done with a curtain at the edge of the light shelf			
Economic assessment			
High. Solar shelfs are more expensive than other external shading systems. It reduces energy costs.			
References and best practices			
- [188] An empirical validation of modelling solar gain through a glazing unit with external and internal shading screens: www.sciencedirect.com/science/article/pii/S135943110600233X - [189] Optimizing performance of the light shelf by modifying ceiling geometry in highly luminous climates: www.sciencedirect.com/science/article/pii/S0038092X07001843			

Image gallery
 *Figure 168. Light shelf operating in summer and winter. Source: www.works.bepress.com.*

2.1.47 Use of argon in chambers of double and triple glazing

Measure code: EL47i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) X Physiological (2) ☐ Social

Description

This measure consists in the use of argon gas instead of air to fill the chamber between double or triple glass panes. Argon is more efficient than air because its transmittance is lower.

Benefits

- Increase the soundproofing performance
- Low transmittance
- It can be used in all climates
- Windows filled with argon can block ultraviolet rays
- Argon will not corrode the window material as oxygen will do

Limitations

- The glass must be sealed properly to avoid leakage due to the fact that argon gas windows do not expand or contract, meanwhile glass do
- If the argon has been pumped using two holes, the window is more likely to fail than if pumped with one hole
- The use of non-metallic spacer should be considered to avoid gas leakage as well as conduction of heat and sound

Economic assessment

Initial investment: high. Argon gas filled windows will add 30€ to 40€ per window compared to air filled windows. The additional cost will be recouped on short time.

References and best practices

- [190] Comparison of sound insulation of windows with double glass units: www.sciencedirect.com/science/article/pii/S0003682X15000092
- [191] Do I Really Want Radioactive Windows?: www2.buildinggreen.com/blogs/do-i-really-want-radioactive-windows

Image gallery

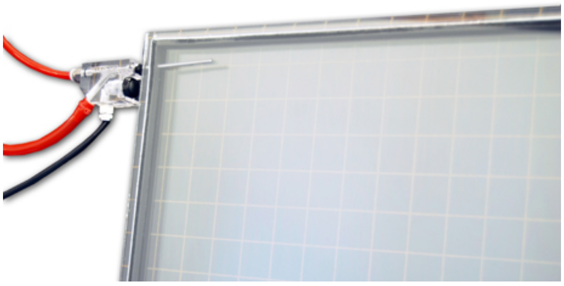


Figure 169. Gas Filling Equipment. Source: [www.quanex.com.](http://www.quanex.com)

2.1.48 Automatic control of mobile and flexible external devices

Measure code: EL48i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling ☐ DHW X Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) X Physiological (2) ☐ Social

Description

The measure consists in installing automatic devices which control the external solar shading systems, changing the inclination of louvres or the opening of blinds, awnings or shutters depending on the solar radiation, interior brightness and temperature, or depending on the time of the day or period of the year.

Benefits

- If an integrated approach for automatic control of motorized shading system is used in conjunction with controllable electric lighting systems, substantial reduction of the energy demand for cooling and lighting could be achieved
- Increase thermal and visual comfort
- The optimal effectivity of the shading system does not depend on users behaviour

Limitations

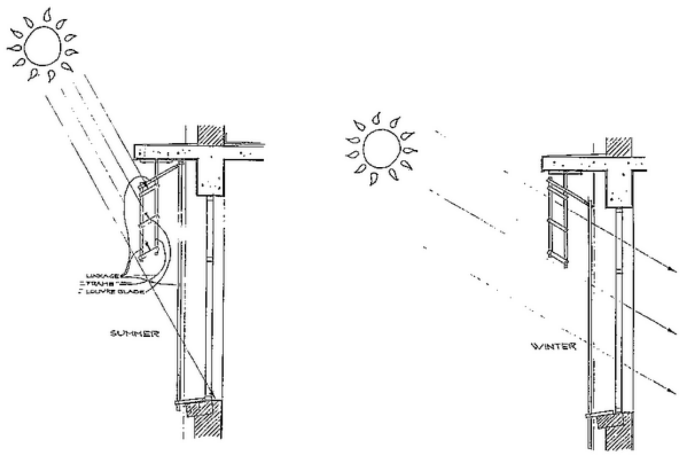
- The control of devices cannot be done manually, so in some cases users can feel discomfort
- The shading system controlled automatically need more maintenance because the moving parts can fail

Economic assessment

Initial investment: high. The installation of the automatic control device could be expensive, but it allows a rapid payback period.

References and best practices

- [192] Optimal orientation and automatic control of external shading devices in office buildings: www.iuav.it/Ateneo1/docenti/architettu/docenti-st/Carbonari-/Pubblicazi/PLEA2001A.pdf
- [193] Towards energy efficient facade through solar-powered shading device: www.sciencedirect.com/science/article/pii/S187704281501784X

Image gallery
 Figure 170. Summer and winter louvres position. Source: www.collections.infocollections.org.

2.1.49 Use of Phase Change Materials (PCMs)

Measure code: EL49i			
Environment or playable world: ☐ Residential X Academic X Offices ☐ All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling ☐ DHW X Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) X Physiological (2) ☐ Social

Description

PCMs could be used in external walls or in windows glasses to give more thermal inertia to the building. These types of materials are able to accumulate heat and then, after a determined period, release it changing its phase.

Benefits

- Reduce peak loads in cooling and heating
- Avoid overheating during cooling period
- It is favourable in buildings with permanent use
- Increase thermal comfort

Limitations

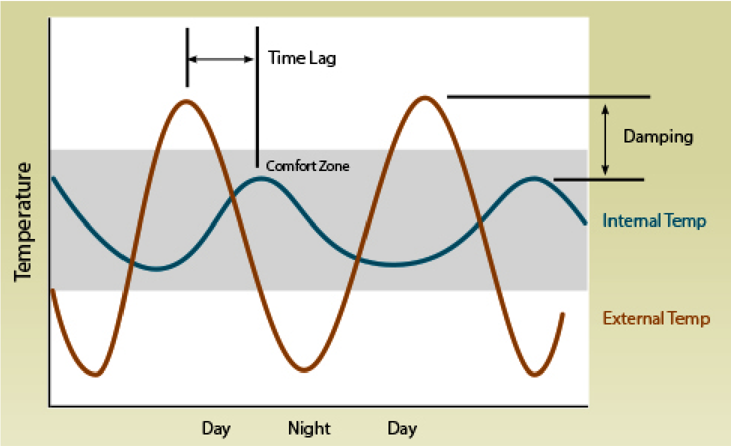
- If used in windows glass, it can reduce the contribution of natural light
- Heating or cooling of buildings with great inertia is slow
- The knowledge about these materials is not already spread

Economic assessment

Initial investment: high. The material cost depends significantly on the classification of the PCM (i.e., organic, inorganic, or biomaterial). It reduces energy costs.

References and best practices

- [194] A review on energy conservation in building applications with thermal storage by latent heat using phase change materials: www.sciencedirect.com/science/article/pii/S0196890403001316
- [195] Annual energy analysis of concrete containing phase change materials for building envelopes: www.sciencedirect.com/science/article/pii/S0196890415006160

Image gallery
 *Figure 171. Damping and time lag due to thermal mass. Source: www.precast.org.*

2.1.50 Installation of a green wall

Measure code: EL50i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) X Physiological (2) X Social (2)

Description

Green walls are self-sufficient vertical garden with a structure system anchored to the external wall of the building. The plants of the vertical garden receive water and nutrient from the structure which support them.

Benefits

- Increase thermal inertia of the building
- Avoid peak of temperature on the external walls
- Attractive aesthetic
- Protect the external walls from the weather
- Reduce the energy needed for heating and cooling through shading and evapo-transpiration
- Increase sound insulation
- Remove pollutants and carbon dioxide from the air and transform them in oxygen

Limitations

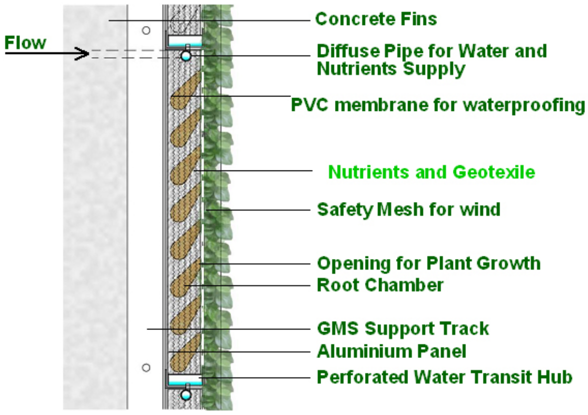
- The maintenance of plants could be intensive although the irrigation system is automatic
- If the maintenance is not properly done, green walls can attract unwanted pests, insects, and birds
- The plant species should be selected depending on the climate zone, local habitat and orientation
- Entails water consumption

Economic assessment

Initial investment: high. Cost is approximately between 900 - 1500 €/m^2

References and best practices

- [196] Green wall systems: A review of their characteristics: www.sciencedirect.com/science/article/pii/S1364032114006637
- [197] Life cycle assessment (LCA) of green façades and living wall systems: www.sciencedirect.com/science/article/pii/B9780857097675500194

Image gallery
 *Figure 172. Section of a green wall system. Source: www.community.theaquaponicsource.com.*

2.1.51 Convert courtyards into atriums

Measure code: EL51i			
Environment or playable world: ☐ Residential X Academic X Offices ☐ All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) X Physiological (2) X Social (2)
Description			
This measure consists in transforming open courtyards in closed atriums through the installation of a glazed roof which could be totally closed or flexible and shaded or not.			
Benefits			
• It could reduce the energy needed for heating and cooling through shading in summer time and functioning as a greenhouse in winter time • Increase of useful floor area • Reduce the heat loss from parent building walls and windows • Protect parent building walls from the weather conditions • The installation of a fountain or plants inside the atrium guarantees a moderate environment during different seasons			
Limitations			
• Reduce daylight penetration, so increases electricity consumption • The efficiency of the system in the cooling season is possible only if the cover system is openable and the atrium is shaded to prevent overheating conditions inside • To obtain a full control of the temperature and daylight inside the atrium the shading system should be movable as well as the glazed roof openable			
Economic assessment			
Initial investment: high. The costs of installation include roof glazed, shading system and manpower cost. The cost depends on the surface of the courtyards, the height of the atrium and the construction type of parent buildings.			
References and best practices			
- [198] Energy performance of courtyard and atrium in different climates: www.academia.edu/6711608/Energy_Performance_of_Courtyard_and_Atrium_in_Different_Climates			

Image gallery

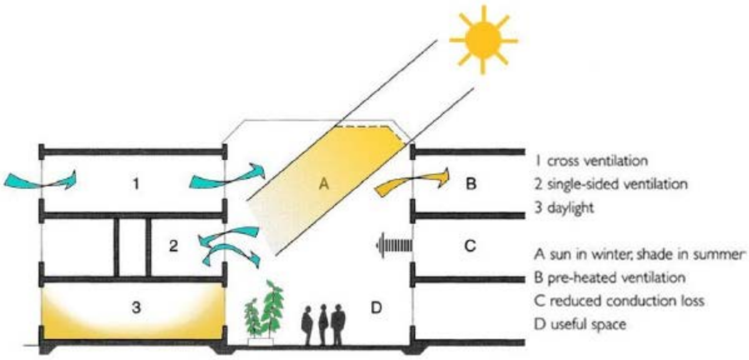



Figure 173. Environmental benefits of an atrium. Source: Baker and Steemers, 2005.

2.1.52 Convert traditional in motorized roller shutters

Measure code: EL52i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) ☐ Physiological X Social (2)

Description

This measure consists in installing motorized roller shutter instead of traditional ones to avoid thermal bridge considering that motorized roller shutters eliminate the roller tape guide.

Benefits

- Reduce the energy required for heating and cooling
- Increase thermal comfort
- Reduce glare problems caused by daylight
- Allow control in privacy and light transmission.
- Avoid thermal bridge caused by roller tape guide and roller shutter box
- They are more comfortable than traditional ones
- They could be remote controlled

Limitations

- Direct exposure to weather reduces the lifetime of the systems
- The optimal effectivity of the measure depends on users behaviour
- Motorized roller shutters do not works without electricity

Economic assessment

Initial investment: low. The installation requires a professional installer but it is not expensive. It is not necessary to change the shutter. The cost depends also on the devices selected to control the motorized shutter. It reduces energy costs.

References and best practices

- [199] A control algorithm for optimal energy performance of a solarium/greenhouse with combined interior and exterior motorized shading: www.sciencedirect.com/science/article/pii/S1876610212016281

Image gallery
 Figure 174. Device to control or program motorized roller shutter. Source: www.somfy.com.au.

2.1.53 Installation of transpired air collectors for ventilation preheating

Measure code: EL53i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** X Heating ☐ Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) ☐ Physiological ☐ Social

Description

This measure consists in installing a dark perforated metal wall on the south façade of a building leaving an air chamber between the external wall and the metal wall of about 15 cm. The dark metal wall functions as a solar collector, warming the air in the chamber. At the top of the building's wall the fans connected with the ventilation system which utilize pre-heated air to heating the building are located. In summer season, the metal wall function as ventilated façade and the fans use air directly from the exterior environment.

Benefits

- Reduce the energy required for heating because the thermal loads are reduced
- Reduce heat losses through external wall
- Protect external wall from the weather
- Give new appearance to the building façade.

Limitations

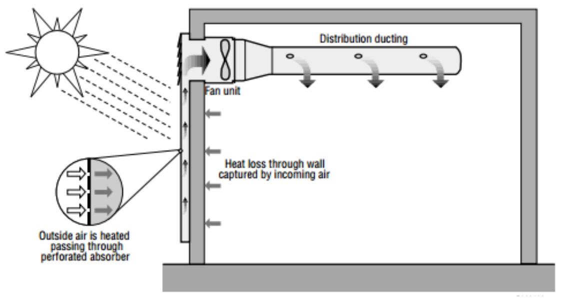
- It should be installed only on the south façade of the building
- It works adequately in sunny locations where the heating seasons are long
- The amount of energy and money saved by a transpired collector depends on the type of fuel, occupant use, building design, length and availability of sunlight during the heating season.
- In summer, the external wall may overheat and consequently heat the interior of the building
- It reduces heating energy costs

Economic assessment

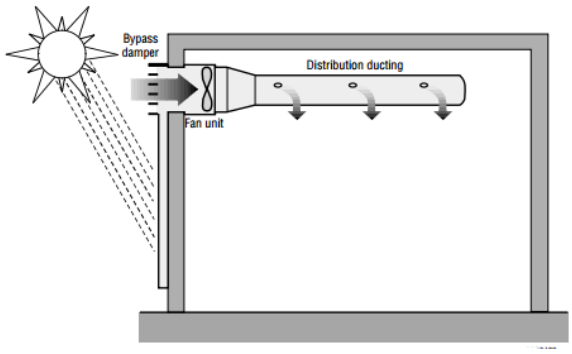
Initial investment: high. Approximately 300 €/m^2

References and best practices

- [200] Transpired solar collectors for ventilation air heating: www.epubs.surrey.ac.uk/712673/1/ener164-101.pdf
- [201] An experimental investigation of the flow structure over a corrugated waveform in a transpired air collector: www.sciencedirect.com/science/article/pii/S0142727X12000975

Image gallery


Transpired collector operation during the winter months.



Transpired collector operation during the summer months.

Figure 175. Transpired collectors (solar preheaters for outdoor ventilation air). Source: [www.energy.gov.](www.energy.gov)

2.2 HVAC measures

2.2.1 Installation of a condensing boiler

Measure code: HL1i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** X Heating ☐ Cooling X DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) (3) X Contextual (2) (3) X Psychological (2) (3) ☐ Physiological ☐ Social

Description

It is a boiler that produces water at low temperature (40-60°C), with high performance and low emissions of CO_2 and NOx. It is designed to use the latent heat released by condensation of the water vapour contained in the combustion products. It is necessary that the boiler can drain the condensates from the heat exchanger in liquid form through the condensation drainage. Gases, when condensing, transfer part of the latent heat to the water in the primary circuit. Being a medium temperature boiler, it is compatible with radiators and underfloor heating installations.

Benefits

- Better performance than conventional boilers
- Higher rate of modulation
- Noiseless
- Until 27.5% savings on heating consumption
- Simple controls

Limitations

- It needs a drain for the remains of the condensation, consisting of a single tube
- The vapor that emerges from the condensation may be visible on certain occasions, therefore the output of gases should be placed where it does not disturb.

Economic assessment

Investment: between 1800€ and 3000€.
Annual economic saving: 0.43€ per constructed m^2 and year for systems with radiators; 0.51€ per constructed m^2 and year for underfloor heating installations.
Payback time: A minimum of 11.33 years for individual systems. Between 5.06 and 7.73 years for centralized systems.

References and best practices
- [202] Condensing boilers evaluation: retrofit and new construction applications: www.gsa.gov/portal/mediaId/197387/fileName/GPG_Condensing_Boilers_NREL_06-2014.action - [203] Installation of decentralized natural gas condensing boilers at Lagan Valley Hospital, Lisburn: www.dfpni.gov.uk/good_practice_case_study_no.1.pdf
Image gallery

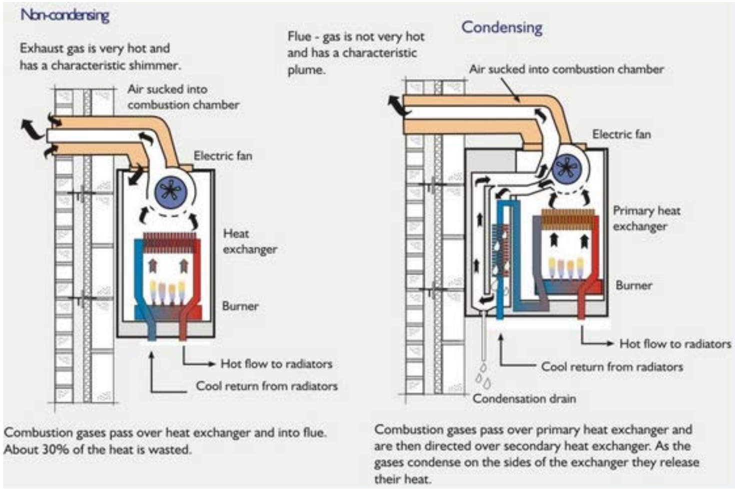


Figure 176. Difference between non-condensing and condensing boilers. Source: www.cliftonparktankless.com.

2.2.2 Installation of a biomass boiler

Measure code: HL2i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** X Heating ☐ Cooling X DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) (3) X Contextual (2) (3) X Psychological (2) (3) ☐ Physiological ☐ Social
Description			
They are compact equipment specifically designed to be powered with biomass. All of them have ignition-regulation automatic systems and even some, removal of ashes that facilitate the handling to the user. The boilers designed for pellets are very efficient and more compact than the rest of biomass boilers due to the characteristics of this fuel: calorific value, compacting, etc.			
Benefits			
• Biomass is a renewable and environmentally friendly fuel • Biomass helps to prevent fires and reduces harmful emissions that provoke the greenhouse effect			
Limitations			
• The investment costs are high • It requires more space than what it is needed for liquid and gaseous fuel boilers, due to the necessity of storing fuel with a calorific value rather lower than that of diesel • Fire safety measures required are difficult to achieve in the retrofitting of buildings. Biomass causes traffic of heavy vehicles which it is probably unacceptable in the urban area of a city			
Economic assessment			
The price of biomass is very variable. It may be cost zero, in the case of biomass of own production, or prices of up to about 0.4 €/kg. In most of the cases, users get biomass produced locally at much more competitive prices on cooperatives farming. Therefore each season user will use biomass with the most competitive price in the market. Regarding to the boilers, there are boilers from 5500€ for single family buildings to 39000€ for large multi-family buildings.			
References and best practices			
- [204] Impact of using biomass boilers on the energy rating and CO_2 emissions of Iberian Peninsula residential buildings: www.sciencedirect.com/science/article/pii/S0378778813004702 - [205] Wood pellet-fired biomass boiler project at the Ketchikan Federal building: www.propellets.at/wpcms/wp-content/uploads/gpg_wood-pellet-fired_biomass_boilers_06-20141.pdf			

Image gallery
 Figure 177. Inside of a wood pellet boiler. Source: [www.biomassinnovation.ca.](http://www.biomassinnovation.ca)

2.2.3 Installation of an evaporative condenser

Measure code: HL3i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating X Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) (3) X Contextual (2) (3) X Psychological (2) (3) ☐ Physiological ☐ Social
Description			
An evaporative cooling system consists of cooling the air thanks to the evaporation of water. When the water evaporates in the bosom of the air to cool, the latter is humidified. This process is called direct evaporative cooling. The indirect evaporative cooling is when the air is kept separated from the process of evaporation and, therefore, it is not humidified in the cooling process.			
Benefits			
• High performance • Renewable energy can be used, reducing significantly the production of CO_2 for buildings cooling			
Limitations			
• Legionella virus may be developed in the cisterns of water • It only applies in arid zones or with low content of moisture in the air, or in internal areas where the latent load is very small and the sensitive component of the load is maximum			
Economic assessment			
Evaporative condensers are only available through selected manufacturers and are produced at very low volumes resulting in relatively high incremental costs. Incremental costs may be reduced in some cases by equipment downsizing by ½ ton due to the reduced capacity degradation of evaporative condensers at high outdoor air design conditions.			
References and best practices			
- [206] Measure guideline - evaporative condensers: www.davisenergy.com/wp-content/uploads/2012/06/BA_measure_guide_evap_condensers_PUBLISHED.pdf - [207] Incorporated evaporative condenser: www.sciencedirect.com/science/article/pii/S1359431106003309			

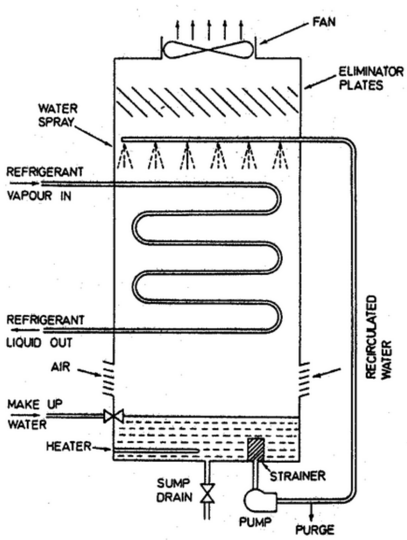
Image gallery


Figure 178. Evaporative condenser working principle. Source: www.fao.org.

2.2.4 Installation of a heat recovery system in the ventilation air

Measure code: HL4i			
Environment or playable world: ☐ Residential X Academic X Offices ☐ All	**Carried out by:** ☐ Public building users (1) X Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** X Heating ☐ Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) (3) X Contextual (2) (3) X Psychological (2) (3) ☐ Physiological ☐ Social

Description

Heat recovery systems are heat exchangers, in which air from the interior of the building and the air coming from the outside are put in contact. In winter, the cold outside air is preheated before entering the building, thus reducing heating consumption. In summer, the electric consumption associated with air conditioning is also reduced, through the pre-cooling of the outside air used for renovation.

Benefits

- The energy consumption reduction potential is considered low-medium, although it may be higher when outside temperatures are very low or very high
- Depending on the model of heat recovery used and external conditions, a reduction in air conditioning consumption of between 20% and 40% can be obtained

Limitations

- Often waste heat is of low quality (temperature)
- It can be difficult to efficiently utilize the quantity of low quality heat contained in a waste heat medium
- Heat exchangers tend to be larger to recover significant quantities which increases capital cost

Economic assessment

Initial investment: low. It depends on the existing ventilation system and if it is necessary to do some kind of work.

Capital cost: The capital cost to implement a waste heat recovery system may outweigh the benefit gained in heat recovered. It is necessary to put a cost to the heat being offset.

Maintenance of Equipment: Additional equipment requires additional maintenance cost.

References and best practices

- [208] A comprehensive review of heat recovery systems for building applications: www.sciencedirect.com/science/article/pii/S1364032115002403
- [209] Experimental investigation of heat recovery system for building air conditioning in hot and humid areas: www.sciencedirect.com/science/article/pii/S0378778812000047

Image gallery

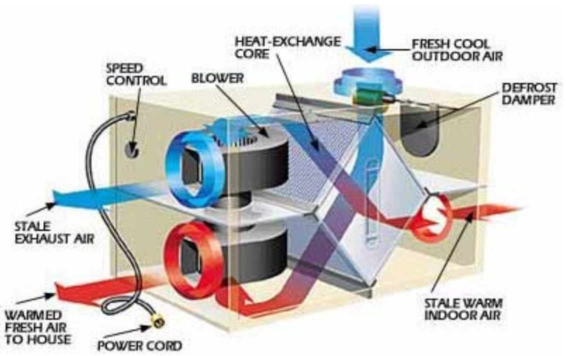


Figure 179. Description of a heat recovery unit. Source: www.daviddarling.info.

2.2.5 Installation of Variable Frequency Drives (VFDs) on motors

Measure code: HL5i			
Environment or playable world: ☐ Residential X Academic X Offices ☐ All	**Carried out by:** ☐ Public building users (1) X Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling ☐ DHW ☐ Lighting X Electric devices	**Type of driver:** X Physical environmental (2) (3) X Contextual (2) (3) X Psychological (2) (3) ☐ Physiological ☐ Social
Description			
VFDs efficiently meet airflow or water flow variation requirements by adjusting the frequency and voltage of the power supplied to an AC motor to enable it to operate over a wide range of rotational speeds. External sensors monitor flow, liquid levels, or pressure, and then transmit a signal to a controller that adjusts the frequency and speed to match process requirements.			
Benefits			
• Small decreases in equipment rotating speed or fluid flow yield to significant reductions in the energy use. For example, reducing speed (flow) by 20% can reduce power requirements by approximately 50% • VFDs also allow the savings of energy consumption at the start-up • Reduce wear and tear on the motors • Provide more precise levels of control of applications			
Limitations			
• In Direct Current (DC) motors, the relationship between power and speed is directly proportional, so the savings are not so high • The profitability of a VFD increases with the load variation and the number of working hours			
Economic assessment			
Investment: medium-high. Payback: high.			
References and best practices			
- [210] Adjustable speed pumping applications: www.sciencedirect.com/science/article/pii/S0262176210700328 - [211] Variable frequency drives fundamentals: www.danfoss.com/nr/rdonlyres/8c303cb7-23a2-4b8b-aa92-1efe1f83f927/0/waterintrolesson.pdf			

Image gallery
 Figure 180. AC and DC drives. Source: www.automationdirect.com.

2.2.6 Installation of high efficient motors for fans and pumps

Measure code: HL6i			
Environment or playable world: ☐ Residential X Academic X Offices ☐ All	**Carried out by:** ☐ Public building users (1) X Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling ☐ DHW ☐ Lighting X Electric devices	**Type of driver:** X Physical environmental (2) (3) X Contextual (2) (3) X Psychological (2) (3) ☐ Physiological ☐ Social
Description			
A High Efficiency Motor (HEM) is a motor that increases in around 3% the performance of a conventional motor. The energy savings at partial load are also significant, and sometimes, even higher than at full load. The energy savings that this implies is a factor that should be taken into account when deciding whether replacing or repairing a motor (although the replacement has a lower economic cost).			
Benefits			
• Include smaller and more efficient fans • Lower magnetic charges • Noiseless • Better power factor			
Limitations			
• Only in the case of working at a load of 25% or less it is profitable to replace a motor by another with less power			
Economic assessment			
Investment: high (except if the motor replacement is due to its end of life). Payback: high.			
References and best practices			
- [212] Motors, drives, pumps and fans: www.energyrating.gov.au/wp-content/uploads/Energy_Rating_Documents/Library/Industrial_Equipment/Motors/lga-motors.pdf			

Image gallery

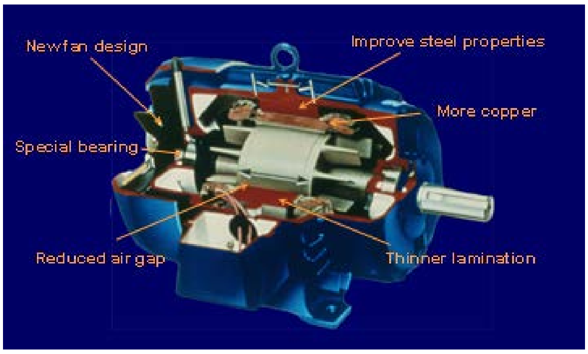



Figure 181. Composition of a High Efficiency Motor. Source: www.altenergymag.com.

2.2.7 Installation of a wireless room energy control system

Measure code: HL7i			
Environment or playable world: ☐ Residential X Academic X Offices ☐ All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) ☐ Physiological X Social (2)

Description

The wireless key-card access switch is powered by a technology that converts the slipping of a plastic key-card through the cavity into a small amount of electricity. This electricity is used to transmit a wireless signal that communicates with the devices enabled wireless relay that is controlling the power to the HVAC unit in the room.

Benefits

- Maintenance free (no batteries)
- Setup in minutes
- Easy to use
- Independent savings (no central system required)

Limitations

- Occupant acceptance

Economic assessment

Minimal installation cost. Fast Return On Investment (ROI).

References and best practices

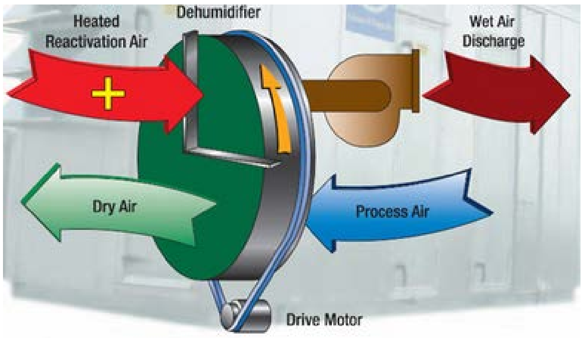
- [213] Guest room HVAC occupancy based control technology demonstration: www.apps1.eere.energy.gov/buildings/publications/pdfs/alliances/creea_guest_room_occupancy-based_controls_report.pdf

Image gallery

Figure 182. Key card access switch. Source: www.commscentre.com.

2.2.8 Installation of a desiccant dehumidification system

Measure code: HL8i			
Environment or playable world: ☐ Residential X Academic X Offices ☐ All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** X Heating ☐ Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) ☐ Physiological X Social (2)
Description			
Desiccant dehumidification and cooling involves using a material (desiccant) that removes moisture from air and is regenerated using heat. Desiccant systems in HVAC applications are used primarily where simultaneous maintenance of temperature and humidity control is an important benefit to the user.			
Benefits			
• Independent control of latent loads in the ventilation air • Eliminate condensation on cooling coils and in drip pans, and reduce humidity levels in ducts • Lower humidity levels in occupied spaces provide equivalent comfort levels at higher ambient temperatures • Reduce the mechanical cooling load, permitting the use of smaller chillers and possibly even smaller ducting in new construction			
Limitations			
• Increase upfront cost • Increase maintenance of the added desiccant equipment • Cost of energy (usually natural gas) to regenerate the desiccant at a high temperature to drive off the entrained moisture			
Economic assessment			
Upfront costs comparable to those of multi-zone roof- top air conditioners.			
References and best practices			
- [214] A review of desiccant dehumidification technology: www.nrel.gov/docs/legosti/old/7010.pdf			

Image gallery
 *Figure 183. Desiccant dehumidification. Source: www.everything-ice.com.*

2.2.9 Installation of pollutant detectors

Measure code: HL9i			
Environment or playable world: ☐ Residential X Academic X Offices ☐ All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) ☐ Physiological X Social (2)
Description			
These detectors reduce the level of ventilation if the source of pollution and/or the pollution level is low, and thus save energy. However, the supplier of the system needs to be careful when designing the system to ensure that reducing the ventilation rate in response to a low level of one pollutant does not result in a high level of other pollutant.			
Benefits			
• Lower operating costs • Higher employer productivity and/or student performance • Increase market value • Reduce liability			
Limitations			
• Occupants need to understand why and how to use windows and fans, and how to avoid activities and products that create indoor air pollution			
Economic assessment			
Some indoor pollutants can be measured easily, at an affordable cost. However, it can be difficult and expensive to detect many air pollutants of concern, especially for organic pollutants that require special laboratory analysis. Building operators may be able to afford more expensive pollutant monitoring packages for criteria pollutants, VOCs, and thermal conditions.			
References and best practices			
- [215] Protecting commercial buildings from outdoor pollutants: www.rocis.org/sites/default/files/user-files/ROCIS_CommercialFINAL1120.pdf - [216] Indoor air pollutants: detection and control measures: www2.ca.uky.edu/hes/fcs/FACTSHTS/HF-LRA.162.PDF			

Image gallery

Figure 184. Gas pollutant detector. Source: www.alibaba.com.

2.2.10 Installation of ground-air heat exchangers

Measure code: HL10i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) ☐ Physiological ☐ Social
Description			
Also known as earth tube, this system takes air from the exterior to introduce to the ventilation system or directly in interior spaces, after the air passes through pipes installed underground. Ventilation air is simply drawn through underground pipes at 1.5m deep which pre-heats the air in winter and pre-cools the air in summer.			
Benefits			
• Reduce costs in heating and cooling because the air provided to the ventilation system is pre-temperate • The efficiency is higher if it is used with a heat recovery system • Increase thermal comfort • It can be installed in all climates • Lower investment than conventional HVAC if the demanded thermal loads are not excessively high • Reduce energy requirements for the fluid transport • Low maintenance			
Limitations			
• It is necessary an excavation of 2 metres as minimum to install the underground pipes • The length of the pipes depends on the temperature of the ground • Initial installation costs are likely to be higher than the comparable conventional refrigerant based systems • The system´s performance is not constant • The tubes are open and they can be clogged due to the dirt			
Economic assessment			
Initial investment: high (2000 to 3000€). Payback is often long given the expected energy savings (between 10 and 20 years). To the cost of earth tubes, it is necessary to add the cost of the excavation. The final cost depends on the depth of excavation, on the type of the ground to excavate and on the length and type of pipes.			

References and best practices
- [217] The cooling potential of earth–air heat exchangers for domestic buildings in a desert climate: www.sciencedirect.com/science/article/pii/S0360132305000405 - [218] Earth-to-air heat exchanger design evaluation: www.energy.gov.yk.ca/pdf/earth_tubes_report.pdf
Image gallery

Figure 185. Ground-heat exchanger connected to ventilation system. Source: www.rehau.com.

2.2.11 Installation of radiant floor heating

Measure code: HL11i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** X Heating ☐ Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) ☐ Physiological X Social (2)
Description			
The most common type of radiant floor uses a network of polyethylene pipes installed underfloor, where the hot water will circulate in a range of temperatures between 34°C to 46°C. Thus a temperature between 18 and 22 °C is achieved. It is ideal option to combine with solar thermal energy or geothermal heat pumps, since the temperature at which the water circulates is around 40°C, while in conventional radiator systems it is necessary to raise it up to 60°C or more.			
Benefits			
• Create a uniform heat. The environment is not dry • Better use of the space by eliminating vertical radiators • Possibility of using cold water to cool in summer • Medium-high energy savings, above all in cold weather (10-30% of heating generation energy)			
Limitations			
• Expensive work installation in existing buildings • It is recommended to avoid the installation of wood or cork floors • It has a great thermal inertia, which means long times of on and off			
Economic assessment			
Initial investment: high (between 60-120€/m^2) Payback: high (over 10 years if it is a replacement of an existing system)			
References and best practices			
- [219] Radiant floor heating in theory and practice: www.taco-hvac.com/uploads/FileLibrary/Radiant_Floor_Heating_-_ASHRAE_Journal_2002-7.pdf - [220] Radiant floor heating system: www.cdn.intechopen.com/pdfs-wm/19887.pdf			

Image gallery
 Figure 186. Radiant floor heating. Source: www.arqhys.com.

2.2.12 Installation of radiant ceiling cooling

Measure code: HL12i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating X Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) ☐ Physiological X Social (2)

Description

Radiant ceiling cooling systems, also known as “chilled beam” systems, incorporate pipes in the ceilings through which chilled water flows. The pipes lie close to the ceiling surfaces or in panels, and they cool the room via natural convection and radiation heat transfer.

Benefits

- Energy saving
- Maximum comfort
- Low maintenance
- Noiseless
- Better IAQ
- No air streams

Limitations

- The thermal load covered is very limited due to the risk of condensation in the pipe

Economic assessment

Initial investment: high (between 60-120€/m^2)
Payback: high (over 10 years if it is a replacement of an existing system)

References and best practices

- [221] Ceiling panel cooling systems: www.doas-radiant.psu.edu/Journal2.pdf

Image gallery

Figure 187. Radiant ceiling cooling. Source: www.energium.es.

2.2.13 Installation of an absorption cooling system

Measure code: HL13i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating X Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) ☐ Physiological X Social (2)

Description

Absorption coolers use heat rather than electricity as their energy source. Because natural gas is the most common heat source for absorption cooling, it is also referred to as gas-fired cooling. Other potential heat sources include propane, solar-heated water, or geothermal-heated water.

Benefits

- Low consumption (only pumps)
- Absence of moving parts wear
- Low noise level
- Possibility of solar integration

Limitations

- Lower COP (0.6-0.8) than compression cycle equipment
- Less availability of products in the market (above all for equipment with less than 50 kW)

Economic assessment

The profitability of an absorption cooling system depends mainly on the price of the heat energy used and the cost of investment in comparison with a conventional cooling system.
Payback: between 2.6 and 3.2 years.

References and best practices

- [222] A review of absorption refrigeration technologies: www.sciencedirect.com/science/article/pii/S136403210100003X

Image gallery

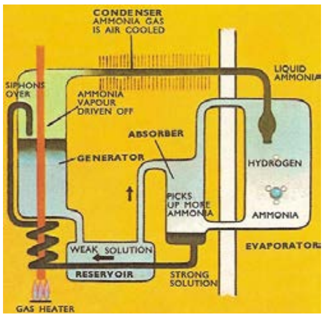
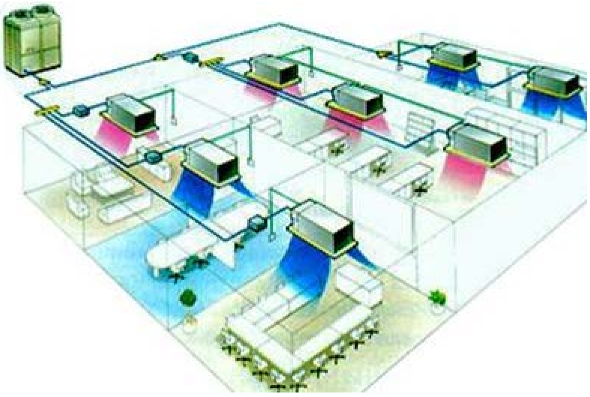


Figure 188. Absorption refrigeration cycle. Source: www.daviddarling.info.

2.2.14 Installation of Variable Refrigerant Flow (VRF) system

Measure code: HL14i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) ☐ Physiological ☐ Social
Description			
VRF systems are air-to-air heat pump systems (some manufacturers include indoor units that use water rather than air) with an outdoor unit and multiple indoor units with individual control. This system is very suited to rooms with areas that have very different needs of air conditioning, which allows improving the comfort and improving efficiency in a 25%.			
Benefits			
• VRF systems benefits from the advantages of linear step control in conjunction with inverter and constant speed compressor combination, which allows more precise control of the necessary refrigerant circulation amount required according to the system load • Excellent seasonal energy efficiency • Minimize or eliminate ductwork completely. This reduces the duct losses often estimated to be 10% to 20% of the total airflow in a ducted system • Inverter compressor technology is highly responsive and efficient • It is possible to include cooling and heating in a single system which avoids duplicating systems • Energy sub-metering with VRF systems is relatively simple and inexpensive by placing an electric meter on one or a few condensing units			
Limitations			
• VRF systems are not suitable for all applications • VRF systems raise the spectre of refrigerant leaks which can be difficult to find and repair, particularly in inaccessible spaces • Like all split systems, VRF systems do not provide ventilation of their own, so a separate ventilation system is necessary			
Economic assessment			
High initial cost. Payback: 3 to 8 years with rebate. Cost savings between 30-50%.			
References and best practices			
- [223] HVAC Variable Refrigerant Flow systems: www.seedengr.com/Variable%20Refrigerant%20Flow%20Systems.pdf - [224] Simulation and experimental validation of the variable-refrigerant-volume (VRV) air-conditioning system in EnergyPlus: www.sciencedirect.com/science/article/pii/S0378778812001053			

Image gallery
 *Figure 189. VRF system. Source: www.jkcomforts.com.*

2.2.15 Installation of micro-cogeneration boilers

Measure code: HL15i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling X DHW X Lighting X Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) ☐ Physiological ☐ Social
Description			
Combined heat and power (CHP), or cogeneration, is the simultaneous production of useful heat and electricity from a single source, close to the point of use. Large scale CHP, suitable for industrial and commercial applications, has been available in the market for some time. Micro-CHP refers to the small-scale production of heat and power for individual commercial buildings, apartments and individual homes. These units meet the demand for space heating and hot water whilst providing electricity to supplement or replace the grid supply.			
Benefits			
• Carbon emissions are reduced by generating electricity at the point of use, avoiding the system losses associated with central power production • Heat, hot water and electricity can be produced all from the same source • By generating electricity on-site carbon dioxide emissions could be saved compared with using grid electricity and a standard heating boiler • There is little difference for an installer in replacing a standard boiler with a micro-CHP system • Any excess energy can be sold back to the national grid • Increase efficiency. CHP systems act as energy multiplier which saves energy, money and reduces carbon emissions by up to 30 percent • Increase reliability. The system is independent of the grid and therefore immune to grid-level blackouts			
Limitations			
• It is not an actual energy source, only a means of extending energy • It could end up obstructing more sustainable options • It is only suitable where there is a need for both electricity and hot water on site • Heating and electricity demand must remain fairly consistent • Capital intensive • It is not long term sustainable when based on fossil fuel technology • Heating demand must be continuous • Efficiency claims are sometimes overstated since heat energy and electricity are not equivalent			

Economic assessment
Unit cost for 2 to 6 kW systems is on the order of 9000 to 18000€. Payback: between 2 and 5 years. Cost savings between 20-25%. Economic savings are generated for the user, by reducing imported electricity and by selling surplus electricity back to the grid.

References and best practices

- [225] Micro CHP – a sustainable innovation? : www.tips-project.org/DOWNLOAD/Graz_Innovation_Micro_CHP.pdf
- [226] Micro-CHP systems for residential applications: www.sciencedirect.com/science/article/pii/S0196890406000124

Image gallery

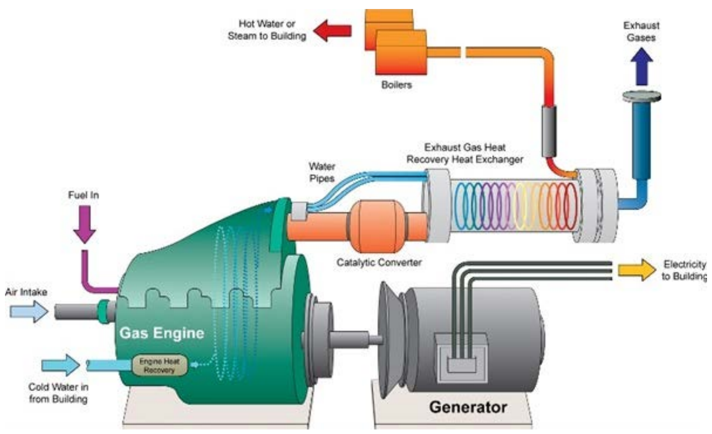
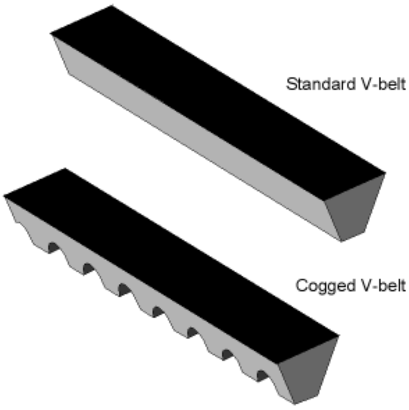


Figure 190. Diagram of working of a micro CHP. Source: www.smartsourceenergy.com.

2.2.16 Replace V-belts with cogged or synchronous belt drives

Measure code: HL16i			
Environment or playable world: ☐ Residential X Academic X Offices ☐ All	**Carried out by:** ☐ Public building users (1) X Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling ☐ DHW ☐ Lighting X Electric devices	**Type of driver:** X Physical environmental (2) (3) X Contextual (2) (3) X Psychological (2) (3) ☐ Physiological ☐ Social
Description			
Belt drives are a common method of power transmission between a motor and its driven load. The driven load may be any rotating drive shaft for equipment such as fans, conveyors, compressors, or pumps. The conversion of V-belt drives to cogged V-belt or synchronous belt drives reduces power transmission losses associated with belt slip.			
Benefits			
• It can be used with the same pulley wheels as standard V-belts • Run cooler • Last longer • Cogged belts have an efficiency that is around 2% higher than that of standard V-belts • Synchronous belts offer an efficiency of around 98% and maintain this over a wide load range			
Limitations			
• Synchronous belts can be noisy and transfer vibrations. They are unsuitable for shock loads			
Economic assessment			
If a cogged V-belt is installed as a replacement for a worn standard V-belt, the only incremental cost is the higher cost of the cogged V-belt. Payback is typically less than one month. Typical payback times for synchronous belt conversions are around 1–2 years. Longer payback times are typical for larger systems.			
References and best practices			
- [227] Replace V-belts with notched or synchronous belt drives: www.nrel.gov/docs/fy13osti/56012.pdf			

Image gallery
 *Figure 191. Difference between a standard and a cogged V-belt. Source: www.globalspec.com.*

2.2.17 Installation of a low temperature boiler

Measure code: HL17i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** X Heating ☐ Cooling X DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) ☐ Physiological ☐ Social
Description			
The low-temperature boilers get a seasonal performance around 94%, which means about 20% of energy savings compared with a conventional boiler. They allow obtaining water at low temperature, between 35-40°C, with better results of efficiency than conventional, and without generating problems of corrosion.			
Benefits			
• Do not need traditional chimneys • Low temperature boilers are typically direct vent systems • Better performance and operation			
Limitations			
• Corrosion may occur because it produces an acidic condensate • Problems with clogged heat exchangers • Incompatibility of the boiler with the existing distribution system • Small heat exchanger volumes			
Economic assessment			
The most efficient boilers require a greater effort of investment (between 25-30% more). However it must be taken into account that the higher cost of a boiler of this type can be amortizable thanks to the potential energy savings to obtain, and the change of a boiler by other more efficient can also be financed. Investment: 40-60€/kW. Payback: high (between 8 and 10 years). Maintenance costs for low-temperature boilers are typically much higher than with conventional equipment.			
References and best practices			
- [228] Low temperature hot water boilers: www.carbontrust.com/media/7411/ctv051_low_temperature_hot_water_boilers.pdf - [229] Experimental study and mechanism analysis on low temperature corrosion of coal fired boiler heating surface: www.sciencedirect.com/science/article/pii/S1359431115001118			

Image gallery
 *Figure 192. Low temperature boiler. Source: www.archiexpo.com.*

2.2.18 Replacement of electric radiators or unit heaters by heat pumps

Measure code: HL18i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** X Heating ☐ Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) ☐ Physiological ☐ Social

Description

The greatest advantage of a heat pump resides in its energy efficiency in heating, since it is capable of providing more (thermal) energy that it consumes (electrical), approximately between 2 and 3 times more. This is because the equipment recovers free energy from the outside environment and incorporates it as useful energy for heating.

Benefits

- High energy savings (more than 50% of the consumption due to electric equipment)
- By reversing the operation of the heat pump, this works as a cooling equipment, being able to meet the demand for cooling in summer

Limitations

- Low performance in extreme climates

Economic assessment

It consumes less energy than the unit heaters or electric radiators and, of course, the cost is also lower.
Initial investment: Medium (1000€/kW).
Payback: medium. For a high number of working hours, around 5 years.

References and best practices

- [230] Advances in heat pump systems: A review: www.sciencedirect.com/science/article/pii/S030626191000228X
- [231] Best practice guide: heat pump technologies: www.seai.ie/Publications/Your_Home_Publications_/Heating/Best_Practice_Guide_Heat_Pump_technologies.pdf

Image gallery

Figure 193. Heat pump. Source: www.airconditioning-narre-warren.street-directory.com.au.

2.2.19 Installation of electronic expansion valves (EEVs) in the cooling equipment

Measure code: HL19i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating X Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) ☐ Physiological X Social (2)

Description

EEVs control the flow of refrigerant entering a direct expansion evaporator. They do this in response to signals sent to them by an electronic controller. A small motor is used to open and close the valve port. The motor is called a step or stepper motor. Step motors do not rotate continuously. They are controlled by an electronic controller and rotate a fraction of a revolution for each signal sent to them by the electronic controller.

Benefits

- Ideal for working in those cases in which loads are suffering large variations
- Optimize the condensation and cooling pressures of the evaporator
- Control efficiently the overheating
- Save energy
- Protect the operation of the system avoiding the return of liquid in the compressor
- Lower maintenance

Limitations

- No air must escape from the plant after the valve is installed
- The surfaces of heat exchangers must be clean
- Filters in air handling systems should not be blocked

Economic assessment

Payback: Even on machines that do not operate continuously, the costs can be recouped within three years. Costs depend on the size of the plant, but a typical valve would be around 2800€ plus another 1400€ to install. On a 100kW cooling capacity chiller operating for 2 hours a year, the expected savings would be 3000€ – paying back the investment in 1.5 years.

References and best practices

- [232] Energy savings and economic benefits of using electronic expansion valves in supermarket display cabinets: www.ijlct.oxfordjournals.org/content/3/3/147.full.pdf
- [233] How to implement electronic expansion valves: www.coolconcerns.co.uk/CTL054_EEVs.pdf

Image gallery
 Figure 194. Electronic expansion valve. Source: www.achrnews.com.

2.2.20 Installation of modulating burners and oxygen sensors

Measure code: HL20i

Environment or playable world:	**Carried out by:**	**Reduce consumption of:**	**Type of driver:**
☐ Residential ☐ Academic ☐ Offices X All	☐ Public building users (1) X Owners (2) X Operators (3) ☐ All	X Heating ☐ Cooling ☐ DHW ☐ Lighting ☐ Electric devices	X Physical environmental (2) (3) X Contextual (2) (3) X Psychological (2) (3) ☐ Physiological ☐ Social

Description

The modulating burners regulate boiler heat output in proportion to demand at any time, reducing the number of turning on and off with respect to conventional burners, achieving greater efficiency in the generation of heat. This measure consists in the substitution or adaptation, in the cases where it is possible, of one or two step burners by modulating burners. Oxygen sensors, also called lambda probes, operate in a way that they measure the free oxygen concentration continuously inside the boiler, and thus regulate the relation between fuel-air, thus maintaining optimal combustion conditions.

Benefits

- These devices may present at least 5% fuel savings
- The maximum benefit is reached when oxygen sensors are combined with modulating burners

Limitations

- In order to have acceptable investment return periods, oxygen sensors should be applied in large boilers, of powers higher than 500 kW and with continued consumption

Economic assessment

Investment: medium. Between 4000 and 6000€ depending on the power.
Payback: medium. Between 3 and 5 years in high power boilers.

References and best practices

- [234] Technical Guide: Boiler Controls: www.seai.ie/Your_Business/Technology/Buildings/Boiler_Controls.pdf
- [235] Combustion control and sensors: a review: www.nuigalway.ie/chem/Donal/reviewcomb.pdf

Image gallery

Figure 195. Modulating gas burner. Source: www.burnercontroller.net.

2.2.21 Replacement of diesel and fuel oil per natural gas

Measure code: HL21i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** X Heating ☐ Cooling X DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) (3) X Contextual (2) (3) X Psychological (2) (3) ☐ Physiological X Social (2)
Description			
Replacement of diesel and fuel oil as a fuel for natural gas, a cheaper and less polluting fuel.			
Benefits			
• Continuous supply without the need for storage • Better maintenance of the systems • Better performance of the combustion			
Limitations			
• It is necessary that a natural gas distribution network is available next to the installation • The implementation involves conditioning of the boiler room for the new fuel and change of the burner and boiler (depending on the type of existing boiler)			
Economic assessment			
Investment: medium depending of the installation. Payback: medium. Between 3 and 5 years. Cost savings: high. 30% of the fuel price.			
References and best practices			
- [236] Good practice case study: Conversion of major boiler houses to natural gas at Queen's University Belfast: www.dfpni.gov.uk/good_practice_case_study_no.5.pdf			

Image gallery
 *Figure 196. Natural gas vs. oil for boilers. Source: www.popularmechanics.com.*

2.2.22 Convert the constant volume system to a Variable Air Volume (VAV) system

Measure code: HL22i			
Environment or playable world: ☐ Residential X Academic X Offices ☐ All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) ☐ Physiological X Social (2)

Description

In tertiary buildings a CAV (Constant Air Volume) system is normally used for ventilation and air-conditioning. In order to keep the room temperature in required level during the summer period quite high airflow rates and higher amounts of energy for heating and distribution of air are needed. By changing the system to VAV operation, considerable energy savings can be achieved.

Benefits

- The technology saves heating and cooling energy along with fan energy
- There is virtually no need to retrofit, demolish, or install ductwork or terminal units
- Lower first cost than a full system VAV retrofit with VAV boxes
- Less system down time and disturbance to building occupants than there would be with a full VAV system retrofit
- Improve occupant comfort and productivity

Limitations

- The system as a whole must be adapted to the new way of operation
- Each terminal unit has an air valve and possibly a coil which require electrical and/or pneumatic service
- VAV requires the use of diffusers with proven distribution characteristics over a wide range of air flows
- Potential indoor air quality problems if proper precautions are not taken

Economic assessment

Investment cost: high.
Payback: between 2 to 15 years depending on the type of building and whether the system operates continuously or for 12 hours a day, 5 days a week.

References and best practices

- [237] Energy savings by changing Constant Air Volume systems (CAV) to Variable Air Volume systems (VAV) in existing office buildings. Experience from a plant reconstruction based on a new supply air terminal device concept: www.energy-management.se/attachments/documents/79/article_final_version_mlm_ljr.pdf

Image gallery

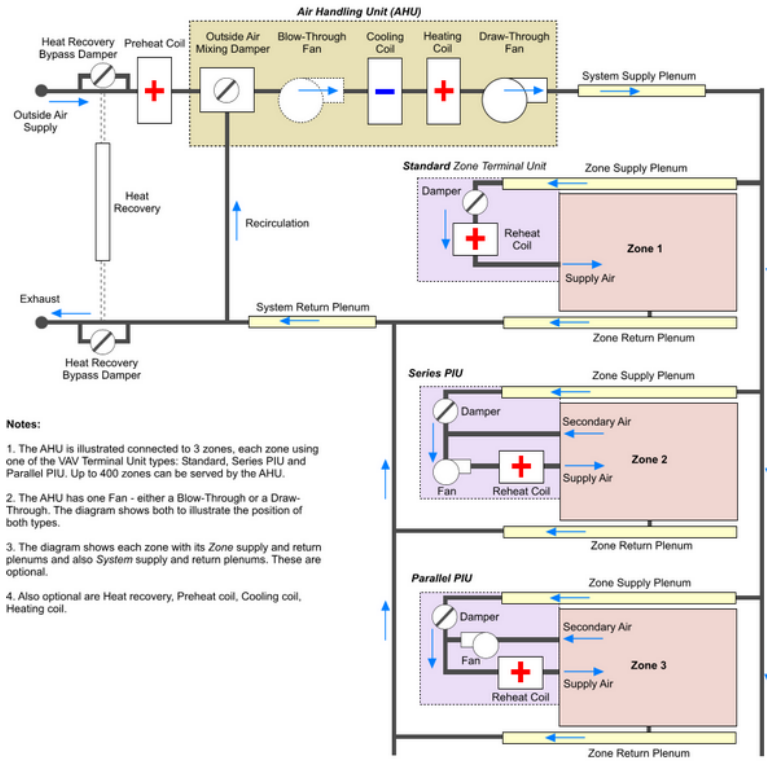


Figure 197. VAV compact HVAC airflow schematic. Source: [www.designbuilder.co.uk.](http://www.designbuilder.co.uk)

2.2.23 Install small modular boilers

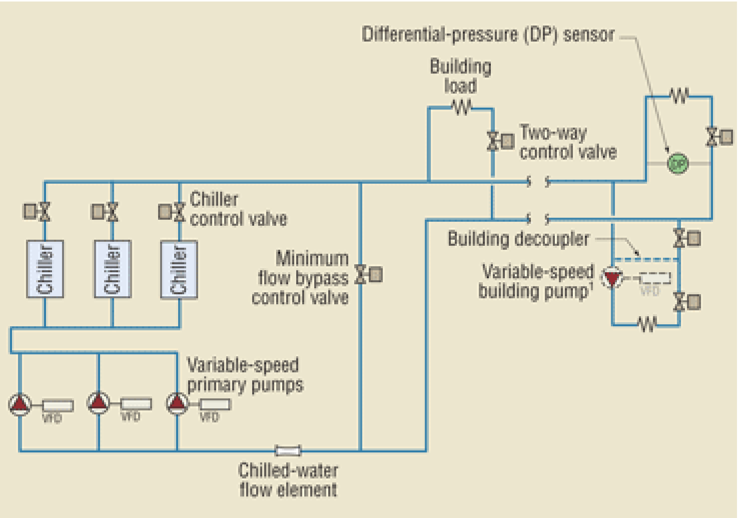
Measure code: HL23i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** X Heating ☐ Cooling X DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) ☐ Physiological ☐ Social
Description			
Modular boilers are designed as an alternative to large single boilers and offer a very efficient approach to tertiary heating. Each module can be a separate boiler installed alongside another in a horizontal arrangement, or as a vertical stack of boiler modules one above another.			
Benefits			
• It is more efficient to operate smaller boilers when the heating load is 25% to 50% of the design capacity than it is to use one large boiler to meet a partial load • Easier to install • Increase system security • Load matching and control • Cost reduction and energy savings			
Limitations			
• Managers should employ controls to stage the boilers on as required to match the load			
Economic assessment			
The drawback to install multiple high-efficient boilers is the large initial capital cost. Often a high-efficient boiler is two to three times the cost of a similar capacity mid-efficient boiler. In many cases using a combination of high efficient and mid-efficient boilers in a boiler plant can achieve the same efficiency performance as a system with all high-efficient boilers.			
References and best practices			
- [238] Modular boilers: www.cibse.org/getmedia/b317995b-a96b-4c8d-94ff-934bc4be6036/modularboilers.pdf.aspx			

Image gallery
 Figure 198. Small modular boilers. Source: [www.triadboiler.com.](http://www.triadboiler.com)

2.2.24 Convert the primary/secondary chilled water plant to variable flow primary

Measure code: HL24i			
Environment or playable world: ☐ Residential X Academic X Offices ☐ All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating X Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) ☐ Physiological ☐ Social

Description
Evaluate the opportunity to remove the primary chilled water pumps, and use the secondary pump (which can be resized as needed) as the variable flow primary pump with a modified control sequence.
Benefits
• Less space required • Reduce pump peak power • Lower pump annual energy usage
Limitations
• The complexity and possible failure of the bypass control • The complexity and possible failures associated with chiller staging
Economic assessment
Lower first costs and lower pump energy costs.
References and best practices
- [239] Primary-only vs. primary-secondary variable flow systems: www.google.es/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0CCIQFjAAahUKEwiRl8aNq9DGAhVMWBQKHX0XArY&url=https%3A%2F%2Fwww.ashrae.org%2FFile%2520Library%2FdocLib%2FPublic%2F20031015143441_686.pdf&ei=-JufVZG7MsywUf2uiLAL&usg=AFQjCNG6aw0woaudDdKBsgSEcVh6GrZpww&sig2=hJAYp88C6OwljcGM8x-FAA&bvm=bv.96952980,d.d24&cad=rja

Image gallery
 Figure 199. A typical variable-primary flow system. Source: www.hpac.com.

2.2.25 Installation of a Thermally Active Building System (TABS)

Measure code: HL25i			
Environment or playable world: ☐ Residential X Academic X Offices ☐ All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) ☐ Physiological X Social (2)

Description

TABS are an embedded water-based surface heating and cooling system, where the pipe is embedded in the central concrete core of a building's construction. The important feature of this type of radiant surface system is the thermal coupling of the emitting element (e.g., pipe coil) with the main building structure (concrete ceiling or wall).

Benefits

- The slab can store the cold air that is available during the night
- "Gentle cooling" without draft effects
- Reduce air exchange in combination with ventilation systems
- No Sick Building Syndrome
- Use of alternative energy sources
- Low flow temperatures mean efficient performance of alternative energy sources

Limitations

- At excessively low temperatures, there is a risk of condensation forming on the room facing surface and the difference between the temperature of the cooling surface and the rest of the room would not be pleasant for the people located in the room

Economic assessment

Low investment (30€/m^2) and operating costs. There is not amortization period of TABS since only the savings in energy generation equipment is greater than the full cost of the TABs installation.

References and best practices

- [240] Thermally Activated Building Systems (TABS): Energy efficiency as a function of control strategy, hydronic circuit topology and (cold) generation system: www.sciencedirect.com/science/article/pii/S0306261910003260

Image gallery

Figure 200. Building a slab with TABs system. Source: www.fenercom.es.

2.2.26 Installation of aero-thermal energy

Measure code: HL26i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) ☐ Physiological ☐ Social

Description

Aero-thermal pump is very similar to a heat pump, except that the energy is transferred to the water to allow a radiant heat floor. It helps to cool with cold water through a central fan coil or recessed cabinets in each room, all with an outdoor unit similar to the equipment used with a conventional heat pump.

Benefits

- Energy savings
- Adaptable installation
- Lower maintenance
- It can be used both for radiators and radiant floor
- High performance

Limitations

- Higher cost than a gas installation
- Full dependency on electricity consumption
- Sensitive to the external conditions

Economic assessment

Initial cost: medium.
Payback: 3.5 years.

References and best practices

- [241] Aerothermal energy: www.ijser.org/researchpaper%5CAEROTHERMAL-ENERGY.pdf
- [242] Aerothermal energy use by heat pumps in japan: www.eneken.ieej.or.jp/data/3680.pdf

Image gallery

Figure 201. Aero-thermal system. Source: www.certificadoenergeticodevivienda.com.

2.2.27 Installation of zoning valves with time and temperature controls

Measure code: HL27i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** X Heating ☐ Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) (3) X Contextual (2) (3) X Psychological (2) (3) ☐ Physiological X Social (2) (3)

Description

A zone valve is a specific type of valve used to control the flow of water or steam in a hydronic heating or cooling system. In the interest of improving efficiency and occupant comfort, such systems are commonly divided up into multiple zones.

Benefits

- Lower power consumption
- Ease to maintain certain models

Limitations

- Zone valves are inherently more unreliable and prone to a very high failure rate. Zone valves operated by electric timing motors are not "fail safe" (failing to the "open" condition)
- No inherent redundancy for the pump. A zone-valved system is dependent upon a single circulator pump. If it fails, the system becomes completely inoperable
- The system can be harder to design, requiring both Single-Pole Double-Throw (SPDT) thermostats or relays and the ability of the system to withstand the fault condition whereby all zone valves are closed simultaneously

Economic assessment

Lower initial installation cost.

References and best practices

- [243] Central heating systems: www.pearsonschoolsandfecolleges.co.uk/FEAndVocational/Construction/Plumbing/Levels-2-and-3-Diploma-in-Plumbing-Studies/Samples/FreesamplechapterPlumbing/Level2_PLUMB_SB.pdf

Image gallery

Figure 202. Zoning valve. Source: www.homeadditionplus.com.

2.2.28 Installation of air curtains

Measure code: HL28i			
Environment or playable world: ☐ Residential X Academic X Offices ☐ All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) ☐ Physiological X Social (2)
Description			
An air curtain is a device that creates a controlled stream of air and directs it across the full width and height of an opening to create an energy saving air seal. This seal separates different environments, allowing a smooth, unhindered flow of traffic and unobstructed vision through the opening.			
Benefits			
• Energy savings (1-10% depending on climate) • Floor space is not compromised • Use less supplemental heat • Safe, unhindered traffic flow • Improve sanitation • Enhance comfort • Maintain visibility and safety			
Limitations			
• Appropriate installation • Enough traffic passages to be cost-effective			
Economic assessment			
Initial investment: 1500-2000€/unit. Lower construction costs. Payback: 1-3 years.			
References and best practices			
- [244] Experimental analysis of energy savings and hygrothermal conditions improvement by means of air curtains in stores with intensive pedestrian traffic: www.sciencedirect.com/science/article/pii/S0378778813005550 - [245] Air curtains: a proven alternative to vestibule design: www.cdn.thomasnet.com/ccp/00164277/35841.pdf			

Image gallery

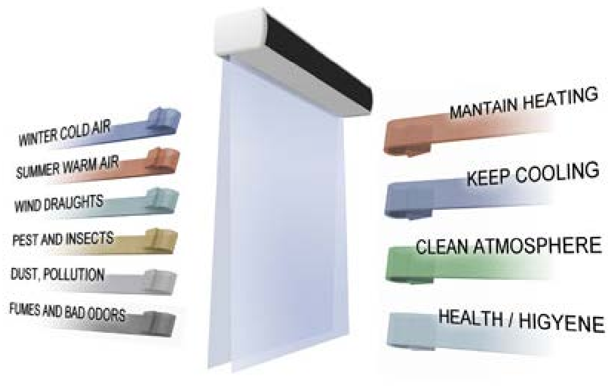



Figure 203. Air curtain benefits. Source: www.dooraircurtain.com.

2.2.29 Installation of a gas powered heat pump

Measure code: HL29i			
Environment or playable world: Residential X Academic X Offices ☐ All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) ☐ Physiological ☐ Social

Description

The gas engine driven heat pump is a traditional heat pump system in which the compressor runs on an internal combustion engine with natural gas instead of a conventional electric engine. The use of the gas combustion engine for running the heat pump compressor provides a source of extra heat that guarantees higher performance and optimal comfort in extreme operating conditions.

Benefits

- Possibility of fitting the building with three services (heating, air conditioning and DHW) with a single system
- Increase energy efficiency
- Increase comfort in severe weather conditions
- Improve reliability of the equipment
- Primary energy savings
- Reduce emissions of CO_2 to the environment

Limitations

- Less coefficient of performance than electric heat pump

Economic assessment

- Lower costs of electricity connection and the transformation centre
- Lower economic cost of natural gas compared with electricity

References and best practices

- [246] Comparison of natural gas driven heat pumps and electrically driven heat pumps with conventional systems for building heating purposes: www.sciencedirect.com/science/article/pii/S037877881000006X
- [247] A review of gas engine driven heat pumps (GEHPs) for residential and industrial applications: www.sciencedirect.com/science/article/pii/S1364032107001268

Image gallery
 *Figure 204. Gas heat pump air-conditioning system. Source: www.yanmar.com.*

2.2.30 Eliminate reactive power with the installation of capacitor banks

Measure code: HL30i			
Environment or playable world: Residential X Academic X Offices ☐ All	**Carried out by:** ☐ Public building users (1) X Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) (3) X Contextual (2) (3) X Psychological (2) (3) ☐ Physiological ☐ Social

Description

The reactive power is the energy required to magnetize the magnetic circuit of a piece of machinery. It is not useful energy, but it is inherent in the equipment connected to the network, so that its consumption is inevitable. The battery of capacitors reduces the reactive power generated by the energy systems.

Benefits

- Decrease the apparent energy and therefore increase the available power
- Decrease the voltage drops
- Decrease the temperature of drivers with the resulting decrease of losses by Joule effect
- Decrease of the work power of the transformers work increasing its useful life
- Avoid the economic penalty on the bill for power factors below 0.95

Limitations

- Although this measure does not involve energy savings, it gets significant economic savings in systems that present reactive power and it increases the useful life of the systems

Economic assessment

Initial investment: medium depending on the system.
Payback: low. Less than three years.

References and best practices

- [248] Automatic capacitor bank identification in power distribution systems: www.sciencedirect.com/science/article/pii/S0378779614000406

Image gallery

Figure 205. Capacitor bank. Source: www.sawengineering.com.

2.3 DHW measures

2.3.1 Substitution of instant system for accumulation system

Measure code: DL1i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling X DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) (3) X Contextual (2) (3) X Psychological (2) (3) ☐ Physiological ☐ Social
Description			
The instant systems heat water as demanded, so a lot of energy and water are wasted until water reaches the energy consumption end point at the required temperature and besides the continuous on and off significantly increase energy consumption. Its replacement by a more efficient accumulation system is recommended. The latter systems heat the water and a water heater tank that stores water and keep it warm. In this way the boiler operates more continuously and efficiently and continuous start-ups and stops of the system are avoided.			
Benefits			
• Savings of up to 50% of the energy that was used to heat the water can be obtained			
Limitations			
• The energy-saving potential depends on the type of building, being the highest in residential buildings			
Economic assessment			
Initial investment: medium, although it depends on each particular situation, since the cost of the equipment varies depending on its capacity.			
References and best practices			
- [249] High efficiency water heaters: www.energystar.gov/ia/new_homes/features/WaterHtrs_062906.pdf - [250] Emerging hot water technologies and practices for energy efficiency as of 2011: www.docs.caba.org/documents/IS/IS-2013-84.pdf			

Image gallery
 Figure 206. Efficient DHW accumulator tank. Source: www.accumulatortanks.co.uk.

2.3.2 Installation of a hot water return circuit

Measure code: DL2i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling X DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) (3) X Contextual (2) (3) X Psychological (2) (3) ☐ Physiological ☐ Social
Description			
An action that can be carried out to improve the efficiency of the DHW system consists in installing a hot water return circuit in the distribution network.			
Benefits			
• Maintain the circuit water warm reducing significantly the losses of water and energy			
Limitations			
• Only for collective installations			
Economic assessment			
Energy savings will vary, depending on the design of the plumbing system, method of control and operation, and homeowner use. The system is easily installed and costs less than 400€.			
References and best practices			
- [251] Domestic hot water recirculation systems application, selection & installation guide: www.taco-hvac.com/uploads/FileLibrary/100-41.pdf			
Image gallery			

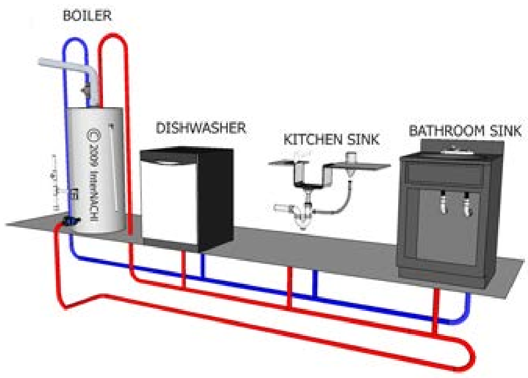


Figure 207. Dedicated loop hot water recirculation system. Source: www.nachi.org.

2.3.3 Installation of a heat recovery in the condensers of the air conditioning system

Measure code: DL3i			
Environment or playable world: ☐ Residential X Academic X Offices ☐ All	**Carried out by:** ☐ Public building users (1) X Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling X DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) (3) X Contextual (2) (3) X Psychological (2) (3) ☐ Physiological ☐ Social
Description			
In the cooling systems, the heat produced by the condenser can be reused through heat exchangers for the DHW production. This exploitation can be not only a significant energy saving for the production of DHW, but also a reduction in the electric consumption of the air conditioning equipment.			
Benefits			
• The saving potential is low. Some HVAC/DHW equipment have already integrated such a measure			
Limitations			
• Only applicable for those buildings with mechanical cooling			
Economic assessment			
The cost is variable, but it can be low and affordable.			
References and best practices			
- [252] Heat recovery from air conditioning units: www.wec.ufl.edu/extension/gc/harmony/documents/eh126.pdf - [253] Efficient usage of waste heat from air conditioner: www.e-ijaet.org/media/41I9-EFFICIENT-USAGE-OF-WASTE.pdf			

Image gallery

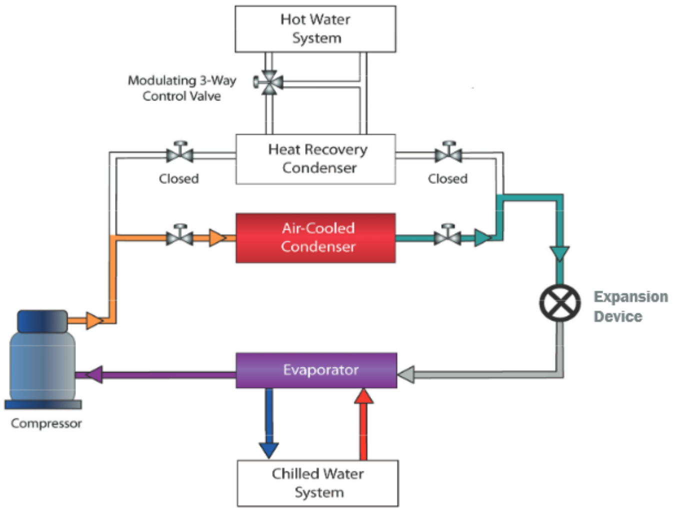



Figure 208. Air-cooled chiller with heat reclaim capabilities: Cooling-only mode. Source: www.dms.hvacpartners.com.

2.3.4 Installation of a CO_2 heat pump

Measure code: DL4i			
Environment or playable world: ☐ Residential X Academic X Offices ☐ All	**Carried out by:** ☐ Public building users (1) X Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling X DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) (3) X Contextual (2) (3) X Psychological (2) (3) ☐ Physiological X Social (2) (3)
Description			
The CO_2 heat pump is a recently developed and more efficient alternative than traditional systems to produce DHW. The CO_2 heat pump technology is capable of producing up to 4 kW of thermal energy from 1kW of power supply (from electricity), while a conventional gas or oil boiler can only produce less than 1 kW of thermal energy from 1kW of power supply (from fuel).			
Benefits			
• Energy savings can reach up to a 78% compared to a standard gas boiler (90% efficiency) • Non-contaminant and high GWP refrigerant gas is used			
Limitations			
• High working pressures • Limited flexibility • Minimum evaporation temperature: - 56°C • Condensation temperature maximum: 31°C • More expensive facilities operating with conventional refrigerants • Heavier than air. In case of escape, the CO_2 is coupled to ground level and displaces air • In case of leaks, there is no warning based on smell (odourless)			
Economic assessment			
Lower life cycle maintenance/repair costs. Payback estimated: 3-7 years, depending on the system configuration and other issues.			
References and best practices			
- [254] CO_2 heat pump systems: www.sciencedirect.com/science/article/pii/S0140700701000330 - [255] CO_2 heat pump water heater: characteristics, system design and experimental results: www.sciencedirect.com/science/article/pii/S0140700798000176			

Image gallery

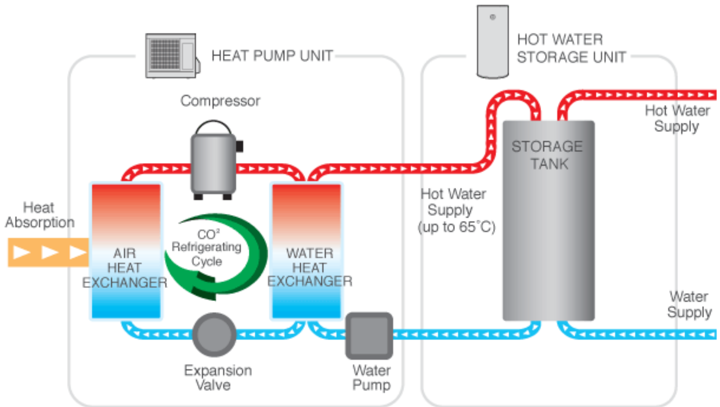
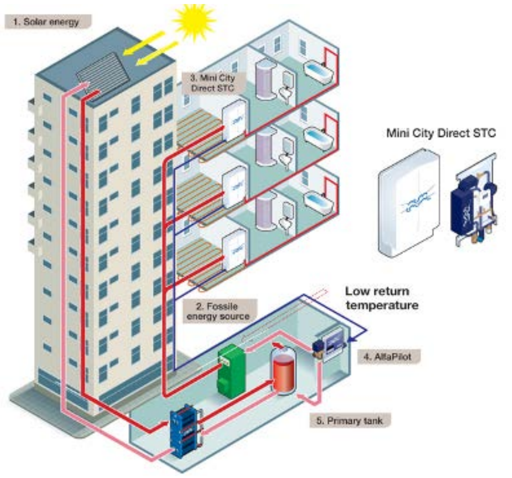


Figure 209. Diagram of a hot water heat pump system. Source: www.sanden-hot-water.com.au.

2.3.5 Change from an individual to a collective DHW system

Measure code: DL5i			
Environment or playable world: X Residential ☐ Academic ☐ Offices ☐ All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling X DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) ☐ Physiological X Social (2)
Description			
This measure consists in substituting each individual DHW system in a residential building by a sole collective system which supplies DHW to all the dwellings.			
Benefits			
• The power required to supply DHW is considerably lower than the addition of the power of each individual installation • Fuel rates can be lower • Application of the accumulated hot water can be diversified			
Limitations			
• Occupant acceptance • It is not an easy installation • Depending on the performance of the individual DHW system it may not be interesting			
Economic assessment			
Initial investment: high Payback: high			
References and best practices			
- [50] Best practices for efficient hot water distribution in multifamily buildings: www.aceee.org/files/proceedings/2012/data/papers/0193-000030.pdf			

Image gallery
 Figure 210. Collective DHW system. Source: www.solarthermalworld.org.

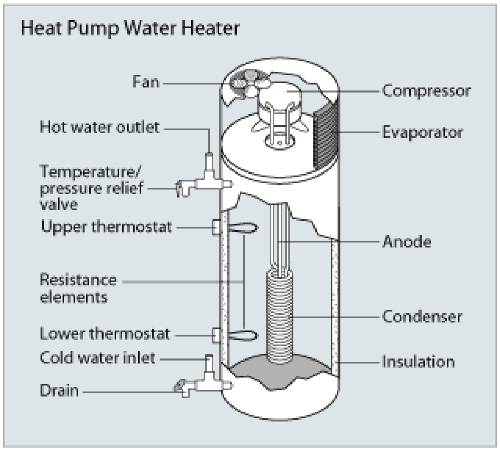
2.3.6 Installation of Drain Water Heat Recovery (DWHR) systems

Measure code: DL6i			
Environment or playable world: X Residential ☐ Academic ☐ Offices ☐ All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling X DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) ☐ Physiological ☐ Social
Description			
Drain water heat recovery units consist of coiled tubes wrapped around drain pipes that capture heat from waste water as it leaves the building. They then return the heat to the hot water system, reducing the energy required to provide hot water in the building.			
Benefits			
• Store recovered heat for later use • Increase water heating capacity • Undersized water heater • Lower the water heating temperature without affecting the capacity			
Limitations			
• Qualified plumbing and heating contractor to install the system			
Economic assessment			
Initial investment: range from 300€ to 500€. Installation will usually be less expensive in new home construction. Paybacks range from 2.5 to 7 years, depending on how often the system is used.			
References and best practices			
- [256] Drainwater heat recovery performance testing at CCHT: www.cmhc-schl.gc.ca/odpub/pdf/65680.pdf?lang=en			
Image gallery			

Figure 211. DWHR system. Source: www.citygreen.ca.

2.3.7 Replace existing DHW system with heat pump water heaters

Measure code: DL7i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling X DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) ☐ Physiological X Social (2)
Description			
Heat pump water heaters need to be installed in applications where the cold air discharged from the evaporator can be exhausted from the space or used to cool the facility (well suited for hot climates).			
Benefits			
• Reduce energy use by 40% to 60% compared to a standard electric resistance heater • An air-source heat pump system that combines heating, cooling, and water heating can also be installed			
Limitations			
• Require installation in locations that remain in the 4.4°–32.2°C range year-round and provide at least 28.3 m^3 of air space around the water heater • Tend to cool the spaces where they are installed • It works more efficiently in warm climates			
Economic assessment			
Initial investment: higher initial costs than conventional storage water heaters. Lower operating costs. Payback: less than 3 years.			
References and best practices			
- [257] Heat pump water heaters: www.energy.gov/energysaver/articles/heat-pump-water-heaters			

Image gallery
 *Figure 212. Heat pump water heater. Source: energy.gov.*

2.4 Lighting measures

2.4.1 Installation of program warm-start ballast

Measure code: LL1i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) ☐ Owners (2) ☐ Operators (3) X All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW X Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (1) (2) (3) X Contextual (1) (2) (3) X Psychological (1) (2) (3) X Physiological (1) X Social (1)
Description			
Program warm-start ballasts incorporate a precise starting sequence to turn on a lamp while minimizing lamp filament wear.			
Benefits			
• These ballasts enable lamps to last about 100,000 switching cycles, whereas instant-start ballasts enable lamps to last only 10,000-15,000 switching cycles • Programed warm-start ballasts precisely pre-heat lamp filaments to their optimal temperature prior to start. Once the lamp is ignited, the filament heating is removed, prolonging lamp and ballast life.			
Limitations			
• Only applicable for frequently switched applications, such as when using motion sensors where the lights will be cycled on and off multiple times per day			
Economic assessment			
Initial investment: medium. Around 30 euros/unit. Payback: medium. More than 5 years. Lower maintenance costs.			
References and best practices			
- [258] Best practices in lighting: www.iesanz.org/_r103/media/system/attrib/file/805/1_quality_%26_sustainability.pdf - [259] Some basic facts and some advanced information on ballasts for fluorescent lamps: www.leonardo-energy.com/sites/leonardo-energy/files/root/pdf/2012/Ballasts.pdf			

Image gallery

Figure 213. Warm start ballast. Source: [www.helvar.com.](http://www.helvar.com)

2.4.2 Installation of electronic ballast

Measure code: LL2i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) ☐ Owners (2) ☐ Operators (3) X All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW X Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (1) (2) (3) X Contextual (1) (2) (3) X Psychological (1) (2) (3) X Physiological (1) X Social (1)

Description

Electrical ballast is a device whose aim is limiting the amount of current that passes through a discharge lamp during the start-up. First, they provide the necessary voltage to start up the lamp and after that they limit the current. Lamps that use ballast are halogen lamps, fluorescent lamps and High Intensity Discharge lamps (HID).

Benefits

- A reduction in the energy consumption of 16% can be reached
- With dimmable electronic ballasts, the intensity of light can be controlled and adjusted reaching an additional reduction in the energy consumption up to 70%
- The typical flickering and the stroboscopic effect disappear because of their high frequency
- Extend the lifetime of the lamps
- Noiseless
- One electronic ballast can substitute more than one magnetic ballast

Limitations

- Electronic ballasts have shorter lifetime than electromagnetic ones
- Non-recyclable

Economic assessment

Initial investment: medium. Around 30 euros/unit.
Payback: medium. More than 5 years.

References and best practices

- [260] CELMA Guide for the application of the Commission Regulation (EC) No. 245/2009 on “Tertiary lighting sector products”: www.tridonic.com/cn/download/CELMA_Ecodesign_1st_edition_Dec2009_full.pdf
- [261] Energy savings analysis and harmonics reduction for the electronic ballast of T5 fluorescent lamp in a building’s lighting system: www.sciencedirect.com/science/article/pii/S0378778815002510

Image gallery
 Figure 214. Electronic ballast. Source: philipslightingcontrols.com/ESROVR.

2.4.3 Replacement of conventional halogen lamps by Infrared Reflective Coating (IRC) halogen lamps

Measure code: LL3i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) ☐ Owners (2) ☐ Operators (3) X All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW X Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (1) (2) (3) X Contextual (1) (2) (3) X Psychological (1) (2) (3) X Physiological (1) X Social (1)

Description

The innovative IRC technology increases the efficiency of halogen lamps by reflecting a major part of the generated useless IR radiation back to the coil where it is converted into visible light. The infrared reflective coating at the outside of the burner acts as an IR mirror but it lets nearly 100% of visible light pass through.

Benefits

- High efficiency halogen lamps save between 30% and 40% of the energy that consume conventional halogen lamps while maintaining the same chromatic characteristics and the same luminous intensity
- The installation of these lamps do not require any special equipment and a conventional one can be directly replaced so it is recommended the application of this measure in a progressive way as installed lamps are burnt out
- They have a lifespan 60% more than the conventional ones

Limitations

- Fire risk

Economic assessment

Initial investment: low. Around 10 euros/unit.
Payback: low. Less than 1 year.

References and best practices

- [262] Energy efficient lighting. Technology report: www.environment.nsw.gov.au/resources/business/140017-energy-efficient-lighting-tech-rpt.pdf

Image gallery
 Figure 215. IRC halogen lamp. Source: www.friarsmarketing.com.

2.4.4 Replacement of incandescent lamps by Compact Fluorescent Lamps (CFLs)

Measure code: LL4i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) ☐ Owners (2) ☐ Operators (3) X All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW X Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (1) (2) (3) X Contextual (1) (2) (3) X Psychological (1) (2) (3) X Physiological (1) X Social (1)

Description

In a CFL, an electric current is driven through a tube containing argon and a small amount of mercury vapor. This generates invisible ultraviolet light that excites a fluorescent coating (called phosphor) on the inside of the tube, which then emits visible light.

Benefits

- CFLs use a more efficient technology reaching the same levels of light with a power up to a 80% lower than incandescent lamps
- Lifespan 15% more than incandescent lamps
- CFLs can directly replace incandescent lamps since they carry integrated auxiliary equipment

Limitations

- Turning them on and off too frequently can reduce their lifetime
- They are meant only for ambient light
- Presence of mercury in CFLs
- A regular CFL is not meant to be used with a dimmer switch as it may burn out quickly. The same applies to use CFLs with timers

Economic assessment

Initial investment: low, around 5-7 euros/unit.
Payback: low, less than one year.
Lower maintenance costs than incandescent ones.

References and best practices

- [263] Measurement of actual efficacy of compact fluorescent lamps (CFLs): www.sciencedirect.com/science/article/pii/S0378778814009141
- [262] Energy efficient lighting. Technology report: www.environment.nsw.gov.au/resources/business/140017-energy-efficient-lighting-tech-rpt.pdf

Image gallery
 *Figure 216. CFL lamp. Source: www.onnit.com.*

2.4.5 Installation of Lighting Emitting Diode (LED) lamps

Measure code: LL5i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) ☐ Owners (2) ☐ Operators (3) X All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW X Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (1) (2) (3) X Contextual (1) (2) (3) X Psychological (1) (2) (3) X Physiological (1) X Social (1)
Description			
Light in an LED is emitted by a solid, rather than a gas object as it is the case of the fluorescent tubes. The LED is a semiconductor diode that emits light when it is crossed by an electric current. Wavelength of the emitted light and therefore color basically depends on the chemical composition of the semiconductor material used. When the current flows through the diode, energy is released in the form of photons that is light.			
Benefits			
• The start-up occurs instantly at 100% of its intensity without flicker or start-up periods • Unlike other systems, it does not degrade by the number of starts • Less polluting since they do not contain mercury • LEDs have higher efficiency in cold environments, and they are able to turn-on at low temperatures (up to -40° C)			
Limitations			
• LEDs can shift color due to age and temperature • LED performance largely depends on correctly engineering the fixture to manage the heat generated by the LED, which causes deterioration of the LED chip itself			
Economic assessment			
Initial investment: high (ten times the price of a conventional installation). However, it is an emerging technology and it is expected a decrease in the prices in a short term. Payback: high. Over 5 years. Massive reduction of maintenance costs.			
References and best practices			
- [262] Energy efficient lighting. Technology report: www.environment.nsw.gov.au/resources/business/140017-energy-efficient-lighting-tech-rpt.pdf - [264] Techno-Economic Analysis of LED Lighting: A Case Study in UTeM's Faculty Building: www.sciencedirect.com/science/article/pii/S1877705813001471			

Image gallery

Figure 217. LED lightbulbs. Source: www.energy.gov.

2.4.6 Replacement of fluorescent tubes by others with less diameter

Measure code: LL6i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) ☐ Owners (2) ☐ Operators (3) X All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW X Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (1) (2) (3) X Contextual (1) (2) (3) X Psychological (1) (2) (3) X Physiological (1) X Social (1)

Description

The most commonly used fluorescent lamps today are the T8 (ø 26 mm). However, the T5, (ø 16 mm) which only work with auxiliary electronic equipment, have been developed. This, along with its minor diameter provides a high luminous efficiency, which can reach up to 104 lm/W.

Benefits

- T5 tubes energy consumption about 35-45% less than T8
- The start-up is almost instantaneous and without flicker
- The standard average lifespan of T5 tube is three times more than traditional T8
- T5 tubes have a lower content of mercury (4 times less)
- Adapters do not require lamp change and the transformation is performed as if it were a simple tube change

Limitations

- Cause Glare

Economic assessment

Installation cost: high. T5 tube is around 50-60% more expensive than traditional T8.
Payback: between 3-5 years.

References and best practices

- [262] Energy efficient lighting. Technology report: www.environment.nsw.gov.au/resources/business/140017-energy-efficient-lighting-tech-rpt.pdf

Image gallery

Figure 218. T8 and T5 tubes. Source: www.emopa.com.

2.4.7 Replacement of standard fluorescent tubes by triphosphorous fluorescent tubes

Measure code: LL7i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) ☐ Owners (2) ☐ Operators (3) X All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW X Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (1) (2) (3) X Contextual (1) (2) (3) X Psychological (1) (2) (3) X Physiological (1) X Social (1)
Description			
Lamps that contain the next generation of phosphors offer improvements in efficiency as well as very good colour rendering.			
Benefits			
• Provide between a 12 and 15% more light • Longer lifespan (around 12,000-19,000 hours) • Better light quality • Less mercury content (2 mg against 8 mg) • High efficiency, around 75-93 lm/W whereas the standard tubes has 67-79 lm/W			
Limitations			
• Higher cost than standard tubes			
Economic assessment			
Initial investment: high cost. This is due largely to the scarcity and cost of the rare earth activator materials employed in the triphosphorous components, such as Europium, Cerium and Terbium. Payback: the triphosphorous lamps cost roughly twice as much to purchase but this initial expenditure is rapidly recouped through lower electricity consumption costs for a fixed lighting level.			
References and best practices			
- [262] Energy efficient lighting. Technology report: www.environment.nsw.gov.au/resources/business/140017-energy-efficient-lighting-tech-rpt.pdf			

Image gallery
 Figure 219. Triphosphorous fluorescent tubes. Source: www.arteleta.it.

2.4.8 Installation of more efficient luminaires with suitable light distribution

Measure code: LL8i			
Environment or playable world: ☐ Residential X Academic X Offices ☐ All	**Carried out by:** ☐ Public building users (1) X Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW X Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) (3) X Contextual (2) (3) X Psychological (2) (3) ☐ Physiological X Social (2) (3)
Description			
The efficiency of a luminaire is the relation between the luminous flux that leaves it and the luminous flux of the lamp that holds. With high efficient luminaires with modern reflection, transmission and/or refraction systems that produce light in the correct direction and well distributed illumination will be more adequate and better used, achieving an important energy reduction and an improvement in comfort and visual conditions. Also, it is essential to select the right type of luminaire for each need.			
Benefits			
• The efficiency can achieve up to 125 lm/W • Savings of 35% of the energy consumed, reaching up to 75% in combination with dimmable technologies, presence detectors and daylight sensors • Avoid glare			
Limitations			
• An efficient fixture do not provide by itself an efficient illumination, because it has to be also considered its placement, its light distribution, the maintenance and other factors that may lead to a reduction in the illuminance perceived at the work place • Direct luminaires can cause glare and discomfort			
Economic assessment			
Initial investment: around 5 euros/m^2. Payback: around 4 years.			
References and best practices			
- [265] Preferred luminance distribution in working areas: www.fagerhult.com/Global/Light_support/Research/Fagerhult_Preferred-luminance-distribution-in-working-areas.pdf			

Image gallery

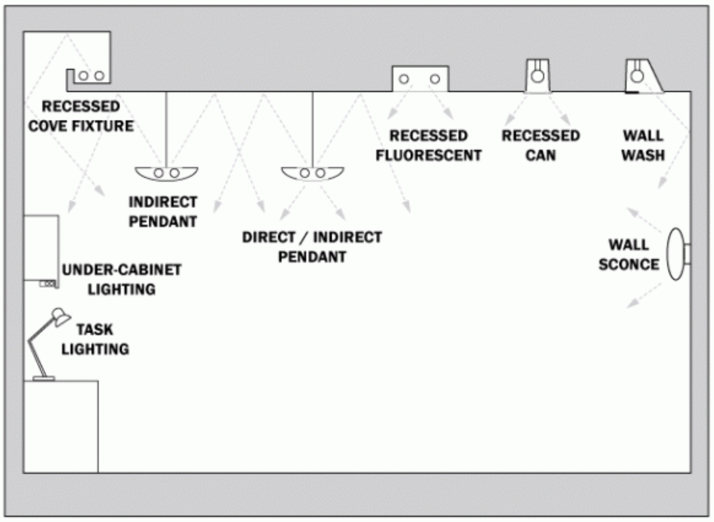


Figure 220. Types of luminaires. Source: www.archtoolbox.com.

2.4.9 Installation of presence detectors in sporadic use zones

Measure code: LL9i			
Environment or playable world: ☐ Residential X Academic X Offices ☐ All	**Carried out by:** ☐ Public building users (1) X Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW X Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) (3) X Contextual (2) (3) X Psychological (2) (3) ☐ Physiological X Social (2) (3)
Description			
Presence detectors are used to connect or disconnect the lighting of any space according to the existence or not of people in the same. With this, the turn on and off control is performed automatically, without forcing anyone to operate it, so a switch will only remain on when it is really required that the room is illuminated, achieving energy savings which can be important at the same time.			
Benefits			
• Energy consumption due to carelessness is eliminated • Energy savings around 40% of the typical consumption of sporadic use zones are achieved • Easy to install and configure.			
Limitations			
• Only recommended in toilets, corridors and intermittent waiting room areas with low or medium people traffic • The reliability of a motion sensor may also be affected by rapid environmental changes and direct sunlight			
Economic assessment			
Initial investment: medium. Around 80 euros/unit. Payback: medium. 3 to 5 years.			
References and best practices			
- [266] The lighting handbook: www.zumtobel.com/PDB/teaser/EN/lichthandbuch.pdf - [267] The beginner's guide to motion sensors: www.safewise.com/resources/motion-sensor-guide			

Image gallery

Figure 221. Presence detector. Source: www.schneider-electric.com.

2.4.10 Installation of time delay switches in sporadic use zones

Measure code: LL10i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) ☐ Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW X Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (3) X Contextual (3) X Psychological (3) ☐ Physiological ☐ Social

Description

Timing switcher is a device that once it has been pressed, it remains on during an established period of time and then automatically turns off. In this way, there is not waste of light because of carelessness of users.

Benefits

- Energy savings about 25-40% can be obtained
- Easy to install – direct replacement for existing light switches
- Ideal for new and retrofit application
- Simple to operate

Limitations

- Just applicable in sporadic use zones (toilets, corridors…)

Economic assessment

Initial investment: low. Around 20-45 euros/unit.
Payback: short. The average period is 12 months.
No maintenance costs.

References and best practices

- [268] Switching control and time-delay identification: www.sciencedirect.com/science/article/pii/S1007570414001816

Image gallery

Figure 222. Time delay switches. Source: www.mselectronics.co.uk.

2.4.11 Installation of manual potentiometer switches

Measure code: LL11i

Environment or playable world:	Carried out by:	Reduce consumption of:	Type of driver:
☐ Residential ☐ Academic ☐ Offices X All	☐ Public building users (1) ☐ Owners (2) ☐ Operators (3) X All	☐ Heating ☐ Cooling ☐ DHW X Lighting ☐ Electric devices	X Physical environmental (1) (2) (3) X Contextual (1) (2) (3) X Psychological (1) (2) (3) X Physiological (1) X Social (1)

Description

It is a high frequency push/rotatory or slide dimmer switch. The DC supply can be increased or decreased by the switch to affect the resistance, hence the dimness of the lamp. This form of dimming requires a dimming pair of cables to be run around to each fitting in the circuit in order for it to operate.

Benefits

- An older system which some contractors feel more comfortable with
- No interference with the switching of the luminaire
- Inexpensive and easy to use position sensor

Limitations

- A separate dimming pair must be wired to each fitting in the circuit
- Limited control options
- Daylight linked dimming, or movement detectors

Economic assessment

Initial investment: low.
Payback: low.

References and best practices

- [269] A self-controlled energy efficient office lighting system: www.sciencedirect.com/science/article/pii/S1815385211000368#

Image gallery

Figure 223. Potentiometer switch. Source: www.lighting.philips.es.

2.4.12 Installation of programmable timer switches

Measure code: LL12i			
Environment or playable world: ☐ Residential X Academic X Offices ☐ All	**Carried out by:** ☐ Public building users (1) X Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW X Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) (3) X Contextual (2) (3) X Psychological (2) (3) ☐ Physiological X Social (2) (3)
Description			
Scheduling switches turn on and off lights according to an established schedule for each zone, avoiding that the lamps are lit at times that they are not necessary, as nights, holidays and weekends.			
Benefits			
• Low-medium energy savings. Around 10% of the total electric consumption			
Limitations			
• If an exceptional change on schedule happens, there may be lights switched-on in unoccupied spaces • Only applicable for lighting installations with a cyclic operation			
Economic assessment			
Initial investment: low. Between 80-100 euros/unit. Payback: less than one year.			
References and best practices			
- [258] Best practices in lighting: www.iesanz.org/_r103/media/system/attrib/file/805/1_quality_%26_sustainability.pdf			
Image gallery			

Figure 224. Programmable timer switches. Source: www.homedepot.com.

2.4.13 Installation of daylighting sensors (on/off)

Measure code: LL13i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) ☐ Owners (2) ☐ Operators (3) X All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW X Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (1) (2) (3) X Contextual (1) (2) (3) X Psychological (1) (2) (3) X Physiological (1) X Social (1)

Description

It is a system that automatically adjusts the quantity of light emitted by the lamp according to the contribution of natural light in the area where it is located. The lamps are connected/disconnected automatically to detect a level of determined brightness (they are turned on at night and turned off during the day).

Benefits

- Medium energy savings depending on the natural light contribution in the rooms (up to about 30%)
- Ability to designate lighting zones
- Lower maintenance

Limitations

- More complicated lighting schematics & installation
- Longer installation
- Products require initial calibration
- May not work properly if installed in an improper location

Economic assessment

Initial investment: medium. Depending on the type of installation and the type of existing luminaires.
Payback: medium. Between 3 and 5 years.

References and best practices

- [270] Evaluation of lighting performance in office buildings with daylighting controls: www.sciencedirect.com/science/article/pii/S0378778801000676

Image gallery
 Figure 225. Daylight sensor control (on/off). Source: www.wattstopper.com.

2.4.14 Installation of daylighting sensors (dimmer)

Measure code: LL14			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) ☐ Owners (2) ☐ Operators (3) X All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW X Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (1) (2) (3) X Contextual (1) (2) (3) X Psychological (1) (2) (3) X Physiological (1) X Social (1)
Description			
It is a system that automatically adjusts the quantity of light emitted by the lamp according to the contribution of natural light in the area where it is located. The amount of light emitted by the lamp gradually changes according to the contribution of natural light that there is at every moment.			
Benefits			
• Medium energy savings depending on the natural light contribution in the rooms (up to about 30%) • Ability to designate lighting zones • Lower maintenance			
Limitations			
• More complicated lighting schematics & installation • Longer installation • Products require initial calibration • It may not work properly if it is installed in an improper location.			
Economic assessment			
Initial investment: medium. Depending on the type of installation and the type of existing luminaires (between 60-100 euros). Payback: medium. Between 3 and 5 years.			
References and best practices			
- [271] The impact of daylight fluctuation on a daylight dimming control system in a small office: www.sciencedirect.com/science/article/pii/S0378778806002623			

Image gallery
 Figure 226. Daylight sensor control (dimmer). Source: www.graybar.com.

2.4.15 Reduce lamps wattage or illuminance where there is over-illumination

Measure code: LL15i			
Environment or playable world: ☐ Residential X Academic X Offices ☐ All	**Carried out by:** ☐ Public building users (1) ☐ Owners (2) ☐ Operators (3) X All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW X Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (1) (2) (3) X Contextual (1) (2) (3) X Psychological (1) (2) (3) X Physiological (1) X Social (1)

Description

The measure consists in reducing the illuminance (and consequently wattage) levels in areas where, after the measuring of illuminance levels, result that lighting is higher than the maximum values established for the developed activity in that area.

Benefits

- Energy savings in lighting depending on how much the over-illumination is
- Over-illumination can cause headaches, fatigue, medically defined stress and anxiety
- Increase workers productivity
- Increase visual comfort

Limitations

- A preliminary lighting study is necessary

Economic assessment

Initial investment: medium. It depends mainly on the type of lamps that are installed and on the quantity of lamps which have to be replaced. If this measure is combined with the replacement of inefficient lights for efficient ones is very profitable.

References and best practices

- [272] Health effects about over-illumination: www.healthfitnessportal.com/health-effects-about-over-illumination.html

Image gallery

Figure 227. A digital photometer. Source: www.phys.ufl.edu.

2.5 Electric devices measures

2.5.1 Purchase of Energy Star label devices

Measure code: EDL1i			
Environment or playable world:	**Carried out by:**	**Reduce consumption of:**	**Type of driver:**
☐ Residential X Academic X Offices ☐ All	☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	☐ Heating ☐ Cooling ☐ DHW ☐ Lighting X Electric devices	X Physical environmental (2) X Contextual (2) X Psychological (2) ☐ Physiological ☐ Social

Description

The Energy Star label can be found on computers, monitors, copiers, printers, faxes and scanners, among others, and it ensures that equipment meet some minimum energy efficiency requirements, after a time without being used, they turn to a resting state in which the consumption is a 15% of the normal one.

Benefits

- The savings potential is medium to high. It can be obtained savings over 50% of electrical energy used in the electrical equipment
- The higher price compared with equipment with similar performance is quickly amortizable
- Reduce electricity cost

Limitations

- The price difference in equality performance is high

Economic assessment

If the purchase of equipment is managed properly, it can be saved up to 85% of its cost of operation.

References and best practices

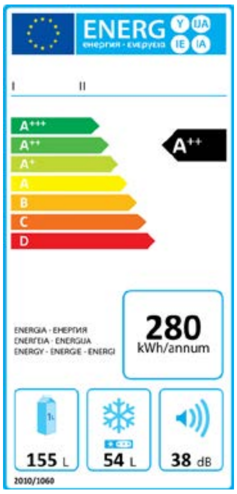
- [273] Topten Europe: www.topten.eu
- [274] Energy Star: www.energystar.gov

Image gallery

Figure 228. Energy Star label. Source: www.energystar.gov.

2.5.2 Purchase of A+++ electrical appliances

Measure code: EDL2i			
Environment or playable world: X Residential ☐ Academic ☐ Offices ☐ All	**Carried out by:** X Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW ☐ Lighting X Electric devices	**Type of driver:** X Physical environmental (1) (2) X Contextual (1) (2) X Psychological (1) (2) ☐ Physiological X Social (1) (2)
Description			
The EU established a system of energy labelling for better information on energy consumption of existing appliances on the market. It consists of A+++ to G rating (according to the energy consumption) with the A+++ having the best performance. E.g. a refrigerator of class A+++ consumes a 50% less compared with one of class A+.			
Benefits			
• The energy savings for a household with efficient equipment with respect to the same with inefficient appliances, can be up to 70% • The higher price compared with equipment with similar performance is quickly amortizable			
Limitations			
• The price difference for equal performance is high			
Economic assessment			
There is a renewal plan which consists of a grant aid to consumers to replace their appliances by more efficient ones. In Spain, the replacement of 2,600,000 appliances by others more efficient thanks to renewal plan of 2006 is expected to generate a total energy saving of more than one billion euros. The payback time could be of 3 or 4 years and there is a reduction of electricity cost.			
References and best practices			
- [275] Council Directive 92/75/EEC of 22 September 1992 on the indication by labelling and standard product information of the consumption of energy and other resources by household appliances: www.eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:31992L0075 - [275] Directive 92/75/EC was replaced by Directive 2010/30/EU which must be applied from 31 July 2011: www.eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:32010L0030			

Image gallery
 *Figure 229. Example EU energy label for a refrigerator. Source: [www.prefieres.es.](http://www.prefieres.es)*

2.5.3 Purchase of laptops instead of desktop computers

Measure code: EDL3i			
Environment or playable world: ☐ Residential X Academic X Offices ☐ All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW ☐ Lighting X Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) X Physiological (2) X Social (2)
Description			
In general, laptops are more efficient equipment than desktop computers. They have screens of liquid crystal which consumes much less energy than any conventional PC monitor, and they incorporate more energy-saving options.			
Benefits			
• Laptop computers consume up to 80% less electricity than desktop computers • Laptop are portable and can run on battery power • The higher price compared to desktop computers is quickly amortizable			
Limitations			
• Desktop computers can reach better performance than laptops • The choice between a desktop computer and a laptop could not be only based on its energy efficiency. It depends mainly on the users' needs • Often, the reason of not buying the highest score appliances is the price difference for equal performance			
Economic assessment			
A desktop computer price starts as low as 400€. Laptops can reach 1500€ or more depending on the brand and could cost up to a 40% more than a desktop computers.			
References and best practices			
- [276] Analyzing the environmental impacts of laptop enclosures using screening-level life cycle assessment to support sustainable consumer electronics: www.sciencedirect.com/science/article/pii/S095965261500801X - [277] Evolving materials, attributes, and functionality in consumer electronics: Case study of laptop computers: www.sciencedirect.com/science/article/pii/S0921344915000683			

Image gallery
 *Figure 230. Laptop. Source: www.forums.hardwarezone.com.*

2.5.4 Purchase of monitors with LCD screen

Measure code: EDL4i			
Environment or playable world: ☐ Residential X Academic X Offices ☐ All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW ☐ Lighting X Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) X Physiological (2) X Social (2)
Description			
Monitors with LCD (liquid crystal) screen consume between a 50-70% less energy in on mode than conventional screens of CRT (cathode ray). The most efficient LCDs monitors are those which are back illuminated with LED known also as LED monitors.			
Benefits			
• For an average of eight hours of workday, the energy savings of a LCD monitor against a CRT of the same size can reach up to 100 kWh/year • LCD screen occupies less space compared with a CRT monitor • The visualization of image on LCD screen is better than on CRT monitors			
Limitations			
• The price of a LCD screen is higher, but is quickly amortizable			
Economic assessment			
Initial investment: medium. The cost of a LCD monitor of 24” back illuminated with LED costs approximately 300€. It reduces electricity cost.			
References and best practices			
- [278] Life Cycle Assessment of CRT, LCD and LED monitors: www.sciencedirect.com/science/article/pii/S2212827115000414			

Image gallery
 *Figure 231. LED back illuminated monitor versus fluorescent back illuminated monitors (LCD). Source: www.computeropedia.com.*

2.5.5 Purchase double-sided copiers and printers

Measure code: EDL5i			
Environment or playable world: ☐ Residential X Academic X Offices ☐ All	**Carried out by:** ☐ Public building users (1) X Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW ☐ Lighting X Electric devices	**Type of driver:** X Physical environmental (2) (3) X Contextual (2) (3) X Psychological (2) (3) ☐ Physiological X Social (2) (3)
Description			
It is recommended to purchase copiers and printers that print double-sided.			
Benefits			
• The savings potential is medium to high, although it depends on the equipment and the use of them. It can be obtained savings over 50% of electrical energy used in the electrical equipment			
Limitations			
• Often, the reason of not buying the highest score appliances is the price difference for equal performance, despite being quickly amortizable			
Economic assessment			
If the purchase of equipment is managed properly, it can be saved up to 85% of its cost of operation.			
References and best practices			
- [273] Topten Europe: www.topten.eu - [274] Energy Star: www.energystar.gov			
Image gallery			

Figure 232. Double sided copiers and printers. Source: [www.pcmag.com.](www.pcmag.com)

2.5.6 Purchase bi-thermic washing machines

Measure code: EDL6i			
Environment or playable world: X Residential ☐ Academic ☐ Offices ☐ All	**Carried out by:** X Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW ☐ Lighting X Electric devices	**Type of driver:** X Physical environmental (1) (2) X Contextual (1) (2) X Psychological (1) (2) ☐ Physiological X Social (1) (2)

Description

The "bi-thermic" washing machines have 2 inputs of water: the cold and the hot, so hot water can be provided by the DHW system, which could use solar thermal energy.

Benefits

- Extend the lifespan of the washing machine because there are not resistors which are often vulnerable
- Savings up to 70% can be reached
- Washing time reduced

Limitations

- Often, the reason of not buying the highest score appliances is the price difference for equal performance, despite being quickly amortizable

Economic assessment

Initial investment: high. In the Spanish Plan Renove program a support of 105€ was available upon replacement of an old washing machine. It reduces costs in electricity.

References and best practices

- [279] Dishwasher and washing machine heated by a hot water circulation loop: www.sciencedirect.com/science/article/pii/S1359431106001694
- [280] Assessing the benefits of domestic hot fill washing appliances: www.sciencedirect.com/science/article/pii/S0378778815001322

Image gallery

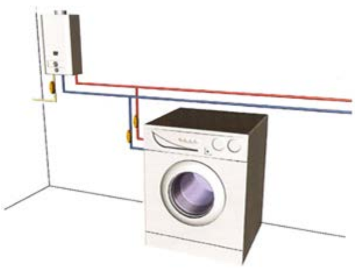


Figure 233. Connection of a bi-thermal washing machine. Source: www.gasnaturaldistribucion.com/.

2.5.7 Purchase bi-thermic dishwashers

Measure code: EDL7i

Environment or playable world:	**Carried out by:**	**Applicable to:**	**Type of driver:**
X Residential ☐ Academic ☐ Offices ☐ All	X Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	☐ Envelope ☐ HVAC ☐ DHW ☐ Lighting X Electrical devices ☐ Other	X Physical environmental (1) (2) X Contextual (1) (2) X Psychological (1) (2) ☐ Physiological X Social (1) (2)

Description

The "bi-thermic" dishwashers have 2 inputs of water: the cold and the hot, so hot water can be reached from the DHW system, which is heated by solar thermal energy.

Benefits

- Extend the lifespan of the dishwasher because there are not resistors which are vulnerable
- Savings up to 68% can be reached
- Reduce wash time

Limitations

- Often, the reason of not buying the highest score appliances is the price difference for equal performance, despite being quickly amortizable
- It is convenient this type of washing machine if it is habitual to wash with hot water

Economic assessment

Initial investment: high. In the Spanish Plan Renove program a support of 105€ was available upon replacement of an old dishwasher and it also reduces cost in electricity.

References and best practices

- [279] Dishwasher and washing machine heated by a hot water circulation loop: www.sciencedirect.com/science/article/pii/S1359431106001694
- [280] Assessing the benefits of domestic hot fill washing appliances: www.sciencedirect.com/science/article/pii/S0378778815001322

Image gallery

Type of energy	Conventional dishwasher	Hot-fill dishwasher
Electricity consumption (kWh)	1.27	0.79
Gas consumption (kWh)	-	0.86

(Wash programme at 65ºC, water consumption: 18 litres)

Figure 234. Comparative dishwashing consumption. Source: www.gasnaturaldistribucion.com/.

2.5.8 Install vending machine misers

Measure code: EDL8i			
Environment or playable world: ☐ Residential X Academic X Offices ☐ All	**Carried out by:** ☐ Public building users (1) X Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW ☐ Lighting X Electric devices	**Type of driver:** X Physical environmental (2) (3) X Contextual (2) (3) X Psychological (2) (3) ☐ Physiological X Social (2) (3)
Description			
The vending misers use sensors which control the occupancy near the vending machine and the temperature inside the machine. The vending miser will turn off the advertising light if the area near the vending machine is vacancy for more than 15 minutes and will power down the machine when the temperature of beverages and snacks is reached.			
Benefits			
• Extend life of fluorescent lamps inside the machine • Savings in electricity consumption are between 30% and 50% of the vending machine annual consumption • Reduce maintenance cost			
Limitations			
• When the vending miser turn off the light and/or the power of the machine people think that the machine is not operating and vending sales may be reduced. A decal could be placed on the vending machine to avoid this issue • The sensors normally are placed on the wall near the machines, so if you need to displace them, you would need to unmount also the sensor			
Economic assessment			
Initial investment: medium. The cost of a vending miser is approximately 180€. The payback time is short, approximately 1 year depending on the cost of electricity and it reduces cost in electricity.			
References and best practices			
- [281] Boston college vending machine energy audit project report: www.bc.edu/content/dam/files/schools/cas_sites/envstudies/pdf/Student%20Research/5_Vending_Machine_Energy_Efficiency_paper.pdf - [282] Analysis of NREL Cold-Drink Vending Machines for Energy Savings: www.nrel.gov/docs/fy03osti/34008.pdf			

Image gallery
 Figure 235. Vending miser installation. Source: www.vendingmiserstore.com/.

2.5.9 De-lamp vending machines

Measure code: EDL9i			
Environment or playable world: ☐ Residential X Academic X Offices ☐ All	**Carried out by:** ☐ Public building users (1) X Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW ☐ Lighting X Electric devices	**Type of driver:** X Physical environmental (2) (3) X Contextual (2) (3) X Psychological (2) (3) ☐ Physiological X Social (2) (3)

Description

The lighting system of a vending machine consumes an important portion of its total energy consumption, that is, the light and ballast use typically about 180 W and the total consumption of a vending machine is 400W. The measure consists in de-lamping the advertising light inside the machine.

Benefits

- Energy savings up to 45% of the vending machine consumption can be reached

Limitations

- Removing the advertising light could reduce vending sales although a decal could be placed on the vending machine to avoid this issue

Economic assessment

The cost is zero. Savings up to 300€/year, considering an electricity cost of 0.14 €/kWh, could be reached, and the cost in electricity is reduced.

References and best practices

- [281] Boston college vending machine energy audit project report: www.bc.edu/content/dam/files/schools/cas_sites/envstudies/pdf/Student%20Research/5_Vending_Machine_Energy_Efficiency_paper.pdf
- [282] Analysis of NREL Cold-Drink Vending Machines for Energy Savings: www.nrel.gov/docs/fy03osti/34008.pdf

Image gallery

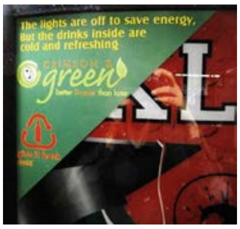


Figure 236. Recall for de-lamped vending machine. Source: www.linkedin.com.

2.5.10 Purchase of induction plates

Measure code: EDL10i			
Environment or playable world: X Residential ☐ Academic ☐ Offices ☐ All	**Carried out by:** X Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW ☐ Lighting X Electric devices	**Type of driver:** X Physical environmental (1) (2) X Contextual (1) (2) X Psychological (1) (2) ☐ Physiological X Social (1) (2)
Description			
The measure consists in installing induction plates in the kitchen instead of gas or electrical cookers.			
Benefits			
• The cooking heat could be adjusted instantaneously and with great precision as well as with gas cookers • Energy is supplied only to the cooking vessel by the magnetic field • There are not heat losses so heat gains in the surroundings are avoided • The efficiency of an induction cooker is about 84% compared with a gas cooker which is 40% • It is safe because the stovetop stays cool • Easy installation • Easy to clean			
Limitations			
• It only works with cooking vessels made of magnetic materials • Induction plates emit radiations which could affect the health of users as it happens with mobile phones • The cost savings compared with a gas cooker depends on gas costs			
Economic assessment			
Initial investment: high. An induction cooker of 4 stoves could cost around of 500€.			
References and best practices			
- [283] Experimental Study of Induction Cooker Fire Hazard: www.sciencedirect.com/science/article/pii/S1877705813002178 - [284] A prediction of the acoustical properties of induction cookers based on an FVM–LES-acoustic analogy method: www.sciencedirect.com/science/article/pii/S0307904X11002241			

Image gallery

Figure 237. Induction stove functioning. Source: blog.estrading.com.au/.

2.5.11 Consider the use of a common laundry instead of in-unit washing machine

Measure code: EDL11ib			
Environment or playable world: X Residential ☐ Academic ☐ Offices ☐ All	**Carried out by:** X Public building users (1) ☐ Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW ☐ Lighting X Electric devices	**Type of driver:** X Physical environmental (1) X Contextual (1) X Psychological (1) X Physiological (1) X Social (1)
Description			
In multi-family buildings consider the use of common washing machines instead of installing washing machines in each apartment unit.			
Benefits			
• Apartment floor spaces is saved • Higher load capacity of common washing-machines • Energy savings • Water savings			
Limitations			
• Community area laundry rooms can result stale, overcrowded, noisy, and generally unfriendly looking places • Common washing machines must be efficient			
Economic assessment			
Initial investment: medium. The economic availability depends mainly if the apartments have already a washing machine installed.			
References and best practices			
- [285] Why community area laundry rooms?: www.mla-online.com/guide.htm			
Image gallery			

Figure 238. Common area laundry facilities. Source: www.allianceforwaterefficiency.org.

2.6 Other measures

2.6.1 Installation of solar thermal panels

Measure code: OL1i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling X DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) (3) X Contextual (2) (3) X Psychological (2) (3) ☐ Physiological X Social (2) (3)
Description			
A solar thermal energy system is a technology that harnesses solar radiation to produce thermal energy, which can be used later on as DHW, heating or for swimming pool heating, among others. Additionally, by means of a trigeneration system, it can be even used for cooling.			
Benefits			
• These systems can generate up to 70% of the energy needed in most residential and commercial establishments to power up the central water heating system. This means that renewable power is always available which can greatly reduce the need of fuel or gas and can help reduce electricity and/or gas (or other fuel) bills • It is a green-energy source, as it does not emit carbon dioxide to the environment • The installation is simple as it can be easily integrated to the existing heating systems			
Limitations			
• This type of system is less effective in winter and an additional auxiliary device should be installed, like boiler or immersion-heater, to ensure that the heating system will still work during the winter months • The best performance occurs during summer months where there is not much need of a heating system			
Economic assessment			
Initial investment: High/middle cost (400-600 €/m^2). An upfront investment to purchase the equipment and pay the installation is required to setup the system. Payback estimated: 5-8 years, depending on the system configuration, subsidies, energy source replaced and others.			
References and best practices			
- [286] A review of solar collectors and thermal energy storage in solar thermal applications: www.sciencedirect.com/science/article/pii/S0306261912008549 - [287] Experience on integration of solar thermal technologies with green buildings: www.sciencedirect.com/science/article/pii/S0960148107003011			

Image gallery

Figure 239. Solar thermal evacuated tubes in a building. Source: [www.yougen.co.uk.](www.yougen.co.uk)

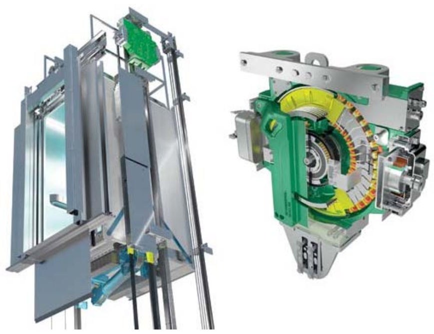
2.6.2 Installation of photovoltaic panels

Measure code: OL2i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW X Lighting X Electric devices	**Type of driver:** X Physical environmental (2) (3) X Contextual (2) (3) X Psychological (2) (3) ☐ Physiological X Social (2) (3)
Description			
Photovoltaic panels (PV) convert solar radiation into electric current. To take advantage of the collected energy, due to its difficult storage, and the high losses that imply, these collection systems are connected to the electric grid, selling electricity in hours of production, and buying it in the hours of use. Isolated systems are used in places away from the grid to achieve a self-sufficient building. The systems can be exploited by individuals, or public and private investors.			
Benefits			
• PV allows covering the needs of electricity consumption of the building, essentially of lighting. • If it covers a 100% of the electricity consumption, it would be around 25% of the total standard consumption in the building • Different technologies allow a great variety of possibilities and benefits • Different configurations			
Limitations			
• The times of collection and production do not match with consumption, and electrical energy is hard to store. • The storage systems with batteries have low efficiency so losses are elevated. • The optimal performance of the system will depend on factors such as the inclination and orientation. The best architectural integration cannot match with the proper installation			
Economic assessment			
The cost of the installation per watt-peak is 3-4 €/Wp. To produce 1 Wp, a surface between 7 and 15 m^2 is required and the installation costs from 1300 €/m^2. The lifespan is approximately 30 years.			
References and best practices			
- [288] Best practice guide photovoltaics (PV): www.seai.ie/Publications/Renewables_Publications_/Solar_Power/Best_Practice_Guide_for_PV.pdf - [289] Building-integrated photovoltaic designs for commercial and institutional structures: www.nrel.gov/docs/fy00osti/25272.pdf			

Image gallery
 Figure 240. PV solar panel. Source: www.grenum.com.

2.6.3 Installation of direct traction electric lifts

Measure code: OL3i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW ☐ Lighting X Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) ☐ Physiological ☐ Social
Description			
The latest generation lifts are electric of direct traction with smaller machines, thus avoiding reduction elements such as gears, bearings, oils, etc. This type of lifts supposes a significant technological change in what refers to energy consumption and energy efficiency.			
Benefits			
• The saving potential is medium-low, but it depends on the lift and its use. In large buildings savings can be up to 20% of the energy and 30% on the electricity bill • These lifts consume between 25% and 40% less than conventional electric lifts and around 60% less than hydraulic lifts • They generate up to ten times less noise			
Limitations			
• Its maximum speed is 2.5 m/s • A machines room in the last level or rooftop is required • It is used in buildings with less than 50 levels			
Economic assessment			
Initial investment: medium-high, depending on the type of lift, its use and if it is used by other persons/companies in the same building.			
References and best practices			
- [290] Energy-efficient elevators and escalators in Europe - An analysis of energy efficiency potentials and policy measures: www.sciencedirect.com/science/article/pii/S0378778811006530 - [291] Advancing elevator energy efficiency: www.prefieres.es/images/articulos/Biblioteca-138.pdf			

Image gallery
 Figure 241. Energy efficient elevator. Source: www.hightechfinland.com.

2.6.4 Installation of mechanisms of selective manoeuvre for several lifts

Measure code: OL4i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW ☐ Lighting X Electric devices	**Type of driver:** X Physical environmental (2) (3) X Contextual (2) (3) X Psychological (2) (3) ☐ Physiological X Social (2) (3)

Description

To optimize the rides, in case of being available several lifts, mechanisms of selective manoeuvre can be installed, which activate only the call of the closest lift to the required point and provide a faster and more energy-efficient service.

Benefits

- The energy saving potential is medium-low, but it depends on the lift and its use. In large buildings savings can be up to 20% of the energy and 30% on the electricity bill.

Limitations

- It is only applicable in the case of several lifts

Economic assessment

Initial investment: medium-high, depending on the type of lift, the use of the same and if it is used by other persons/companies in the same building.

References and best practices

- [290] Energy-efficient elevators and escalators in Europe - An analysis of energy efficiency potentials and policy measures: www.sciencedirect.com/science/article/pii/S0378778811006530
- [291] Advancing elevator energy efficiency: www.prefieres.es/images/articulos/Biblioteca-138.pdf

Image gallery

Figure 242. Mechanisms of selective manoeuvre for several lifts. Source: www.five.es.

2.6.5 Installation of a Building Energy Management System (BEMS)

Measure code: OL5i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling X DHW X Lighting X Electric devices	**Type of driver:** X Physical environmental (2) (3) X Contextual (2) (3) X Psychological (2) (3) X Physiological (2) (3) X Social (2) (3)

Description

BEMS are computer-based systems that help to manage, control and monitor building technical services (HVAC, lighting etc.) and the energy consumption of devices used within the building. They provide the information and the tools that building managers need both to understand the energy usage of their buildings and to control and improve their buildings' energy performance.

Benefits

- Increase energy efficiency
- Energy savings between 5% and 40%
- Improved environmental conditions
- More efficient use of staff
- Improve fire, security and other emergency procedures
- Improve standards of plant/building performance
- Improve the management of the building

Limitations

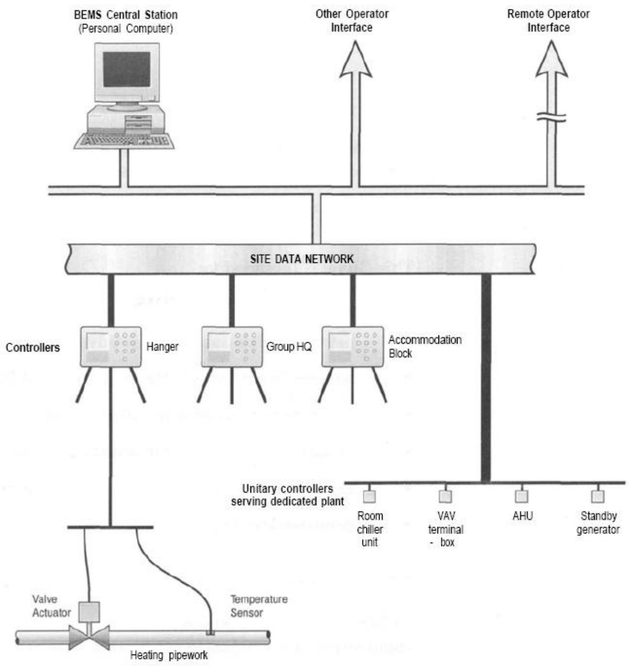
- It needs a skilled operator
- It requires commitment at all levels throughout its operational life to maintain maximum effectiveness

Economic assessment

Higher initial costs for design and installation. Operation and maintenance costs might be higher compared to simpler management systems. However, the BEMS is also capable of reducing overall costs through improved energy efficiency and more efficient use of staff.

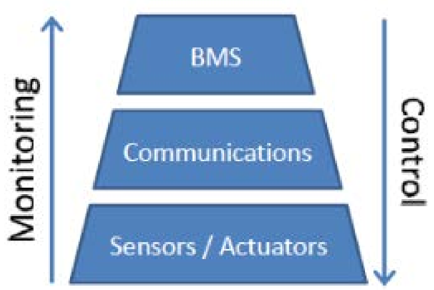
References and best practices

- [292] Building energy management systems. Towards energy smart buildings: www.envirocentre.ie/includes/images/Building%20Energy%20Management%20Systems.pdf

Image gallery
 *Figure 243. Main components of a BEMS. Source: www.climatetechwiki.org.*

2.6.6 Installation of an ICT system

Measure code: OL6i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling X DHW X Lighting X Electric devices	**Type of driver:** X Physical environmental (2) (3) X Contextual (2) (3) X Psychological (2) (3) ☐ Physiological ☐ Social
Description			
ICT has been identified as one possible means to design, optimize, regulate and control energy use within existing and future (smart) buildings. ICT could not only be used for decreasing the energy consumption in buildings, but also to create new business opportunities driven by the need of energy efficiency.			
Benefits			
• Monitor that the performance and energy efficiency are stable during the life time of the building and do not decrease • Achieve more energy savings combining the operation of the different systems in the building • Provide feedback to change user's behaviour and install new energy efficient technologies or fine tune those already installed			
Limitations			
• Battery life of the devices • Some portable devices are heavy • Small screens and keyboards • Low bandwidth			
Economic assessment			
The feasibility of an investment in ICT for energy efficiency depends on a variety of factors, such as: structure of energy bills, the actual or expected consumption levels, features of the building, users' profiles, etc. For this reason, prior to the investment, an audit should be carried out to assess the possible savings to be achieved, combining traditional retrofitting actions with the use of ICT awareness tools.			
References and best practices			
- [293] Reducing energy consumption in buildings with ICT-analysis of data from EU pilot Projects-smart 2013/0073: www.ict4ee-analysis.eu/result.html			

Image gallery
 *Figure 244. ICT infrastructure. Source: [www.ict4ee-analysis.eu.](http://www.ict4ee-analysis.eu)*

2.6.7 Installation of smart meters

Measure code: OL7i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) X Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling X DHW X Lighting X Electric devices	**Type of driver:** X Physical environmental (2) (3) X Contextual (2) (3) X Psychological (2) (3) ☐ Physiological X Social (2) (3)
Description			
A smart meter is usually an electronic device that records electricity consumption in intervals of an hour or less and communicates that information at least daily back to the utility for monitoring and billing.			
Benefits			
• Remove estimated meter reads and generate accurate invoices • Reduce the cost of including a "pedestrian read" in the energy prices			
Limitations			
• Smart meters could control, regulate, and ration the use of an utility (load limiting) • Introduction of time in use tariffs			
Economic assessment			
Initial investment: around 500 euros per unit. Payback: less than four years.			
References and best practices			
- [294] Smart meter devices and the effect of feedback on residential electricity consumption: Evidence from a natural experiment in Northern Ireland: www.sciencedirect.com/science/article/pii/S0140988312003209 - [295] Smart metering for residential energy efficiency: The use of community based social marketing for behavioural change and smart grid introduction: www.sciencedirect.com/science/article/pii/S0960148113005983			

Image gallery

Figure 245. Smart meter. Source: www.deepresource.wordpress.com.

2.6.8 Installation of a Geothermal Heat Pump (GHP)

Measure code: OL8i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling X DHW ☐ Lighting ☐ Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) ☐ Physiological ☐ Social
Description			
Geothermal energy uses the heat of the layers in the subsoil as a resource for air conditioning cycles. Because of its temperature stability, the subsoil is used both in winter and in summer for HVAC systems with radiant floor. The most recommended geothermal heat pump is a water-water system. These heat pumps with a COP around 5, release and absorb the heat from the ground. Outlet temperature is around 22-30 °C.			
Benefits			
• Energy savings (around 50% of the HVAC energy consumption) • High efficiency of the low temperature equipment • The availability of the energy source for its stability throughout the year • Its durability, with a lifespan between 25 and 50 years			
Limitations			
• Open-loop systems require a large supply of clean water in order to be cost effective. This may be limited by environmental factors or by local and state regulations • Many closed-loop systems use an antifreeze solution to keep the loop water from freezing in cold temperature conditions. Most antifreeze solutions have very low toxicity, but many produce CFCs and HCFCs, which add to environmental concerns • Each unit requires both electrical and plumbing services • Duct systems must be installed to bring outside air to each space • Secondary or backup heat sources are required in cooler climates			
Economic assessment			
Initial investment: high. Depending on the type and characteristics of the building. Payback: high. More than 10 years in existing buildings. In new buildings is between 8 and 16 years, depending on the heating system with which it is compared (fuel or natural gas, respectively).			

References and best practices
- [296] Ground-source heat pumps systems and applications: www.sciencedirect.com/science/article/pii/S1364032106001249 - [297] Geothermal heat pump systems: Status review and comparison with other heating options: www.sciencedirect.com/science/article/pii/S0306261912000542
Image gallery

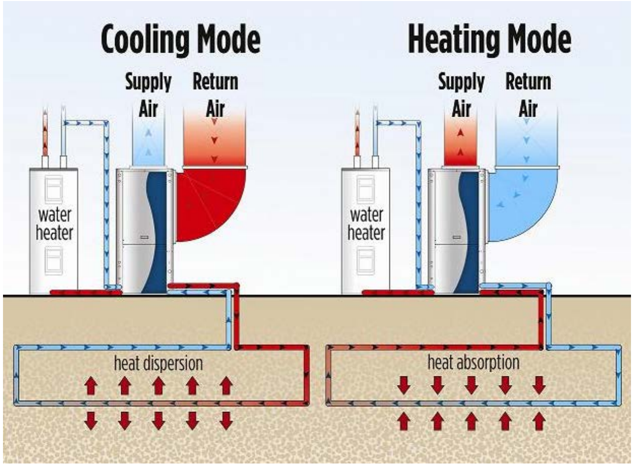


Figure 246. Cooling and heating modes of a geothermal heat pump. Source: www.platinumleedhome.com.

2.6.9 Installation of micro wind turbines

Measure code: OL9i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** ☐ Heating ☐ Cooling ☐ DHW X Lighting X Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) ☐ Physiological X Social (2)
Description			
Small wind turbine is a small turbine that is used for households and farms. They require less wind to operate than utility-scale wind energy applications. Small turbines range from 20 W to 100 kW. They only have three to four moving parts meaning very low maintenance. They have a 20 to 40 year lifespan.			
Benefits			
• The wind is free and with modern technology it can be captured efficiently • Once the wind turbine is built the energy generated does not cause greenhouse gases or other pollutants • Remote areas that are not connected to the electricity grid can use wind turbines to produce their own supply • Wind turbines are available in a range of sizes which means a vast range of people and businesses can use them.			
Limitations			
• There are zoning and permit restrictions that can stop from installing one • The strength of the wind is not constant and it varies from zero to storm force. This means that wind turbines do not produce the same amount of electricity all the time. There will be times when they do not generate electricity • Wind turbines may be noisy, especially at high wind speeds.			
Economic assessment			
Cost remains to be the one of the main factors and challenges in the dissemination of small wind. Initial investment: between 20,000 and 60,000 euros depending on the capacity. Payback: between 15 and 45 years depending on the capacity.			
References and best practices			
- [298] A small wind turbine system (SWTS) application and its performance analysis: www.sciencedirect.com/science/article/pii/S0196890405002074 - [299] Small wind turbines – A unique segment of the wind power market: www.sciencedirect.com/science/article/pii/S0960148112005083			

Image gallery

Figure 247. Small wind turbine. Source: [www.lowenergyhouse.com.](www.lowenergyhouse.com)

2.6.10 Hire a qualified company to conduct an energy audit of the building

Measure code: OL10i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling X DHW X Lighting X Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) ☐ Physiological X Social (2)
Description			
Conducting energy audits allows knowing in detail the condition of the energy equipment and systems and proposing actions to improve the energy efficiency and to achieve energy and economic savings.			
Benefits			
• Know the current energy situation both regarding energy consumption and contracting terms and conditions • Make an inventory of the main energy equipment and systems • Performing measurements and records of the main electrical, thermal and comfort parameters • Analyze the possibilities of optimization of the fuel and electricity supply • Suggest improvements and perform its technical and economic evaluation			
Limitations			
• the expectations of the customers are not exactly known • Difficulty of implementing new systems by owners • Decisions guided by protocols and previous experiences • Impersonal attitude with respect to the operation of the building			
Economic assessment			
Initial investment: low-medium. Between 0.8 and 1.2 euros/m^2. If the proposed measures are carried out, the cost of the audit increases the payback in less than one year.			
References and best practices			
- [300] Energy audit of an educational building in a hot summer climate: www.sciencedirect.com/science/article/pii/S0378778811005792 - [301] A detailed comparison of energy audits carried out by four separate companies on the same set of buildings: www.sciencedirect.com/science/article/pii/037877889090034G			

Image gallery

Figure 248. Energy audit. Source: www.nrel.gov.

2.6.11 Installation of an Energy Storage System (ESS)

Measure code: OL11i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling X DHW X Lighting X Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) ☐ Physiological ☐ Social
Description			
ESS can actually store energy and use the stored energy whenever the need arises.			
Benefits			
• It compensates the intermittency of renewable energy, such as wind and solar • It helps grid system operators to maintain a constant frequency • It can be used for curtailment of electricity from renewable energy sources • It can be used to defer transmission and distribution network upgrades and investment			
Limitations			
• Energy lost in “round trip” inefficiencies • Additional cost and complexity • Additional infrastructure and space requirements			
Economic assessment			
It enables commercial and residential owners to cut energy costs. Electricity stored during off-peak time can be used during on-peak hours so that home/commercial owners can cut peak demand and electricity cost. ESS integrated with PV can maximize the consumption of solar energy by using electricity stored off-peak.			
References and best practices			
- [302] Energy storage systems—Characteristics and comparisons: www.sciencedirect.com/science/article/pii/S1364032107000238 - [303] Electrical energy storage systems: A comparative life cycle cost analysis: www.sciencedirect.com/science/article/pii/S1364032114008284			

Image gallery
 *Figure 249. Energy storage station. Source: [www.ecopowernt.com.au.](http://www.ecopowernt.com.au)*

2.6.12 Installation of fuel cells

Measure code: OL12i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling ☐ DHW X Lighting X Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) ☐ Physiological X Social (2)

Description

A fuel cell is an electrochemical device that combines hydrogen and oxygen to produce electricity, with water and heat as its by-products. As long as fuel is supplied, the fuel cell will continue to generate power.

Benefits

- Installation of smaller stationary fuel cells leads to a more stabilized and decentralized power grid
- Fuel cells have higher efficiency than diesel or gas engines
- Most fuel cells operate silently, compared to internal combustion engines
- Operating times are much longer than with batteries, since doubling the operating time needs only doubling the amount of fuel and not the doubling of the capacity of the unit itself
- The maintenance of fuel cells is simple since there are few moving parts in the system
- The absence of combustion and moving parts means that fuel cell technologies are expected to provide an improved reliability over traditional combustion engines
- Use a variety of fuels, renewable energy and clean fossil fuels

Limitations

- Fuelling fuel cells is still a major problem since the production, transportation, distribution and storage of hydrogen are difficult
- Reforming hydrocarbons via reformer to produce hydrogen is technically challenging and not clearly environmentally friendly
- Fuel cells are in general slightly bigger than comparable batteries or engines. However, the size of the units decreases
- The technology is not yet fully developed and few products are available

Economic assessment

Fuel cells are currently very expensive to produce, since most units are hand-made. Some fuel cells use expensive materials.

References and best practices

- [304] Introduction to fuel cell technology: www3.nd.edu/~msen/Teaching/DirStudies/FuelCells.pdf

Image gallery

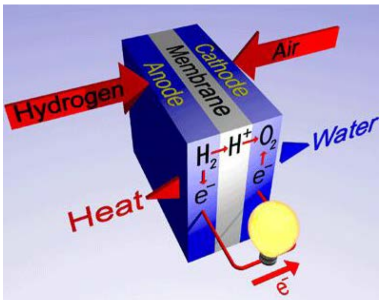


Figure 250. Fuel cell. Source: www.npl.co.uk.

2.6.13 Integration of hybrid Photovoltaic Thermal solar collectors (PVT)

Measure code: OL13i			
Environment or playable world: ☐ Residential ☐ Academic ☐ Offices X All	**Carried out by:** ☐ Public building users (1) X Owners (2) ☐ Operators (3) ☐ All	**Reduce consumption of:** X Heating X Cooling X DHW X Lighting X Electric devices	**Type of driver:** X Physical environmental (2) X Contextual (2) X Psychological (2) ☐ Physiological X Social (2)

Description

PVTs are systems that convert solar radiation into thermal and electrical energy. These systems combine a solar cell (PV module), which converts sunlight into electricity, coupled with a heat exchanger arrangement and a coolant circuit containing a heat transfer fluid for heat provision from the same collector area. The capture of both electricity and heat allow these devices to have higher exergy and thus have a total energy efficiency higher than solar photovoltaic (PV) or solar thermal systems alone.

Benefits

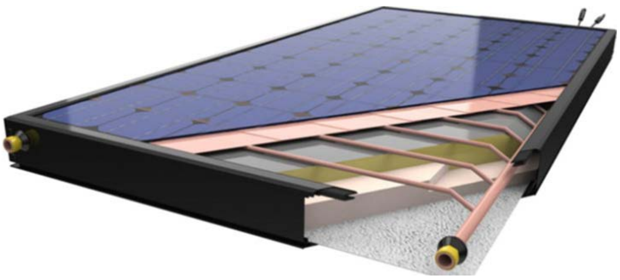
- The rest of the solar irradiance not converted in electricity by the PV cells and turned into residual heat is transferred through a heat-carrying fluid (such as air or water) to a solar accumulator
- Increase the electricity production in about 15%
- Produce more electrical and thermal energy than a corresponding area covered half with conventional PV-panels and half with conventional thermal collectors
- Reduce the space required by both separated systems by around 40%
- Provide architectural uniformity on the roof, in contrast to a combination of both PV and thermal systems separated.

Limitations

- A design conflict arises between the electrical and thermal performance because to achieve high electricity generation, low quality heat is produced, while if thermal energy is the objective, the electricity generated will be reduced
- Installing this system requires both piping and cabling for thermal and electrical circuitry respectively, and hybrid units may be heavier than separate units
- Any failure of the coolant fluid to circulate through the panel may lead to PV cell overheating

Economic assessment

A PVT module can reduce the (upfront) investment costs by about 10% compared to the joint use of PV and solar collector modules and also has the potential to reduce the financial and energy payback of PV systems depending on the location.

Payback: Around than 5 years without any Government incentive (such as Feed-in Tariffs).
References and best practices
- [305] PVT Roadmap A European guide for the development and market introduction of PV-Thermal technology. The 6th Framework Programme: www.docstoc.com/docs/59363494/pvtroadmap - [306] A UK-based assessment of hybrid PV and solar-thermal systems for domestic heating and power: System performance: www.sciencedirect.com/science/article/pii/S0306261914000907
Image gallery
 *Figure 251. PVT collector. Source: www.products.newformenergy.ie.*

3 CONCLUSIONS

The analysis of energy efficiency measures to be considered in TRIBE project has been carried out considering the main energy efficiency requirements of the real pilots and an extensive and exhaustive bibliography research complemented with the technical experience in other similar projects.

Even though the main objective of this task for TRIBE project is fulfilled, which is to identify a set of energy efficiency measures expected from the public building users, owners and operators aiming to maximize energy savings, a critical analysis of the selected measures and their interactions with the rest of the project should be undertaken, as explained in the following paragraphs.

A big effort has been carried out in trying to find uniformity between the different energy efficiency measures by means of a common template, but once starting filling in each measure “card”, the uniformity has not been always maintained due to the significant amount and different field of the measures as well as the different data obtained. Consequently, not all the measures include specific or potential energy or economic savings not even estimations, but this lack of information has been replaced with useful references or case studies where the measures were applied. Nevertheless, the specific energy and economic assessment of the measures applied to the pilot buildings of TRIBE project will be calculated and shown in Task 4.3 *“Measures and actions effects on pilots and virtual pilots”.*

In addition, a significant difficulty has appeared when categorizing the measures, because depending on their application they may be included as short or long term, or carried out by different type of users, or applied in different type of buildings. For that reason, at the beginning of each template four boxes to specify the main characteristics of the measure regarding TRIBE project have been implemented, named: i) *“Environmental or playable world”*; ii) *“Carried out by”*; iii) *“Reduce Consumption of”* and iv) *“Type of Driver”*.

The information contained in each template has been introduced bearing in mind that the objective is to explain in a basic way the main effects of each measure so that the player can have criteria at the time of selecting them.

The 250 measures shown are the final ones for this deliverable. However, considering the large number of measures, there may be incompatibilities between some of them regarding the social behaviour (WP3), monitoring (WP5) or simulation engine development (WP6). As consequence, the measures may suffer some modifications or even be replaced for other measures. This issue will be addressed in the following tasks of WP4 (Task 4.2 *“Measures and actions effects on the players’ and avatars’ behaviour change”* and Task 4.3 *“Measures and actions effects on pilots and virtual pilots”).*

In any case, it should be noted that the measures shown in this deliverable represent a valuable starting point and a solid basis for the next steps of TRIBE project.

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