ENERGY EFFICIENCY

EXISTING BUILDINGS

Presented by

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What I shall talk about

- Case study
  - A Passivhaus retrofit in Hereford
- Energy policy and market failures
- Heating energy supply in 2050?
- Heat supply today in Denmark in particular

Energy Efficiency

in

Existing Buildings

Summary - Passivhaus Standard

- Opaque U-values <0.15 W/m^2K, usually <0.10 W/m^2K.
- "Thermal bridge-free" construction.
- Glazing U-value <0.8 W/m^2K.
- Air leakage <0.6 air changes/hour @ 50 Pa
- Peak space heating load <10 W per m^2 floor area
- Space heating useful energy <15 kWh/m^2yr.
- Consequently no separate heating system, only water-air heat exchanger(s); i.e., plumbing coil(s), in ventln. ductwork.
- Vent. system specific fanpower <1.44 W per l./s.
- Ventln. system equiv. heat recovery >75% as seasonal average, excl. fan heat gains and the benefit of the earth tube heat exchanger if used.
- Highly energy-efficient lighting systems, electrical appliances & office equipment.
- Primary energy consumption <120 kWh/m^2yr.
- Pushes energy efficiency far beyond existing UK awareness, custom or practice.
- Germany has 100 times as many retrofits to the Passivhaus standard as the UK has *new* Passivhaus buildings.
- See www.passiv.de

Case Study

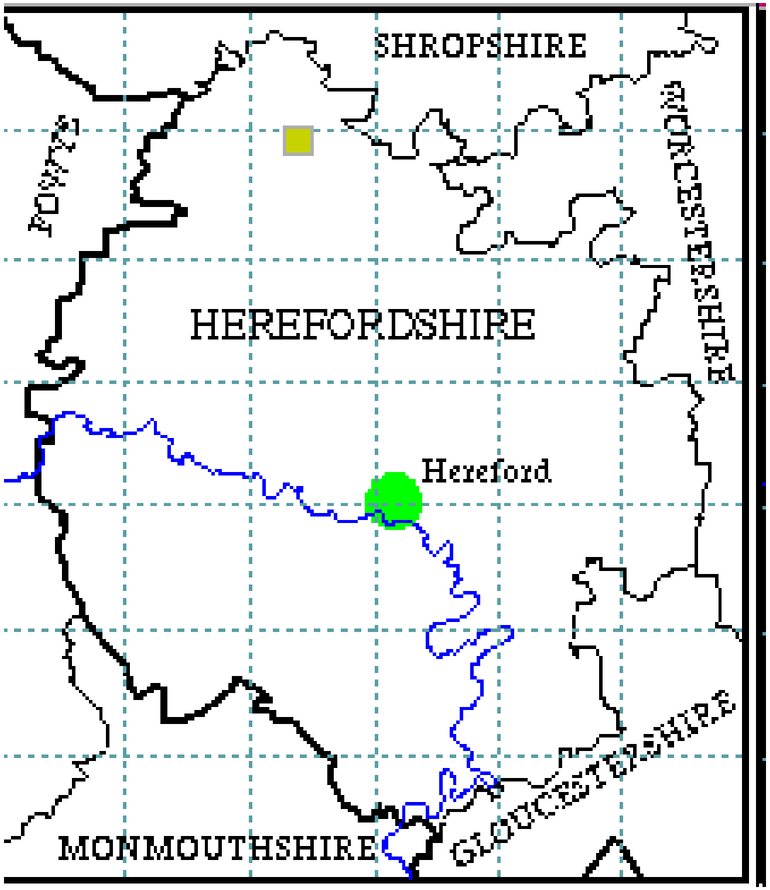
A Passivhaus
Retrofit in Hereford

Location

Hereford cathedral

Courtesy picturesofengland.com

A small agricultural county on the border of England and Wales



Oak-framed houses in Weobley village

View from The Street

Project Description and Location

•Existing Victorian “detached” house on fairly narrow 14 m plot, 25 mm away from the adjacent house to one side, and with passageway to the other side.

•External walls solid 215 mm brickwork, 330 mm in basement.

•House in poor cosmetic condition and in need of major refurbishment. Plumbing and windows to be replaced, loft to be “converted”.

•Neighbourhood within walking distance of River Wye and of the countryside, 10-12 minutes’ walk from Hereford city centre.

•Not in a conservation area.

•Mature garden.

•Mediocre solar orientation. Street façade faces WSW; garden façade faces ENE.

Summary of Project Aims

•To bring a “hard-to-heat” Victorian home up to an energy efficiency standard representing “international best practice”, and close to the best level which has been widely demonstrated on new buildings.

•The USA and Canada had projects in 1979-80, which were termed “superinsulated retrofits”. So did Sweden and Denmark. Interest in this work waned after energy prices dropped from 1982 onwards.

•The process (re)-commenced in Germany in the late 1990s, after being applied to new buildings in the very early 1990s.

•Such thorough renovation is still a new concept in the UK. Not even new homes meet this thermal standard.

Summary of Energy Targets

•Calculated space heating energy falls by 95% from 380 kWh/m^{2}yr to 18 kWh/m^{2}yr, water heating from about 40 to 19 kWh/m^{2}yr.

•The figure of 380 kWh/m^{2}yr is based upon the existing house being fully- and well-heated. It may be an underestimate. Gas consumption in 2006-07, when special efforts were taken to keep the main rooms warm, was 400 kWh/m^{2}yr.

•The new figure of 19 is based upon approaching the Passivhaus limit to air leakage or permeability of <0.6 ac/h @ 50 Pa (<0.75 m^3/m^{2}hr @ 50 Pa). Similar retrofits in Germany have met this figure. The result on this project was 0.97 m^3/m^{2}hr @ 50 Pa, raising calculated heat demand to 19 kWh/m^{2}yr.

•Energy consumption for lighting, electrical appliances and cooking can fall by the same factor, 2-10, as on new homes fitted with high-efficiency lights and A++ appliances.

Insulating The New Roof With 450 mm Mineral Fibre on Top of the Existing Roof Structure (1)

Insulating The New Roof, on Top of the Existing Roof Structure (2)

Insulating The New Roof, on Top of the Existing Roof Structure (3)

Breather Membrane and Slating Counter-Battens

The New Roof Being Slated

About 60% of the Welsh slates, dating from c.1880, were capable of re-use. The rest were discarded.

Junction of Roof and External Wall of Adjacent House

The cavity between the two houses is 25 mm wide. It has been filled with expanding PU foam. This helps with energy and acoustics.

The Basement Ceiling Is Well-Insulated and Draughtproofed from the House Above

The New Plumbing Is Well-Insulated, Reducing Pipe Heat Losses Dramatically

Delivery of Water Pipe Insulation, Including Vapour Barrier Where Needed

Summary of Costings

•The main contractor was very well-known to the clients. For this reason, rather than sign a fixed-price contract, it was decided that work would proceed on a day rate basis; i.e., time plus materials.

•Detailed costings carried out before the project began gave £600-800 per m^2 for the combination of the renovated existing house and the small rear extension which is being added at the same time. Work to date bears this out. This excludes internal work on the existing house; all the energy-related work was carried out externally.

•This experience would be not dissimilar to “eco-renovations” in Germany, Austria and Switzerland. In those countries, such work on old buildings, dating from 50+ years ago, is now relatively routine.

•The project is tantamount to giving a house a “100 year service”. The house was purchased in the knowledge that much of it was worn out.

•In popular neighbourhoods, with established social networks, renovation is an attractive alternative to demolition and replacement.

Project Limitations

•Was and is designed by individuals who are experts in their field but have relatively little influence on UK national energy policy.

•Present UK policy supports neither extensive energy efficiency improvements, nor provision of low-carbon heat in the most cost-effective manner, nor a rational combination of the two.

•The retrofit was designed on the basis of future energy supplies for heating becoming scarce and expensive as, for instance, oil and LPG already are in the countryside - they have often cost 5.5-7 p/kWh in recent years versus mains gas at 2.5-3 p/kWh. It did not explicitly allow for the future possibility of piped heat from low-carbon sources such as gas CHP, solar, industrial waste heat et al being made available to small cities of 50,000 people.

/ …

Project Limitations

•Such dense neighbourhoods as this actually appear suitable for connection to piped heat. A typical detached house in the street has a frontage of 10-12 m and the terraced houses have 5-6 m.

•Optimum insulation and draughtproofing levels would be less than applied to this house *if* low-carbon heat was available. Lesser insulation levels could also be *much* easier to install in the millions of houses which are *not* in need of a 100 year service.

•Local precedent - in late 1980s & early 1990s, Bulmers Ltd. made extensive use of CHP plant for their cider manufacture and many wanted to extend it further afield; political barriers blocked it.

•If piped heat becomes available in cities, this project may turn out to be a closer model to follow in the countryside and dispersed suburbia - the 15-20% of the UK where no piped gas is available, let alone piped heat.

Energy Market and Policy Failures

The Perpetual Story of Energy in the UK?

Energy Policy Failures

•One might expect this project to be eligible for grant aid, as in Germany, where one could finance the whole cost of the work by a 30 year fixed rate mortgage at a rate of 3.4%/yr, or a 25 year mortgage at 3.2%/yr.

•However, the UK's "Warm Front Program" cannot help. This is because the house has no insulation on the attic floor and has no cavity wall, except possibly the 25 mm gap between it and the neighbouring detached house! There is no UK help towards solid wall insulation, air sealing, floor insulation, better windows or insulation within a sloping roof.

•The UK's "Low-Carbon Buildings Program" offers no help either except possibly towards a future solar water heating system. But in a small city such systems appear to be far less cost-effective than using public funds to help finance large-scale solar collectors and heat mains, as in Denmark.

Energy Market Failures

If we wish to minimise the resource cost of CO_2 reductions, we should be systematically investing in the best buys first; i.e. starting with technologies which save CO_2 for £2/, £5/ … £15/tonne and so on, well before we buy technologies costing £30/ let alone £80/tonne.

•Economists would define this as a functioning “market”. The consequence of implementing cheaper options before the expensive ones is that capital and other scarce resources are efficiently-allocated.

•However, UK investment capital is going into CO_2-saving measures in the cost range £50-500/tonne well before measures costing £2, £5 or £10/tonne have been exhausted or even assessed.

•This is a significant misallocation of resources. Economic ill-effects are very likely if low-cost investments are repeatedly passed over in favour of high-cost ones.

UK Space and Water Heating in 2050?

Small-Scale Use of Solid Biofuels?

- Biomass is a scarce and valuable resource, UK sustainable potential c.250 TWh/yr, with many future demands upon it including some transport, steel-making, glass-making, cement manufacture, chemical feedstocks, some cooking and CHP or other generating plant as needed to help keep the national grid stable.

- Automatic solid-fuelled systems need a boiler house or plant room. Non-automatic ones tend to be very inefficient.

- A net heat load of 20-300 kWh/month; e.g., small Passivhaus buildings with solar water heating, leads to low conversion efficiency if burning solid fuels, probably nearer 50% than 90%.

- Capital cost is higher than boilers fuelled by liquid or gaseous fossil fuels (e.g., oil, LPG, mains gas) or biofuels (e.g., biodiesel, biomethane, bioDME). / …

Small-Scale Use of Solid Biofuels?

- Exhaust emissions are at best level with a rather old oil boiler and at worst are 100-300 times higher. The main problems are particulates, tars and PAHs. The particles themselves are a GHG.

- It seems unwise to risk sacrificing public health for doubtful benefits which could also be secured by using solid biofuels in large plants which can clean up their flue gases; e.g., the 500 MW(t) CHP plants heating Copenhagen.

- Older wood combustion technologies emit enough unburned CH_4, N_2O and soot that they are worse for climate change than an oil boiler. Do not use these technologies. See; e.g., Swedish and US government sources such as:

  http://www.eia.doe.gov/oiaf/1605/gg02rpt/methane.html;
  http://www.vtwoodsmoke.org/pdf/Johansson03.pdf;
  http://pubs.giss.nasa.gov/docs/2007/2007_Hansen_etal_2.pdf

Electric Heat Pumps?

- Beware of the Green Electricity Illusion
  www.aecb.net/energyinbuildings/php#background

- All consumers in a region receive the same supply mix from the national grid - about 78% from fossil fuels, 16% nuclear, 6% “renewable”.

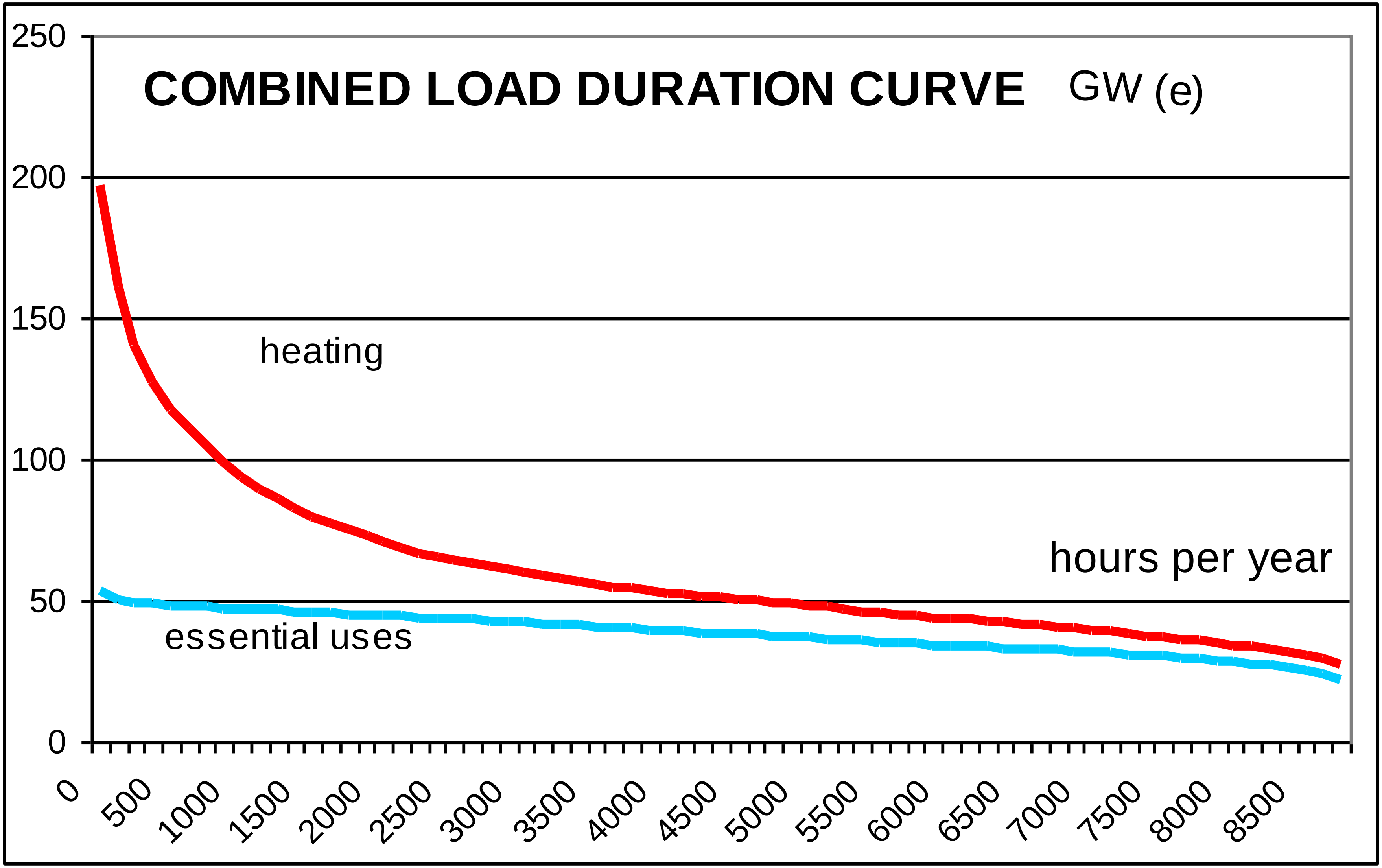
- “Green tariffs” are a misnomer. Too little is being produced to meet the suppliers’ minimum legal obligation of 9% in 2009.

- Growth in demand; e.g., due to electric heating, is met by raising the output of coal- or gas-fired plant. Marginal CO_2 emissions in winter from coal plant are c.0.9 kg per delivered kWh. Not good.

- The heating load profile differs from that for “essential electricity uses”. Peaks are dictated by UK climate and weather and cannot be materially altered except on geological timescales.

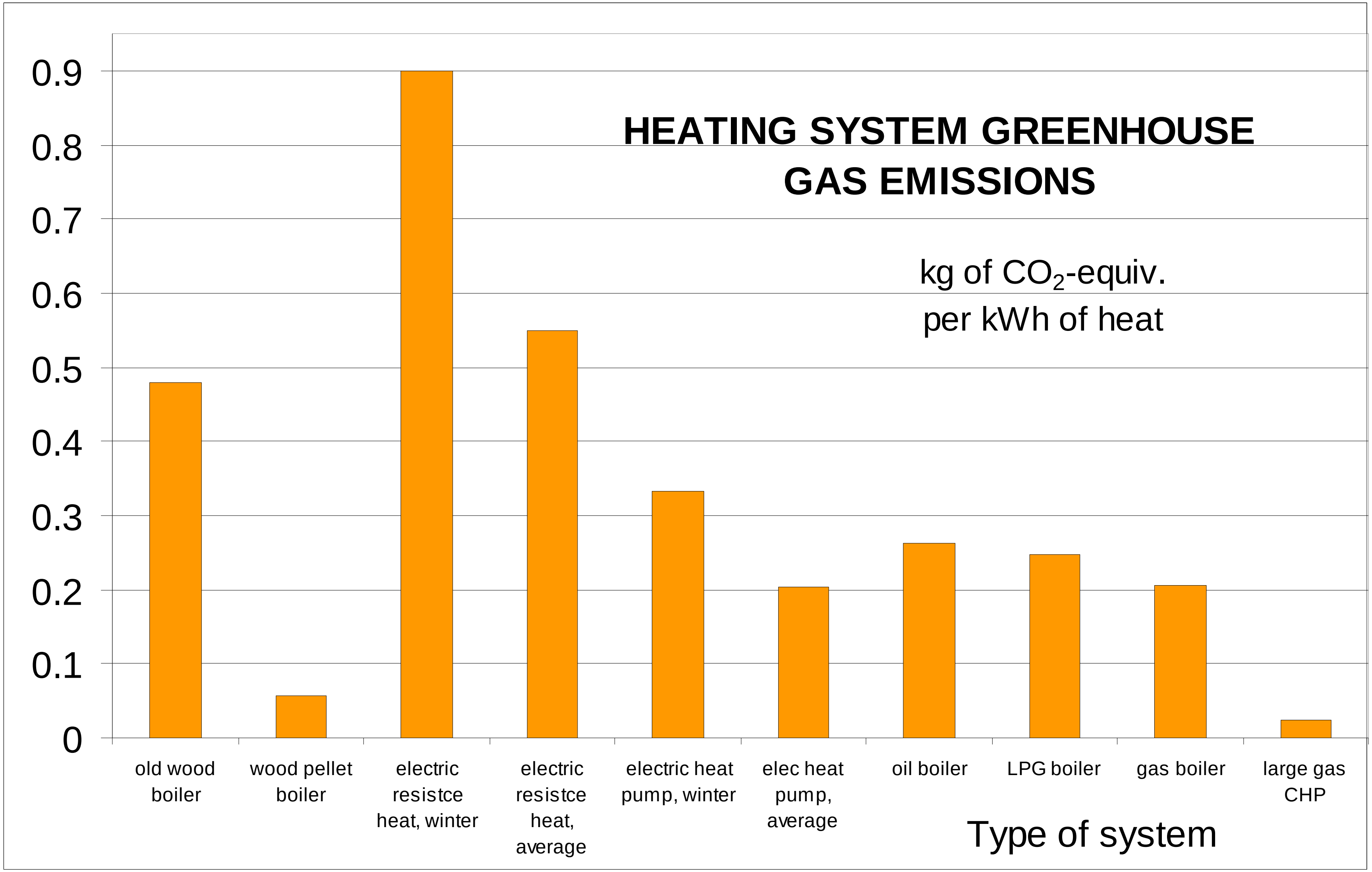
- Ground-source HPs may have a role in heating low-density rural buildings, using; e.g., some of the winter electricity output from biomass CHP plant.

Schematic Load Duration Curve



Typical load duration curve for essential electricity uses based upon data from Italy, where relatively little electricity is used for heating or cooking. http://www.sessa.eu.com/documents/madrid/Ranci.pdf

CO_2 emissions from some “renewable” heating systems are higher than realised.



UK Space and Water Heating, 2050?

- Assume existing non-Grade I/II* listed buildings are heavily-insulated and draughtproofed by 2050 - as per the German program, although their target is actually 2025.

- Overall building heat demand down from c. 220 to an average of 100 kWh/m^2yr despite warmer homes.

- Assume some retrofitted to Passivhaus standard, cutting demand to 25 kWh/m^2yr. For most, this would be too costly.

- Assume new buildings meet AECB Silver Standard from Jan. 2011 - similar to current Swiss Building Code or MINERGIE Std. - the Passivhaus Std. from 2016, the AECB Gold Std. from 2021.

UK Space and Water Heating, 2050?

- *Towns, cities and large villages (c.80% of load, mostly within "gas supply area")* - piped heat. Sources: solid and gaseous biofuelled CHP, geothermal, solar, industrial waste heat incl. biorefineries, lake and ocean source wind heat pumps used to balance the electric grid, biomass heat-only standby & peaking plant.

- *Small villages, open countryside and very dispersed suburbs (c.20% of load, mostly outside "gas supply area")* - active solar backed up by liquid and gaseous biofuels, electric heat pumps in situations where these do not generate new, expensive peaks in demand.

Precedent: Danish National Heat Plan of 1979, Danish Heat Supply Act of 2000 and amendments.

Energy Security?

- Gas-fired CHP - store enough fuel at the CHP plant to survive significant interruptions to the gas supply system. A partial alternative to the UK's much-needed - but non-existent - gas storage. Interruptible loads also pay a lower price in p/kWh for gas.

- System design - use direct connection and back-up system pumps so that all components survive an electricity supply interruption.

- CHP can then deliver heat and electricity conspicuously more reliably than the current system.

- Rural buildings - incorporate small battery backup, maybe 1-3 kWh, so that pumps and controls work during electricity supply interruptions and LPG and oil heating work - if not electric heat pumps.

- Insulate and draughtproof all buildings. Their cooling time constant lengthens from 5-30 hours to 300-1000 hours, making them more resilient in the face of supply interruptions.

Heat Planning in Denmark

“The objective of this Act is to promote the most economically-advantageous and environmentally-beneficial utilisation of energy for heating buildings and supplying them with hot water, while reducing the dependency of the Danish energy system on oil. …

Article 3. It is the duty of each district council, in consultation with the supply companies and other interested parties, to prepare a plan for the supply of heat in the [district]. …

The Minister of Energy and Environment shall give an account of the more important measures planned in accordance with this Act to the Parliamentary Energy Committee. …

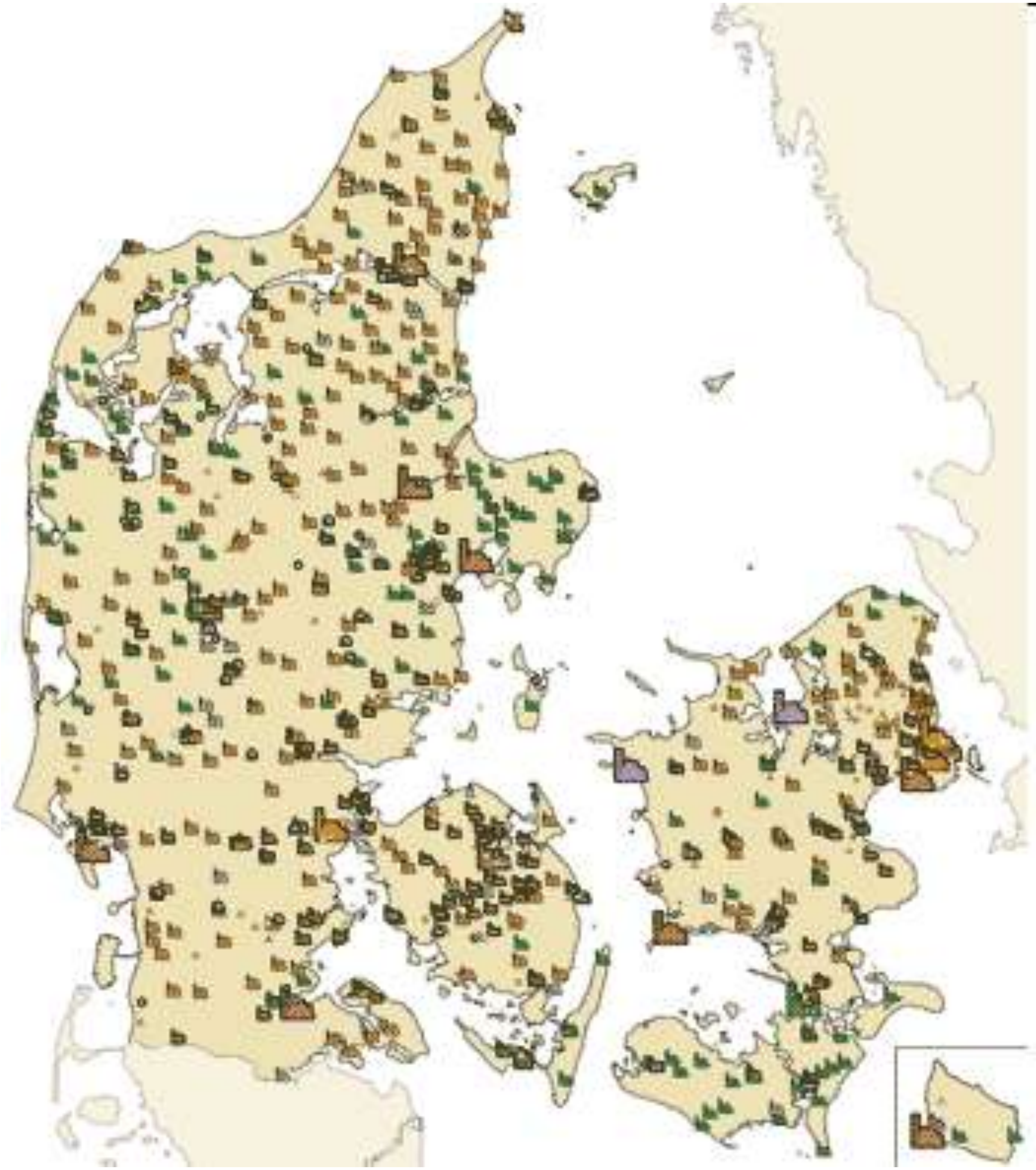
The Minister of Energy and Environment may establish rules on the distribution of costs between electricity and heat production at biomass-fired CHP plants. …”

Extracts from the Danish Heat Supply Act, July 2000, unofficial English translation.

Map of Danish District Heating Systems

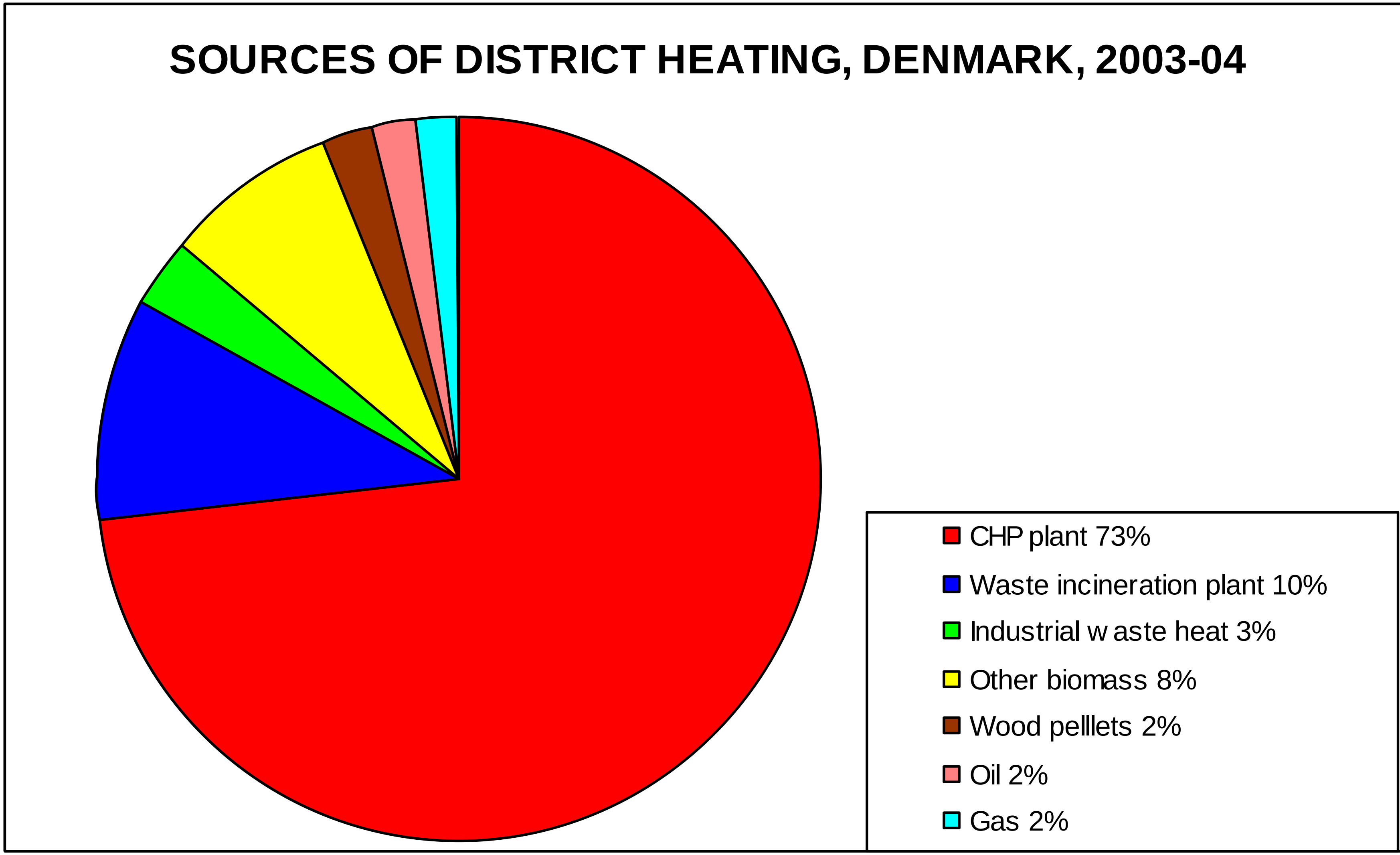
Denmark's population is 5M; i.e., similar to Scotland, the West Midlands or South-West England.

Most cities, towns and large villages have heat mains. Between 1995 and 2005, 400,000 more consumers were connected to DH.



Picture and figures courtesy Danish Board of District Heating (DBDH).

Where the Heat Comes From



Source: DBDH.

District Heating Infrastructure

CHP in Denmark

Left - transmission line from CHP plant to nearby town

Top right - cross-linked polyethylene twin pipe developed for use in low-density areas; e.g., suburbia.

Geothermal district heating in northern Italy

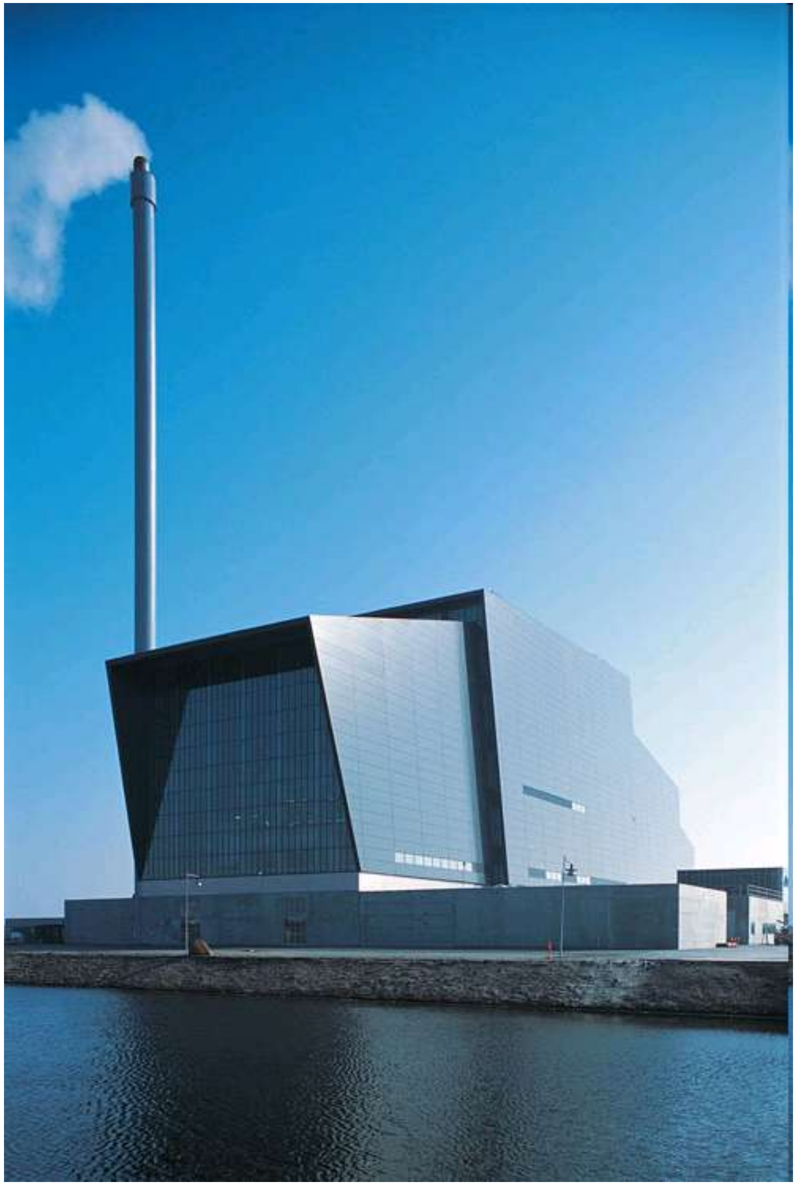
Bottom right - extension to a distribution system

Pictures courtesy Danish Board of District Heating, www.logstor.com, www.pipesystems.com and www.isoplus.de

Waste-Fired CHP Plant

Helps to heat the town of Esbjerg on the west coast of Denmark.

Many similar plants elsewhere on mainland Europe. They owe their existence to the fact that it is not cost-effective to separate the different plastics found in waste streams. By contrast, glass, paper and metals and putrescible kitchen waste are more easily identified, sorted and dealt with in an economic manner; the putrescible waste can be digested to methane.



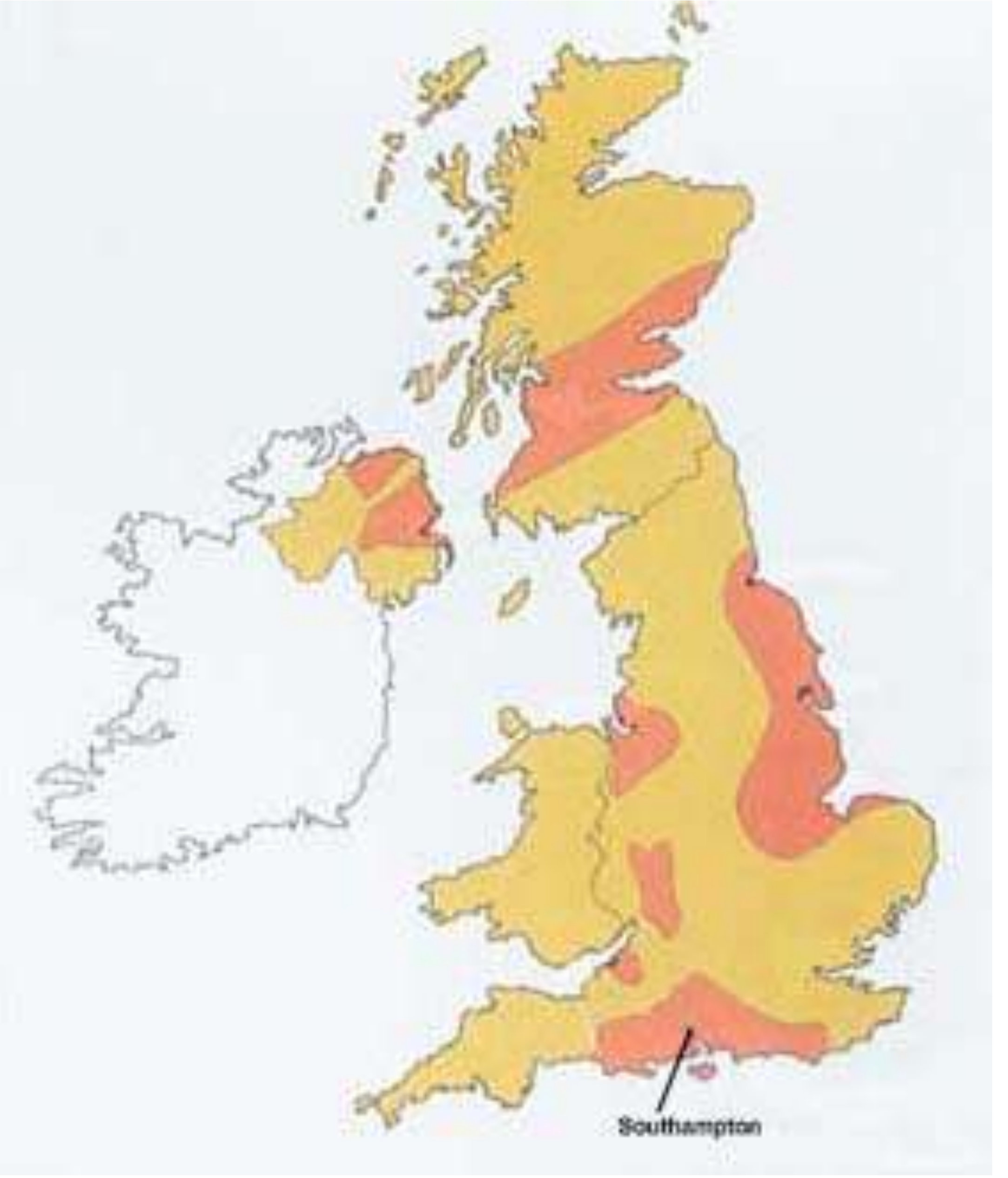
Picture courtesy DBDH.

Geothermal Aquifers - UK

In the red areas hot water may be available at 1.75-2 km depth; e.g., the 1 km deep potash mine at Boulby, Cleveland is at 40ºC and Bath has 42ºC water at the surface.

Water at 75ºC has helped to heat central Southampton since 1981. Since 2004 geothermal has supplied 1% of the Copenhagen DH system.

Geothermal DH was first used in France in the 1300s. Today it heats part of Paris.



More Solar Collectors - Sweden

10,000 m^2 of solar collectors were retrofitted to the district heating system of Kungalv, 20 km north of Gothenburg in 2001. There is 1,000 m^3 of buffer heat storage. Biomass and oil are also used. The supply temperature is 70ºC in summer and in mild mid-season weather, rising to 90ºC on severely cold days. The return temperature is 40ºC, year-round. At an annuity factor of 0.08, the solar heat input costs 3 p/kWh, lower than biomass or oil heat-only plant.

Courtesy: Kungalv Energi AB

Ground Source Heat Pumps

Below left and top right - 10 kW(t) spring source system, Wales with a 700 litre buffer store.

Bottom right - ground coil under construction, Germany.

All pictures courtesy John Cantor Heat Pumps Ltd.

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