DESIGN OF ENERGY-EFFICIENT NON-DOMESTIC BUILDINGS

Presented by

David Olivier

What I shall discuss

- Some past work on energy-efficient buildings
- Strategic issues and priorities
- Construction detailing for low heat loss
- What can high energy efficiency standards achieve?
- Case studies

The case for drastic cuts in greenhouse gas emissions is taken as given. The background arguments for this are available from other sources.

Some Past Work on Energy-Efficient Buildings

Applied Research on Energy-Efficient Buildings in Other Countries

1. Canada - National Research Council (Div. of Bldg. Research) issued design guidance on correct use of air and vapour barriers in 1960. Saskatchewan Conservation House in Regina,1976.
2. USA, Sweden and Denmark - Pioneering experiments began after the first oil crisis in 1973: “Zero-energy house” in Lyngby, Denmark 1975. 1000s of “superinsulated” houses in USA by early 1980s.
3. Interest in energy-efficient buildings grew rapidly in German-speaking world in 1980s, culminating in “zero-energy” building projects in Switzerland by 1990 plus parallel work in Germany and Austria.
4. In all these initiatives, large buildings like blocks of flats, offices, schools, hospitals and other non-domestic lagged behind small buildings; e.g., one-off detached houses.
5. Rented and leased buildings lagged well behind owner-occupied ones. Landlords had no interest in saving someone else’s running costs.

Voluntary Higher Energy Efficiency Standards

1 Germany - Passivhaus Standard www.passiv.de

- Began 1988 with discussions between Swedish and German experts followed in 1990 by four pilot row houses in Darmstadt - monitored in detail until 1995;
- Pioneered very high insulation and airtightness standards, first used in Sweden and Canada in the 1970s; e.g., Saskatchewan Conservation House;
- Used highly energy-efficient lighting, ventilation, electrical appliances and equipment;
- 80% overall reduction in energy use and CO_2 emissions vs. the German dwelling stock.
- Applied to non-domestic projects since 1998
- All new building construction in Frankfurt must now meet the Passivhaus Standard

2 Switzerland - 50% of new dwellings meet MINERGIE Standard, www.minergie.ch, a record achievement for any standard in any country. Being applied to refurbishment. Also MINERGIE-P - close to Passivhaus.

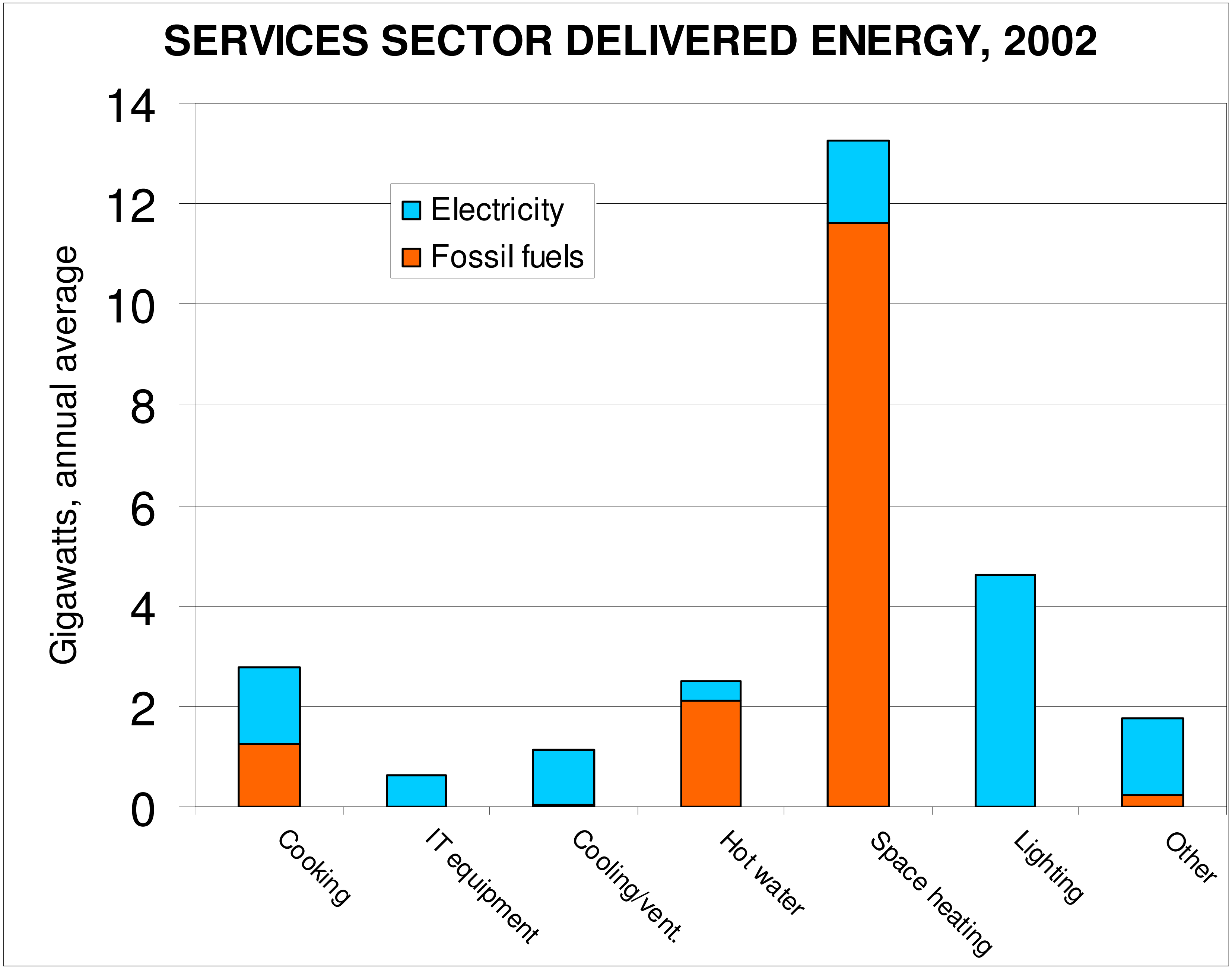
3 Austria - 8% of new dwellings meet the Passivhaus Standard.

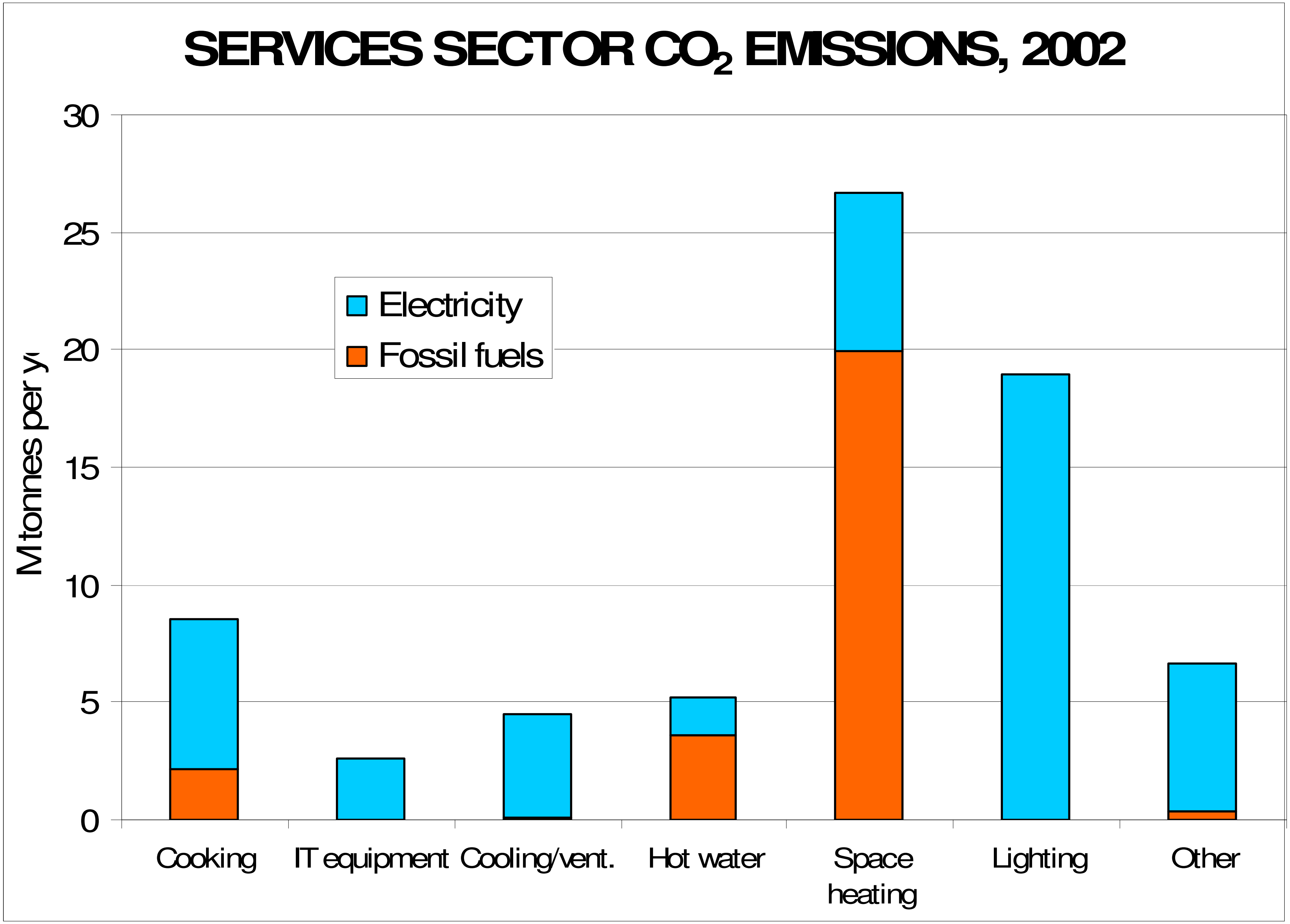
4 USA - Energy Star nationally plus many programs at state, city or county level.

5 Canada - R-2000 Program, C-2000 Program, Factor Nine Standard, etc.

6 UK - many new buildings since 2005 meet AECB Silver Standard and somee meet Gold Standard, see www.aecb.net.

Strategic Issues and Priorities


SERVICES SECTOR DELIVERED ENERGY, 2002
Gigawatts, annual average
0
2
4
6
8
10
12
14
Electricity
Fossil fuels
Cooking
IT equipment
Cooling/vent.
Hot water
Space heating
Lighting
Other


SERVICES SECTOR CO_2 EMISSIONS, 2002
Electricity
Fossil fuels
Mtonnes per y
30
25
20
15
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5
0
Cooking
IT equipment
Cooling/vent.
Hot water
Space heating
Lighting
Other

Shape and Plan Form

Assess all possibilities at a *very* early design stage.

Energy-wise, the optimum shape for a building in virtually all climates and certainly temperate ones is not cube-shaped, but relatively long and thin, with its glazing facing primarily north and south and with the longer axis extending from roughly east to west.

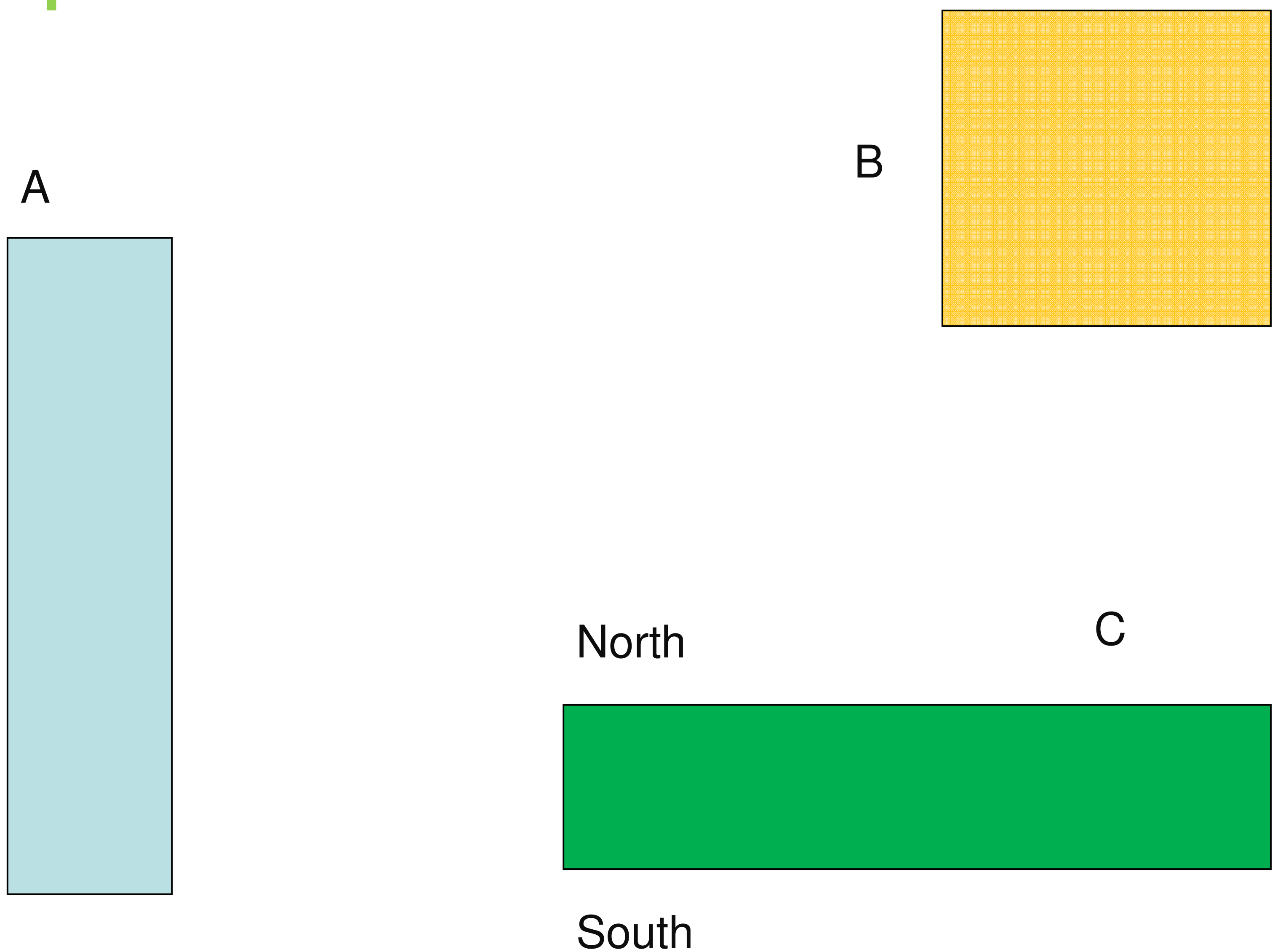
These buildings use less energy than (a) buildings whose long axis lies north-south or (b) deep-plan buildings with an extremely compact form.

This point has been known for many years. See for instance Olgyay's work in USA 50 years ago. Also extensive work by Dr. Nick Baker, Cambridge Univ. Dept of Architecture in 1980s and 1990s; search for "LT method".

We now know how to construct buildings with much lower envelope heat loss. This strengthens the case for shallow-plan designs with extended surface areas. The extra space heating energy, if any, is less than the electricity saved (a) on lighting and (b) perhaps on summer cooling and/or ventilation.

Do what you can, given site limitations. In some circumstances, changing the shape of a building can potentially reduce its energy consumption by 40-50%.

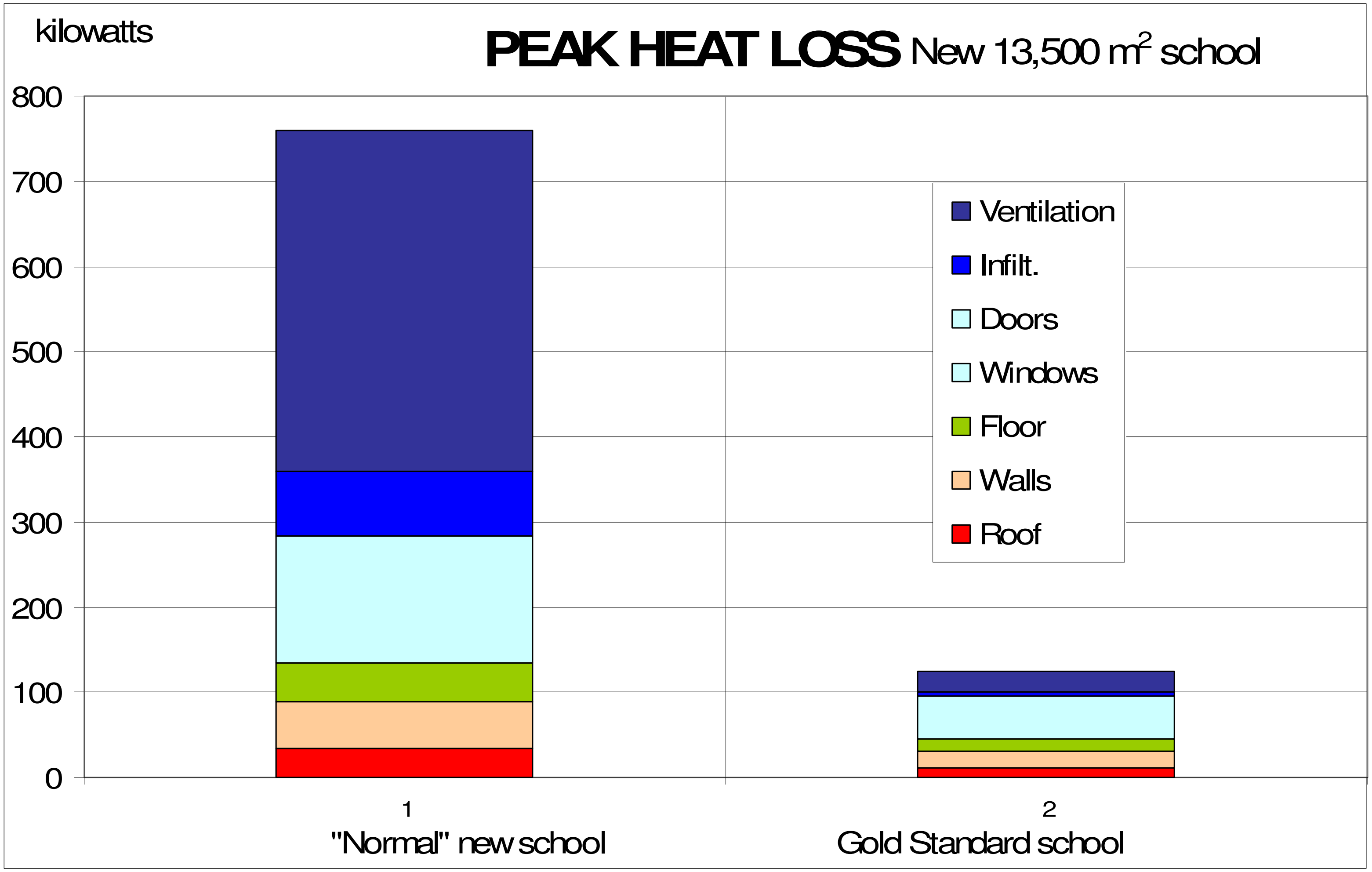
Shape and Plan Form



Space Heating

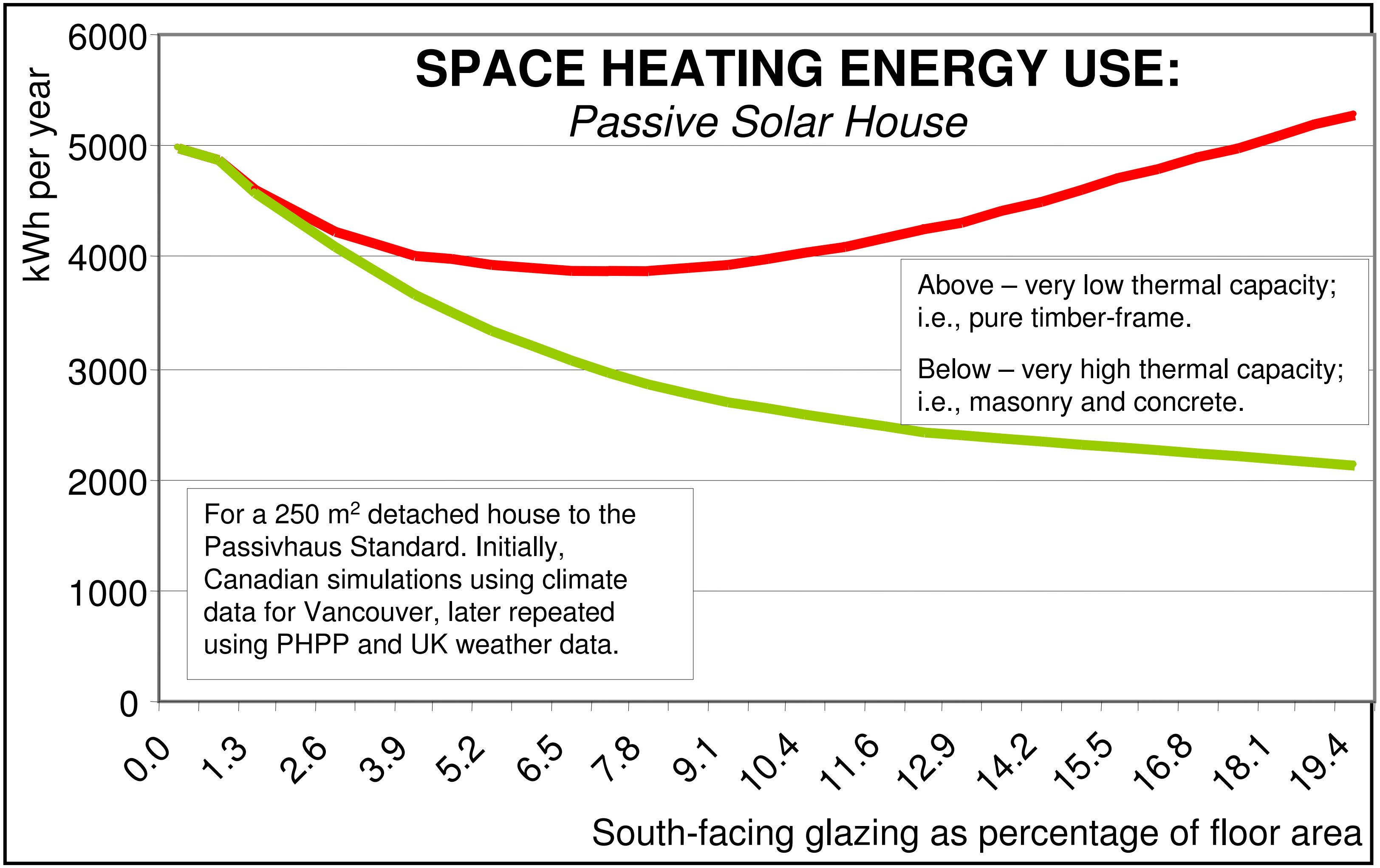
Where is the peak heat loss of your proposed building, measured in W/m², on the scale below?

NOTE: Normal school meets ADL-2002, reduced loss is from one meeting AECB Gold Standard.



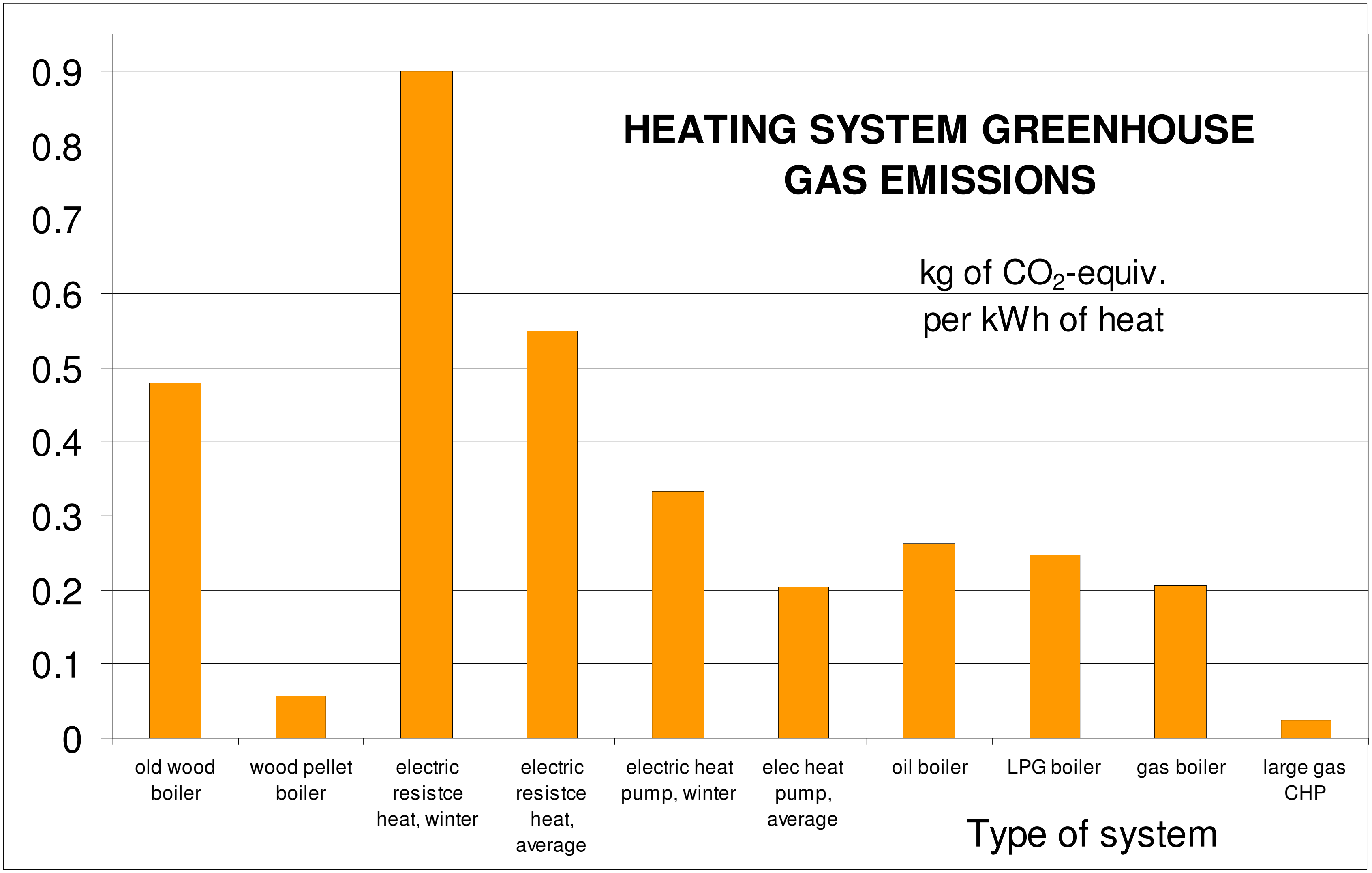
Passive Solar

Greater scope in the UK or Ireland than on the continent owing to the long, cool heating season and cool summer. Needs attention to the available thermal capacity and *in extremis* needs summer-only solar shading.



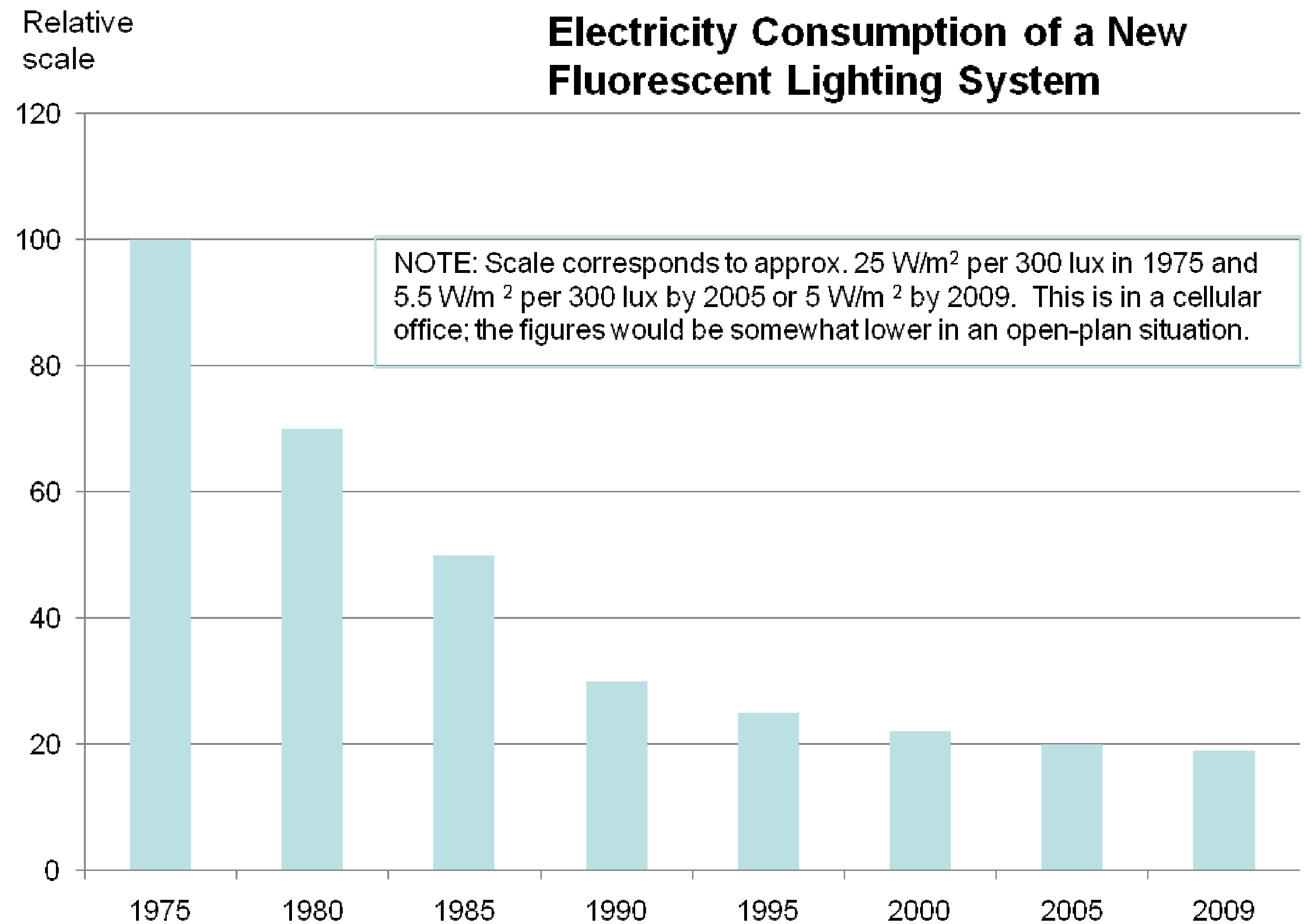
Space Heating

What are the CO2 emissions of the heating system in your proposed building, measured in kg per kWh of heat?



Lighting

- How does your proposed lighting system rate compared to the graph below. Is it of 1980 energy efficiency or 2008-09 good/best practice?!
- Because lighting consumes as much energy as heating, you should arguably spend as much of the design and construction budget on reducing lighting energy as on reducing heating energy.



Renewables

Not a straightforward replacement for fossil fuels. Low-cost & “firm” supplies are limited. Biomass and hydro already supply over 10% of world energy but expansion is problematic.

Most other renewables including wind, PV, wave, etc, have a resource cost (p/kWh delivered energy) ten to 100 times higher than the cheap oil and gas on which industrial societies have been built.

In some new dwellings, as much heat is lost through the tank insulation and from the distribution pipes as a small solar hot water system would provide

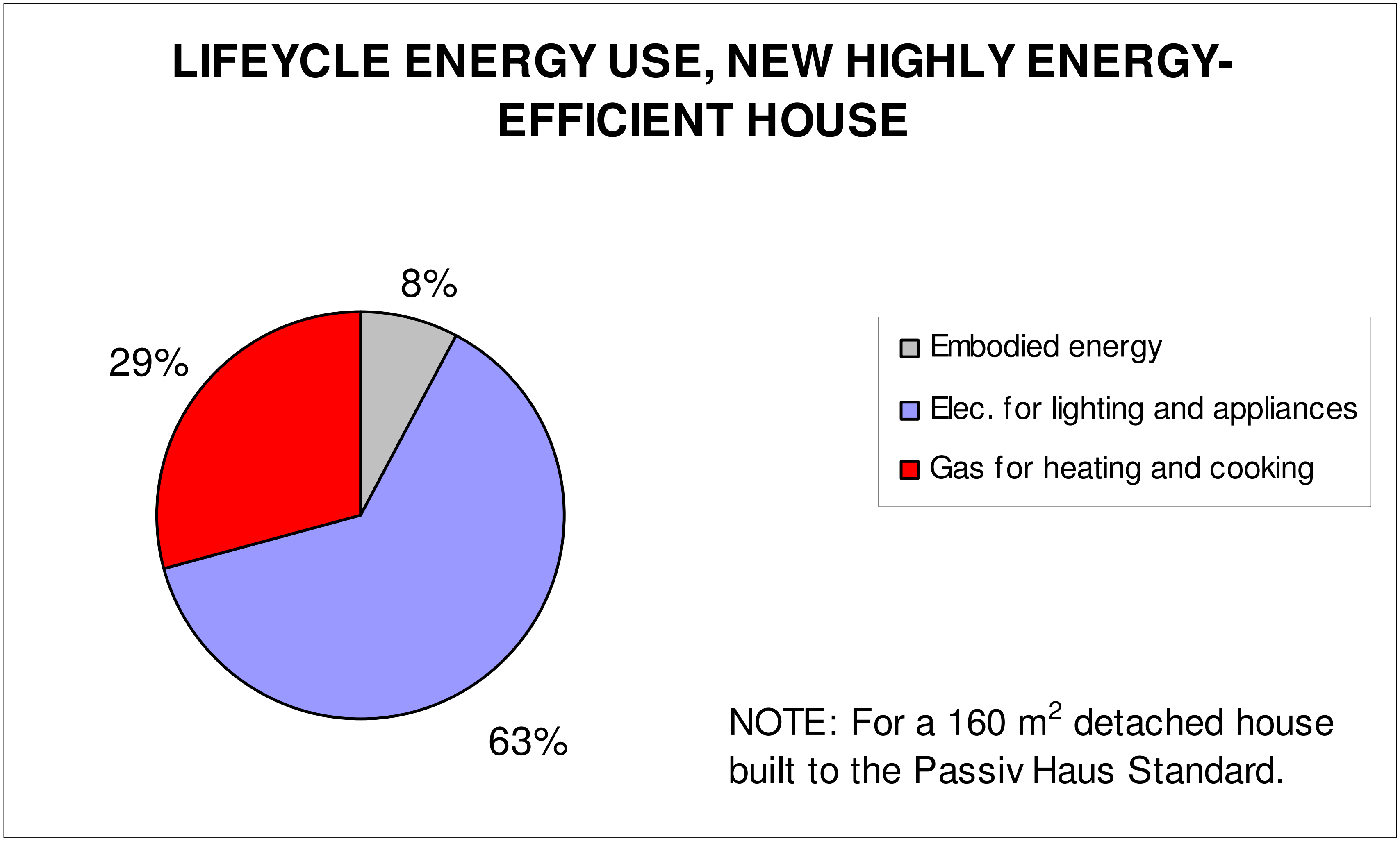
Not all renewables appear top priority for scarce resources while a large and cheap energy efficiency potential remains largely unexploited.

Some building-integrated renewables which form part of the fabric; e.g., passive solar building design, daylighting design of offices or schools, are a high priority and should always be incorporated at design stage where possible.

As yet, there are no government incentives for such renewables, only for “bolted-on” ones. Nor are there any incentives for technologies such as increased DHW tank or pipe insulation. This is perverse.

Embodied Energy

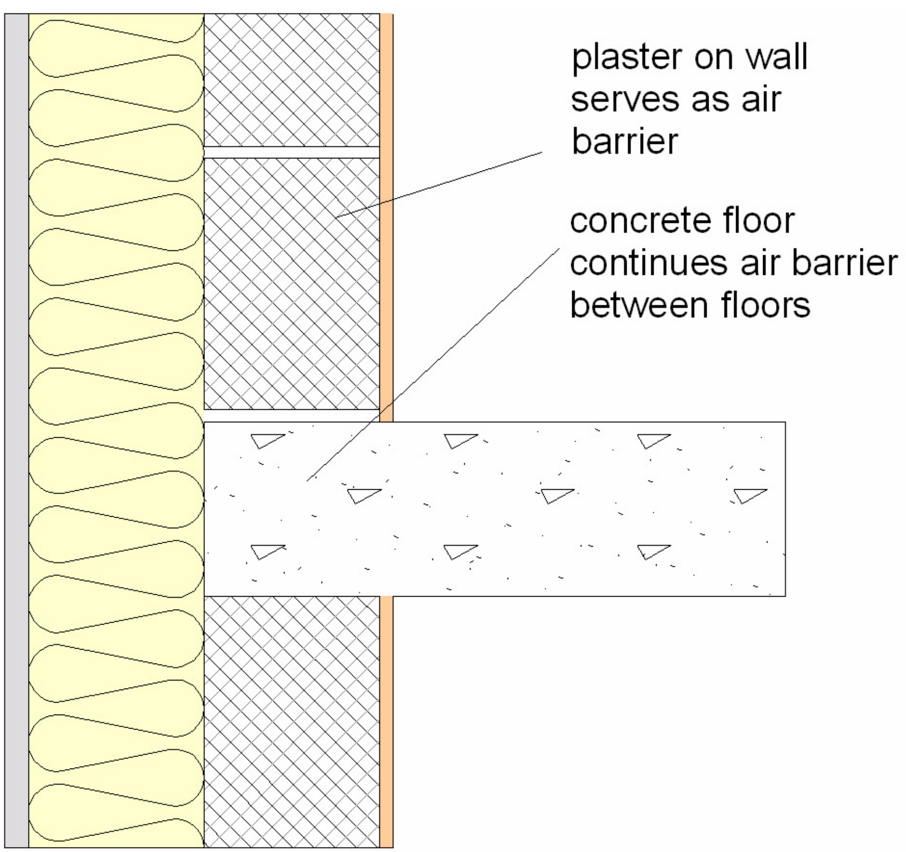
Be aware of this at the design stage of a new building. But do not overemphasise it if a proposed reduction only comes at the expense of higher operational energy, or higher maintenance costs.



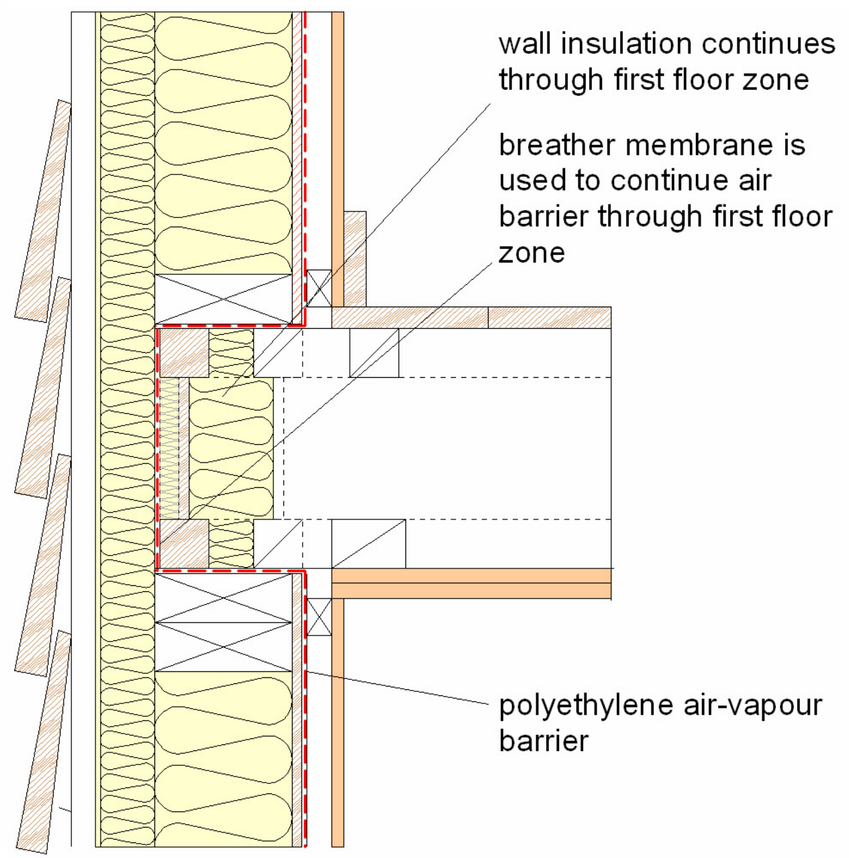
Construction Detailing for Low Heat Loss

Examples of Sound Thermal Envelope Design

Solid Masonry,
External Insulation

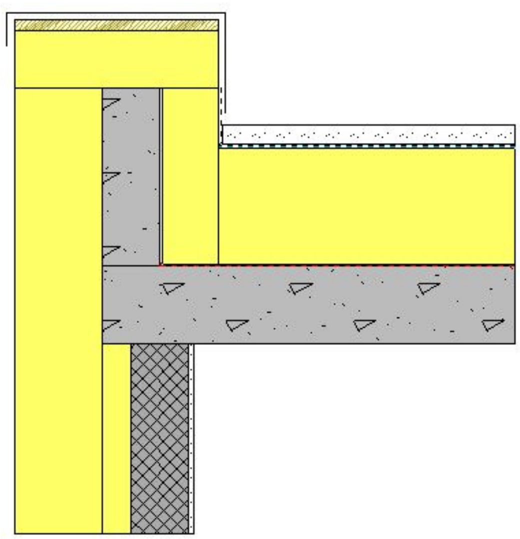


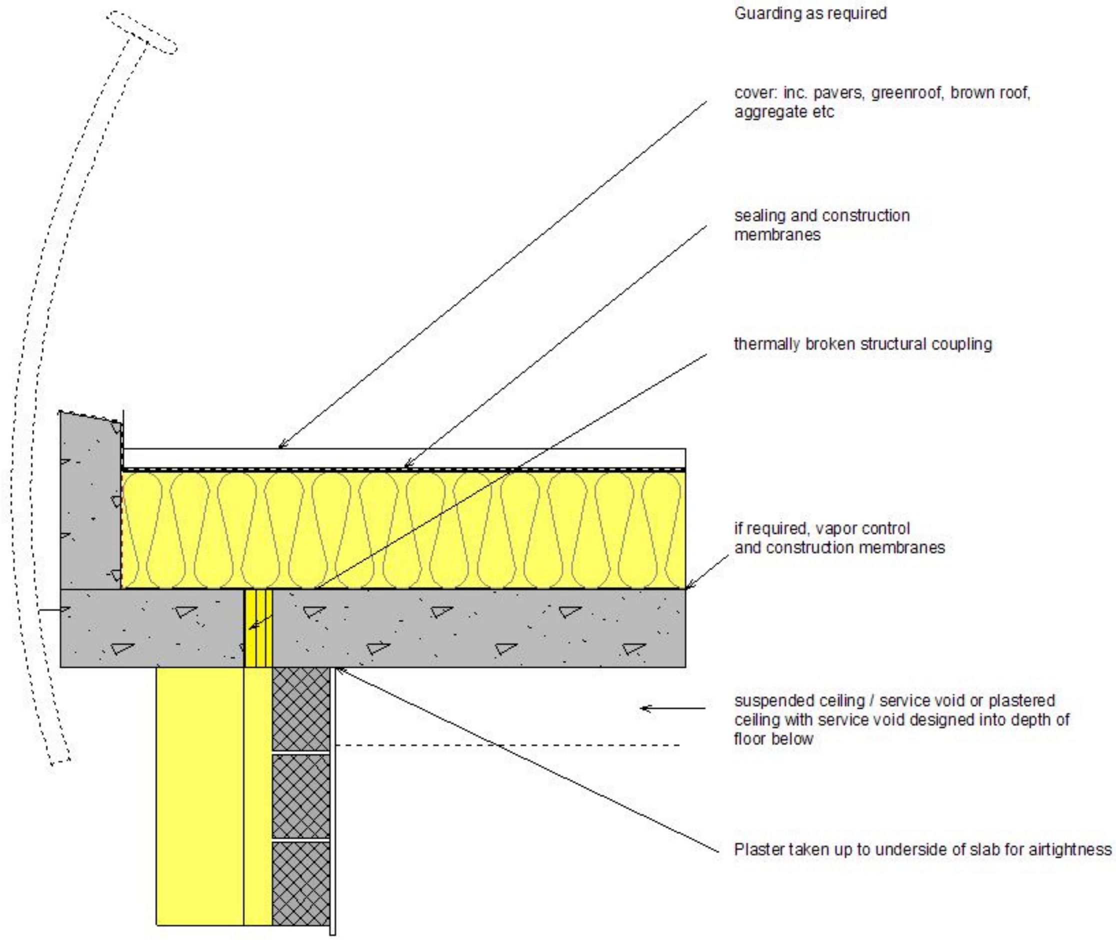
Timber-Frame



In Situ Concrete-Frame

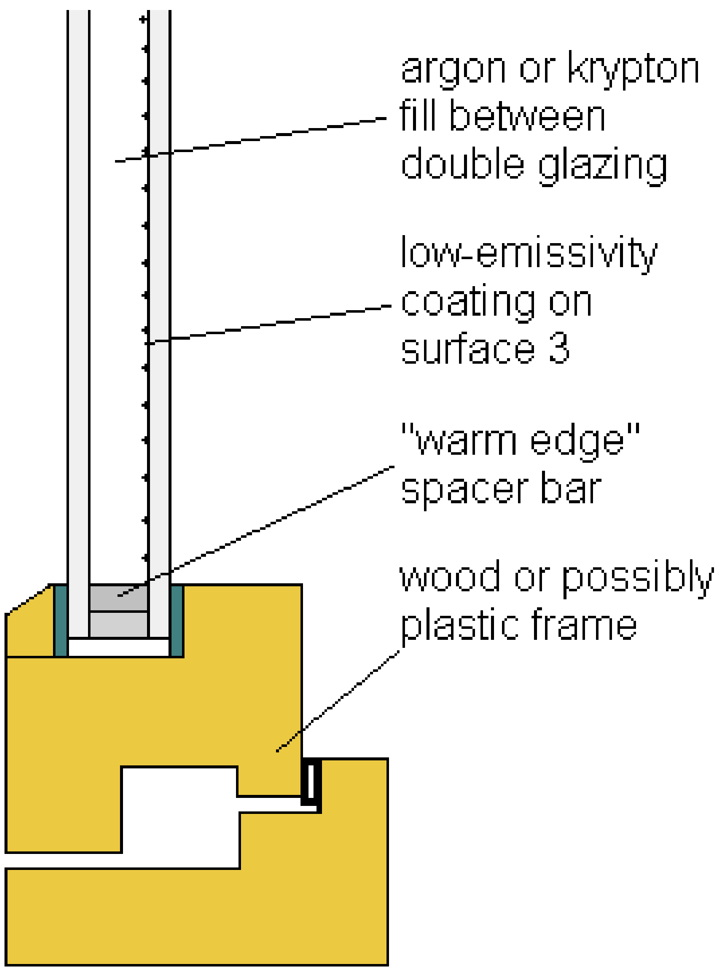
These details are taken from AECB *Silver Standard Design Guidance (*published 2007) and AECB *Gold and Passivhaus Design Guidance* (in press, 2009). See www.aecb.net or www.carbonlite.org.uk



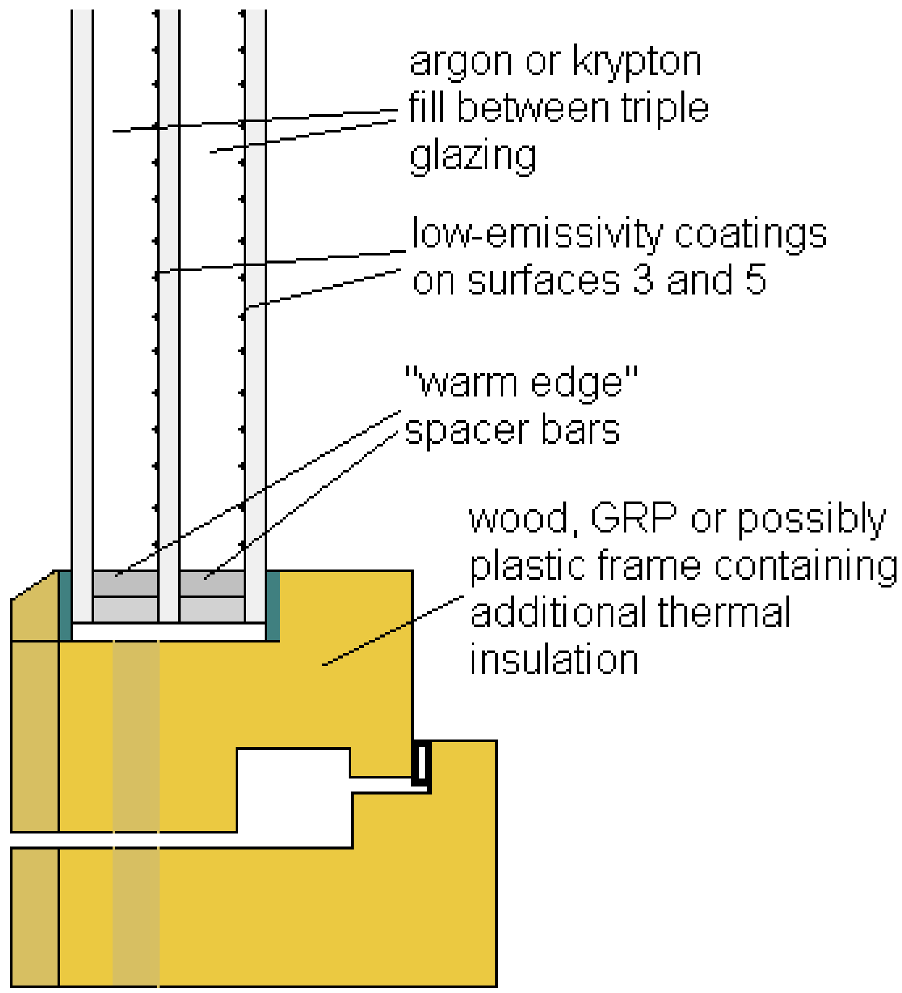


Typical Windows In Low-Energy Buildings

U-value down to 1.1 W/m²K

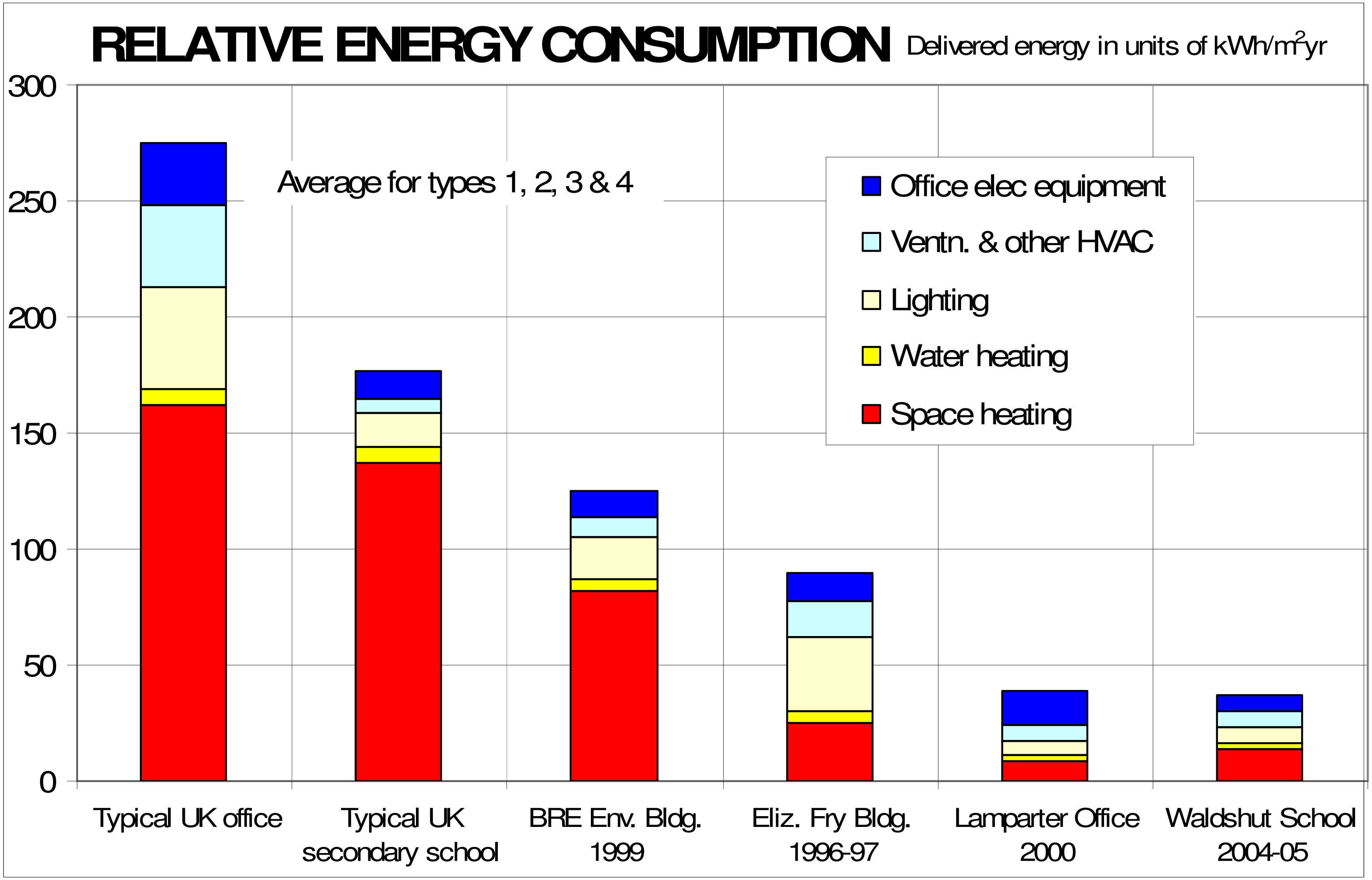


U-value down to 0.7 W/m²K

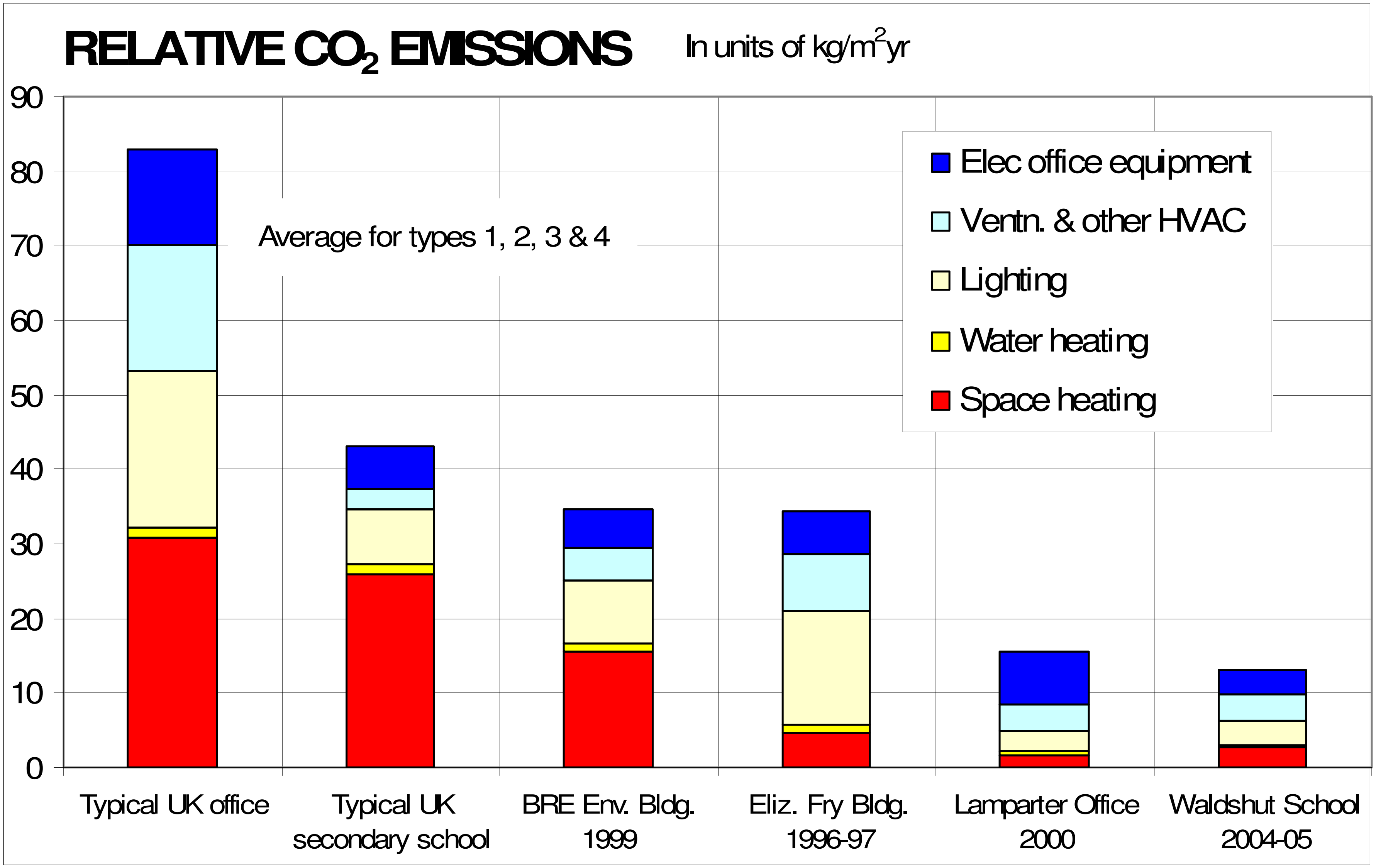


What Can High Energy Efficiency Standards Achieve?

Impact of Energy Performance Standards on Non-Domestic Building Energy Use



Impact of Energy Performance Standards on Non-Domestic Building CO_2 Emissions



Case Studies

Mostly Non-Domestic (or Residential but with Important Lessons for Larger Buildings)

Rocky Mountain Institute Headquarters

Old Snowmass, Colorado, USA (built 1983, photovoltaics added 1992).

Single-storey 400 m^2 passive solar house and office building with superinsulated roof,walls, floor and windows. No backup space heating; small amount of LPG is used as backup to solar water heating and for cooking. Most energy usage is electricity for office equipment. “”Zero net energy” since 1992.

Photograph courtesy RMI.

Dumont House

Saskatoon, Saskatchewan, Canada (built 1992).

Photographs: Courtesy Dr Rob Dumont, formerly of Saskatchewan Research Council.

North façade

South façade

Measured Energy Use from 1993-2005:
Electricity 40 kWh/m^{2}yr.
Heat Loss
5 kW at -40^{o}C outside for a 400 m^2 house; each floor including the basement is 130 m^2.
Air Leakage
0.5 ac/h @ 50 Pa.
Insulation
8 tonnes of cellulose fibre.

Reyburn House

London SW13
(designed 1985).

Mid Terrace Infill House and Home Office

Measured Energy Use from 1990-2005:

Gas 90 kWh/m^{2}yr.
Electricity 22 kWh/m^{2}yr.
Total 112 kWh/m^{2}yr.

Photographs courtesy
Stephen Reyburn

Viewed from South in Summer

In the 2003 & 2006 heatwaves, it was the only “inhabitable” house in London SW13 - apart from one which had air conditioning.

Features

- High thermal capacity, similar to a mainland European house.
- All glazing faces due N or S.
- Some shading by a fortuitously-sited decid-uous tree to the SW.
- In heatwaves, windows are opened by night and closed by day; the MVHR system keeps the coolth in the house by day.

The Elizabeth Fry Building *UEA, Norwich 1994*

3,500 m^2 of floorspace on four floors, footprint c. 14x62 m. Peak space heat demand 18 W/m^2. Has three 24 kW domestic wall-hung condensing boilers, but the third proved unnecessary. No refrigerative cooling needed, only automated summer night ventilation using the hollow-core concrete floors. Highest score ever in PROBE user survey. Large lectures in basement, seminar rooms and offices on other floors. Measured gas usage 25-30 kWh/m^2yr since 1996-97.

Photographs courtesy John Miller and Partners.

A Detached House to the Passivhaus Standard

Hohen Neudorf, Brandenburg, Germany (2004).

Photograph courtesy Ralf Lenk, Architect

The first School to the Passivhaus Standard

Waldshut, Germany (designed 2000-01, finished 2003).

Photograph courtesy
Passiv Haus Institut

An Office Block to the MINERGIE-P Standard

EMPA, Duebendorf, Switzerland (2004-05).

Floor Area. 8,000 m² on six floors.

Orientation. Due to site limitations the building's axis is elongated north-south.

Measured Energy Use 2005-07. Electricity 22 kWh/m²yr plus hot water 2-3 kWh/m²yr from site district heating system. Primary energy 65 kWh/m²yr. Embodied energy 120,000 MWh.

Cooling. None needed. Automatic, computer-controlled solar shading with toughened glass blinds.

Concrete frame, *in situ* conc. floors and roof and lightweight external wall elements

Photographs| courtesy EMPA

The Pines Gardens Calyx

St. Margaret's Bay, east Kent (built 2005-06).

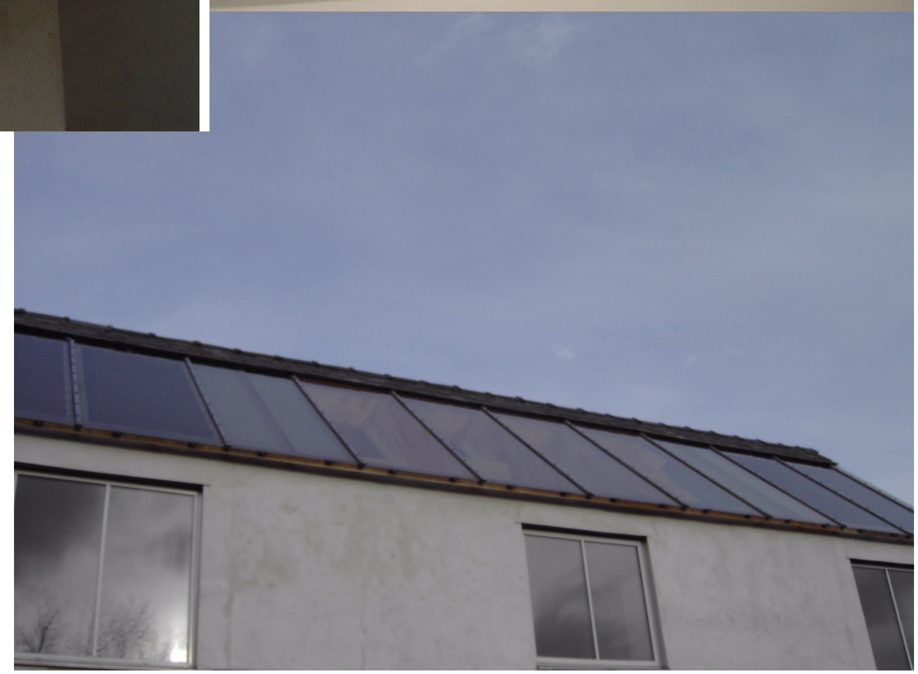
400 m^2 visitor and conference centre.

Externally-insulated rammed chalk walls, *in situ* conc. floors and frame

Courtesy: St. Margaret's Bay Trust

Energy Showcase Project

Rural site, north-west Herefordshire



The project will produce all its energy from solar, mainly passive gains, an experimental solar water heating system and roof-integrated photo-voltaics. Cooking will use biofuels. Includes residential and office floorspace.

What Do The Foregoing Case Studies Have in Common?

•They are very or extremely well-sealed - from five to 50 times more airtight than normal new UK building construction.

•Their long facades face south and their long axis is elongated east-west so far as the site allows. Their shape and form is directed at creating a building which is intrinsically warm in winter, cool in summer and naturally lit.

•Their thermal insulation is two to ten times thicker than local Building Codes required at the time of construction.

• Out of nine high-performance buildings, only three have any photovoltaic cells and four have solar water heating. Most of them have no “active” renewables at all, including the UK’s most energy-efficient large non-domestic building to date. But they generally reduced, or will reduce, energy and CO_2 by 70-95+%.

For more information:

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