Project: TRAINENERGY

IEE/08/536 SI 2.528397

Identification of Existing Training Material

Deliverable 3.1

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Date: 12/06/2010

Supported by INTELLIGENT ENERGY EUROPE

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1 Introduction

The first step in working package three was to identify training resources worked out within IEE projects and national resources in the project countries to use for the development of training materials by TRAINENERGY.

An extensive search of training material was carried out to determine the scope of new material that needed to be developed. All partners were involved in this search and information passed on to CIT. The content experts evaluated this information and found some relevant material, but in general it was noted that the training content required for TRAINENERGY was quite broad and it was decided that a lot of new content would need to be developed.

The difficulty arose from developing content that would cover all aspects of the EPBD whilst also delivering the material at a level that a tradesperson could understand, considering they may not have any foundation level learning, and may not have attended training courses for a number of years. Hence, new training material needed to be developed.

However, one particular resourse that was extensively used for the TRAINENERGY programme was the Passive-On programme

http://www.passive-on.org/en/

The material was particularly suited to TRAINENERGY on completion of a lot of foundation modules.

Also, building regulations and other government standards were used for delivery of the course and are continuously referred to in the training modules.

2 Passive-On

The Passive-On project examined how to take the Passive House concept forward, especially in Southern Europe. In these regions the problem of household energy use is one not only one of providing warm houses in winter but also, and in some cases more importantly, of providing cool houses in summer.
http://www.passive-on.org/en/

3 Country specific standards

Country specific building regulations standards were referred to throughout the course. By referring to these standards, the training material will automatically contain up to date information as building standards and regulations change.

4 Appendix: Sample Material

sei SUSTAINABLE ENERGY IRELAND

power of one

Householders

be your own energy manager

Introduction

The aim of this booklet is to assist householders to be their own energy manager. By becoming more energy aware, and understanding how, and where, we use energy at home, we can take steps to change our behaviour and develop more energy-efficient habits. This will reduce the energy we use, save money and in turn benefit the environment.

By following a five step plan, we can reap the rewards of reducing our energy use by up to 20%. And because all these changes involve changing our daily habits at home, the more you commit, the greater the savings you can achieve.

The approach we've adopted here is based on that taken by professional energy managers in large businesses with proven energy saving results. It involves following a set of planned actions: commit, identify, plan, take action, review. Once homeowners have agreed they want to reduce their energy use, they identify what their actual energy use is and set a reduced target figure, they then plan which actions they will take according to our five step plan and carry them out. At the end of the process they review how they did against their set target.

Why we use energy

We use energy to heat and light our homes and to run our appliances, TVs and computers. The residential sector is one of Ireland's largest energy consumers, accounting for almost 25% of our energy use. We also use energy to run our cars, and personal mobility is a central part of modern life. Here in Ireland, emissions from transport are growing at a faster rate than any other sector. Some energy usage is essential in the modern world, but hopefully this booklet will tell you the many practical ways each of us can save energy and make a difference to climate change.

Where our energy comes from

Most of the energy we use in Ireland comes from oil, coal, peat and gas. These are called fossil fuels. We burn these fossil fuels in our power stations to produce electricity and we also use the fuels directly to heat our homes and run our cars. Burning fossil fuels releases carbon dioxide (CO_2) into the atmosphere and is a major contributor to climate change.

Why change our patterns of energy consumption?

- ➔ We must ensure we leave sufficient energy reserves for future generations.
- ➔ We must act now to minimise the impact our energy use is having on our climate.

To achieve these outcomes, we have to change how we use energy and the types of energy we use.

Energy and climate change

The earth's climate is not constant. Scientists now agree that a definite link exists between the energy we use and climate change. When we burn fossil fuels to produce energy, we release CO_2, the main greenhouse gas into the atmosphere. Greenhouse gases act like an insulating blanket, allowing heat from the sun into the atmosphere and trapping it there. Over time, this trapped heat causes the atmosphere to slowly warm up, and this changes the global temperatures, and wind and rainfall patterns worldwide. In other words, it causes climate change. We can already see its impact on shifting weather patterns. Extreme conditions such as floods, droughts and storms are on the increase all around the world and without action these will continue and worsen in the future.

Sustainable energy

Sustainability means adopting a common-sense approach to living so that we don't waste resources, including energy, or needlessly damage the world around us. It means:

- ➔ Using energy more efficiently;
- ➔ Using renewable energy alternatives that are less harmful to the environment (wind, sun, oceans and rivers).

Being sustainable in how we use energy isn't just about helping the environment. It offers sound financial and practical benefits:

- ➔ It will save you money on your electricity, heating and motoring bills.
- ➔ Your home will be more comfortable.
- ➔ You will be helping to reduce climate change.

Behavioural change

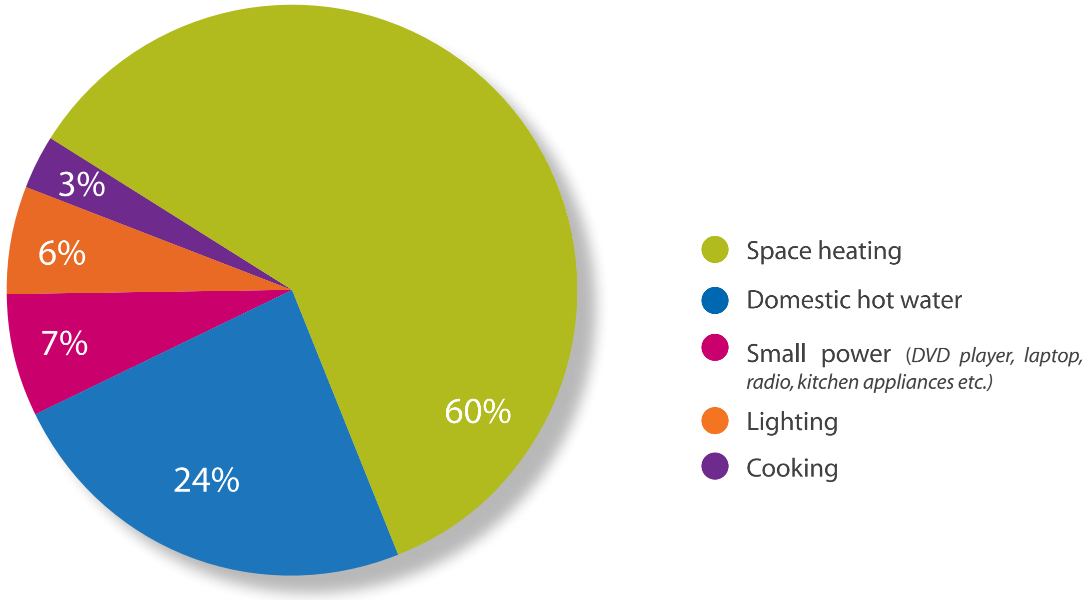
Save energy at home — being smart

Energy is essential to the comfort of our homes, providing heat and electricity. However, there are lots of ways we can be more efficient in how we use energy, while still meeting all our energy needs.

Some things you can start doing straight away and they won't cost you anything. Others take more time and effort, but by becoming more energy aware at home, you can save money, increase the comfort of your home and help reduce climate change.

It's a good idea to find out how much you spend on energy, and on what. (See the table on page 27). And it's a good idea to set some energy-saving targets, not only will achieving these save you money, they will also help to make your home more comfortable.

How do we use energy in the home?



What can I do?

Thinking and acting in an energy-efficient way in the home can reduce domestic energy consumption by 15% or more. You can achieve this by:

- ➔ Changing your behaviour and applying simple tips on how you use energy in the home;
- ➔ Considering energy efficiency when you make energy-consuming purchases.

In other words, by buying energy-efficient products and by using energy efficiently.

The five step programme

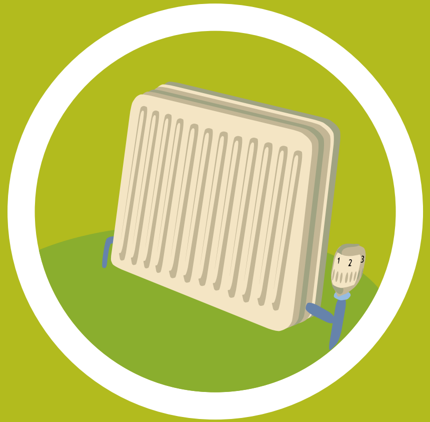
In the following sections, there are a list of tips and recommendations that you can use to reduce your energy consumption with little or no cost. By focusing on the areas that use the most energy in the home, there's greater potential for saving money. The categories we will focus on are:

- ➔ Space heating (5 weeks)
- ➔ Domestic hot water (4 weeks)
- ➔ Small power (3 weeks)
- ➔ Lighting (2 weeks)
- ➔ Cooking (1 week)
- ➔ Transport (for the duration of the whole project)

Space heating and domestic hot water are allocated more time (5 and 4 weeks) because they account for the largest percentage of energy consumption in the home (60% and 24%), and it takes a bit more time to become familiar with how these energy systems work, e.g., how they are controlled, and how to make the most effective adjustments to them to save energy.

Under each of the following energy sections are a list of tips which are organised in order of importance. The first tip in each section is a 'must do' tip. Even if you are unable to try any of the other tips listed — this tip will have a significant impact.

step 1 Space Heating



The objective here is to learn how to make your home comfortable with the minimum amount of heat, by using the heating systems and the controls that you have, e.g., programmers, timers, thermostats, and radiator valves. Experiment with the following tips and mix and match to see what works for you.

This step will take  **5 weeks**

Obtaining the ideal room temperature

Essential tips

* Switch the heating system on later in the morning and off earlier in the evening. The best way to find the right balance for your house is to experiment a little, first of all try turning on the central heating 30 minutes before you get up and off 1 hour earlier in the evening.

* Turn the heating in living areas down to 20°C – this could save you 10% off your heating bill. The temperature in hallways and bedrooms should be cooler – ideally 15-18°C. Use temperature cards (available from SEI) in a number of rooms, to prevent overheating and familiarise yourself with what different temperatures feel like.

➔ If you have a thermostat on your central-heating boiler, experiment to get the lowest setting (some systems may require a plumber). You can reduce it in mild weather, but don't go below 60°C. Typically, the optimum setting is between 70°C and 80°C (i.e. adjust the dial between 'min' & 'max' on gas boilers) — but it really pays to experiment. Make a note of the settings you try, and the results you obtain to control the heat output in response to the weather and indoor temperatures.

➔ Use Thermostatic Radiator Valves (TRVs) to adjust heat output from radiators when in rooms in response to your heating needs.

Zoning

➔ Use internal doors to maintain heating zones and distribution of heat throughout the main spaces. Close doors to separate heated from unheated areas of your home, and minimise the heated area.

➔ Turn off radiators in rooms which are not used very often.

Heating efficiency

➔ Turn off your heating at night when you're in bed and likewsie when you're not there, or if you're going to be away for a few days.

➔ Open the curtains and blinds in rooms facing south during the day to let in the heat of the sun.

➔ Use conservatories during sunny winter days to heat the house by opening the doors from them into the house while it's sunny, but by closing them when it's overcast and dark outside.

➔ Effective use of windows to provide sufficient ventilation without overcooling rooms. Don't leave external doors and windows open unnecessarily.

Actual Energy Savings

Below are examples of the energy savings made during the Power of One Street campaign which worked with a number of families around the country as they reduced their energy consumption, and who were able to make significant savings by applying the energy tips and by changing their behaviour.

The Meehan Family

A family of six, living in a detached, cavity wall house, built in 2004.

Step 1: Space Heating

➔ Energy Reduction = 31%

➔ CO_2 Reduction = 2.2 tonnes

➔ Cash Saving = €680 per year

The Horler Family

A family of five, living in a detached, cavity wall house, built in 2004.

Step 1: Space Heating

➔ Energy Reduction = 32%

➔ CO_2 Reduction = 1.7 tonnes

➔ Cash Saving = €450 per year

Some low-cost options to save energy on space heating

Timer or programmer

Most houses have far too few controls on their space-heating systems. For only a small outlay, you can rectify this easily. Ideally, the space heating and domestic hot-water circuits should be separate. A time clock or programmer will allow the householder to ensure that the boiler will operate to provide heat only when required for various heating periods during different days of the week and also (with suitable motorised valves) allowing separate control of the water heating. This will guarantee that the domestic hot water can be provided in the summer using the boiler even though central heating is not required.

Room thermostat

By installing a thermostat in an area of the house that is indicative of the general heat conditions required, this will turn the burner off when the temperature in the area rises or falls below the value at which you have set the dial. 18-20°C will be sufficient in most cases.

Thermostatic Radiator Valve (TRV)

TRVs may be installed instead of the hand-wheel valve. The TRV has a number of settings, which the householder may use to set the desired air temperature for each room. In locations where a high level of heating is required, e.g., living area, the TRV will be set at the top setting. If only background heating is desired, e.g., hallways, then the valve can be fixed at its lowest setting.

Maintenance

Regular maintenance of your heating system can reduce fuel consumption e.g. maintain the boiler casing and burner, and check for corrosion and airlocks in the radiators.

Portable heaters

When buying portable heaters, make sure that they are the right size for the rooms they are to heat, and that they have thermostatic controls. Use a space or portable heater instead of the central heater if only one room needs heating.

Grants may be available if you are upgrading your boiler or heating controls.

For more information log on to **www.sei.ie/grants**

step 2 Domestic Hot Water

The objective here is to minimise unnecessary heating of hot water for use in sinks, showers, baths and appliances by considering the amount of hot water needed and when it is required and by determining the most efficient use of your central heating systems and immersion heaters.

This step will take  **4 weeks**

Essential tip

* Evaluate your routine of hot-water demand, i.e., when you need hot water and how much you need, and adjust the timer settings. If you use an immersion heater or central heating to heat your water, adjust the length of time they are used per day, i.e., 1 hour in the morning and 2 hours in the evening, depending on your needs.

- ➔ If your hot water is being heated by the central-heating boiler and your hot-water cylinder has a thermostat, you should set the thermostat to 65 °C.
- ➔ Make sure your immersion thermostat is working correctly. (Have an electrician check this for you.)
- ➔ Prioritise use of the shower over a bath. A typical shower uses only 20% of the energy of a full bath.
- ➔ Never leave a hot tap running unnecessarily.
- ➔ Ensure your hot-water cylinder is properly lagged. A lagging jacket will keep the water hotter for longer.

Actual Energy Savings

The Horler Family

A family of five, living in a detached, cavity wall house, built in 2004.

Step 2: Domestic Hot Water

- ➔ Energy Reduction = 22%
- ➔ CO_2 Reduction = 0.9 tonnes
- ➔ Cash Saving = €170 per year

The Crowley Family

A family of three, living in a detached bungalow, solid block house, built in the 1970s.

Step 2: Domestic Hot Water

- ➔ Energy Reduction = 25%
- ➔ CO_2 Reduction = 0.49 tonnes
- ➔ Cash Saving = €102 per year

Some low-cost options to save energy on domestic hot water

Immersion heater timer

By installing an immersion-heater timer, it allows the householder to set the immersion to come on for the minimum length of time necessary to ensure that you have just enough hot water for washing, bathing and washing up. Usually this means having it come on for a short time in the early morning and evening.

Lagging jacket

The hot-water cylinder should always have a lagging jacket to minimise heat loss and to keep the water hotter for longer; it will pay for itself in just 2–3 months. It is better still if the water cylinder has factory-applied insulation.

Cylinder thermostat

If the hot water is being heated by the central-heating boiler, you should fit a cylinder thermostat to moderate the temperature of the water.

step 3 **Small Power**

The objective here is to build good habits of switching electrical equipment off when not in use and making use of efficiency settings on all electrical appliances e.g., washing machines, fridges, freezers, TVs, PCs, DVDs etc.

This step will take  **3 weeks**

Washing machines, dishwashers and dryers

Essential tip

* The cycle selected on a washing machine or dishwasher should have the lowest water temperature required for the items being washed.

- ➔ A full load in the washing machine or dishwasher is more energy efficient than two half loads.
- ➔ If your washing machine, dishwasher or dryer has an economy button/reduced time–temperature, then use it whenever appropriate.
- ➔ Minimise use of the dryer, dry heavy articles separately from light articles.
- ➔ Make use of a clothes horse indoors or dry clothes outdoors when possible.

Fridges and freezers

Essential tips

* Evaluate and adjust fridge temperature settings, keep the fridge temperature between 2–3°C and the freezer at -15°C.
* It is best to always keep the fridge and freezer as full as is reasonably possible.

- ➔ Don't let frost build up in the freezer as this increases energy consumption. Defrost the inside of your fridge and freezer at least every 6 months.
- ➔ Don't put warm or hot food straight into the fridge or freezer, let it cool down first.
- ➔ Don't leave the fridge door open for too long while getting food, for every 10–20 seconds the door is open it takes 45 minutes for the fridge to cool down to its original temperature.

Home entertainment and electronic equipment

Essential tip

* Appliances on standby can use up to 20% of the energy that they would use if on, so make sure they are fully switched off, e.g., TVs, PCs, DVDs, VCRs, printers, games consoles, satellite boxes/players/recorders and kitchen appliances etc.

- Use one large power strip for your computer, broadband modem, scanner, printer, monitor, and speakers as they can be switched on and off easily at once.
- Configure your PC/laptop, printer and scanner to 'energy saving' mode in which they will automatically change to the state of low energy consumption when not in use.
- Switching off the monitor saves more energy than letting the screensaver run. Animated screensavers can use more energy than the computer itself!
- You should turn off your PC/laptop whenever you are not going to use it for more than an hour.
- Unplug chargers and surge protectors when not in use — monitor when phones/rechargeable batteries are fully recharged.
- Switch off all unnecessary electrical equipment and appliances at night.

Electric blankets

- Switch on electric blankets no more than 30 minutes before you go to bed and switch it off just before you get into bed.

Actual Energy Savings

The Heffernan Family

A family of five, living in a detached, solid wall house, built in the 1970s.

Step 3: Small Power

- Energy Reduction = 20%
- CO_2 Reduction = 1.4 tonnes
- Cash Saving = €332 per year

The Conway Family

A family of four, living in a semi-detached, cavity block house, built in the 1970s.

Step 3: Small Power

- Energy Reduction = 35%
- CO_2 Reduction = 1.3 tonnes
- Cash Saving = €248 per year

Some low-cost options to save energy on small power

Replacing appliances

When replacing electrical equipment, appliances or electronics, try to choose the most energy-efficient ones. Even small reductions in the amount of electricity consumed daily can add up to a significant saving over their lifetime. Appliances are labelled to indicate energy consumption and are rated from A to G with A being the most efficient. The label helps you to compare how efficient each appliance is. An A-rated appliance will use about 55% of the electricity of a similarly sized appliance with a D rating. The difference in cost of an A-rated appliance compared to a lower rated appliance may be a lot lower than you think (or even zero).

When purchasing a television, consider the following; plasma televisions are the least energy efficient, followed by conventional CRT television sets. LCDs are the most efficient. Newer LED type TVs are even more efficient. Generally, for any particular technology, the larger the screen the greater the energy consumption.

step 4 Lighting

The objective here is to maximise awareness and behaviour of when and where lights are being used, and to control lighting in response to need whilst making maximum use of daylight.

This step will take  **2 weeks**

Natural daylight

Essential tip

* Maximise use of daylight, e.g., hold off switching on lights in the evening until necessary.

- Rooms should be furnished to allow daylight in and activities for which daylight or sunlight is essential should be positioned near windows, e.g. reading.
- Furniture and other obstacles should not obstruct daylight penetration of the room. Net curtains and blinds will reduce daylight penetration of a room.
- Dirt on windows can reduce performance by 10% and even more if the dirt is allowed to build up on skylights.
- Paint the surfaces of rooms, including ceilings, with colours of high reflectance to maximise the daylighting opportunities. Light colours reflect 80% of light while dark colours reflect less than 10%.

Artificial lighting

Essential tip

* Switch off lights when rooms are not in use.

- Make use of task lighting wherever possible, e.g., lamps rather than whole room lighting when a small amount of light is required.
- Regularly clean light fittings, reflectors and lampshades.
- Use dimmer switches and multiple light switches effectively and only light the area of the room you are using rather than the whole room.
- Switch off all possible lights at night (if needed select one as a nightlight to be kept on — remember to switch it off during the day)
- Replace failed light bulbs with Compact Fluorescent Lamps (CFLs) when appropriate and take account of things such as shape, size, colour and natural light in a room, before deciding what wattage CFL light bulbs the rooms in your house require (see **www.sei.ie/powerofone**).

Actual Energy Savings

The Brennan Family

A family of four, living in a detached, timber frame house, built in 2003.

Step 4: Lighting

- Energy Reduction = 34%
- CO_2 Reduction = 0.5 tonnes
- Cash Saving = €110 per year

The Joyce Family

A family of four, living in a detached, cavity block house, built in 1991.

Step 4: Lighting

- Energy Reduction = 32%
- CO_2 Reduction = 0.25 tonnes
- Cash Saving = €50 per year

Some low-cost options to save energy on lighting

Energy-efficient light bulbs

When purchasing new light bulbs, choose energy efficient CFLs, for spotlights use Infra Red Coated Halogen Bulbs (IRCs) or use fluorescent tubes for lighting as appropriate.

Compact Fluorescent Lamps (CFLs)

CFLs use 80% less electricity and last up to 10 times longer than ordinary light bulbs. Start by installing 3 or 4 of these CFLs in those areas where lighting is used for the longest periods, e.g. hall, landing, kitchen and living room.

Electrical switches

Having several independently switched lights in a room allows the appropriate lighting level to be selected to suit the activity.

step 5 Cooking

The objective here is to build good habits when planning or organising meals, such as cooking meals together and making best use of your cooking appliances.

This step will take  **1 week**

Planning

Essential tip

* Aim for one cooking time for everyone's main meal.

- Evaluate/explore cooking enough for more than one meal at once, then storing and reheating.

The oven

Essential tip

* The oven is expensive to use, try to use it sparingly and as efficiently as possible. Where possible use it for more than one item at a time and remember you can cook at a higher temperature at the top of the oven, and at the same time at a lower temperature at the bottom.

- Do not open the oven door to check cooking too often, every time you do so, you lose 20% of the accumulated heat.
- Don't use the oven to cook a single dish, bake a few items at the same time and freeze them for later if necessary.

The hob/cooker

Essential tip

* Put lids on pots and turn down the heat when the water starts to boil. The lid not only keeps in the heat but also reduces condensation in the kitchen

- Use pots and pans that cover the whole of the cooker ring.
- At a certain point in cooking, turn off the rings and use their residual heat to finish cooking.

Small appliances

Essential tip

* When making tea or coffee, only boil as much water as you need in the kettle (make sure that the element of the kettle is covered).

- A slow casserole, pressure cooker, insulated deep-fat fryer or microwave oven will cook food in an energy-efficient way.

- Use a microwave for smaller meal amounts.
- The toaster is more efficient than the grill for toasting bread.
- Use an electric kettle to boil water for cooking instead of using the hob.
- Be careful in your approach to using general kitchen appliances, e.g., iron, food processor or sandwich maker. Make sure to only use at the correct temperature and for the required amount of time.

Actual Energy Savings

The Joyce Family

A family of four, living in a detached, cavity wall house, built in 1991.

Step 5: Cooking

- Energy Reduction = 15%
- CO_2 Reduction = 0.084 tonnes
- Cash Saving = €19 per year

The Heffernan Family

A family of five, living in a detached, solid wall house, built in the 1970s.

Step 5: Cooking

- Energy Reduction = 9%
- CO_2 Reduction = 0.08 tonnes
- Cash Saving = €18 per year

Some low-cost options to save energy when cooking

Electric ovens

Electric ovens are labelled to indicate energy consumption, purchasing the most energy efficient one will save you money on your energy bills.

Replacing small kitchen appliances

Think energy efficient when buying any household appliance. Slow casseroles, insulated deep fat fryers, microwave ovens, fan convector ovens, and pressure cookers all save energy and time, and give you better, safer results.

Transport and Efficient Driving

The number of cars on Irish roads has increased by over 50% in the past 10 years. Private car use now accounts for over 40% of home energy use. As a result, transport emissions represent a large proportion of overall polluting emissions (78% of carbon monoxide emissions and 22% of CO_2 emissions). In addition, transport fuels are expensive to import, and they cause their own environmental impacts in extraction, refining and shipping.

This step can be started straight away.

Think about when you drive

Essential tip

* Avoid using the car for short or unnecessary journeys. Try to walk, cycle or use public transport instead.

➔ Share car journeys when you can. Organise car pools for regular commuters.

➔ Try using less congested routes and avoid rush-hour traffic.

Think about how you drive

Essential tip

* Driving between 65 and 80 km/hr, where safe and practicable, will significantly reduce emissions compared to higher speeds.

➔ Drive smoothly and efficiently, harsh acceleration and heavy braking can use up to 30% more fuel and can cause increased wear and tear on the vehicle.

➔ After starting the engine, it is best to drive off immediately. Idling causes pollution and excessive fuel consumption.

➔ Try switching the engine off when stopped for even short periods, e.g. two minutes or more. It is more economical to switch the engine off and start it again when necessary.

➔ Reduce unnecessary drag. Removing unused bike racks or roof boxes will save 15-40% fuel consumption.

➔ Keep cool by using the car's vents, rather than leaving the windows or sun roof open, this will save a further 3-5%.

➔ Keep tyres inflated to correct pressure and save up to 10% on fuel consumption. Incorrect tyre pressure increases fuel consumption, shortens the life of tyres and is dangerous.

➔ Use air-conditioning sparingly; running air conditioning continuously increases fuel consumption by 10% or more in city driving.

➔ Keep your engine regularly maintained and serviced for better fuel economy and lower emissions.

Think about what you drive

Essential tip

* When buying a car, chose one that meets your requirements and is fuel efficient.

- Check the environmental labelling of cars. Under EU and Irish law, the motor industry must clearly display the fuel economy and CO_2 emissions of new passenger cars. Labels indicate the energy performance of cars on an A to G range, with A being best. Cars registered are now subject to Vehicle Registration Tax (VRT) and annual road tax based on their CO_2 emissions, so the more efficient the car, the lower its VRT and tax.
- To find out how your car rates, check out the 'How Clean is Your Car' section of the SEI website which lists the fuel consumption, CO_2 emissions, and other performance figures of cars from the year 2000 on **www.sei.ie/howcleanisyourcar**

How much energy does your home consume?

Do you know how much you spend on energy in your home? The first step in managing your household energy is to find out how much you do spend. This varies from month to month, so you need to think about energy consumption on a yearly basis. If you are well-organised, you will have a record of all your energy bills (ESB, gas, oil, solid fuel). If not, you need to start gathering the bills. You can always make an estimate of the odd extra bag of coal. In fact, with whatever bills you have to hand, you can make an intelligent estimate of your total energy cost. Here's what to do.

Use the chart (overleaf) to build up as accurate a picture as you can of your energy costs over the year. Use any bills you can find, and make intelligent guesses where necessary. Use the 'comments' space to record any notes about why a particular bill might have been particularly high or low. Was it a cold spell over the past couple of months? Were more people in the house during the period? Did you stay in more?

As you build up an accurate picture for each period, you can amend the estimates you made, so that you will have a more realistic basis on which to plan in future.

What could you achieve?

We have already suggested that being efficient at home could save you 20% or more in energy costs. So the next step towards really managing your home energy is to set yourselves some targets for the next 12 months. Make it a challenging but achievable figure, and remember you will be most effective if the entire household joins in.

Reading your Energy Bill

Energy Bill

Account Details:

Account Number: 0000000000XX Date of Issue: 00/00/00
Invoice Number: 0000000000XX Other details: 000x000x00

Name of Bill Payer
Address here
This Road
This county

Details of Bill

1 unit of electricity = 1 kWh = 1000 watts of electricity being used in 1 hour

xx number of days standing charge @ €xxx / day

xx number of units @ €xxx per unit

Payment method: dd | Payment due: 00/00/00 | Net cost: xxxxxx

VAT@xx: xxxxxx

Total cost: xxxxxx

one unit of energy will generate

Instantaneous electrical shower	7 – 10 mins
Immersion water heater	15 – 20 mins
Cooker (1 large ring) / Kettle	20 – 40 mins
Tumble dryer / Toaster (2 slice)	40 – 60 min
Washing machine / Dishwasher	70 – 100 mins
Desktop computer (including monitor)	4 – 6 hours
TV 28”	7 – 9 hours
100 watt ordinary light bulb	10 hours
20watt energy saving (CFL) light bulb	50 hours

(Source: ESB Customer Supply)

How much do you spend on energy?

Fill in the table below as best you can to calculate your annual energy costs.

Month	Electricity	Mains Gas	Oil	Gas Cylinders	Solid Fuel e.g. Coal, Wood, Peat	Total	Comments
January							
February							
March							
April							
May							
June							
July							
August							
September							
October							
November							
December							
Total							

What if you're renovating an existing home?

While renovating your home it makes sense to incorporate energy-saving measures which will help to improve comfort levels and save you money in the long run. You can take the following energy-saving measures while renovating your home:

Draught proofing: Seal leaky doors and windows, letter-boxes, attic hatches, unused chimneys and gaps around pipes penetrating external walls, floors and ceilings.

Insulation: Insulate the walls (pump fill the cavity or dry line the walls) and roof (300mm attic insulation) of your house.

Double-glazing: When replacing existing windows, install double-glazing.

Controls: When installing or replacing a central heating or hot-water system, divide the systems into separate zones and opt for comprehensive controls.

Boilers: When replacing a boiler, consider using the much more efficient condensing oil or gas boilers. If you have storage space, a wood-pellet boiler would be even more environmentally friendly.

Electrical devices: When purchasing electrical equipment, appliances or electronics, try to choose the most energy-efficient ones, e.g., A-rated appliances.

Lighting: Replace existing light bulbs with CFLs. Install electrical switches so that several independently controlled lights in a room will allow the appropriate lighting level to be selected to suit the activity.

Or want to build an energy-efficient home?

If you are planning to build a new house make sure you make it energy efficient. It is easier and more economical to incorporate these features when the house is being built rather than later on:

Site selection: By selecting a location sheltered from the wind, heat loss from the building can be reduced.

Building form and orientation: A compact building form of minimum surface to volume ratio is best for reducing heat loss e.g. a long low building will have greater exposed surface than a two storey square plan building of the same space.

Energy assessment: A Building Energy Rating should be used to compare alternatives at the preliminary design stage.

Insulating the building fabric: The floor, walls and roof should have plenty of insulation to prevent heat loss and to maintain a comfortable internal environment.

Ventilation: Controlled vents should be installed in every room; trickle or slot vents in window-frames can ensure a reasonable amount of fresh air.

Passive solar features: If the house is exposed to low altitude winter sun, glazing should be concentrated on the south-facing wall.

Heating and hot-water systems: Whatever system you opt for, do ensure that the installed system has comprehensive controls. It is also advisable to divide the heating system into separate zones. Consider condensing boilers, wood-pellet boilers or a geothermal system.

Open fires: The installation of a high output back boiler will provide domestic hot water and space heating while increasing efficiency to approximately 40–50%. A closed stove is preferable to an open fire in terms of controlled, efficient heat.

Electrical devices: When purchasing electrical equipment, appliances or electronics try to choose the most energy-efficient ones, e.g. A-rated appliances.

Lighting: Replace existing light bulbs with CFLs. Install electrical switches so that several independently switched lights in a room will allow the appropriate lighting level to be selected to suit the activity.

Renewable energy options for the home

Most of the energy we use today is generated by fossil fuels. Not only are they bad for the environment but they will also eventually run out. The sustainable alternative is renewable energy which will never be exhausted. Renewable energy is available to us in many forms which can often be exploited in the home:

- ➔ Solar energy (the sun) – for space and water heating
- ➔ Geothermal (heat from below the surface of the earth) – heat pumps for space and water heating
- ➔ Biomass (woodchip and pellets) – boilers and stoves for space and water heating
- ➔ Wind powered turbines (the wind) – for electricity generation
- ➔ Hydro electric power (moving water in streams) – for electricity generation

For more detailed brochures for homeowners visit: **www.sei.ie/publications**

Sustainable Energy Ireland
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National Development Plan

SEI is funded by the Irish Government under the National Development Plan with programmes part financed by the European Union.

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Passive-On:

Marketable Passive Homes
for Winter and Summer Comfort

Passive Home Training Module for Architects and Planners

Passive-On

Overview

- Building Sector Energy Consumption
- Passive Systems
- Thermal Comfort
- *Passivhaus* Standard
- *Passivhaus* for warmer climates
- Design Guidelines:
  - Passive Strategies
  - Proposing *Passivhaus* for Southern Europe
- Climate Analysis
- Economics of Passivhaus
- PHPP - Passivhaus Planning Package
- The Passive-On Project

Building sector Energy Consumption

Quick look at Building Energy Consumption

- In the European Union:
  - buildings account for 40% of the final energy consumption
  - yet with estimated economic saving potentials of 28%
  - thus energy efficiency in buildings represent a massive 11% of total EU final energy use (EC Action Plan for Energy Efficiency "*Realising the potential*", Oct. 2006).
- In the EU-15, about 70% of household energy demand is associated to ambient heating (www.odyssee-indicators.org, updated January 2007)
- Energy consumption for cooling is increasingly sharply: demand is expected to double by 2020, as compared to 2003 (*Energy Efficiency in Buildings,* EC leaflet, September 2003) as air conditioning becomes more usual also in residential sector
- Correct design and construction can contribute to dramatically decrease energy consumption and CO_2 emissions of dwellings:
  - Example: at average, each German *Passivhaus* consumes 80% less energy for heating than standard house; this translates into annual avoided CO_2 emissions of 2.4 tonnes/year for one house

Passive Systems

Passive Systems

- A **Passive System** provides indoor environments with heat, cold, ventilation or light by using and controlling the natural energy flows which surround a building, such as solar radiation and wind
- There is a range of passive systems and measures, suitable for different climates
- Examples of Passive Systems in traditional architecture:
  - Painting exterior walls white to keep houses cool in summer
  - Building thick, heavy walls, namely on brick and mud, both for insulation and regulation of indoor temperature
  - Controlling daylight and solar gains by appropriate windows use
  - Promoting a microclimate near the house by use of water and vegetation

Passive Systems

White washed houses and narrow streets in the Santa Cruz district of Seville, Spain. Just two of the many different strategies employed by traditional architecture to keep houses cool in summer.

Passive Design

- The term **Passive Design** has come to indicate buildings which integrate **low energy active components** such as pumps and fans, with Passive Systems
- The energy consumed by the active component remains significantly lower than the energy content of the natural energy flow which the component controls
- In many cases the energy demand of the active system is so low that it can be met economically and feasibly by a renewable energy source such as a PV panel

Low energy active components

Ventilation unit with 78% heat recovery efficiency and low electricity consumption, proven in field measurements.

The heat recovered in an heat exchanger will often be several times greater than the electrical energy used by the heat exchanger fan

Ceiling fan can improve summer thermal comfort with reduced electricity consumption (12 W at low speed, 32 W at medium speed)

Thermal Comfort

What about Thermal Comfort?

- Discussions on low energy buildings should not neglect that buildings must provide **comfortable environments** in which to work, relax and play
- Comfort models describe quantitatively (based on large surveys of people) **in what range of conditions people will feel thermally comfortable** in buildings
- Choosing too **narrow a range** of thermal conditions can lead to **unnecessary consumption of energy**
- Comfort models evaluation may be **based on a variety of parameters** depending on people, such as metabolic rate and clothing, but also on indoor (and outdoor) conditions, such as air temperature and humidity, radiant temperature, air velocity, thermal asymmetries
- For **heating period**, comfort is usually evaluated regarding **operative temperature**: average of air dry bulb temperature and surfaces radiant temperature; for winter comfort, operative room temperature should be **≥ 20 ºC**
- For **cooling period** there are two prevailing comfort models : **Fanger and Adaptive**

Fanger and Adaptive Summer Comfort Models

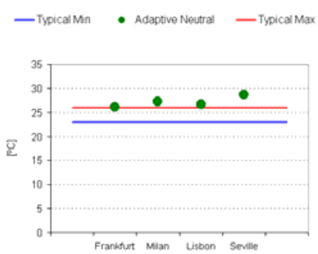
- In the **Fanger Model** the optimum internal condition of a building (that is, the one at which occupants will report comfort) is correlated exclusively to parameters referring to **conditions internal to the building** (for example air temperature and velocity, mean radiant temperature, air humidity) and to the clothing level and metabolic rate of the **occupants**
- The **Adaptive Comfort Model** proposes a **correlation between the comfort** temperature for occupants of a building and the **outdoor air temperature**. The underlying concept is the documented process by which the human body adapts (including making changes to the metabolic rate) to the seasonal and local climate. As a consequence occupants will consider different indoor temperatures as comfortable, depending on the season and location

What comfort model to consider?

- According to EN 15251 (2007) standard, acceptable comfort temperatures actually depend on the type of system used to provide summer comfort:
  - If cooling is provided by an **active system**, then indoor temperatures must respect those defined by the **Fanger Model** plus certain assumption of acceptability for different categories of buildings
  - Instead if summer comfort is provided by **passive cooling strategies** then the upper temperature limit is set by the **Adaptive Model** plus certain assumption of acceptability for different categories of buildings
- When a building doesn't have active cooling system, people are usually more tolerant to temperature swings…
- Air movement caused by natural ventilation or fans increase comfort temperature upper range

Comparing Fanger and Adaptive

- Compared to the Fanger Model, the Adaptive Model considers a wider range of temperatures as "comfortable" and therefore allows for easier integration of passive cooling technologies
  - For example, applying the Adaptive algorithm to typical annual weather data predicts maximum summer neutral temperatures (in correspondence with a sequence of hot days) for Frankfurt, Milan, Lisbon and Seville as respectively 26.1°C, 27.2°C , 26.7°C, and 28.7°C. As a comparison a building cooled by an active air conditioning system will work to a fixed set point chosen between 23°C and 26°C.



Passivhaus Standard

The *Passivhaus* Standard: Energy and Comfort

- The ***Passivhaus*** standard was first established in 1995 and fundamentally consisted of three elements, defined quantitatively by five points:

- Energy limit
  - Useful energy for ***space heating ≤ 15 kWh/m².year***
  - ***Primary Energy demand*** for all energy services (including domestic electricity) ***≤ 120 kWh/m².year***
- Quality requirements
  - ***Air Tightness***: building envelope such that pressurization test result ***≤ 0.6 h⁻¹***
  - ***Comfort***: operative room temperatures ***≥ 20 ºC in Winter***
- A defined set of preferred Passive Systems which allow the energy limit and quality requirement to be met cost effectively
  - All Energy demand values are calculated according to the Passive Hause Planning Package (***PHPP***) and refer to net habitable floor area

Passivhaus in Central Europe

- The **main features of central european *Passivhaus*** standard are:
  - very good insulation, including reduced thermal bridges and well-insulated windows
  - good air tightness and a ventilation system with highly efficient heat recovery
- For Central European climates, it turned out that these improvements in building shell finally result in the possibility to **simplify the heating system**:
  - It becomes possible to keep the building comfortable only by heating the air that needs to be supplied to the building to guarantee good indoor air quality
  - The whole heat distribution system can then be reduced to a small post-heater (heat recovery system)
- This fact renders high energy efficiency cost-efficient: Considering the lifecycle cost of the building, a *Passivhaus* **need not be more expensive** than a conventional new dwelling

The *Passivhaus* Phenomena

- More than **8000 houses** have now been built in Germany and elsewhere in central Europe which conform to the current *Passivhaus* standard. Some of the reasons for such a success:
  - The standard codifies precisely energy and quality requirements for new homes and then provides a relatively standard set of solutions by which these requirements can be met
  - In consequence a *Passivhaus* is a well defined product, understood by the developer, architect and owner
  - The solutions can be integrated into homes which can have the same aesthetics as current standard developments; for example there is no particular need to have large amounts of glazing on the south facade, although this can be included in the design
  - The solutions are relatively cheap; a house built to the *Passivhaus* standard at most costs 10% more than a standard house, though they can be built for the same price. On average a *Passivhaus* costs just 4 - 6% more to build than the standard alternative
  - *Passivhaus* are not only low energy: they are also comfortable to live in!

Passivhaus diversity

Passivhaus may present a diversity of styles

Passivhaus for Warmer climates

Heading South

- The *Passivhaus* standard was born to respond to the requirements of relatively cold central Europe
- Though homes in southern Europe need to be warm in winter, this is accompanied by a need to ensure comfort in summer, which at times can be the predominate issue

Motivations to Passive-On Project:

Diffusion of low energy houses design in Southern Europe, bringing forward the Passivhaus experience and success

Bringing Passive houses out of a niche market and promoting a wider scale development

- Could the *Passivhaus* standard be adapted to warmer southern Europe?
- What elements of the standard could be useful in promoting the diffusion of low energy house design in southern Europe?

Evolution of Standard

- The Passive-On project findings propose an update in the Passivhaus standard (2007), that is adapted to define *Passivhaus* in **cooling climates** as well, including **cooling energy and summer comfort**
- On one hand the analysis has shown that, in certain regions, the solutions proposed by the usual *Passivhaus* can also provide an effective basis for providing cool homes in summer (though some modifications need to be made to reduce the impact of solar radiation)
- On the other hand, research shows that some of the implicit and explicit requirements of the central European *Passivhaus* standard can represent over engineering in southern Europe:
  - For example the German *Passivhaus* standard makes an explicit requirement to limit the permeability of the building envelope ($n_{50} \leq 0{,}6\ h^{-1}$) which makes an implicit need for an active air ventilation system
  - However experience, for example from Spain and Portugal, shows that effective low energy homes can be built without the need for active ventilation systems and with less stringent building shell criteria

Passivhaus Standard (2007)

Current German *Passivhaus* Standard for **Central European Countries**	Proposed *Passivhaus* Standard for **Warm European Climates**
Heating criterion: The useful energy demand for space heating does not exceed 15 kWh per m² net habitable floor area per annum.	
Primary energy criterion: The primary energy demand for all energy services, including heating, domestic hot water, auxiliary and household electricity, does not exceed 120 kWh per m² net habitable floor area per annum.	
Comfort criterion room temperature winter: The operative room temperatures can be kept above 20 °C in winter, using the abovementioned amount of energy.	
Air tightness: The building envelope must have a pressurization test result according to EN 13829 of no more than $0.6\ h^{-1}$. All energy demand values are calculated according to the Passive House Planning Package (**PHPP**) and refer to the net habitable floor area, i.e. the sum of the net floor areas of all habitable rooms.	**Air tightness**: If good indoor air quality and high thermal comfort are achieved by means of a mechanical ventilation system, the building envelope should have a pressurization test (50 Pa) result according to EN 13829 of no more than $0.6\ ach^{-1}$. For locations with winter design ambient temperatures above 0 °C, a pressurization test result of $1.0\ h^{-1}$ is usually sufficient to achieve the heating criterion. **Cooling criterion**: The useful, sensible energy demand for space cooling does not exceed 15 kWh per m² net habitable floor area per annum. **Comfort criterion room temperature summer**: In warm and hot seasons, operative room temperatures remain within the comfort range defined in EN 15251. Furthermore, if an active cooling system is the major cooling device, the operative room temperature can be kept below 26 °C.

Indoor Comfort and *Passivhaus* Standard

- Often the neutral Adaptive Comfort Temperature can be achieved by using passive cooling strategies, such as window shading and night time ventilation. When this occurs the Cooling Demand is effectively reduced to zero and **no mechanical cooling** is required
- However, in some locations guaranteeing the comfort temperatures defined by the Adaptive Model requires some energy
- For example, Palermo in Sicily has low diurnal temperature swings with external night time air temperatures only a few degrees below those in the daytime:
  - In this situation night time ventilation strategies do not provide a really effective way of cooling the building. As a consequence the *Passivhaus* in Palermo has a cooling demand of around 2 $kWh/m^2/year$ which requires the home to have some form of active mechanical cooling system to reduce the peak temperatures (though the main means of cooling is still passive)
  - However, although the *Passivhaus* in Palermo has a cooling demand, it is nevertheless so low, that sum of annual heating and cooling loads remain below the 15 $kWh/m^2/year$ limit set by the *Passivhaus* standard

Passive and Active cooling in *Passivhaus*

- As a consequence, in the proposed revised standard for Warm European Climates, homes must now meet the following requirements:
- If cooling is provided by mainly **passive** means
  - Indoor Comfort Requirements: As defined by the Adaptive Model of the Annex A.2 ("Acceptable indoor temperatures for design of buildings without mechanical cooling systems") of the EN 15251
  - Heating and Cooling demand: < 15 kWh/m^2/year
  - Total primary energy: < 120 kWh/m^2/year
- If cooling is provided by **active systems**
  - Indoor Comfort Requirements: As defined by the Fanger Model of the EN 15251 (i.e. for mechanically cooled buildings)
  - Heating demand: < 15 kWh/m^2/year
  - Cooling demand: < 15 kWh/m^2/year
  - Total primary energy: < 120 kWh/m^2/year
- However, there is a recommendation that mechanical systems should only be used if there are technical limits to the use of mainly passive solutions.

Passive Strategies

Passive Strategies

- Over the centuries, a large diversity of Passive strategies are being developed, from a most empirical to a progressively more scientific and technological approach
- Although not exhaustive, a broad range of passive strategies were selected for presentation, considering the applicability for the target climates
- Each Passive Strategy is presented in terms of
  - **Description**: what does it mean and what is the Physical principle it addresses
  - **Relevance in *Passivhaus* design**: how it relates to targets of energy and comfort and what specific cares should be taken to prevent unwanted effects
  - **Regional Solution/Climate Applicability**: implementing a strategy may be more or less efficient regarding the local climate

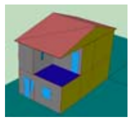
Building Shape

- Description:
  - *Compactness* is the ratio between the total treated volume of the dwelling (TV) and the heat loss surface area (A)
  - Minimum compactness values are around 0.8m and maximum around 2.2m
- Relevance in *Passivhaus* design:
  - higher compactness reduce heat exchange area, therefore reduce heating loads
  - however, medium compactness may favour solar exposure to south and also help release heat during summer
- Regional Solutions/Climatic Applicability:
  - In general, it is desirable to design buildings with high compactness
  - in Mediterranean climates, it is convenient to sacrifice higher compactness in order to increase south oriented glazing area – see Spanish *Passivhaus* description

Example low compactness: detached house

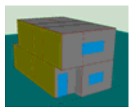
Treated floor area: 157 m^2
Total treated volume (TV): 310 m^3
Heat loss surface area (A): 250 m^2
Compactness (TV/A): 1.24 m

Note: compactness of detached houses are very variable!



Example medium compactness: semi-detached house

Treated floor area: 84 m^2
Total treated volume (TV): 210 m^3
Heat loss surface area (A): 160 m^2
Compactness (TV/A): 1.31 m

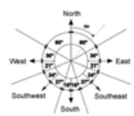


Example high compactness: terraced house

Treated floor area: 110 m^2
Total treated volume (TV): 330 m^3
Heat loss surface area (A): 194 m^2
Compactness (TV/A): 1.70 m

Orientation

- Description:
  - Orientation is defined for each one of the exterior walls (and consequently windows) of the building
  - Different orientation impinge different level of solar radiation on the surface
- Relevance in *Passivhaus* design:
  - A dwelling with a correct orientation should have a high level of heat loss area oriented to the south, with a high percentage of glazing. In summer this measure requires a well designed system of solar control because in other case the building (or at least the adjacent zone) will be overheated. Overhangs are good systems to obtain a good solar control in south oriented walls
  - East and west orientation are avoided because the level of radiation in these ones is very low in winter, and in summer solar control is much more complicated than in south orientation
  - Typically, the percentage of glazing surface related to floor area should be around 20% to the south, and 5% to the north
- Regional Solutions/Climatic Applicability:
  - A good orientation of the building is a goal in all climates. This objective can not always be reached due to external constraints like the urban layout. In these cases other measures have to be used in order to neutralize as much as possible, the effect of inadequate orientation



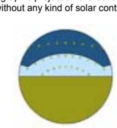
North	α_g < 60; α_g ≥ 300;
East	60 ≤ α_g <111
Southeast	111 ≤ α_g <162
South	162 ≤ α_g <198
Southwest	198 ≤ α_g <249
West	249 ≤ α_g <300

Shading

- Description:
  - Shading avoids solar radiation to impinge on external surfaces of buildings, with particular relevance for windows
  - We can distinguish between three kinds of shading:
    - own shading due to the building surfaces over themselves
    - shading due to near obstacles like overhangs or Venetian blinds
    - and shading due to far obstacles like other buildings in the surroundings
- Relevance in *Passivhaus* design:
  - Solar shading devices have to be designed in a selective way, as they should allow radiation to reach the building in winter and but block the radiation in summer
  - These devices must be designed taking into account the own shading and the shading due to far obstacles that exist in the present or can exists in the future
- Regional Solutions/Climatic Applicability:
  - Shadings should be used to reduce solar heat gains during summer, and are particularly needed in locations with medium to high Summer Climatic Severity

In geometry, the stereographic projection is a certain mapping that projects a sphere onto a plane. Intuitively, it gives a planar picture of the sphere. Stereographic projection finds use in several areas; we use it particularly for the calculation of solar access and sky opening:

Stereographic projection of a south facing window without any kind of solar control system



Stereographic projection of a south facing window with an overhang

Buffer Zones

- Description:
  - A 'buffer' space is a free-running intermediate space between inside and outside, providing thermal (and sometimes acoustic) protection to the interior
  - Thermal buffering reduces heat loss from the interior, can preheat ventilation supply air and be a source of direct solar heat gain
  - When buffer zones are oriented to South, the outer layer is normally glazed to enhance solar gains in winter. Shading is necessary to reduce solar gain and risk of overheating in summer
- Relevance in *Passivhaus* design:
  - Automatic vent opening devices can be incorporated in buffer zones and control natural ventilation in response to the balance between internal and external conditions
  - Buffer zones are 'transitional' spaces i.e. they are only occupied very briefly, and can therefore be allowed to vary in temperature much more widely than an occupied space which is expected to meet accepted thermal comfort criteria most of the time. Conservatories can act as buffer zones, but residents will often want to extend the period of use by heating them (clearly a negative result)
- Regional Solutions/Climatic Applicability:
  - In northern Europe an unheated buffer space can be used to reduce infiltration heat losses in winter, to potentially pre-heat ventilation supply air to the living spaces and improve the effective U-value of the external envelope
  - In summer the potential risk of overheating arising from such space can be minimised by shading or opening it to the exterior

Buffer zones (yellow) in winter night time help minimising heat losses

Buffer zones in summer daytime help sheltering from the outdoor heat

Thermal Mass

- Description:
  - Thermal mass is the term used to describe materials of high thermal capacitance i.e. materials which can absorb and store large quantities of heat (expressed in Joules/kg)
  - Materials within a building which have a high thermal capacitance can provide a 'flywheel' effect, smoothing out the variation in temperature within the building, and reducing the swing in temperature on a diurnal and (potentially) longer term basis
  - Thermal mass may be in the form of masonry walls, exposed concrete soffits to intermediate floors, or possibly embedded phase change materials
- Relevance in *Passivhaus* design:
  - Thermal mass, coupled to the interior of the building, can be of considerable advantage both in the summer and winter:
    - In summer: limits the upper daytime temperature and thereby reduce the need for cooling. This effect can be enhanced by coupling the high capacitance material with night time convection to pre-cool the thermal mass for the following day
    - In winter: mass can absorb heat gains which build up during the day, for release into the space at night, thus potentially reduce heating demand
- Regional Solutions/Climatic Applicability
  - High thermal capacitance is usefull both in heating dominated climates (particularly associated to solar gains) and cooling dominated climates (combined to night cooling)

Heat storing effect of thermal mass during the day

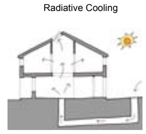
Heat stored in the mass is released at night

Passive Cooling (1)

- Description:
  - Night ventilation:
    - Throughout Europe, summer nights are usually much cooler than day periods, with temperatures dropping well below the "netrual" temperature
    - This cool air can be drawn into the house to flush out any residual heat from the day and to pre-cool the internal fabric for the following day
    - The coupling of the air flow path with well distributed high thermal capacitance materials is vital
    - Automatic vent openings helps to promote adequate cooling and to avoid over cooling
  - Night Sky Radiation:
    - The clear night sky temperature is influenced by outer space temperature and thus is usually quite low (compared to outdoor air temperature)
    - Therefore, clear sky can provide a potential heat sink, by radiation exchange with the relatively warm surface of the roof of the dwelling
    - With well insulated roofs, a technique has to be found to couple the cooling potential with the interior of the dwelling. A range of techniques for exploiting night sky radiation, including irrigated roofs and roof-ponds, are described in book 'Roof Cooling' by Simos Yannas, but to date have rarely been applied to housing in Europe
  - Ground Cooling:
    - The temperature of the Earth 3-4m below ground level is generally stable, and has been found to be equal to the annual mean air temperature for the location (anywhere in the world), varying perhaps by ±2 ºC according to the season
    - The earth is therefore a huge source of low grade heat, which can be used for either heating or cooling

Night-time cooling

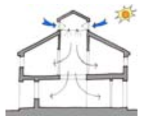
Radiative Cooling



Ground cooling

Passive Cooling (2)

- Evaporation:
  - The cooling potential of evaporating water has been exploited throughout southern Europe, the Middle East and northern India for many centuries
  - As a general rule, a reduction in supply air temperature of 70-80% of the dry bulb/ wet bulb depression can be achieved. This of course varies from only a few degrees when the air is relatively humid to as much as 10 to 12 ºC when the air is relatively dry
  - The upper limit for the application of direct evaporative cooling is considered to be a wet bulb temperature of 24 ºC. Control of the rate of evaporation and the air flow through ventilation openings is vital to optimize performance and to avoid over-humidification


Evaporative cooling

- Relevance in *Passivhaus* design:
  - Passive cooling, where appropriate, can provide substantial energy savings and reductions not only in CO_2 emissions but also in other harmful refrigerants. It may also avoid the need of mechanical systems
- Regional Solutions/Climatic Applicability
  - In northern Europe, careful design of the building envelope (thermal properties, orientation, solar shading) can often remove the need for additional cooling in summer
  - In southern Europe, this may also be the case, but with climate change and with expectations of a high quality internal environment throughout the year, the opportunity of additional cooling needs to be considered
  - In most situations, the exploitation of ambient heat sinks by passive cooling techniques will meet any residual cooling requirements. These oportunities should be considered and assessed before any decision is made to include a mechanical back-up (with attendant environmental and maintenance implications)

Natural Ventilation (1)

- Description:
  - The amount of ventilation for fresh air supply required varies according to the season:
    - Winter: to minimize heat loss, ventilation should be limited to a minimum of 8-10 litres per person per second, to provide for our physiological needs and to maintain internal air quality
    - Summer: if ventilation may also be required for cooling, much larger ventilation rates are needed (~ 80-100 litres/person.second)
  - Natural ventilation is driven by either wind or thermal forces (or a combination of both):
    - Wind driven ventilation is induced by the pressure differences arising due to the change in momentum when the air is deflected (increasing speed and pressure) or when the air speed is reduced. Typically a difference in wind pressure arises between the windward and the leeward sides of a building, and can drive air through the building to achieve simple cross ventilation
    - Thermal buoyancy (stack) occurs when pressure differences arising from differences in temperature between inside and outside of the building create a flow of air between inside and outside. The flow is normally from low level to high level, through openings provided to exploit this. Three factors determine the rate of air movement due to thermal buoyancy: the *pressure difference* (arising from the difference between the average temperature within the building and the outside temperature); the *area of openings* in the building (at high and low level), and the *height difference* between the openings


Single sided ventilation


Cross ventilation


Stack ventilation

Natural Ventilation (2)

- Relevance in *Passivhaus* design:
  - Natural Ventilation can be used very effectively to provide fresh air and improve comfort and igienic conditions for occupants. Despite the variability and difficult of control of the natural driving forces, natural ventilation can reduce energy consumption, capital and running costs of mechanical and electrical plants as well as space for their installation
  - Infiltration can contribute to the minimum fresh air requirement, but uncontrolled infiltration should be minimized to avoid unwanted heat loss in winter and heat gains in summer
  - Air tightness standards in construction vary enormously throughout Europe, but legislation is pushing house builders to achieve greater air tightness
  - The choice between mechanical and natural ventilation for housing depends on the climate characteristics, the air tightness which can be achieved, the value of heat recovery and occupant preferences. Automatic vent opening devices can be incorporated in buffer zones and control natural ventilation in response to the balance between internal and external conditions
    - The sizing of vent openings and the specification of vent actuators needs to be carefully considered to achieve a successful natural ventilation solution
- Regional Solutions/Climatic Applicability:
  - Natural Ventilation by stack effect is very effective in northern European climates where there usually is a greater temperature difference between the indoor and outdoor environments, both in summer and winter
  - Climates where there is a strong diurnal variation are suitable for the employment of thermal mass and night time ventilation
  - For more hot and humid climates, cross ventilation and shading have the advantage of reduce solar gains and improve the perception of coolth by increasing air movement

Primary Energy and CO_2

- Description:
  - Primary energy sources: obtained directly from nature (for example: solar or wind energy) or after an extractive process (like petroleum, natural gas or coal)
  - Energy consumption of a building can be expressed in terms of equivalent consumption in primary energy – Tons of Oil Equivalent - or in terms of CO_2 emissions
  - The factors that allow us to make this change of units depend on the energy sources and the way of generating energy in each country
- Relevance in *Passivhaus* design:
  - A passive dwelling may use conventional energy systems only as a support to passive conditioning systems or measures. The conventional systems used must have high performance level (low levels of emissions and low levels of primary energy consumption)
  - Check energy labelling of heating and cooling systems
- Regional Solutions/Climatic Applicability
  - The best systems in order to reduce CO_2 emissions can be very different for those one that minimize the primary energy consumption due to the "energy mix" in each location
  - For example in Spain a heating or cooling system with a high energy rating could be a direct expansion heat pump with an A-label

Primary Energy (Spain)

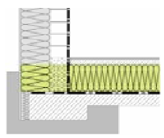
Kind of energy	TOE primary energy /MWh_e energy
Electricity	0,224
Storage electricity based systems	0,174
Fuel and GLP	0,093
Natural Gas	0,087
Coal	0,086

CO_2 emissions (Spain)

Thermal energy	Emissions
Natural Gas	204 gr CO_2/kWh_t
GLP	244 gr CO_2/kWh_t
Coal	347 gr CO_2/kWh_t
Biomass	Neutral
Bio-fuels	Neutral
Electricity	649 gr CO_2/kWh_e
Solar Photovoltaic	0
Storage electricity based systems	517gr CO_2/kWh_e

Ground Insulation

- Description:
  - Ground behaves as an extremely large thermal mass whose temperature fluctuates little during the course of the year. Two to three meters deep, the ground temperature is stable and only slightly above the annual average air temperature during the whole year. Equaly below floor slabs: diurnal, but even annual changes in temperature occur mainly near the boundary
  - During the heating period, heat losses through building elements adjacent to the ground are always lower than those exposed to air (for the same U-value). Nevertheless, losses can be further reduced by thermal insulation
  - In summer, insulation against the ground is generally disadvantageous in European climates: Heat flow to the cooler ground will reduce the indoor temperatures. Perimeter insulation (where outside air temperature has stronger influence) can improve performance
- Relevance in *Passivhaus* design and Regional Solutions/Climatic Applicability :
  - Depending on the climate and the general building properties, insulation of the floor slab or the basement can be necessary, useful or counterproductive
  - If the ground temperatures are low enough, insulation against the ground in indispensable to achieve *Passivhaus* standard (however, insulation is usually thinner than in building elements adjacent to ambient air)
  - In climates such as the lowlands of southern Italy or of the Iberian Peninsula, where heating energy demand can already be minimised by other means, insulation of the floor slab and the basement can be omitted, using the ground as a heat sink in summer



Insulation above the floor slab. The load-bearing wall is placed on a layer of porous concrete to reduce the thermal bridge effect

Foamglas and XPS being installed under the floor slab of a five-storey office building

Wall Insulation

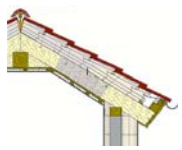
- Description:
  - Insulation of the walls reduces the average heat flow through the wall construction. The effect is characterised by the U-value, given in W/(m2K), which signifies the heat flow through 1 square meter of wall area at a constant temperature difference of 1 K (= 1 °C)
- Relevance in *Passivhaus* design:
  - *Passivhaus*s require an uncompromising reduction of the useful energy demand. This includes minimising heat transmission through the opaque building envelope
  - Good insulation of walls limits the heat losses in wintertime and increases the interior surface temperatures, thus increasing thermal comfort and reducing the risk of damages due to excess humidity
  - During hot periods in summer, it reduces the heat flow from the outside to the inside, including the heat generated by solar radiation on the exterior surface, and support both night ventilation strategies and energy efficient active cooling concepts whenever the interior temperature drops below the daily average of the exterior surface temperature
- Regional Solutions/Climatic Applicability :
  - Depending on the climatic conditions and the building project, the required level of insulation may vary. As a rough guidance, U-values will only be above 0.3 W/ (m^2K) in very mild climates such as in southern Italy or Spain, whereas values of 0.15 W/(m^2K) or below can be required in France

40 cm gable wall compound insulation system in a Passivhaus in Hannover

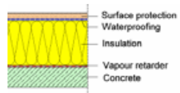
Porous ceramics brick as used in a passively cooled project in Seville

Roof Insulation

- Description:
  - Like for walls, insulation reduces the heat transfer through the roof construction in both directions, during winter and summer
  - Especially during summertime, roofs are generally more exposed to solar radiation than walls, due to their nearly horizontal orientation and to reduced shading from surrounding buildings. Uninsulated roofs contribute significantly to excessive summer temperatures in buildings
- Relevance in *Passivhaus* design:
  - Good insulation of the roof is necessary to reduce heating and cooling energy demand
  - Concerning the insulation thickness, there are usually less constructive constraints in the roof than in the walls. Therefore, roof insulation is typically dimensioned thicker than wall insulation
  - Insulation in inclined roofs can be applied between roof rafters or on top of the rafters below the tiles. For concrete roofs, exterior insulation above the concrete is useful. With modern, water-resistant insulation materials, the lifespan of the main waterproofing layer can be increased by installing it between the insulation and the concrete
- Regional Solutions/Climatic Applicability :
  - Again, the best insulation thickness depends on the climate and the specific requirements of the building. In a *Passivhaus*, a typical U-value of the roof will be below 0.3 $W/(m^2K)$ in mild, southern European climates, and down to 0.1 $W/(m^2K)$ in central Europe



Inclined roof with insulation between and above the rafters



Highly insulated concrete roof construction

Infiltration and Air Tightness

- Description:
  - Leaky building envelopes cause a large number of problems, particularly in cooler climates or during cooler periods: high risk of condensation in the construction, temperature differences between different storeys of a building, drafts and associated discomfort
- Relevance in *Passivhaus* design:
  - In many climates, *Passivhauss* require a mechanical, supply and exhaust air ventilation system with heat recovery. In this case, excellent airtightness of the building envelope is required, otherwise the airflows will not follow the intended paths, the heat recovery will not work properly, and elevated energy consumption will result
  - In very mild climates, it is possible to build *Passivhauss* without heat recovery systems. In such a case, if no ventilation system is present, airtightness is not quite as important. On the contrary, very airtight buildings without ventilation systems run the risk of bad indoor air quality and excess humidity
- Regional Solutions/Climatic Applicability:
  - Good airtightness is mainly achieved by appropriate design and construction: one single airtight layer runs around the whole building, so all building element junctions need to be constructed such that no leakages occur
  - Internal plaster, plywood board, hardboard, particle board and OSB; PE foils and other durably stabilized plastic foils; bituminous felt (reinforced) and tear-proof (reinforced) building paper are all suitable materials for constructing an airtight envelope
  - Airtightness can be tested by means of the so-called blower door test: a ventilator is placed in an exterior door or window which creates a pressure difference of 50 Pa. The corresponding air change rate of the building (n50, expressed in ach-1) indicates the level of airtightness

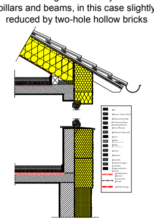
The sealing tape, on which plaster can be applied, will then link the interior plaster and the window

Blower door installed for a pressurization test

Thermal Bridges

- Description:
  - Heat transfer by transmission does not only occur in the regular building elements like walls or roof, but also at corners, edges, junctions etc. Places where the regular heat flow through a building element is disturbed, especially those where it is higher than in the regular construction, are called thermal bridges. Concrete beams that penetrate an insulated wall are a good example
- Relevance in *Passivhaus* design:
  - In order to make good thermal insulation effective, it is necessary to reduce the thermal bridge effects. Few simple design rules eliminate the thermal bridge effects:
    - Do not interrupt the insulating layer
    - At junctions of building elements, the insulating layers have to join at full width
    - If interrupting the insulating layer is unavoidable, use a material with the highest possible thermal resistance
  - Thermal bridges also result in reduced temperatures of interior surfaces in winter, thus increasing the risk of cracks and mould formation
  - Thermal bridge effects can be minimized by installing the window in the insulating layer, not in the load-bearing wall (see lower figure), and by covering part of the frame with insulation
- Regional Solutions/Climatic Applicability:
  - Reduction or avoidance of thermal bridges is generally a cost-efficient means of reducing transmission losses or transmission heat load, respectively

Thermal bridges formed by concrete pillars and beams, in this case slightly reduced by two-hole hollow bricks



Construction example without thermal bridges

Heating Systems (1)

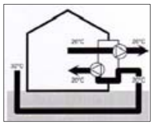
- Description:
  - Heating system energy performance is a function of the efficiency of production (generation), emission, control and distribution: $\eta_g = \eta_e \cdot \eta_c \cdot \eta_d \cdot \eta_p$
  - Overall efficiency is increased by improving the performance of the individual components, regarding these improvements are not incompatible
  - Two principle strategies of improving the heating system's energy efficiency are:
  - Improving seasonal efficiency of production:
  - Low temperature distribution system: potential savings of in the region of 10 – 25% with respect to the seasonal efficiencies offered by traditional three star boilers
  - Ground sources heat pumps have COP's in the region of 4.5 to 5, which considering the average efficiency of electricity generation of 39% , leads to overall system efficiencies of 195% (with respect to fuel LHV). However the overall system efficiency (electricity generation + heat pump) of air sourced heat pumps with COP's of 2 to 2.5 is around 80 to 100% and thus no better or often worse than a condensing boiler
  - Improving seasonal efficiency of emission:
  - Reducing indoor air temperature reduces energy loss, particularly due to ventilation.
  - Since room operating temperature is a weighted function of air and surface radiant temperatures, increasing increasing surface radiant temperatures allows air temperatures to be reduced without affecting indoor comfort. Using floor, wall or ceiling radiant heating systems provide effective and cost effective means by which this can be achieved
  - When used with condensing boilers, low temperature radiant panels provide maximum efficiency

Heating Systems (2)

- Relevance in *Passivhaus* design:
  - Condensing boilers, ground sourced heating pumps and radiant panels are highly efficient solutions. However to a degree the heating system can be considered as an add-on component detached from the building; applicable to any construction in any locality
  - Homes built to the *Passivhaus* standard in central Europe adopt a much more holistic approach: heat demand is reduced by removing infiltration of cold air through the building shell. This in turn requires an active ventilation system be introduced in order to guarantee occupants fresh air. Using an active ventilation system allows for heat recovery from the outgoing exhaust air which again reduces heat demand. If the home is insulated so as to reduce residual heat demand to 10W/m2, heating can be provided by post-heating the incoming ventilation air with a low powered heat pump. Alternatively, infiltration can still be reduced whilst providing fresh air by natural ventilation via automatically controlled vents and trickle ventilators
  - In this solution the heating system and building are intricately combined, For example increasing the permeability of the building shell would render the heating system impracticable. Matching the heating system and building in this way reduces construction costs whilst keeping heating demand below 15 kWh/m^2.year

Subsoil Heat Exchangers

- Description:
  - Ground at 2-3 m deep has an almost constant temperature, equal to the average air temperature over the year, which in Europe depending on locality means 10 – 20°C
  - As the ground temperature can be significantly above (in winter) or significantly below (in summer) the local outside air temperature, it provides a potential for heating or cooling a building with very little energy input
  - This cooling and heating potential is usually accessed by installing a sub soil heat exchanger (typically constructed in smooth-walled, rigid or semi-rigid plastic or metal pipes of 100 to 450 mm diameter) under or close to the building
  - The deeper the heat exchanger, the larger the active temperature difference, and the greater the cooling or heating potential. However excavation costs increase with depth and thus most heat exchangers are buried at between 1.5 and 3m.
  - Three basical configurations:
    - Open: outside air is drawn through a screened intake into tubing roughly 30m in length and then passes directly into the home
    - Closed loop: A portion of air from inside the home or structure is blown through a U-shaped loop(s) of typically 30 to 150m of tube(s) and then brought back into home
    - Combination: unidirectional check valve dampers allow either closed or open operation depending on the season and/or fresh air ventilation requirements
- Relevance in *Passivhaus* design:
  - Subsoil heat exchangers can generaly reduce use of active heating as incoming fresh air is pre-heated; active cooling demand and power may be reduced or even eliminated



Subsoil Heat Exchanger

Closed loop subsoil heat exchanger in use in apartment block restructured to the Passivhaus standard in Hannover, Germany

Appliances and Lighting

- Description:
  - Home appliances and lighting in the average European home typically consume between 30 – 40 kWh/m^2/year
  - Translated into primary energy, (70 - 100 kWh/m2/year), energy demand for home appliances is similar to the primary energy demand for heating in standard new buildings in central, northern and parts of southern Europe
  - By adopting the best technologies currently available on the market average household consumption could be reduced cost effectively by about 35 to 40% though saving potentials of some specific end uses can be much higher, for example regarding lighting
  - Several tools are available to help consumers (including designers) identify the most efficient appliances on the market: European labelling (A++ or A to G), Energy Star originally developed in the USA but in use in Europe since 2000, the Nordic Swan in Scandinavia or the German Blue Angel
- Relevance in *Passivhaus* design:
  - As the heating and cooling demand of buildings and homes is reduced so the relative importance of energy demand by household appliances and lighting grows
  - The *Passivhaus* standard permits a total primary energy demand (for all building services) of 120 kWh/m^2/year, which is not actually that restrictive. However it makes little sense to work hard to reduce heating and cooling demand and then use inefficient household appliances
  - Though it is true that inefficient appliances help reduce heating loads in winter, this is a very inefficient way to heat a house. Also internal gains from inefficient appliances increase summer cooling loads and overall the net balance energy is usually negative
  - Before considering energy efficient products designers should really look at alternative completely passive ways to provide building and home services. For example using a washing line to dry clothes (rather than a tumble dryer) requires no energy

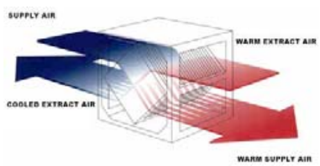
Drying clothes by washing line

Heat Recovery Systems (1)

- Description:
  - A heat recovery ventilator (HRV) can help make mechanical ventilation more cost effective by reclaiming energy from exhaust airflows (recovering). HRVs use heat exchangers to heat or cool incoming fresh air, recapturing 60-80 % of the conditioned temperatures that would otherwise be lost
  - At the heart of the HRV is the heat exchanger in which incoming and outgoing airflows pass through different sides of thermally conducting plates (but are not mixed), allowing conditioned exhaust air to raise or lower the temperature of incoming fresh air
  - Heat exchangers can be one of two types; cross flow or inverse flow. Cross flow heat exchangers have an efficiency of around 60% and are often used in series in order to obtain combined efficiencies of around 80%, Inverse flow heat exchangers can on the other hand potentially achieve efficiencies of 95%
  - Models that exchange moisture between the two air streams are referred to as Energy Recovery Ventilators (ERVs). However ERVs are not dehumidifiers: they transfer moisture between two air streams and their dessicant wheels may saturate after long hot and humid periods
  - After passing through the heat exchanger, the warmed or cooled air may be sent to the HVAC air handler, or directly to various rooms. In a typical system configuration air is supplied to the living room, bedrooms and removed from the kitchen and bathroom
- Relevance in *Passivhaus* design:
  - The heat recover system is an essential part of the central European *Passivhaus*, and allows homes to be built without conventional heating systems. As example the system installed in the *Passivhaus* in Darmstadt-Kranichestein recovers between 3.000 to 4.000 kWh/year thermal energy. By using a low powered (200-300 W) electronically commuted DC motors, energy consumption by the ventilators is limited to 200 – 400 kWh/year. Thus the final the ratio between absorbed and recovered energy is 1:10

Heat Recovery Systems (2)

  - In the coldest months heat recovery may be insufficient to bring the incoming air to the required temperature. Thus the heat recover systems is often combined with a small powered heat pump (electrical power 300- 500 W) to provide post-heating on incoming air
  - Though central to the central European *Passivhaus*, heat (and cold) recovery systems also represents a viable solution for Mediterranean passive design (ex: proposed Italian *Passivhaus)*. In warm climates the heat recover system is used to pre-cool incoming warm air. By installing a reversible heat pump this cooled incoming air can be further cooled to provide
- Regional Solutions/Climatic Applicability :
  - ERVs are especially recommended to dry incoming air in climates where cooling loads place strong demands on HVAC systems. Thay can also be valuable for climates with very cold winters, to humidify incoming air that could otherwise be very dry and cause discomfort



Energy Recovery Ventilator

Heat Losses of Windows

- Description:
  - Heat losses through windows are proportional to their U-value, so in general it is convenient to diminish U-value of the windows in all the orientations
  - However, in the other hand, when U-value is decreased the radiation passing through the window is lower too and consequently solar gains are reduced
- Relevance in *Passivhaus* design:
  - Improve the insulation of the window areas has a tremendous effect for heating but null in general for cooling
  - Additional advantages: reduced condensation and window back – draught risk, increased radiant temperature during the winter period and reduced infiltration rates
  - The improvement on the thermal insulation performance of windows is achieved through a combination of:
    - Increasing number of panes - up to triple glazing or quadrupled-glazed windows
    - Different types of low emissivity coatings - can be soft coatings that are used in sealed glazing units or hard coatings that can also be used in single panes
    - Vacuum windows - Heat transfer is reduced through evacuation of the inter-pane space to a pressure of about 0.01 Pa
    - Aerogel - Aerogel is an interesting material, having a silicate cell structure, with cell sizes less than the mean free path length of air particles. This result in a extremely low value of the material's thermal conductivity. However, it is expensive and not completely transparent.
- Regional Solutions/Climatic Applicability:
  - In severe climates (high Winter Climate Severity) it is recommendable to decrease the U-value of the window
  - Change simple glazing for double or low emissive glazing, shows an important improvement that is especially important in cold climates, and in north directions
  - In moderate climates it is not so clear weather U-value of windows should be reduced, as solar gains may compensate for heat losses

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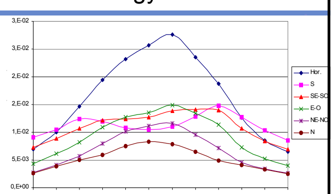
Single glazing	5.7 W/m2K
Double glazing	2.8 W/m2K
Triple glazing	1.9 W/m2K
Sealed triple glazing unit with low-emission coating	1.4 W/m2K
Sealed triple glazing unit with low-emission coating and argon filling	1.2 W/m2K
Sealed triple glazing unit with two low-emission coatings and argon filling	0.8 W/m2K
Vacuum window (high vacuum)	0.5 W/m2K
20 mm Aerogel window (low vacuum)	0.3 W/m2K

Examples of the U-values for the center of windows illustrate the improvements that can be made (The Energy Book, 1996).

Glazing and Solar Energy

- Description:
  - The energy of the sun gets into the buildings as radiation through the windows. The radiation is measured in W/m² of glazing surface and is very important due to:
  - This radiation can diminish the heating demand
  - This radiation can increase the cooling demand
  - As one consequence is positive and the other one negative, it is necessary to make a good design based on taking the benefits of solar radiation in winter and protect against the negative effects during summer in order to avoid overheating
- Relevance in *Passivhaus* design:
  - Solar irradiation is dependent on orientation of the surface (see graph)
  - Radiation in the south is the maximum during winter and it is very low during summer. This means that during winter we can reduce the heating demand using high south-oriented glazing surface, during the summer we have to protect this glazing using shadings, and in any case the solar radiation in this surface will be lower than E/W or SE/SW



Solar irradiation (kWh/m²) for various orientations (North hemisphere)

- Regional Solutions/Climatic Applicability:
  - Buildings should have a high percentage of south-oriented windows (glazing surface to the south between a 75% and a 100% of the total glazing surface), protected in summer with movable shadings or horizontal overhangs – see "shading"
  - The optimum glazing surface for mild winters is equal to 30% of the total surface of the building. In locations with more severe winter this optimum does not exist but it is recommended a glazing surface between a 15% and a 30% of the total surface

Phase Change Materials (PCM)

- Description:
  - Systems that use Phase Change Materials (PCM) can be used to store energy:
    - All substances store energy when their temperature change, but when a phase change is produced in a substance the energy stored is higher. For example, for ice to melt into water (phase change) heat absorbed is 60 times higher than the heat absorbed when it increases its temperature in 10ºC
    - Also, in phase change, heat storage and its recovery occurs isothermally, which makes them ideal for space heating /cooling applications
  - PCM useful for construction systems should: have a life cycle according to their cost; have a high specific heat; be chemically stable; not be toxic, corrosive, or inflammable; have similar densities of solid and liquid state
- Relevance in *Passivhaus* design:
  - The application of PCMs in building can intend to manage natural sources, namely solar energy for heating or night cold for cooling, or manmade heat or cold source
  - PCM's provides storage of heat or cold, necessary to match availability and demand with respect to time and also with respect to power
  - Different ways to use PCMs for heating and cooling of buildings are: in building walls; in other building components other than walls; and in heat and cold storage units
  - The first two are passive systems (associated to high thermal inertia of building): the heat or cold stored is automatically released when indoor or outdoor temperature rises or falls beyond the melting point
  - The third one is active system: the stored heat or cold is in containment thermally separated from the building by insulation. Therefore, the heat or cold is used only on demand and not automatically
  - Depending on where and how the PCM is integrated, PCMs with different melting points are applied. Currently, there is a lack of commercial PCMs in the lower temperature range that is between 5 and 25ºC (cold storage units). Especially between 15 and 20ºC available products show too low enthalpies. Most important PCMs are in the range of 22–25ºC (range for building passive heating and cooling)

Colour of Exterior Surfaces

- Description:
  - Colour of exterior surfaces determines the quantity of radiation that will be absorbed by that surface. This may impact on cooling and heating demand
  - The more insulated the surface, the lower relevance will be the exterior colour, as even if the surfaces absorbs heat its transmission to indoor space will be reduced according to U-value
- Relevance in *Passivhaus* design:
  - In order to diminish the cooling demand using this strategy it is necessary to apply light colours to those façades with more incident radiation during summer (particularly buildings with high area of opaque surfaces to the east or west and roofs of buildings with 1 or 2 storeys)
  - Also, it is necessary to take into account that this measure has a negative effect for the heating demand; this will be higher because the heat gains due to solar radiation will decrease
  - As a consequence, when for aesthetical reasons the colour of all the external façades has to be the same, and all of them will be painted in a light colour, the orientations SE, S and SW will be worst during winter. In this case, the usefulness of the measure has to be evaluated in an annual basis, and only should be applied in those locations with dominant summer
- Regional Solutions/Climatic Applicability:
  - Painting white has been traditionally used in southern Europe (namely Portugal, Spain, Greece), due to severe summer conditions
  - In climates with light summers it is recommended to use this measure, painting E and/or W façades with light colours only if winter is not severe
  - Also, it is possible to apply this measure in the roofs of less than two storey buildings located in the same climatic zone

Proposing *Passivhaus* for Southern Europe

Proposing Passivhaus for Southern Europe

- Different climates, different markets... different approaches: the partners explored the limits of the *Passivhaus* standard and how these could be updated to match the warmer conditions to south:
  - Several passive strategies and approaches were discussed and tested
  - Exploration was made with the aid of building dynamic thermal simulation
  - For different climates across France, Italy, Portugal, Spain and the UK, we present design examples of houses that achieve the Passivhaus standard
  - The exercise was undertaken by the partners with the aim of ***applying the Passivhaus standard, intended as a performance standard rather than a list of prescriptive requirements***
  - Refer to Guidelines for more details!!

Main Outputs

- This has lead to a wide range of design solutions reflected in the national proposals described hereafter
- The exercise revealed that heating loads are relatively low in many southern European countries and generally stay below the 15kWh/m^2 mark
- It emerged that in many cases there are cooling loads to take into account but that often these can be met by passive strategies alone. These show that it is possible to design low energy comfortable homes adopting a raft of appropriate solutions which can avoid the use of active cooling in many locations
- In locations where active cooling was necessary, most of cooling was still achieved by mainly passive means, with little contribution from active cooling; in these cases, the sum of annual cooling and heating demand was still below 15 kWh/m^2.year
- Winter and Summer comfort could be achieved, with very short periods out of comfort temperature range

Passivhaus UK – the house

- The starting point:
  - Standard 3 bedroom, 2 floors semi-detached house, complying with Building Regulation 2006
  - Location: Birmingham
  - Orientation: North-South
- Proposed house is adapted to British context (climate, technical and economical framework; buyer's expectations), for instance:
  - Air-tightness is relaxed (up to 3 ach at 50 Pa)
  - No mechanical ventilation system (thus also no heat recovery); minimum fresh air supply is introduced via the buffer space through automated ventilators; trickle ventilators are installed throughout the house
  - The extra costs of the proposed UK *Passivhaus*, compared to a standard house, is of 49 £/m^2 with a payback period of 19 years

Example of zero fossil energy housing in the UK, Bedzed (Architects: Zed Factory)

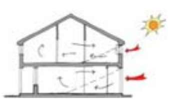
3D of UK *Passivhaus* proposed by SBE

Passivhaus UK – passive strategies

- Combines natural ventilation with a high thermal capacitance interior
- Implementing natural ventilation via manually controlled and automatic controlled openings
- Glazed buffer zones to North (entrance) and South (pre-heating of fresh air)
- Roof vent on top of stairwell, which provides an outlet for stack ventilation
- The glazed buffer space on the south side is provided with Venetian blinds for solar control in summer and insulated shutters against heat losses in winter
- Where space allows, ground pipes can be installed in the garden to deliver pre-heated (or pre-cooled) air to the buffer space

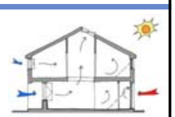
Passivhaus UK – Winter and Summer

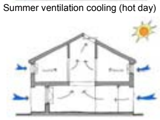

Winter pre-heating (overcast)

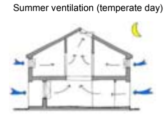

Winter pre-heating (sunny)


Winter night heating (insulation)

- In winter, supply air is preheated through the south buffer space
- The residual heating load is so low that this could be met by a carbon neutral source such as a woodchip boiler which could provide hot water as well
- In summer, during hot days, the buffer space is open to the outside in order to avoid overheating, and acts as an extension to the living space
- At night in summer, automatic control of high level ventilators will promote to cool down the building and the thermal mass of the interior. Security is maintained by using high level automated vents and low level trickle ventilators
- There is no need for active cooling in the UK *Passivhaus* proposal


Summer ventilation cooling (hot day)


Summer ventilation (temperate day)

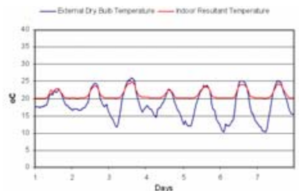

Night cooling ventilation (summer night)

Passivhaus UK – details

- High thermal capacitance interior
  - can be achieved by exposed pre-cast concrete floor panels, or, where lightweight construction is preferred, by the use of phase change materials (PCM) encapsulated within plasterboard
- High levels of insulation are assumed:
  - U-Values ranging from 0.2 W/m^{2}K to 0.15 W/m^{2}K for walls and roof respectively
  - Low-e Double Glazing (not triple glazing as used in the German Passivhaus) is proposed for the inner glazing whilst the outer layer of the buffer space was single glazed. The outer layer could be double glazed also which could improve the performance substantially but modelling predicted that with the glazing described the space achieved the required heating standard. Typical U-values for windows of 1.8 W/m^{2}K are assumed
  - Infiltration rates of 3ach at 50Pa are assumed. In winter, supply air is preheated through the south buffer space

Passivhaus UK – Performance

- Annual heating energy demand:
  - estimated to be a total of 13.8 kWh/m^2
  - complies with the *Passivhaus* standard of 15 kWh/m^2
  - compares with a typical annual heating energy requirement for the same house, built to current building regulations standard, of 55 kWh/m^2
  - Note: this house incorporates an exposed gable wall; therefore a terraced house with the same layout could achieve this performance with a slightly reduced specification
- Active cooling is not required due to the provision of the passive mitigations strategies described
  - Right: typical Dry Resultant Temperatures in summer without additional cooling



Passivhaus Spain – the house

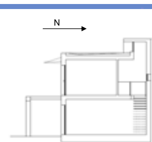
- The starting point:
  - typical 2 floors semidetached Spanish dwelling with three bedrooms and a total treated floor area of 100 m^2. It fulfils the current Spanish regulations called "Building Technical Code" mandatory from 2007
  - Locations: Seville (very severe Summer) and Granada (very severe Winter – for Spanish average!)
  - Orientation: North-South
- Focus on Spain requirements and specificities fordeveloping a *Passivhaus*:
  - No mechanical ventilation system and air tightness compatible to Spainish building characteristics
  - Should achieve maximum energy label A
  - Affordable:
    - extra cost < 5% or 25 €/m^2
    - Discounted Payback around 5 years

Low energy housing in Seville, Spain

Ground and First floor

Passivhaus Spain – passive strategies

- Enlarged area of exposed walls (even sacrificing compactness), with high level of glazing to South
- Very effective shading of south glazing accomplished by overhangs (first floor) and a large pergola (ground floor), together with movable shadings
- North glazing is set to a minimum that guarantees natural lighting
- Living areas (bedrooms, living room and kitchen) oriented to South, WCs and corridor/stairs oriented North
- Natural ventilation combined with a high thermal capacitance interior. Heavy Interior surfaces that are sunlit should have a higher inertia and be exposed to natural ventilation
- Glazed openings in first floor corridor for lighting and stack ventilation, particularly during summer nights

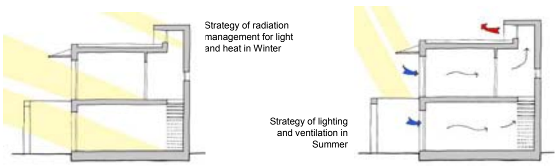


Section

North façade

Passivhaus Spain – Winter and Summer

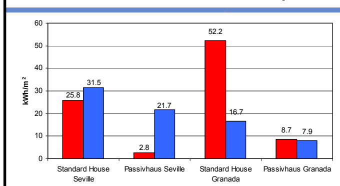
- In winter, the solar gains trough the large areas of glazing to South contribute to significantly reduce the heating loads
- In summer, glazed surfaces are shaded reducing the solar gains, and stack ventilation can provide effective night cooling
- Natural lighting is optimized in all house



Passivhaus Spain – details

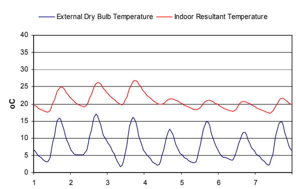
- High thermal capacitance interior
  - Concrete slab between ground and first floor with a ceramic tile finishing guarantees thermal mass is exposed to air.
  - Brick walls for internal partitions (except for Granada for structural reasons: is a seismic zone)
- Exterior shading is applied to all windows
- Medium levels of insulation are assumed:
  - U-Values for Seville ranging from 0.37 W/m^2K to 0.39 W/m^2K for walls and roof respectively. For Granada U-Values are 0.26 W/m^2K and 0.28 W/m^2K
  - In Seville, normal Double Glazing is used to South, to increase solar gains; to North, Low-emission Double Glazing should be used; in Granada, as it presents a more severe winter climate, Low-E Double Glazing is used both to South and North

Passivhaus Spain – Performance



Predicted annual heating demand (red) and cooling demand (blue) for Standard House and *Passivhaus* in Seville and Granada

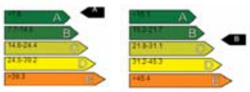
Predicted temperatures during one week winter in the *Passivhaus* in Granada



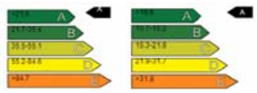
Passivhaus Spain – Performance

- Seville:
  - 2.8 kWh/m² year heating demand and 21.7 kWh/m² year cooling demand; total: 24.5 kWh/m² year
  - this does not fulfil the *Passivhaus* requirements for summer. However, these values correspond to very good levels in the national energy labelling (A in heating - B in cooling). The average total energy demand for a new standard dwelling is 57.3 kWh/m2, the proposed Spanish *Passivhaus* design produces a 57% of reduction in this value

Seville Heating and Cooling labelling



Granada Heating and Cooling labelling



- Granada:
  - 8.7 kWh/m² year heating demand and 7.9 kWh/m² year cooling demand; total: 16.6 kWh/m² year
  - this does fulfil the *Passivhaus* requirements. The average total energy demand for a new standard dwelling is 69.0 kWh/m2, with the proposed design achieving 76% of reduction in this value. This *Passivhaus* proposal would have an energy labelling of A in heating and B in cooling
  - These values are so low that there is virtually no need for active cooling or heating systems (except for the higher cooling demand in Seville). In fact, simulations show that the overall strategy adopted for the design of Spanish *Passivehaus* fulfils the envisaged requirements in terms of heating/cooling and thermal comfort

Passivhaus Portugal – the house

- The starting point:
  - Single floor 2 bedrooms house, total treated floor area of 110 m² complying with the national Building Regulation 2006 (RCCTE, DL 80/2006)
  - Location: Lisbon
  - Orientation: Mainly South
- Focus on portuguese climate, constructions standards and technical and economical framework:
  - Simple prototype (can be easily enlarged to offer more rooms and/or floor area) to allow architects the freedom to design the house
  - No mechanical ventilation system and air tightness of 0.8 ach at 50 Pa
  - Thermal solar system is compulsory for DHW and is proposed to be enlarged to supply part of heating
  - The extra costs of the proposed Passivhaus for Portugal is 57 €/m2 (7.25%) with a payback period of 12 years

Low energy housing near Lisbon, Portugal

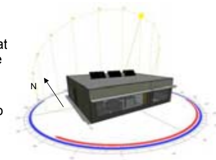
SE view of proposed *Passivhaus* with Thermal Solar Panels on roof

Passivhaus Portugal – passive strategies

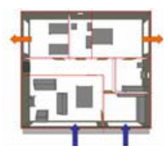
- Although the level of insulation exceeds the national standards and the air infiltration is controlled, these are not the major issues for the current proposal
- The three main aspects explored in the proposed house are:
  - ***relation with the sun***: solar availability is quite high in Portugal, even during the heating season. Solar radiation is captured both directly (windows) and indirectly (thermal solar system). Large windows are mainly oriented south increasing the useful solar gains during winter. Smaller areas are oriented east and west and minimal areas to north. Exterior Venetian blinds protect all windows and overhangs are also applied to south windows
  - The solar heat captured by the thermal solar system is distributed to a ***low temperature hydraulic heat distribution system*** (such as radiant floor) to heat the house
  - ***ventilation for cooling*** (particularly at night)
  - ***high thermal mass*** to control temperature swings
  - Windows distribution contribute effectively for ***natural lighting***

Passivhaus Portugal – Winter and Summer

- Winter:
  - The house combines the ability to collect solar heat (large south windows) and the capacity to regulate inside temperature with its high thermal inertia
  - Contribution of thermal solar system to heating up the house reduces even further the heating load to be covered by conventional systems
- Summer:
  - glazed surfaces are shaded reducing the solar gains
  - High thermal capacitance and large openings for ventilation allows for effective night cooling; in the bedrooms ventilation should take place in the evenings, to avoid drafts during the sleeping period; in all other spaces, all night cooling can be used
  - Passive measures can reduce the power of the active cooling system or make unnecessary its installation
- Natural lighting is optimized in all house



Summer Solar Incidence, view from SW



Summer ventilation strategy

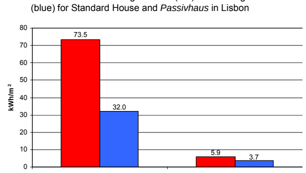
Passivhaus Portugal – details

- Medium insulation levels (high for average Portuguese values) and High thermal capacitance interior:
  - Concrete slab with perimeter insulation takes advantage of stable temperature of ground, insulated perimeter reduces thermal bridges
  - Brick walls for internal partitions
  - Applying external insulation to the roof and walls. However, there is still some scepticism among Portuguese house builders to the mechanical performance of exterior insulation. Therefore, it is proposed to use the traditional double brick wall with an insulation layer in the cavity. U-value for roof is 0.23 W/m^2.K and for walls is 0.32 W/m^2.K
  - Thermal bridges correction on wall's concrete pillars and roof
- Windows:
  - Low-emission double glazing can be very effective in colder climates of Portugal, but in most situations standard double glazing is more cost-effective Windows areas facing south correspond to around 60% of the total glazed area; about 20% of glazed area faces East and another 20% West. This means approximately 1.2 m^2 of south glazing for every 10 m^2 of net area (total of 2.1 m^2 of glazing for every 10 m^2 of net area)
  - Exterior shading is applied to all windows, overhangs (0.6m deep) to south windows
- The thermal solar system provides most of the heating demand of the house
  - solar panels are installed facing south, tilted 50º from horizontal plane, to increase the efficiency during winter

Passivhaus Portugal – Energy Performance

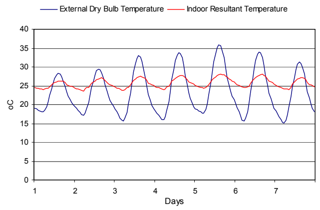
- The annual heating energy demand of the *Passivhaus* proposed for Portugal has been estimated as 16.9 kWh/m^2.year, of which 11 kWh/m^2.year are supplied by the solar system (in this analysis priority of the solar system is given to heating and the solar fraction for domestic hot water is 48%)
- The annual cooling energy demand is 3.7 kWh/m^2.year
- The sum of net heating and cooling demand is 9.6 kWh/m^2.year
- According to the thermal regulation, the limits of heating and cooling for this house built in Lisbon, are 73.5 and 32 kWh/m2.year, respectively
- The proposal would achieve the following labels in Portuguese labelling scheme:
  - **A** without contribution from the Thermal Solar System
  - **A+** (maximum) with the Thermal Solar System)

Predicted annual heating demand (red) and cooling demand (blue) for Standard House and *Passivhaus* in Lisbon



Passivhaus Portugal – Comfort Performance

- For this house, with a low power active cooling system the resultant temperature is kept below 25°C for 71% of the occupied time, and below 28 ºC during 98% of the occupied time
- If no active cooling is to be installed, the size of the windows and the thermal insulation of the walls should be reduced (though this could increase the heating demand)
- In winter, the low power heating system of 10 W/m2 is in use, resulting in only 8% of time with a resultant temperature below 19.5ºC (lower resultant temperature achieved is 18ºC)



Predicted resultant temperatures during very hot summer week in the *Passivhaus* in Lisbon, without active cooling

Passive Home Training Module for Architects and Planners

Passivhaus Italy – the house

- The starting point:
  - 2 bedrooms "rustic villa" style (basement + 2 floors) with 120 m² treated floor area, high compactness
  - Locations: Milan, Rome and Palermo
  - Orientation: Mainly South
- Premise:
  - The design solutions commonly implemented in central European *Passivhaus* are both pertinent to areas of Italy with relatively severe winters (Milan and the North in general) and to mountainous regions further south
  - Aditional measures for passive cooling can be integrated in such a house design
  - The extra costs of the proposed Passivhaus for Milan is 84 €/m2 (7%) with a payback period of 12 years

The *Passivhaus* constructed in Cherasco, Cuneo, North Italy

SE view of proposed *Passivhaus* for Italy

Passive Home Training Module for Architects and Planners

Passivhaus Italy – passive strategies

- Generally, the proposal for Italy applies the same strategies as central European *Passivhaus*, but as winter is milder the criteria can be relaxed and still allow for energy limits and comfort requirements to be met:
  - Good thermal insulation and elimination of thermal bridges
  - Envelope Air tightness
- Attic and basement outside the insulation envelope
- Solar gains by south oriented windows
- Additional measures for cooling mitigation are:
  - Windows shading by roof eaves and Persian shutters
  - Natural night ventilation for cooling, combined with a heavy structure with high thermal inertia
- Mechanical ventilation with heat recovery, complemented with a low power reversible heat pump (ground sourced)
- Ground pre-heating and pre-cooling of fresh air

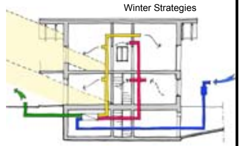
Passive Home Training Module for Architects and Planners

Passivhaus Italy – Winter and Summer

- Winter:
  - Minimises winter heat loss through the highly insulated building shell and the elimination of thermal bridges
  - Provides active ventilation with heat recovery from exhausted air
  - Provides active heating using a reversible low powered (ground sourced) heat pump
  - Allows for solar gains by using 30% glazing of the south facade and reduces losses by limiting glazing on the north facade
- Summer:
  - Minimises solar gains through the highly insulated building shell and shaded windows
  - Exports daytime solar and internal gains from the building shell using a natural and active ventilation at night. Night time air is be passed through the building either by wind or natural buoyancy, or by using the fans of the active ventilation system. The strategy works in Milan though is most effective in Rome
  - Auxiliary cooling by heat pump

Summer Strategies

Winter Strategies



Passivhaus Italy – details

- For U-values: →
- (Note that for Palermo the foundations are not insulated)
- Air permeability (n_{50} value): 1 h^{-1} in Milan and Rome, 1 to 2 h^{-1} in Palermo
- Double pane Low-Emission glazing
- Ground sourced reversible heat pump, heating and cooling power around 1.5 kW

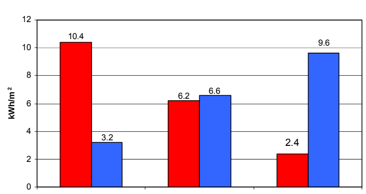
		Milan	Rome	Palermo
External walls	**U-value** (W/m²K)	0.14	0.32	0.23
	Insulation (cm)	25	10	15
Under roof	**U-value** (W/m²K)	0.15	0.32	0.23
	Insulation (cm)	25	10	15
Foundations	**U-value** (W/m²K)	0.32	0.32	1.7
	Insulation (cm)	10	10	0

Passive Home Training Module for Architects and Planners

Passivhaus Italy – Energy Performance

- For all three climates, with the proposed strategies and specifications was possible to achieve a sum of heating and cooling demands below 15 kWh/m².year
- Full night time natural ventilation of the ground and first floors reduces cooling demand by 60% in Milan, 40% in Rome and 20% in Palermo, and increased comfort in all three test localities where otherwise there would be discomfort

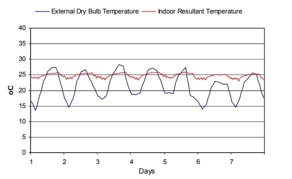
Predicted annual heating demand (red) and cooling demand (blue) for Standard House and *Passivhaus* in Milan, Rome and Palermo



Passive Home Training Module for Architects and Planners

Passivhaus Italy – Comfort Performance (1)

- In ***Milan and Rome*** summer comfort conditions can be provided by entirely passive means. More precisely:
  - In Milan the Adaptive Comfort upper temperature limits (according to EN 15251) is never exceeded, though the neutral temperature is exceeded occasionally in August
  - In Rome the Adaptive Comfort upper temperature limits is never exceeded, though the neutral temperature is exceeded for most of the summer in August
  - In any case passive cooling provides maximum indoor temperatures in both Milan and Rome of around 30°C
- In Palermo, although the night time ventilation strategy does work, indoor temperatures can be reduced using the small powered reversible heat pump. Modest energy consumptions bring summer indoor temperatures consistently below the neutral temperature defined by the Adaptive comfort model. (Maximum temperature around 27.5°C)



The living room temperature in Milan using only passive cooling solutions

Passivhaus Italy – Comfort Performance (2)

- In Palermo, the natural ventilation strategy is less effective (diurnal temperature swings of only 3°C in July, August and September) and some form of active cooling is required to provide acceptable summer comfort conditions
  - if only purely passive means for cooling are applied, maximum temperature reaches 32.5°C
- Even with significant active cooling (9 kWh/m^2.year) in Palermo the neutral comfort temperature is exceeded for a number of days in August, though indoor temperatures always remain significantly lower than the maximum acceptable temperature

Passivhaus France – the house

- The starting point:
  - 3 bedrooms terraced house (basement + 2 floors) with 120 m^2 treated floor area
  - Locations: Nice and Carpentras
  - Orientation: South-North
- Premise:
  - Northern France climate is very similar to German climate, although milder thanks to influence of the Atlantic Ocean; therefore, for such locations the design could follow the German approach
  - For the Mediterranean climates of South of France considered, requisites on insulation levels of walls, roof, basement and windows are relaxed (in Nice the insulation values correspond to the legal requirements)
  - The extra costs of the proposed Passivhaus for France is about 100 €/m^2 (10%) with a payback period of 19 years

Hannover-Kronsberg *Passivhaus* rows. The buildings' geometry is similar to the French *Passivhaus* proposal

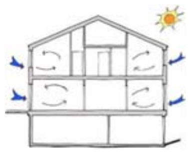
Section of proposed *Passivhaus* for France

Passivhaus France – passive strategies

- The proposals for south of France apply the same strategies as German *Passivhaus*, but criteria can be relaxed accordingly to less severe climate:
  - Good thermal insulation and elimination of thermal bridges (insulation from the exterior)
  - Envelope Air tightness (infiltration less than 1 h^{-1} at 50 Pa)
- Basement outside the insulation envelope
- Solar gains by south oriented windows (next row of houses at 23 m)
- Additional measures for cooling mitigation are:
  - Windows exterior shading
  - Natural night ventilation for cooling, particularly effective for Carpentras
- Mechanical ventilation with heat recovery complemented with a compact heat pump (this unit uses the exhaust air *after* the heat exchanger as a heat source for the integrated heat pump. The heat pump also heats a DHW storage)

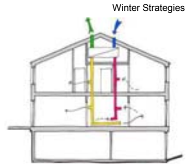
Passivhaus France – Winter and Summer

- Winter:
  - Minimises winter heat loss through the highly insulated building shell and the elimination of thermal bridges
  - Provides mechanical ventilation with heat recovery from exhausted air
  - Provides active heating using compact heat pump
  - Solar gains collected at South façade
- Summer:
  - Insulation of walls and roofs limits the solar heat that comes into the building; exterior shading devices are applied to windows
  - During summer, as outside temperatures are usually below 25ºC, heat recovery can usually be by-passed
  - Night cooling is applied; however, in Nice (lower daily temperature swing and higher relative humidity) auxiliary cooling is necessary, while in Carpentras night flush can guarantee summer comfort



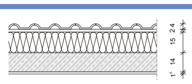
Summer Strategies

Winter Strategies

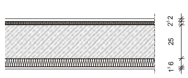


Passivhaus France – details

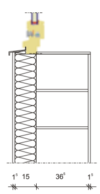
- Double low-e glazing, wooden frame
- Nice: 10 cm insulation in roofs, 6 cm in walls, 2 cm in basement floor
- Carpentras: 15 cm insulation in roofs and walls, 6 cm in basement floor
- Interior partitions: plastered brick masonry for thermal inertia
- Air permeability (n_{50} value): 1 h^{-1}
- Construction details (values for Carpentras):



Concrete **roof** from outside to inside: roof tiles, air gap, insulation, concrete load-bearing panel, plaster. Lightweight constructions can also be used, the effect is comparably small



Basement **floor** (floor between the basement and the ground floor) from inside to outside: Wooden flooring, impact sound insulation, concrete, thermal insulation, plaster



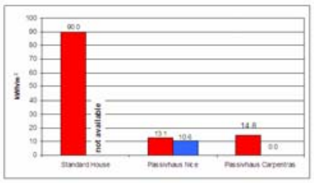
Installation of **window** in the insulation layer to reduce thermal bridge effects. Covering the frame with insulation at the side reveals and the lintel further reduces heat losses

Exterior wall (from outside to inside): Compound insulation system (exterior plaster, 60 % solar absorption, + polystyrene insulation), brick masonry (1400 kg/m³), gypsum plaster

Passivhaus France – Energy Performance

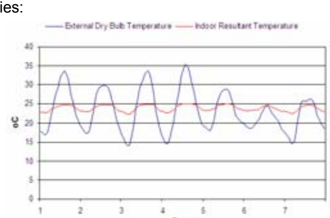
- For both Nice and Carpentras climates, the annual heating demand of the house is slightly below 15 kWh/m².year
- Nice and Carpentras have similar average dry bulb temperatures (although with larger diurnal temperature swing in Carpentras). However, relative humidity is considerable higher in Nice. Therefore in Nice:
  - night cooling is less effective
  - high humidity could cause discomfort
- Therefore:
  - no Active Cooling is needed for Carpentras, provided night ventilation is high and solar protection is effective
  - in Nice the natural ventilation airflow is reduced and active cooling is provided and also performs as de-humidifier

Predicted annual heating demand (red) and cooling demand (blue) for Standard House and *Passivhaus* in Nice and Carpentras



Passivhaus France – Comfort Performance

- In both climates, winter indoor resultant temperature was maintained at 20 ºC within the energy limit referred (for sunny days, temperature could be 1 to 2 degrees higher)
- During summertime, the resulting temperatures stay well below the adaptive comfort temperature during summertime, usign the correspondent cooling strategies:
  - In Carpentras, passive strategies keep the temperatures below 25 °C during more than 99 % of the year in all rooms
  - In Nice, a similar result is achieved with supply air cooling and only moderate additional window ventilation



Typical Dry Resultant Temperatures in summer without active cooling for Carpentras

Climate Analysis

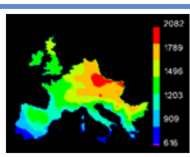
Passive Strategies and Climatic Characterisation

- What is the climatic applicability of the strategies and scenarios introduced in the national *Passivhaus* proposals?
- Although each national proposal contains one or two climatic locations per country, this does not mean that the examples illustrated can be generalised for each country respectively
- Different climates, even within the same country, can imply that one specific design solution or passive strategy may work in one context but not in another
- On the other hand, similar climates may be found across different countries

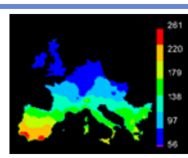
Climatic Applicability

- Energy demand for heating and cooling a building depends on the climate and the thermal characteristics of the building envelope
- The climate parameters with main influence on building's energy demand are the outdoor temperature and the solar radiation
- Potentially the heating and cooling demand can be assessed on the basis of 'degree-days' but this only takes temperatures into account and does not account for the influence of solar radiation
- Thus, in order to compare two different climates we should compare both the outdoor temperature and the solar radiation
- This means that it is possible to extrapolate the use of a passive technique/design strategy from one location to another when both have similar outdoor temperature and similar levels of solar radiation
- But this poses two new questions:
  - ***is it possible to compare outdoor temperatures?***
  - ***is it possible to compare radiation levels in different locations?***

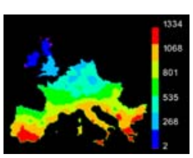
Temperature and Radiation Maps



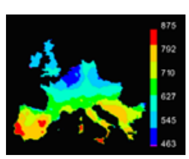
Winter Degree-Days



Radiation over horizontal surface in winter (kW/m^2)



Summer Degree-Days



Radiation over horizontal surface in summer (kW/m^2)

Climatic Severity Index

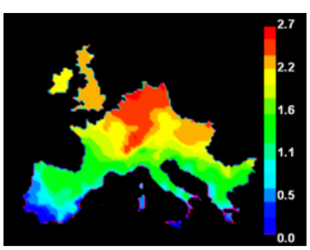
- As seen, the degree-days approach does not account for the influence of either solar radiation or the thermal characteristics of a particular building
- The ***Climate Severity Index*** (CSI) was developed to allow the characterization of climate in relation to a building of known envelope characteristics (Markus et al 1984)
- The CSI (a single number on a dimensionless scale) is specific for each building and location, and accounts for both temperature and solar radiation. The CSI is calculated separately to represent summer and winter conditions
- Two different winter climatic conditions can be considered identical if the heating demand is the same in a certain building, under both climatic conditions. In this case, we can say that both winter climatic conditions have the same Winter Climatic Severity (WCS). The same definition is valid for cooling demand and the term used would be Summer Climatic Severity (SCS)

Climatic Severity Index for Locations

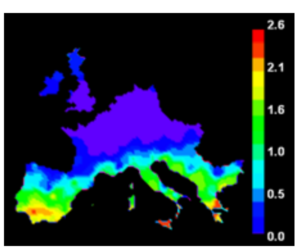
- In the task of building components characterization, the ***heating and cooling demand have been obtained for 8 buildings in 18 locations***
- Taking the average value of heating demand and cooling demand from all the buildings in each location, ***one heating demand and one cooling demand have been assigned to each location***
- In order to standardize, all the heating demands and cooling demand values are divided by Madrid values. By this way, ***we get the Winter Climatic Severity (WCS) and Summer Climatic Severity (SCS) in each location***
- It is possible that two different climatic conditions have equal winter climatic severity (WCS), but different summer climatic severity (SCS). (example: Brighton, UK and Milan, Italy)

Location	Winter Climatic Severity (WCS)	Summer Climatic Severity (SCS)
Germany (Dresden)	3.31	0.00
Germany (Braunschweig)	2.56	0.05
Germany (Freiburg)	2.14	0.10
United Kingdom (Brighton)	1.83	0.01
United Kingdom (Glasgow)	2.59	0.00
United Kingdom (London)	2.22	0.01
United Kingdom (Newcastle)	2.59	0.00
United Kingdom (Nottingham)	2.36	0.00
France (Agen)	1.44	0.19
France (Carcassonne)	1.24	0.37
Italy (Milan)	1.81	0.46
Italy (Rome)	0.83	1.19
Italy (Trapani)	0.32	1.87
Portugal (Lisbon)	0.37	1.05
Spain (Seville)	0.32	2.56
Spain (Madrid)	1.00	1.00
Spain (Granada)	0.81	1.11
Spain (Burgos)	1.96	0.05

Climatic Severity Index Maps



Winter Climatic Severity Index (WCS)



Summer Climatic Severity Index (WCS)

Heating Energy Savings by Improving Elements

- How does energy demand for heating responds to improvements in buildings?
  - Parametric changes on: walls insulation, roof insulation, and improving glazing from normal double to low-emission double
  - Simulation performed for different buildings and climates
- For the roof and walls, the savings in heating energy demand have been expressed in all the cases in kWh per square meter of components when the improvement of their U-value is 0.10 W/m²K; heating energy saving is approximately proportional to reduction of U-value, therefore an extrapolation for other U-value reductions is easily estimated
- In the case of windows, the savings have been expressed in all the cases in kWh per square meter of glazing when double glazing are changing by double low-e windows

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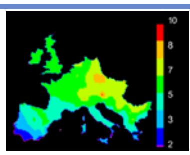
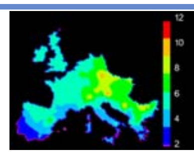
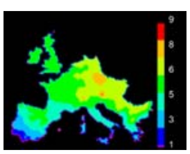
Heating Energy Savings Maps



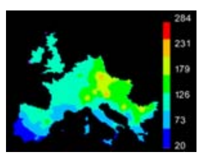
Average Saving in kWh/m² of component:
improving roof (reducing U-value by 0.1 W/m².K)



Average Saving in kWh/m² of component:
improving North oriented façades (reducing U-value by 0.1 W/m².K)



Average Saving in kWh/m² of component:
improving South oriented façades (reducing U-value by 0.1 W/m².K)



Average Saving in kWh/m² of component:
improving N oriented glazing from double to low emissive

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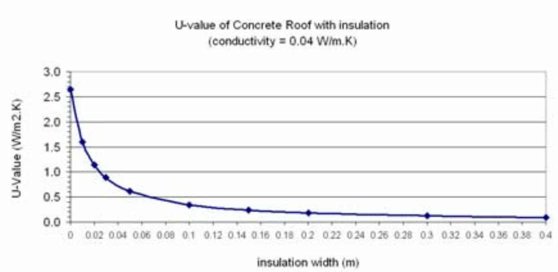
Improving U-value...

- How does U-value varies with insulation?
- For an example of a concrete slab (20 cm) without insulation, U-value is 2.64 W/m².K
- Adding insulation reduces U, but this improvement is not linear with insulation width:



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Economics of *Passivhaus*

Cost of *Passivhaus*

- As seen, a house built to the *Passivhaus* standard at most costs 10% more than a standard house, though they can be built for the same price. On average a *Passivhaus* costs just 4 - 6% more to build than the standard alternative
- The Passive-On project investigated the cost of proposed Passivhaus regarding the Life Cycle Cost of buildings, to evaluate the overall cost of a *Passivhaus* over a time period, compared to a standard alternative
- Analysis was based on:
  - National statistics for the cost of standard residential dwelling
  - Estimates of capital costs of optimised passive alternatives, regarding the different strategies
  - Expected expenditures associated with the operation of the dwellings, both regarding energy costs and maintenance costs
  - Assumptions on the initial and future costs of ownership (1-2%); the period of time over which these costs are incurred or, alternatively, a predetermined period of analysis (10 and 20 years); and the discount rate that is applied to future costs to equate them into a present value (3.5%)

Capital Costs & Extra Costs

- For the national proposals presented, the extra capital costs range between 9% for France and less than 3% for Spain (Seville):

	Standard House €/m²	*Passivhaus* €/m²	Extra Costs €/m²	Extra Costs (%)
France	1100	1203	103	9
Germany	1400	1494	94	6.71
Italy	1200	1260	60	5
Spain (Granada)	720	744,1	24,1	3,35
Spain (Seville)	720	740,5	20,5	2,85
United Kingdom (€)	1317	1390	73	5,54
United Kingdom (£)	881	930	49	5,54

Lif Cycle Cost

		France	Germany	Italy	Spain Granada	Spain Seville	UK
Extra Capital Costs (€/m²)		103	94	60	24,1	20,5	73
Extra Capital Costs (%)		9%	6,71%	5%	3,35%	2,85%	5,54%
Total Energy Savings (kWh/m²/year)		55	75,0	86,0	65,5	37,6	39,7
Total Energy Savings (%)		45%	50,0%	65,4%	57,3%	40,7%	26,4%
Extra Costs per saved kWh/m²/year		1,87	1,25	0,70	0,37	0,55	1,84
LCC 10 years€	Standard	143.731	184.716	193.817	101.828	98.385	108.337
	Passive	152.621	190.104	190.437	95.676	96.100	111.988
LCC 20 years€	Standard	160.343	204.942	221.148	117.928	108.689	117.875
	Passive	160.552	200.579	198.458	103.647	102.290	117.256
Cost-Benefit Ratio, 10 years		-0,72	-0,48	0,39	2,13	0,93	-0,65
Cost-Benefit Ratio, 20 years		0,02	0,39	2,63	4,94	2,60	0,11
Discounted Payback Period (years)		19.5	19	8	4	5	19

Life Cycle Cost Analysis

- Total energy savings predicted to be between 25 – 65%.
- In all cases, the LCC over 20 years was lower for the Passivhaus than the standard house
  - In Spain, a reduced LCC was achieved within 10 years
- The discounted payback period varied from 4 – 19 years
  - Moving south through Europe the discounted payback period reduces
- Results indicate that:

For owner occupiers and social housing providers, the additional investment can be regarded as very worthwhile

For developers, this can be presented to clients as an economical advantage of their products (thus justifying eventual extra costs)

Development of* Passivhaus *in Southern Europe is both energy and cost efficient

PHPP

Passivhaus Planning Package

PHPP

- The PHPP is a software design tool developed by the PHI (*Passivhaus Institut*) for development of *Passivhaus* and verification of *Passivhaus* standard
- It is encoded as an MS Excel spreadsheet
- The PHPP was originally developed for central European countries and therefore focused mainly on heating demand and winter comfort
- It was validated by:
  - Detailed thermal simulation (namely Dynbil)
  - Measurements of numerous buildings (namely the 220 CEPHEUS projects)
- Within the Passive-On project, PHI extended the PHPP to other climatic regions and included some essential passive cooling strategies (such as natural ventilation)

PHPP – What was there?

- Heating demand calculation based on EN 13790 (monthly energy balance) with support in calculation of:
  - U-values, including windows
  - ventilation and infiltration losses
  - passive solar gains, including shading
  - internal gains
- Calculation tools for:
  - household and auxiliary electricity demand
  - primary energy demand
  - peak heating load
  - summer comfort (overheating fraction)

- ~ 4000 copies sold since 1998, ~ 1000 in English. Cost: ~100 €

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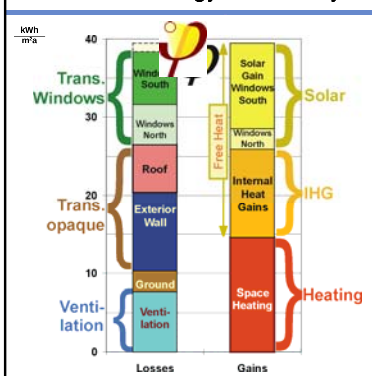
Energy balance by mechanisms



Energy balance for German Passivhaus according to EN 13790:

Heat Losses
=
Heat Gains

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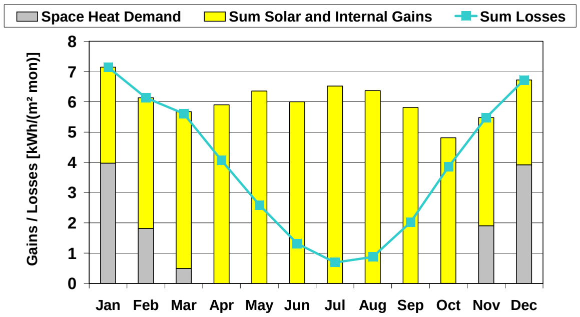
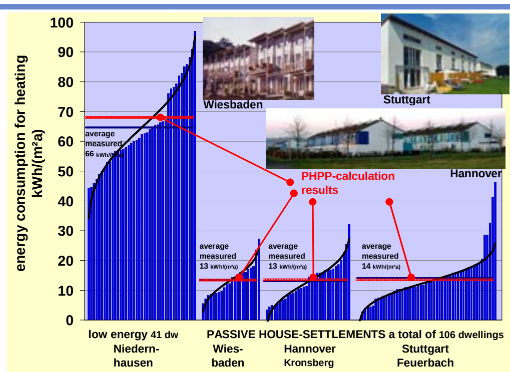
Monthly heat balance (EN 13790)



Excellent agreement with building measurements



PHPP – What was missing?

- Climatic data for Passive-On countries
- Cooling energy demand, sensible and latent
- Consider solar gains through walls & roof
- Peak cooling load procedure
- Check of overheating procedure, extension/adaptation

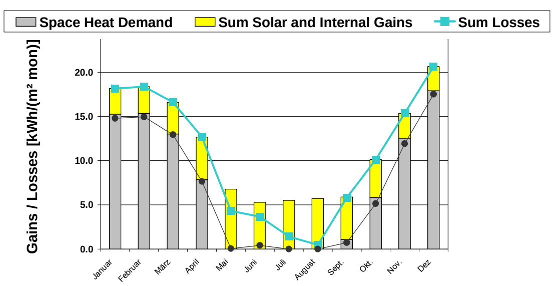
Improving PHPP for cooling climates

- 1st step: EN 13790 monthly method for cooling
- 2nd step: Consider night ventilation; two simple configurations:
  - Mechanical ventilation when useful, airflow constant rate
  - Windows open during 12 coldest hours, airflow rate temperature driven
- 3rd step: Latent heat simplified procedure (assumes constant conditions during whole month)
- 4th step: Cooling load
- 5th step: Thermal comfort for case of passive cooling only
- Plus:
  - Shading routines adapted
  - Climatic database extended

Heating, good agreement with simulation

Frankfurt
- lightweight construction
- poor insulation

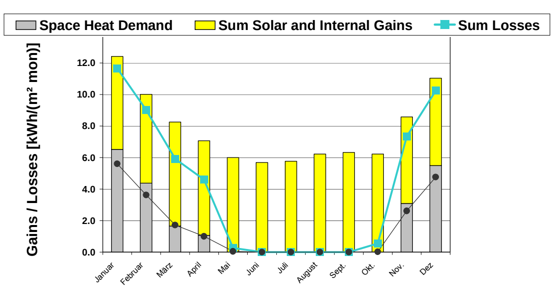
***Dynbil:* 86.1 kWh/m^2.year**
***PHPP:* 88.9 kWh/m^2.year**



Heating, good agreement with simulation

Seville
- lightweight construction
- same insulation as Frankfurt

***Dynbil:* 19.4 kWh/m^2.year**
***PHPP:* 22.2 kWh/m^2.year**

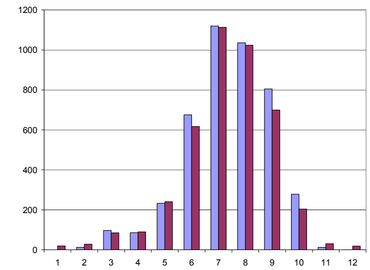


Cooling, also good agreement

Seville

- lightweight construction
- medium insulation level

Dynbil: 36.8 kWh/m².year
PHPP: 35.2 kWh/m².year

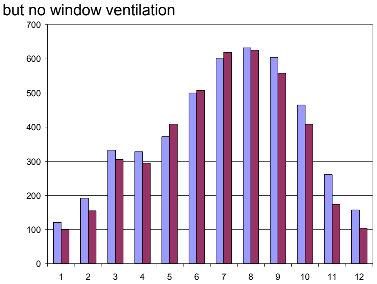


Cooling, also good agreement

Seville

- heavyweight construction
- extremely good insulation, but no window ventilation

Dynbil: 38.6 kWh/m².year
PHPP: 36.0 kWh/m².year

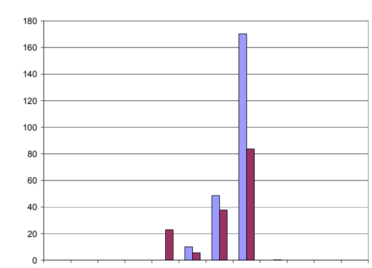


Cooling: not so good for very low values

Frankfurt

- same heavyweight construction

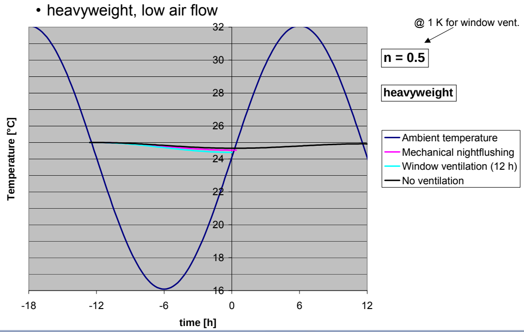
Dynbil: 1.9 kWh/m².year
PHPP: 1.3 kWh/m².year



Cooling with night ventilation (1)

Seville

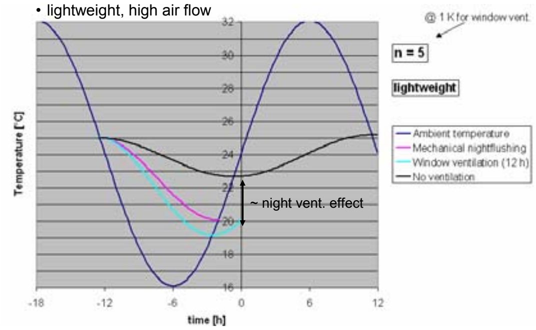
- heavyweight, low air flow



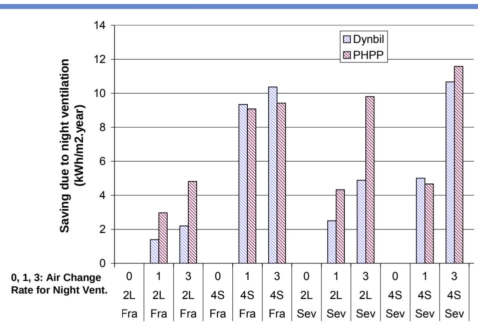
Cooling with night ventilation (2)

Seville

- lightweight, high air flow



Agreement with simulation: not perfect, but still acceptable



Fra: Frankfurt

Sev: Seville

2L: Mild Mediterranic Passivhaus, Lightweight

4S: German Passivhaus, Heavyweight

Summary of current PHPP

- Specific space heat demand for achieving winter comfort (conventional resultant interior temperature: 20 ºC)
- Peak Heating load
- Specific useful cooling energy demand for achieving summer comfort (conventional resultant interior temperature overheating limit: 26 ºC)
- Daily average peak cooling load for low-cooling-energy buildings (not suitable for high diurnal variations of thermal loads)
- Frequency of overheating in case only passive solutions are used
- Primary energy consumption (may consider contribution from renewable sources such as thermal solar systems of PV systems)
- Specific cooling passive strategies implemented:
  - Summer shading
  - Natural and Night ventilation
  - Thermal Mass
  - Ground Coupling

Example: Lisbon *Passivhaus*

- The *Passivhaus* proposed for Lisbon was evaluated regarding heating and cooling demand with both EnergyPlus and PHPP. Results are:

	Heating (kWh/m^2.year)	Cooling (kWh/m^2.year)
EnergyPlus (*)	16.9	3.7
PHPP with thermal bridges	21	7
PHPP without thermal bridges	16	6

(*) Our EnergyPlus model does not consider the linear thermal bridges of perimeter and interceptions

- EnergyPlus and PHPP present very similar heating loads in the same circumstances (no thermal bridges considered)
- For cooling, results are not so similar, but the demand is so low that errors tend to increase
- For highly insulated buildings and cold climates, thermal bridges must be carefully considered, as their relative importance increases

The Passive-On Project

A look at the Passive-On Project

- The Consortium includes participants from several European countries, including 4 Mediterranic countries:

Italy: eERG (project coordinator), Provincia di Venezia, Rockwool Italia

France: International Conseil Energie (ICE)

Germany: Passivhaus Institut

Portugal: Natural Works and Instituto Nacional de Engenharia, Tecnologia e Inovação (INETI)

United Kingdom: School of the Built Environment, Nottingham University

Spain: Associación de Investigación y Cooperación Industrial de Andalucia (AICIA)

ieea http://www.passive-on.org

Passive-On project

Passive-On – Main Achievements (1)

- **Update on Passivhaus standard**: The Passive-On project contributed to an update in the Passivhaus standard (2007), that is now adapted to define Passivhaus in cooling climates as well, thus including cooling energy and summer comfort
- **Passive strategies analysis:** a wide range of passive strategies was discussed and climate applycability was adressed
- **Passivhaus proposals for different Southern climates**: partners proposed examples of houses with different designs and specifications that allow to achieve the Passivhaus 2007 standard, both regarding energy demands for space heating and cooling and the prescribed comfort criteria both for Winter and Summer
- **Economic analysis**: shows that *Passivhaus* adapted to warm European climates can be very cost effective
- ***Passivhaus* design tool:** extended to cover warmer climates and main passive cooling strategies

Passive-On – Main Achievements (2)

- **Policy**: how to move Passive Homes from a niche market to a wider scale development, thus effectively contributing to reduce the energy consumption and associated CO2 emissions? More than 70 interviews to building professionals industry, local and national governments were the basis for a policy analysis (european, national, regional and local level) in all partner countries was performed, resulting in proposed mechanisms to support the development of the passive house market
- **Dissemination**: results are being disseminated to different target audiences (designers, planners, promoters; decision makers) and to multipliers (for example university lecturers, architectural and engineering professional bodies, energy agencies)