ENERGY EFFICIENCY

IN BUILDINGS

By David Olivier

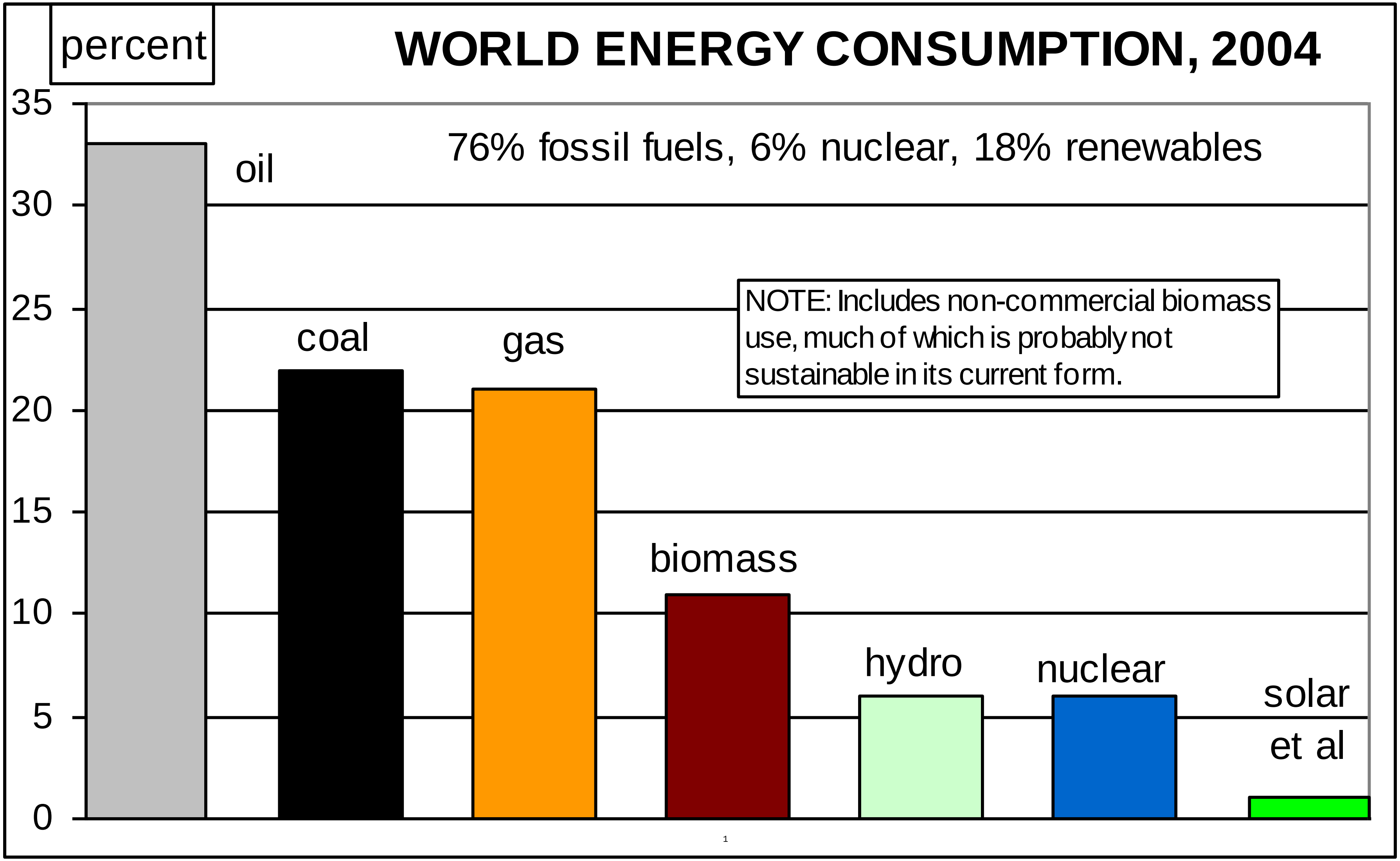
Talk to Hereford FoE, 1st October 2008.

What I shall talk about

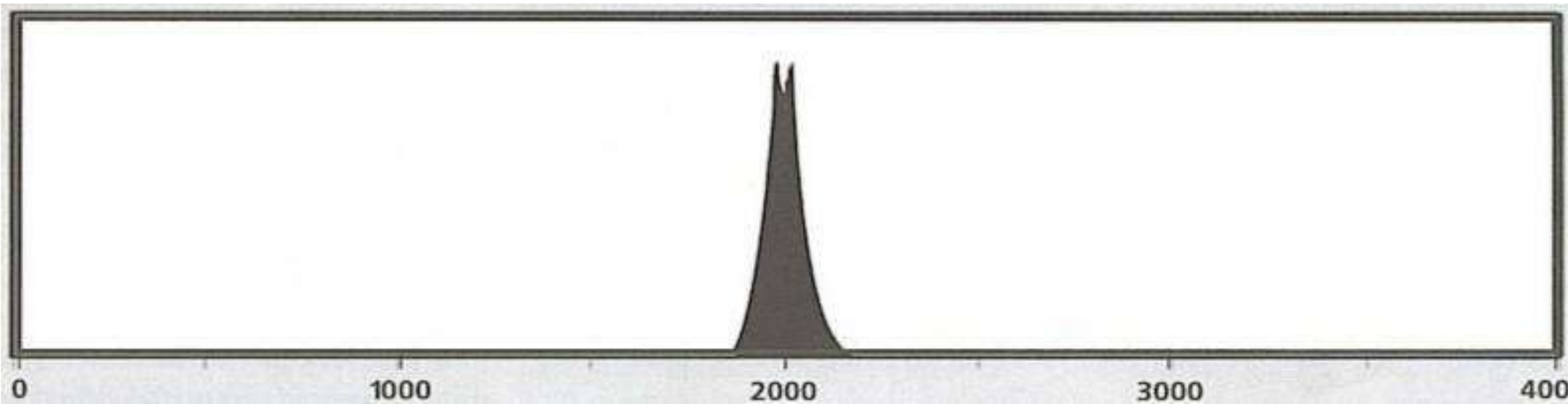
- Some major strategic issues faced by the UK's energy supply & use system
- More efficient energy use in buildings, such as housing
- Some case studies, including my own house
- Abroad - sustainable energy in Denmark

Some Major Strategic Issues

World Fossil Fuel Dependence



Peak Oil:
Likely To Be Followed by Peak Gas



Oil production & consumption in a historical context.

Actual profile 1870-2003 and predicted profile 2003-2130.

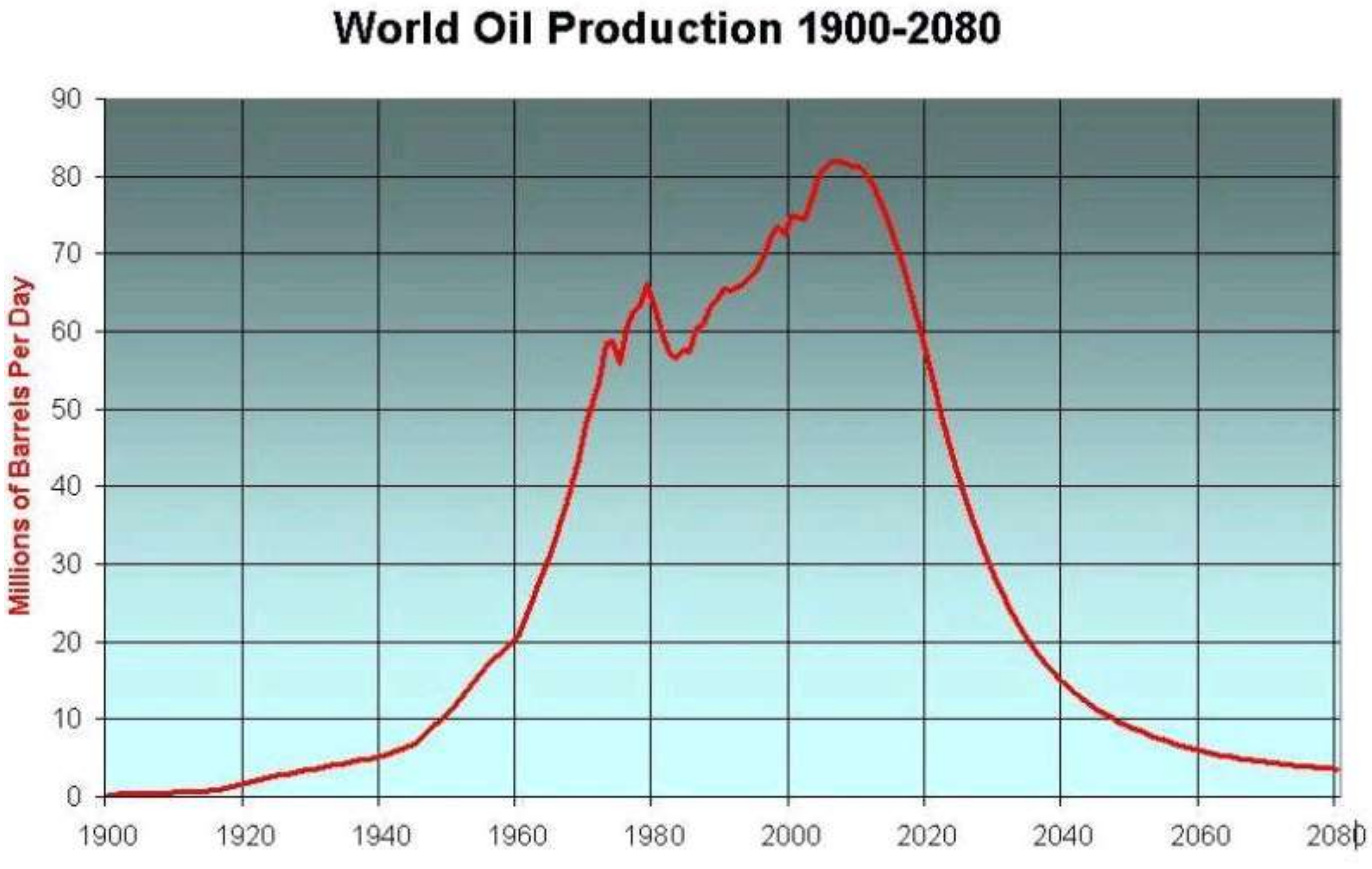
“The world has never faced a problem like this. Without massive mitigation more than a decade before the fact, the problem will be pervasive and will not be temporary. Previous energy transitions were gradual and evolutionary. Oil peaking will be abrupt and revolutionary."

US Dept. of Energy, internal March 2005 report.

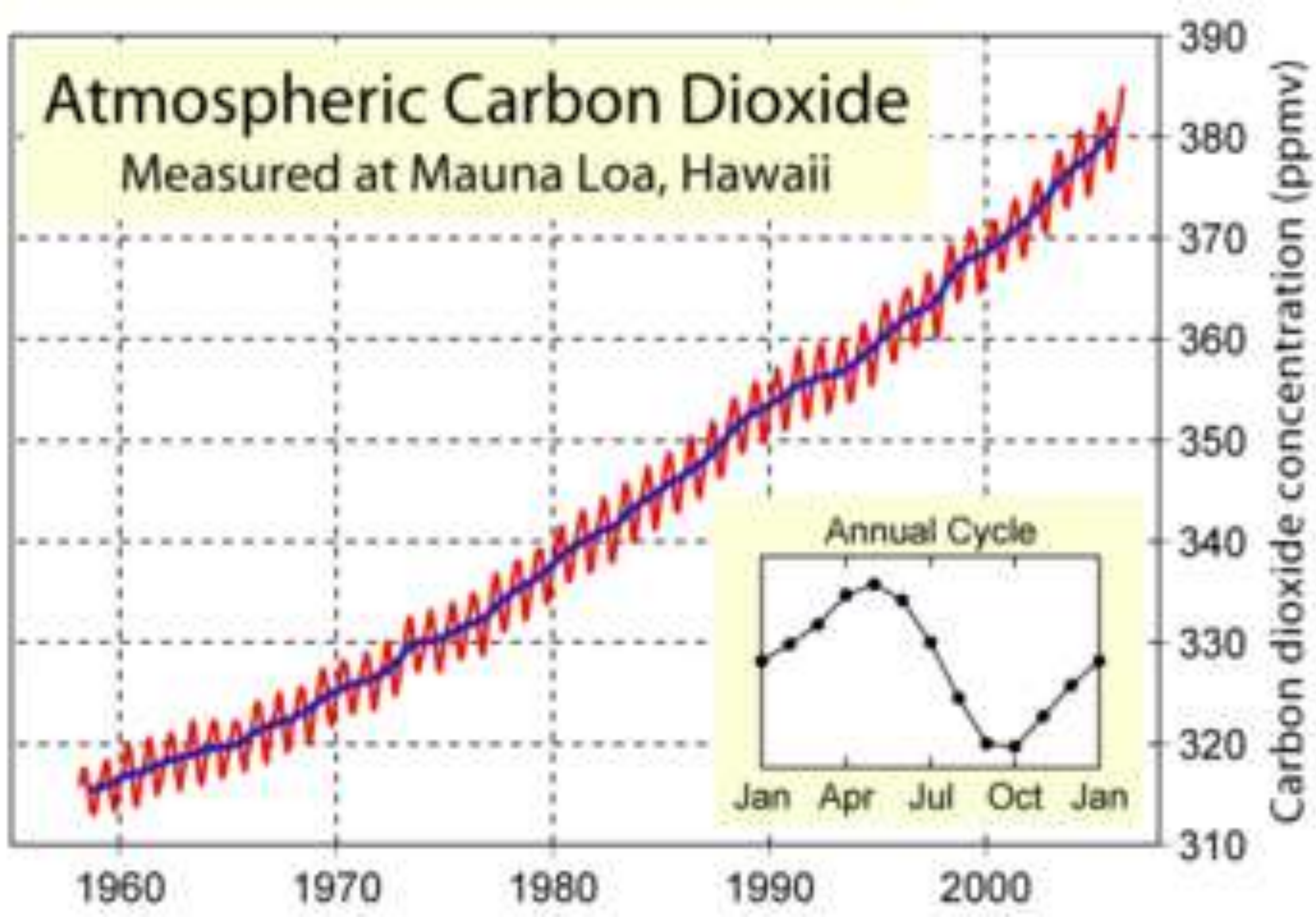
See also www.oilendgame.com

Peak Production of Conventional Oil Probably Occurred In 2005

See [**www.lifeaftertheoilcrash.net**](http://www.lifeaftertheoilcrash.net)

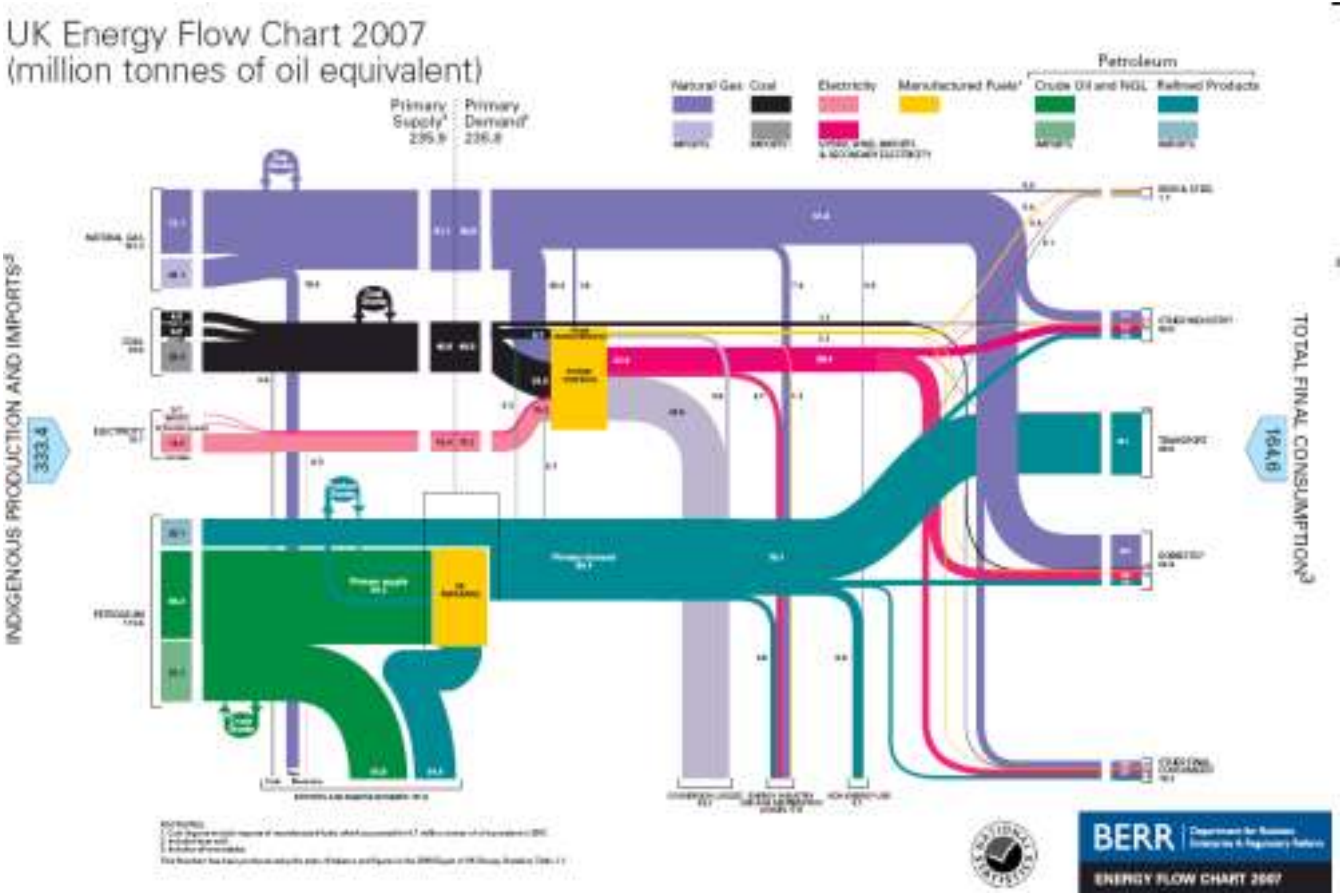


Rising Atmospheric CO_2 Equivalent



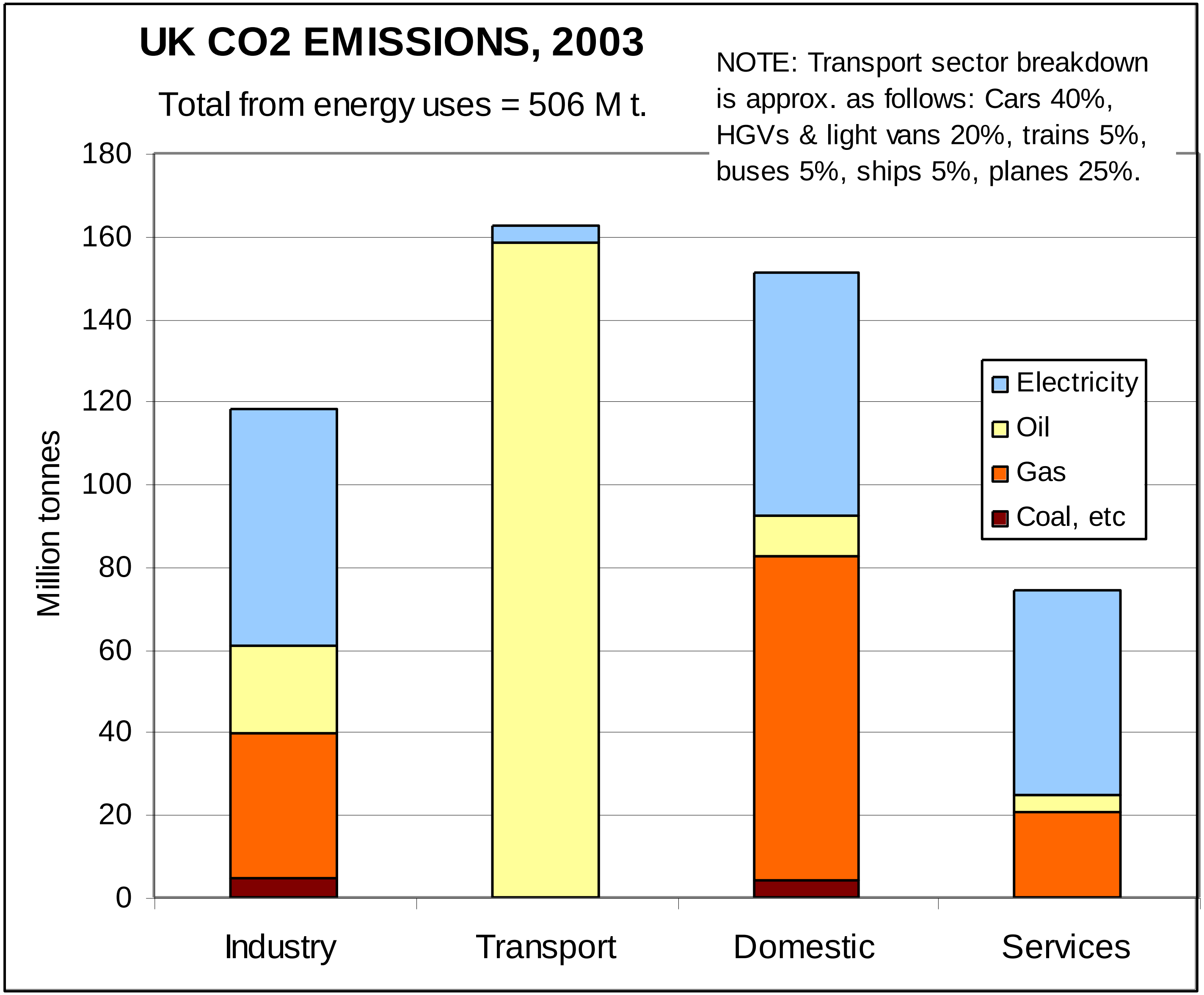
63% of GHG Emissions are from World Energy Use.
37% are from Ruminants, Tropical Deforestation, Rice Paddies, etc.

UK - Oil and Gas Dependence

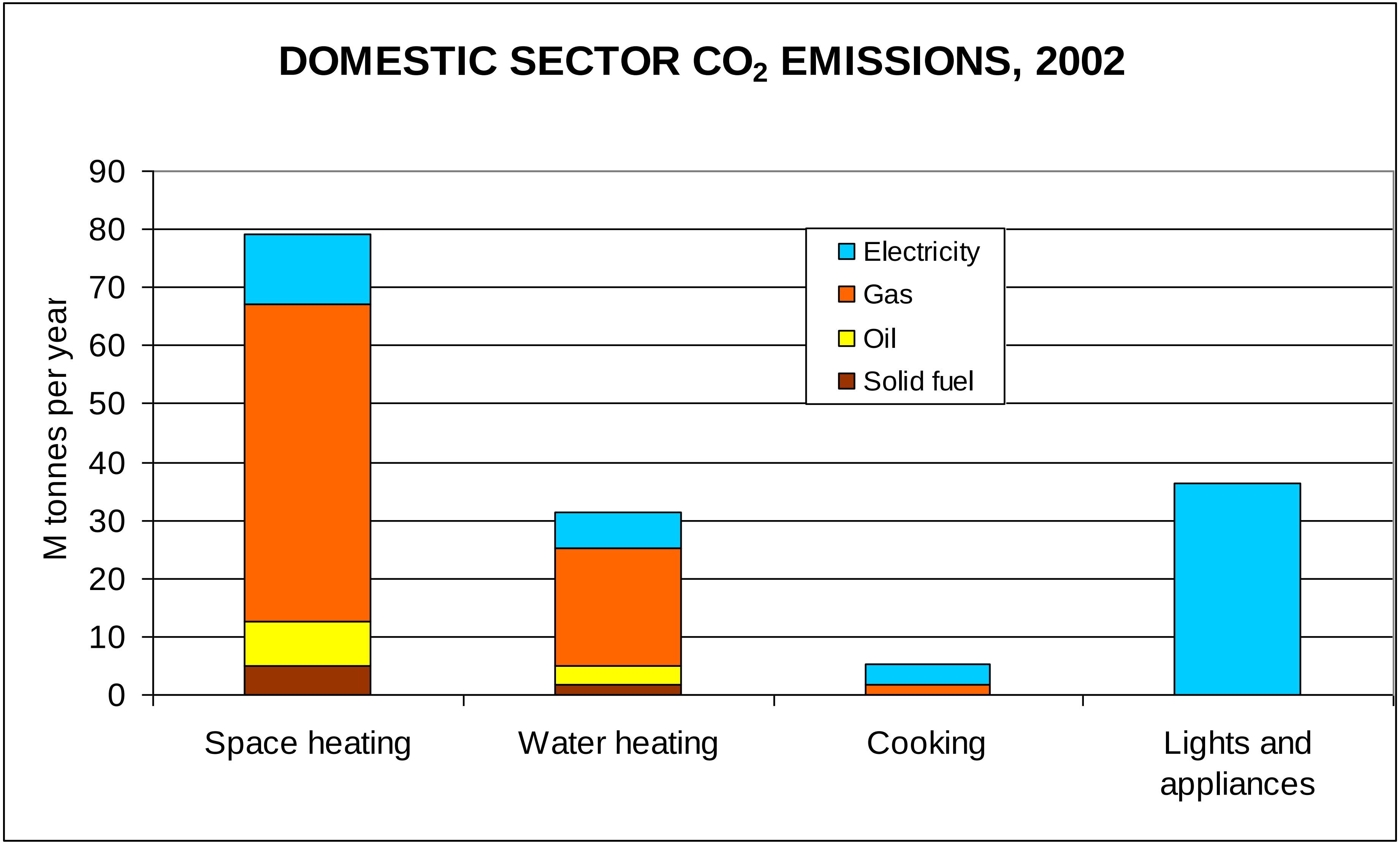


The largest single energy flow is oil for transport. More heat is rejected from power stations than the amount of gas consumed to heat buildings.

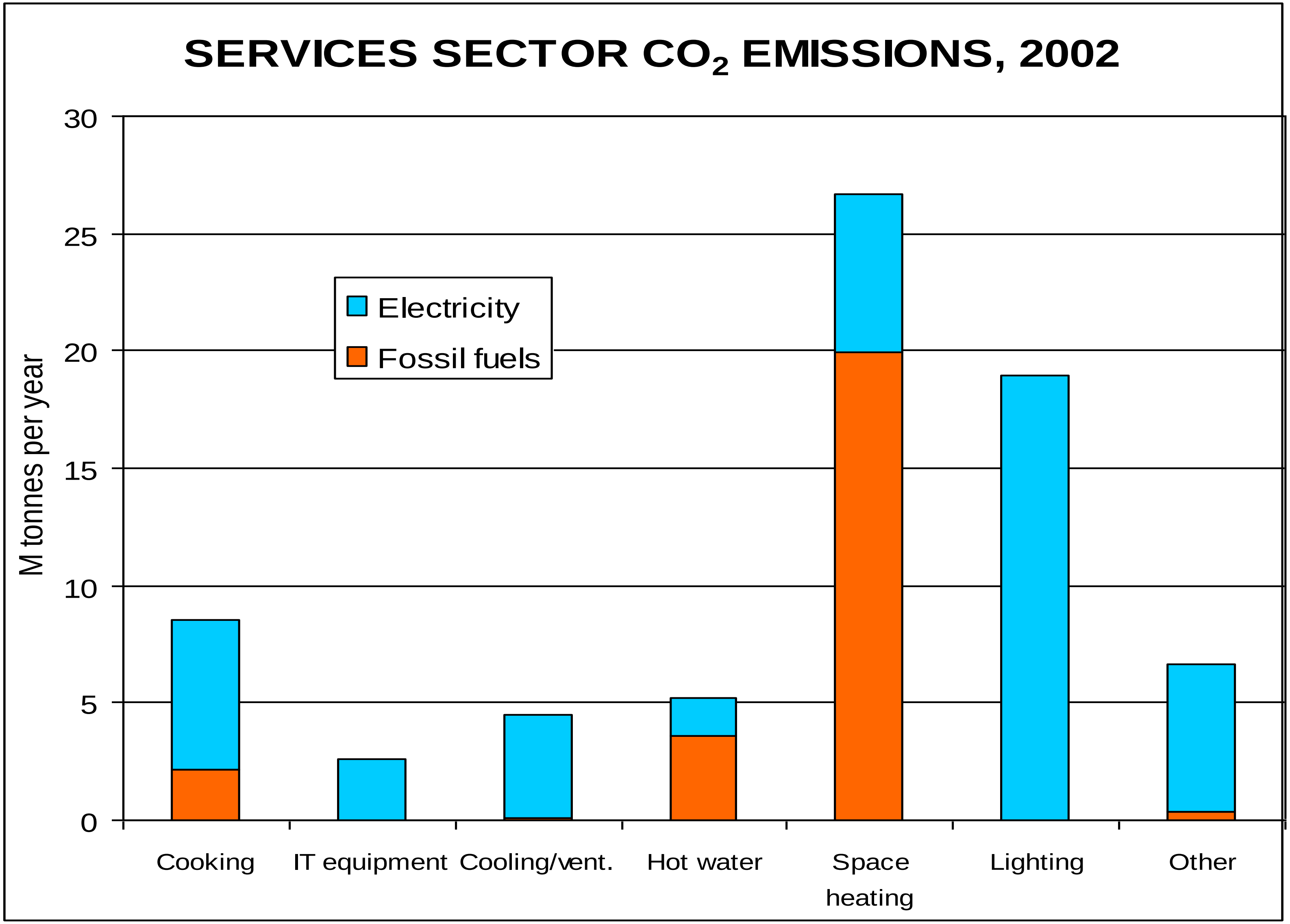
UK Situation



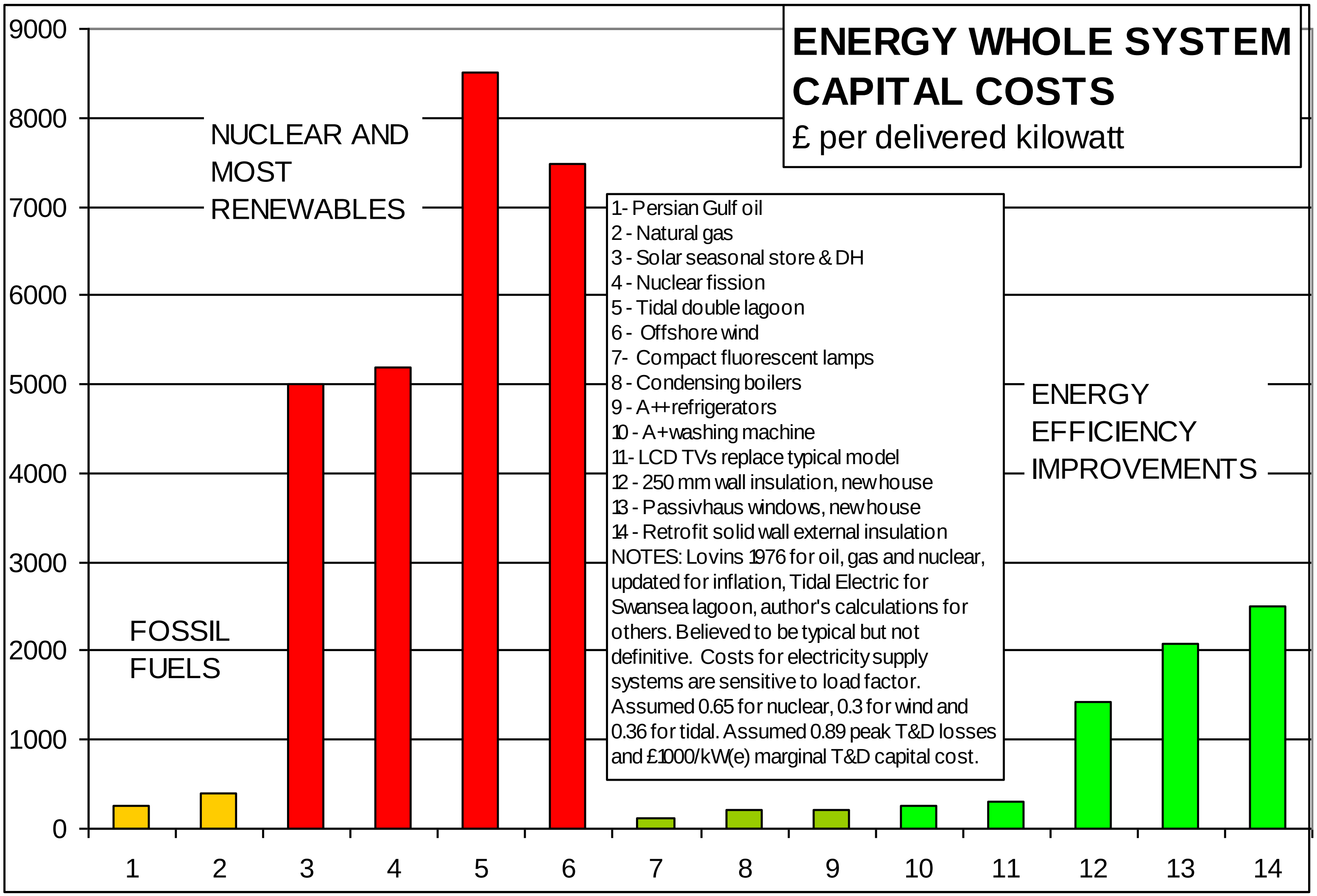
CO_2 Emissions From the Domestic Sector



CO_2 Emissions From Non-Domestic Buildings



The Very High Costs of Non-Fossil Energy Supply Systems



A Rational Way Forward?

- With the rising cost of new energy supply systems, if we simply attempt to replace 1 kWh oil or gas by 1 kWh of renewable energy, the world's energy resource costs per unit GDP would rise by *one to two orders of magnitude*, probably with very adverse economic consequences.
- Unlike new sources of energy supply, most energy efficiency measures assessed to date compete with the resource cost of oil, let alone with its world market price.
- Lavish investment in energy efficiency, reducing consumption (kWh) drastically, could keep total annual bills at more acceptable levels despite the forecast rise in energy supply costs (in pence per kWh).

Energy Efficiency in Buildings

(1) Dwellings - houses and flats

(2) Non-domestic - schools, offices, hospitals, hotels, retail, warehouses, etc.

Countries Which Lead

in Energy/Building Work

1. **Canada** - Issued guidance on air-vapour barriers *in 1960*, launched the R-2000 Program 25 years ago, the C-2000 Program, etc. Pioneered mass builder training on making normal new homes more airtight;
2. **USA** - Participates in most IEA Tasks related to energy-efficient solar buildings. Superb government websites by the Office of Energy Efficiency and Renewable Energy of the US Dept of Energy;
3. **Germany** - Work by independent institutes and state governments. German and Swedish experts developed the Passivhaus standard in the late 1980s. Passivhaus buildings can obtain 30 year fixed rate mortgages at 3.4%/yr;
4. **Austria** - Much grassroots action. 60% of all new dwellings are self-build one-offs. More Passivhaus buildings per capita than Germany;
5. **Switzerland** - Voluntary MINERGIE and MINERGIE-P Standards; former met by many new buildings. Many good documents by Swiss Institute of Architects and Engineers;
6. **Sweden** - Even its Building Code is close to the Passivhaus Standard;
7. **Denmark** - New buildings *in 1975* had 100 mm wall insulation. 60-65% of all buildings are heated by CHP or by industrial waste heat;
8. **Norway** - State Housing Bank wrote two voluntary low-energy standards for dwellings. Main window producer makes a certified Passivhaus window.

Countries Which Lag

in Energy/Building Work

1 UK - In heat loss terms, the England & Wales Building Regulations of 2006 are about level with the Swedish and Norwegian Building Codes of 1965 and their actual building practice in 1950. But it is not only us who set a poor example …

2 France - Has land borders with Switzerland, Germany and Belgium, but strangely many insulation measures which are now compulsory in those regions are voluntary or almost unknown on the French side of the border!

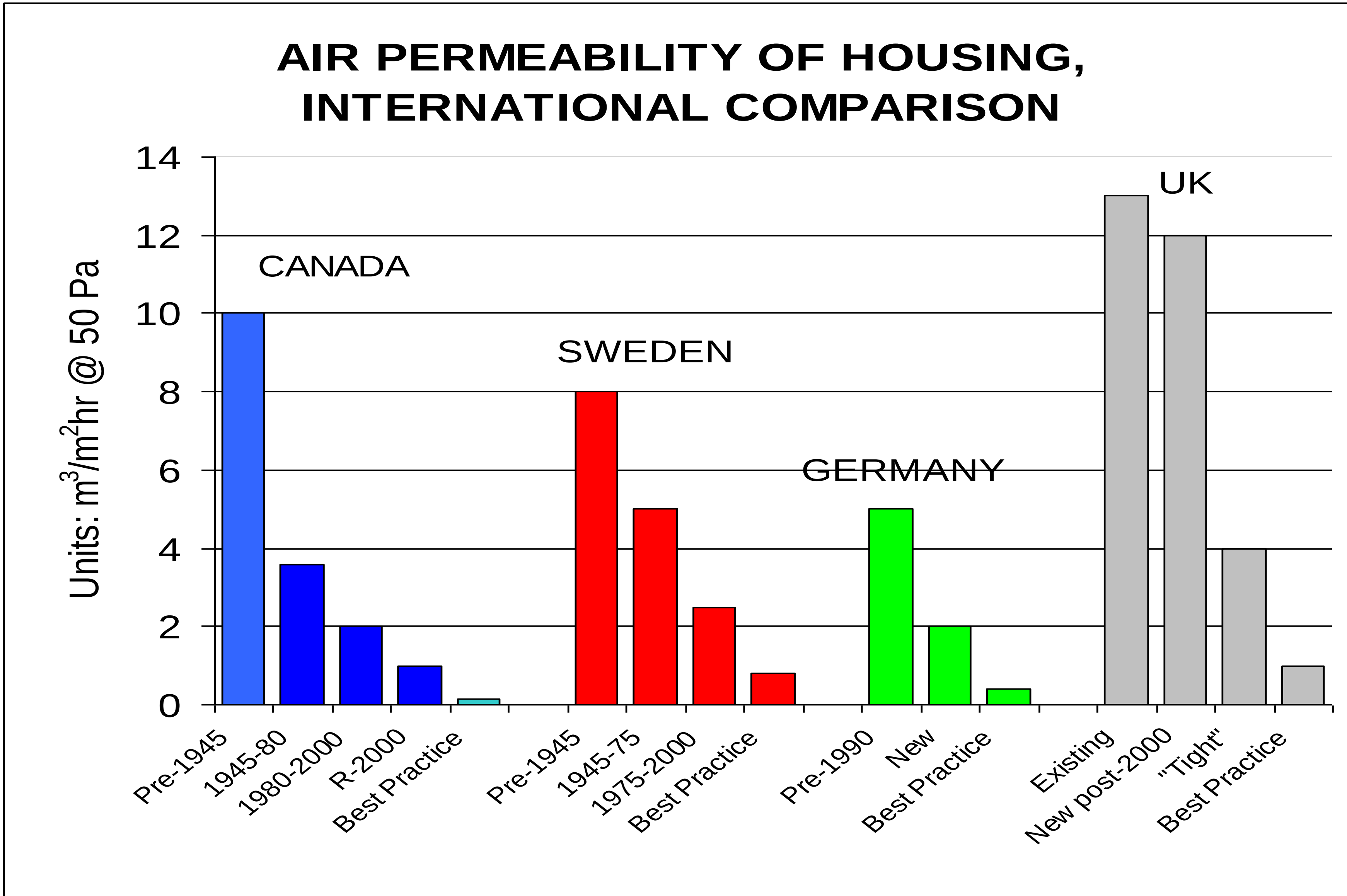
3 Ireland - Independent work showed that housing built in the late 1990s and the 2000s uses more energy per unit floor area than pre-1990 housing. But at least Ireland made the measurements. The UK authorities have declined to fund such work.

4 Japan - Imported US & Canadian wooden housing, with walls of 38 x 90 mm timbers, and 90 mm glass fibre insulation, is revered for its thermal comfort compared to traditional Japanese timber buildings. Yet the climate of Japan resembles that of the eastern & north-eastern USA, where walls with this little insulation are now rare or even illegal.

5 China - Minimal insulation standards. Yet winters in the continental interior are as cold as those of central Canada or Siberia. Harbin's mean January temperature of -20^{o}C is the same as Winnipeg. They are the two coldest major cities - popn. over 500,000 - on earth.

The UK still builds in ways which fail to keep the heat

New dwellings are leakier than those built in Canada, Sweden or Germany 60 years ago.



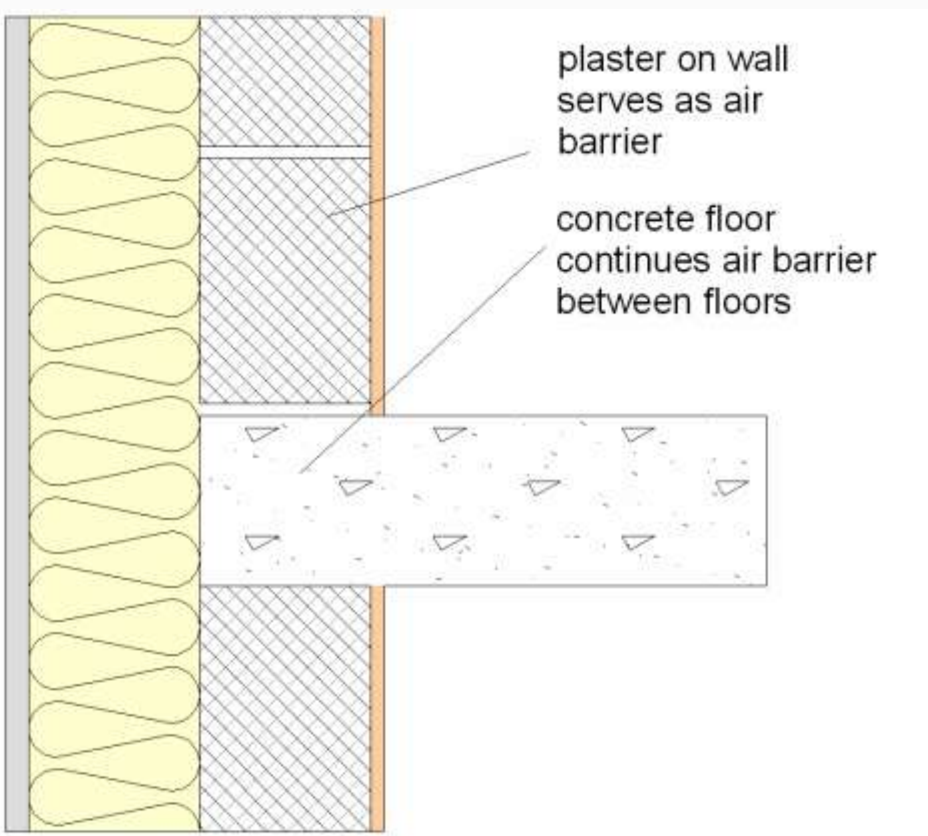
The construction industry is unfamiliar with the design of buildings which properly keep in the heat.

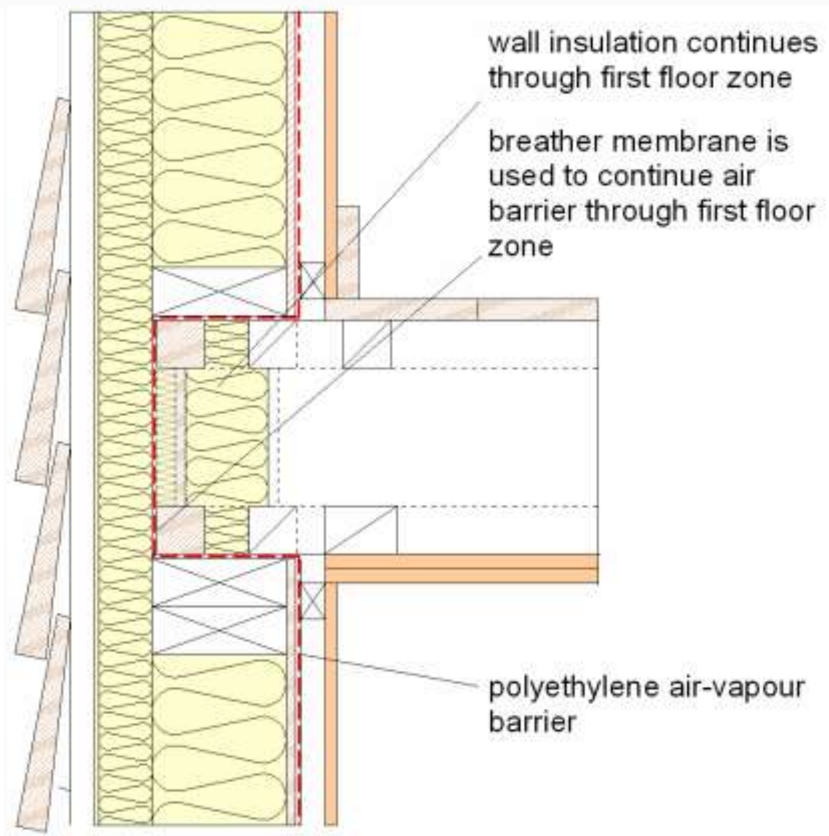
Examples of good design.

See www.carbonlite.org.

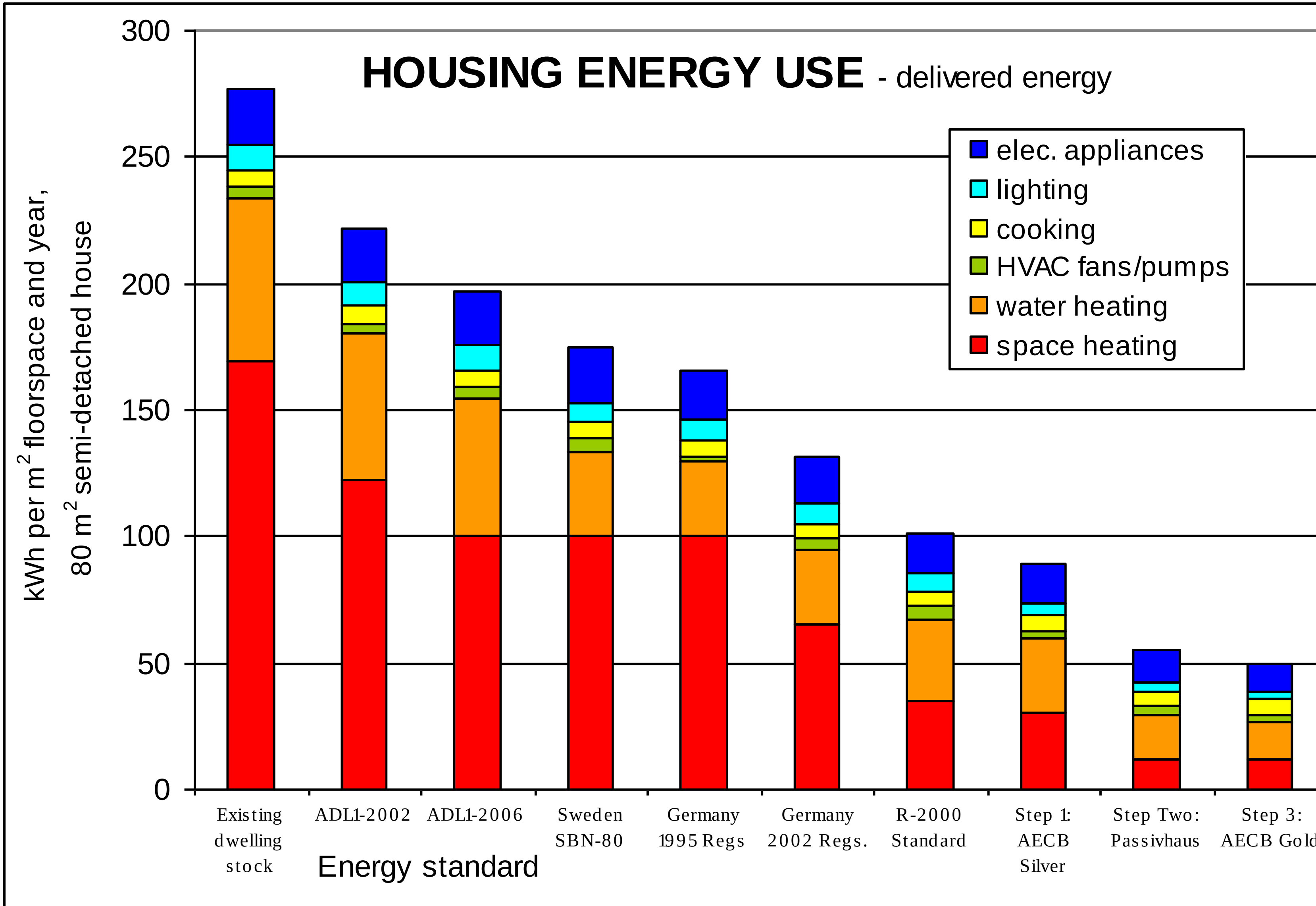
SOLID MASONRY,
EXTERNAL INSULATION

TIMBER-FRAME

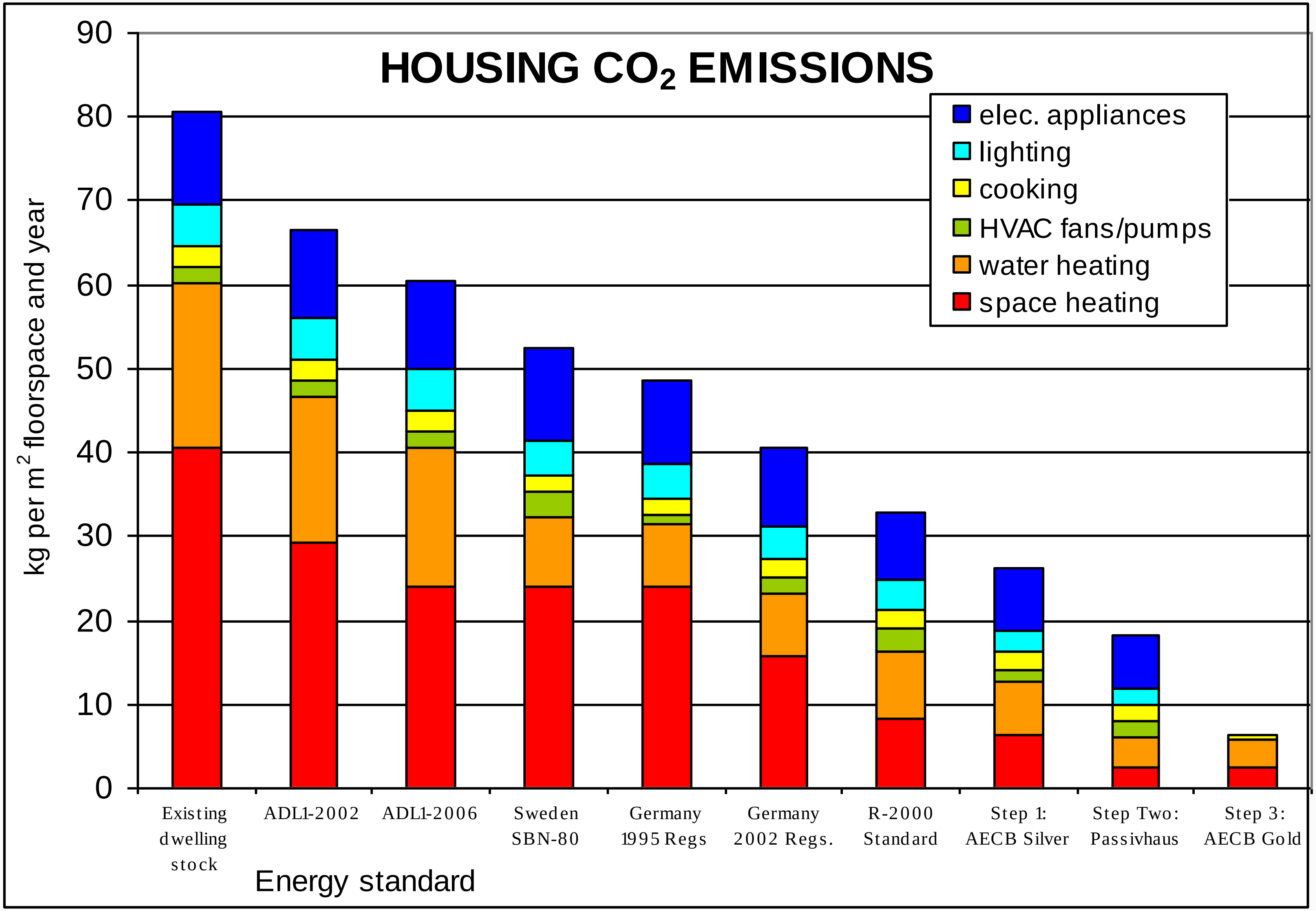




The Impact of Effective Energy Performance Standards on Energy Consumption.



The Impact of Effective Energy Performance Standards on CO_2 Emissions.



Case Studies

Buildings of High Energy and Environmental Performance

Headquarters of the Rocky Mountain Institute *Old Snowmass, Colorado, USA* (built in 1983, photovoltaics added in 1992). Picture courtesy RMI.

The Elizabeth Fry Building.

UEA, Norwich (designed 1992-93, built 1994-95).

3,500 m^2 of floorspace on four floors. Heated by two 24 kW(t) domestic wall-hung condensing boilers. No cooling provided or needed, only automated summer night ventilation using hollow-core concrete floors. High score in PROBE user survey. Large lecture theatres in basement, seminar rooms and offices on other floors. Gas usage 25-30 kWh/m^2yr since 1997. Pictures courtesy John Miller & Partners.

A Detached House to the Passivhaus Standard.
Hohen Neudorf, Brandenburg, Germany (2004).

Picture courtesy Ralf Lenk.

The first School to the Passivhaus Standard. *Waldshut, Germany* (designed 2000 onwards, finished 2003).

Picture courtesy PHI.

The ENERGY SHOWCASE Project

North-west Herefordshire

- The project is named after a 1980 project in Canada
- This is to recognise the early lead set by Canada - followed by USA, Sweden and Denmark - in work on energy-efficient and solar-heated buildings after the first and second oil crises in 1973 and 1979 respectively.
- The building will eventually produce all its energy from renewables, mostly solar, as follows:

(a) Passive solar space heating;
(b) An experimental solar water heating system;
(c) Solar electricity for ventilation, lights & appliances;
(d) Biofuels for cooking.

Summary - Main Features of Project

- A 110 m^2 detached “cottage” on a 1,300 m^2 plot in the open countryside, constructed on a standard self-build budget. Site had detailed planning permission for a replacement dwelling. This was amended to permit the house’s rear façade to face due south.

- A garden which is large enough for extensive home food production and the demonstration/exploration of “permaculture” techniques.

- The location was chosen because, in towns and villages, planning consent for a new house with a large garden is now almost impossible to obtain. Ironically, UK planning policy reflects central government guidance on so-called “sustainable settlements!”

View of the North Roof

A “catslide”. Clad in reclaimed, mostly purple Welsh slates. Fixed with Belgian stainless steel slate hooks and stainless steel screws. Gives a much more secure fixing than nails in high winds and permits the better re-use of very old slates.

Two rooflights, of an experimental design. The larger one is above the house stairwell; the smaller one is above the porch.

The outer portion of both lights comprises a single pane of toughened glass, an oak frame and a stainless steel flashing.

View of the South Roof

Clad in ten toughened glass panels:

(a) Four panels contain photovoltaic cells for electricity generation.

(b) Two panels are blank.

(c) Four panels will comprise part of the solar water heating system.

The glazing bars between the panes are stainless steel. This has a lower embodied energy than the more common aluminium bars.

The lean-to greenhouse adjacent to part of the ground floor is not yet constructed.

External View of the Windows

Made by Thermotech Ltd. of Ottawa, Canada, who have been producing very high-performance glazing since 1991-92. Krypton-filled, double low-emissivity, warm-edge triple glazing, in insulated pultruded fiberglass frames. Very low frame profile, seen in elevation and higher passive solar gains than the majority of today's European-made energy-efficient windows.

Internal View of the Windows

Fixed window to the left faces south; higher solar gains than an opening light.

Opening window to the right faces west.

Internal View of the Rooflight

Their basic configuration was first utilised in the 1st Advanced House at Brampton, Canada in 1989. The inner glazing is an ultra-high-performance triple-glazed sealed unit, the same as used in the vertical windows, in a pine frame.

The two-part so-called 3+1 construction reduces thermal bridging and gives a heat loss some 75% less than from a standard European "high-performance" triple-glazed rooflight.

Also seen is the 500 mm thickness of the reveal, owing to the use of very thick thermal insulation.

Some Views of the Interior

On the left is the staircase, clad with green Lake District slate. The solid balustrade is topped with blue sandstone offcuts. The hall floor is clad with gneiss offcuts. On the right is the kitchen floor, clad with granite offcuts. Most offcuts came from a kitchen worktop manufacturer. Had this material not been salvaged, it would have gone to landfill. So would another 70 m^2 which is used elsewhere, internally and externally.

Space Heating Energy Use

- House will be heated by passive solar and internal gains. No space heating system installed or needed. Predicted standard of thermal comfort; e.g., hours below 20ºC, is on a par with a normal home with a conventional heating system.
- Factors contributing towards this goal:

(a) Very high thermal insulation;

(b) Very draughtproof construction;

(c) Mechanical ventilation with heat recovery, including an earth-buried tube to preheat fresh air in winter and precool it in summer, with a novel technique to augment the winter preheat;

(d) Windows on the south façade which gain more heat than they lose, even in a grey and gloomy southern English winter;

(e) Very high thermal capacity;

(f) Other site-specific techniques.

- Dynamic computer modelling used historic Kew weather data. Since cross-checked with other more local temperatures and solar radiation; e.g., Birmingham, Ross-on-Wye, Credenhill, Shobdon airfield.

Water Heating Energy Use

- A novel, building-integrated solar water heating system on the second floor, within the slope of the pitched roof. Directly-fed by pressurised water, with medium-term heat storage. Construction of this system is incomplete.

- The system design is based *inter alia* on pioneering work by solar engineer Norman B Saunders in Weston, Massachusetts, USA from 1965 to 1990. His research was popularised by the physicist William A Shurcliff of MIT, Cambridge, Mass. Also informed by work on the Self-Sufficient Solar House at the Fraunhofer Institute, Freiburg, Germany from 1988 to 1996.

- Aims for a solar fraction in the high 90s%, avoiding the need for backup by stored fuel; i.e., LPG. Hot baths in December?!

Energy Use for Cooking and Domestic Electrical Appliances

- With extremely energy-efficient electrical appliances and ventilation, a 1.2 kW(e) roof-integrated photovoltaic (PV) system will produce slightly more electricity than the house consumes. This is even so if it were to be “fully-occupied” for its floor area; i.e. by a four-person family. Estimated electricity generation = 1,050 kWh/yr.
- The house will be connected to the national grid. In the long term, PV as used here is expected to be just one of many different renewable electricity sources contributing to the UK national grid.
- The house will use fossil propane for cooking, approx. 500 kWh/yr until equivalent biofuels such as bioDME are available. The residual CO_2 emissions will be offset by afforestation on the site and other accepted CO_2 sequestration measures. In the fossil fuel stage, note that a combination of *clean* fossil fuel combustion and biomass CO_2 sequestration is less environmentally-damaging than small-scale wood combustion.

Replicability

- The house is a demonstration/pilot project. Its approach is applicable to other one-off houses in the open countryside of southern England, Wales or indeed Ireland, on sites which are inaccessible to mains services such as gas or district heating.
- However, 88% of the UK population lives in cities, towns and villages of 1,000 people or larger (ref.: Environment Agency). Most of these areas are accessible to mains services.
- In such developments, collective energy systems are usually more appropriate and technically easier. In built-up areas, active solar district heating (later slides) can be used and seasonal heat storage becomes feasible. About 200 such systems have been constructed in Denmark, Canada, Sweden and Germany from 1977 to date.
- More advantageous sources of renewable electricity would be available to some building projects; e.g. micro- or mini-hydro, tidal lagoons and/or large community-supported wind turbines. The national grid is likely to utilise a mixture of technologies, with no single source predominating.

Energy Use in Industrial Countries

- About 40% of delivered energy is used for low-temperature heat below 100 degC; e.g., space heating and hot water.
- Just over 20% of energy is used for higher-temperature heat; e.g. glass-making, cement and steel manufacture, cooking.
- 30% of energy is used in the transport sector for motive power.
- Just under 10% of energy is used in electricity-specific applications; e.g., lighting, aluminium manufacture, domestic electrical appliances, computers, other office electrical equipment; heating controls, HVAC fans and pumps, security systems, smoke detectors, telecommunications, the internet, etc.
- Proportions apply to UK, Denmark and indeed most other European countries.

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