Net Zero: The past and future role of domestic building energy efficiency

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UCL Energy Institute

”The world will not be destroyed by those who do evil, but by those who watch them without doing anything." -- Albert Einstein

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Agenda

- History
- Lessons for the Future?
- UCL Energy and Buildings Research
- What climate emergency?

Meet the Team

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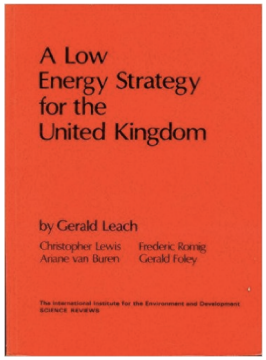
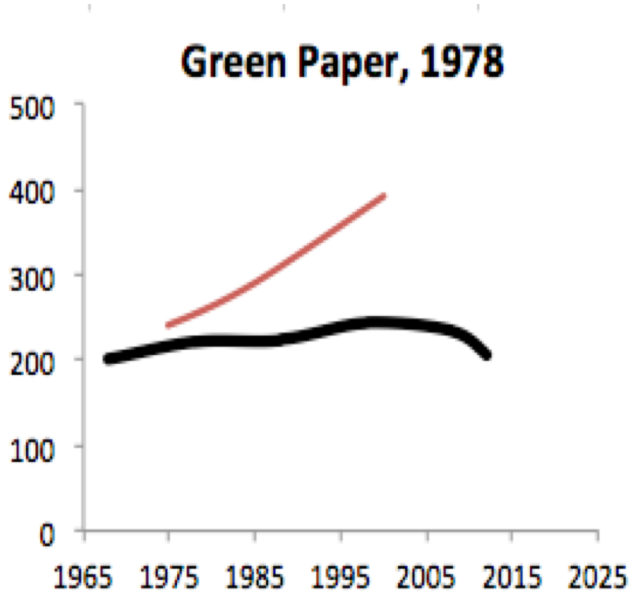
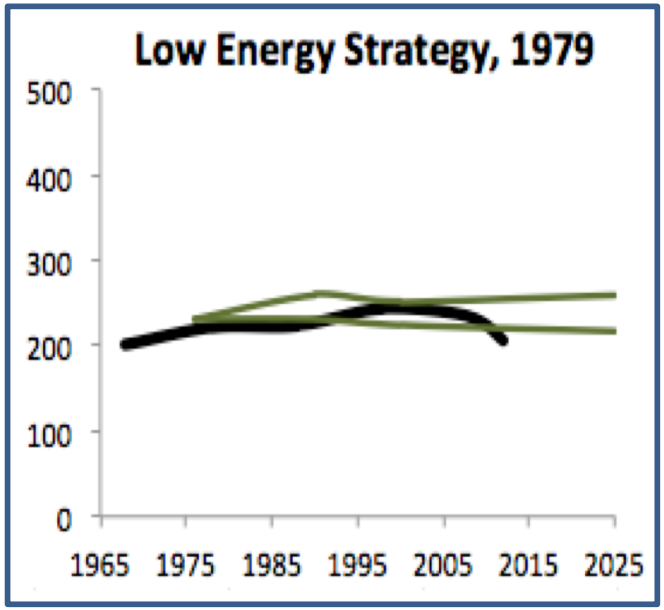
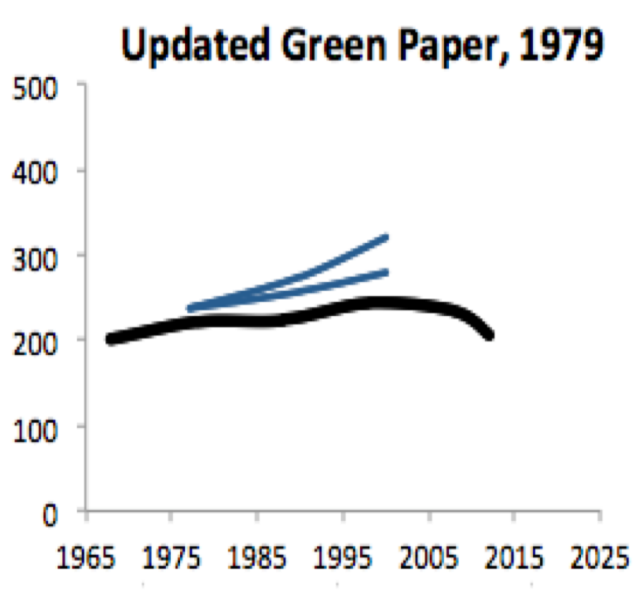
What have we delivered and how?
1970's Scenario choices and actual transitions



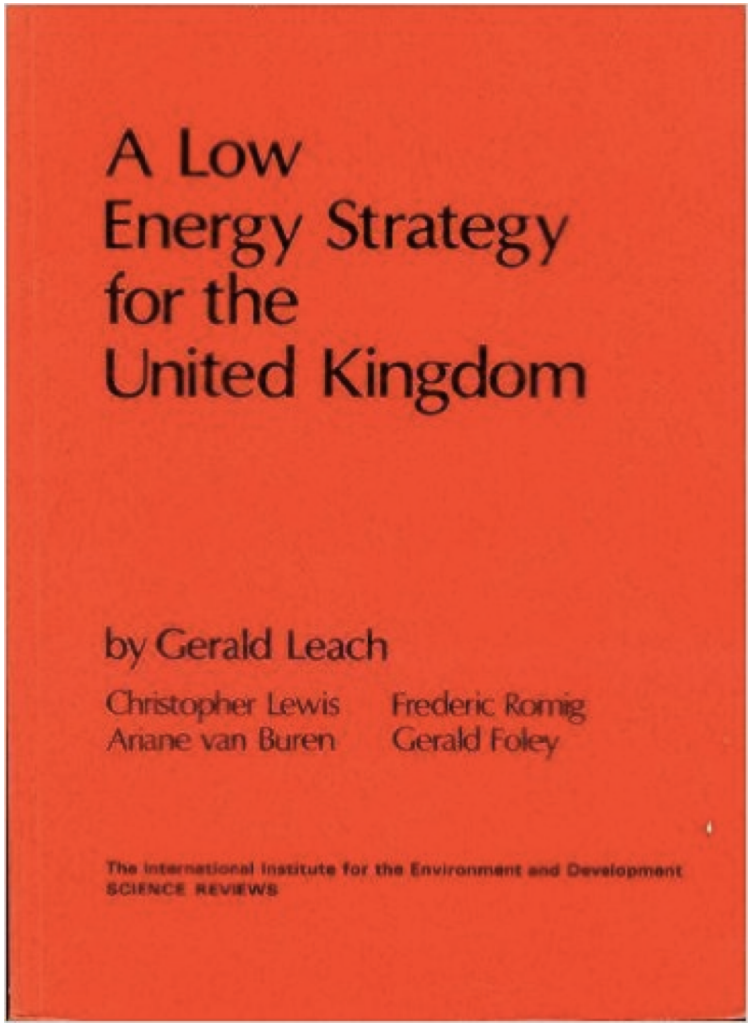






Source: Energy scenario choices: Insights from a retrospective review of UK energy futures, by Evelina Trutnevyte, Will McDowall , Julia Tomei , Ilkka Keppo, UCL Energy institute presented at UKERC General meeting 21st of March, 2016,

A Low Energy Strategy for the United Kingdom



In 1979, motivated by energy security and prior to climate change.
First energy strategy for the UK proposing for the first time a decoupling between growth and energy use based on bottom up physically constrained assumptions.

2010 Scenario: a 50% reduction in domestic delivered energy by:

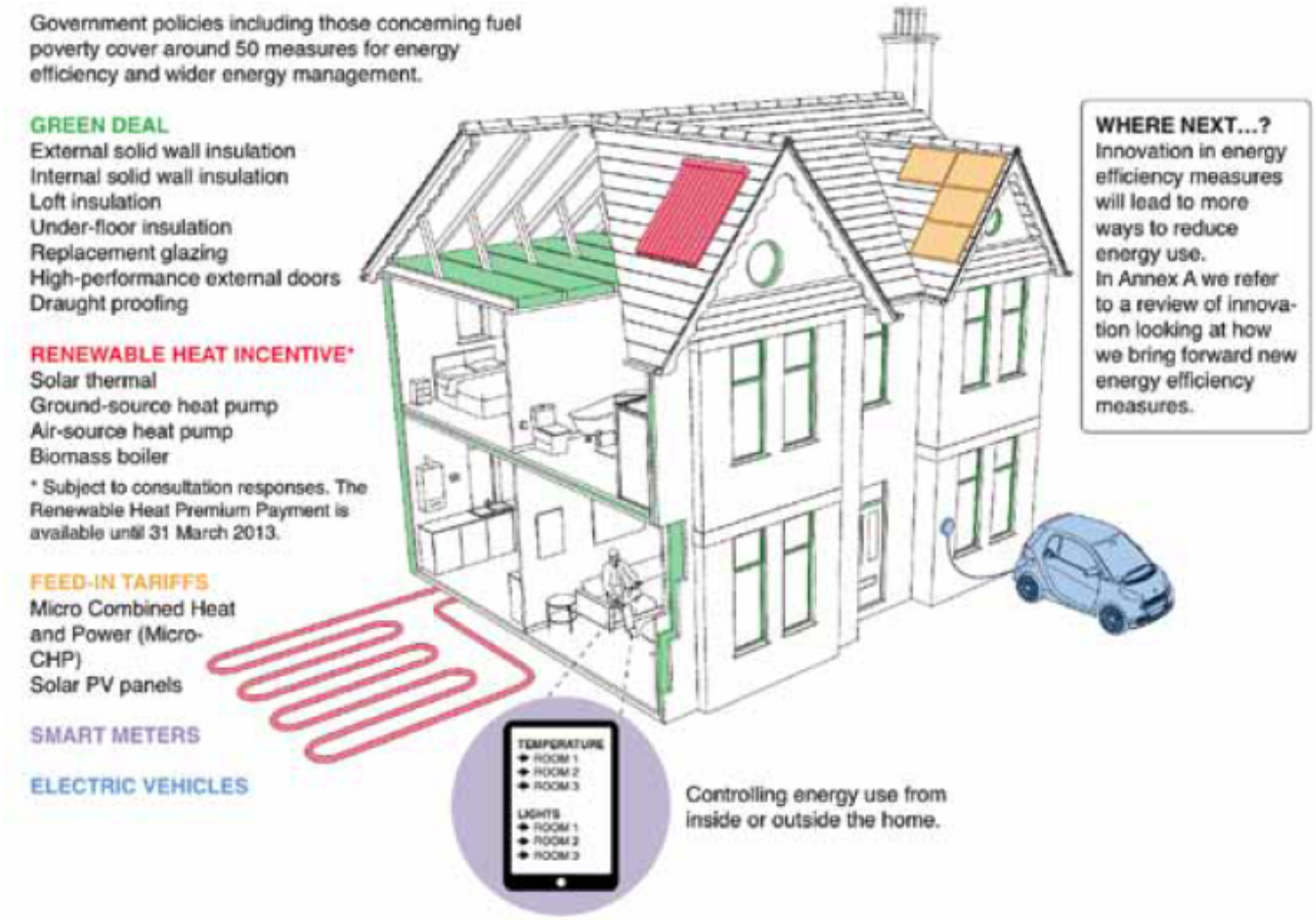
- Cost effective insulation (loft, wall and windows)
- Improved heating efficiency (including heat pumps, solar thermal and district heating).
- Improved cooking and electrical appliances (half the electricity).

With an increase in service:

- Increased population, housing and internal temperatures.

- So what actually happened?

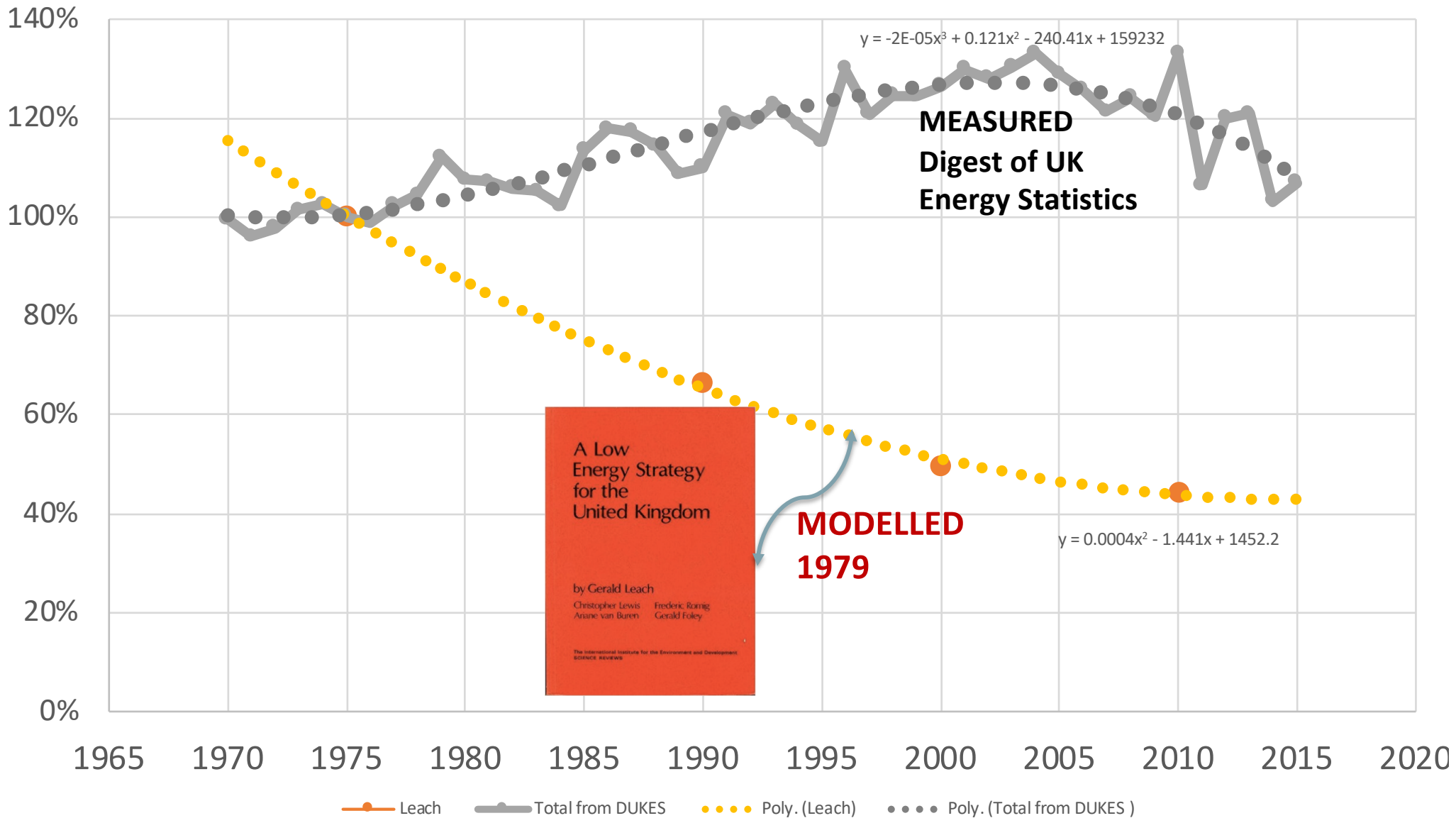
Figure 10: 19th century house... 21st century energy management



39 Analysis from DECC Insulation Statistics (July 2012)
http://www.decc.gov.uk/en/content/cms/statistics/energy_stats/en_effic_stats/home_ins_est/home_ins_est.aspx

Source: DECC 2012: The Energy Efficiency Strategy: The Energy Efficiency Opportunity in the UK

Percentage change in total energy **delivered energy** compared to 1975



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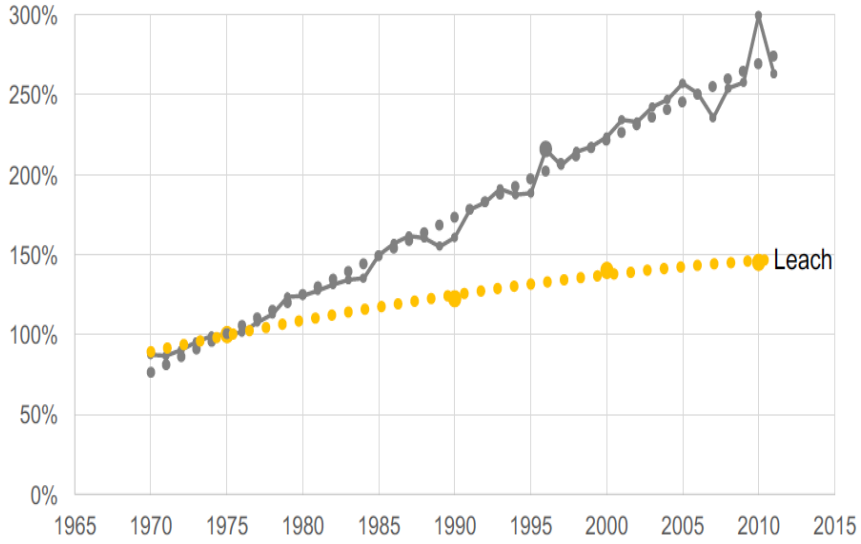
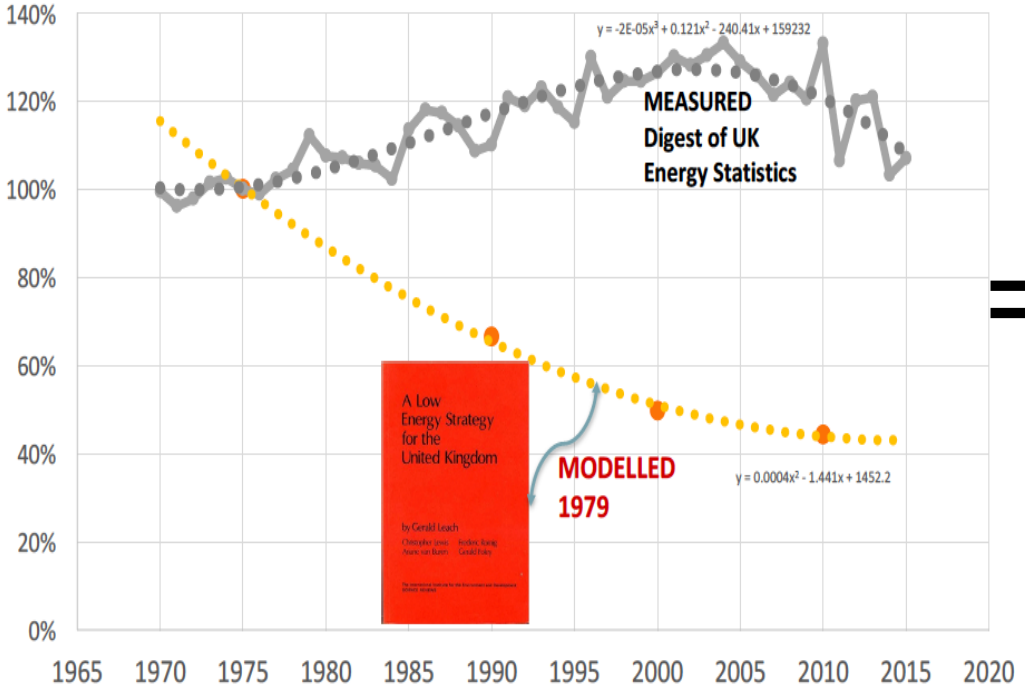
Why?

- We do not know!
- We are spending billions but do not really know what is happening in even some of the simplest detail – that is changing (smart meters, 3DStock model, etc)
- My best guess historically.

Service (useful energy)



Delivered



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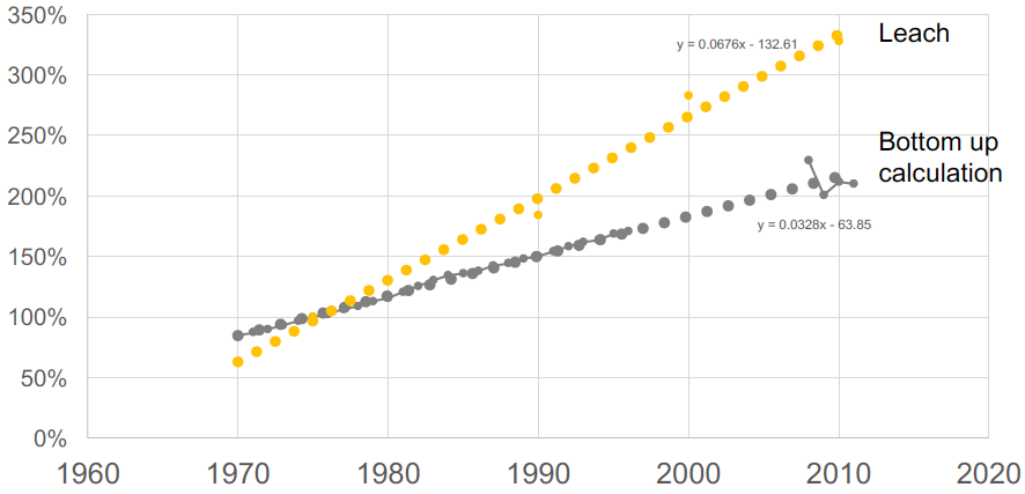
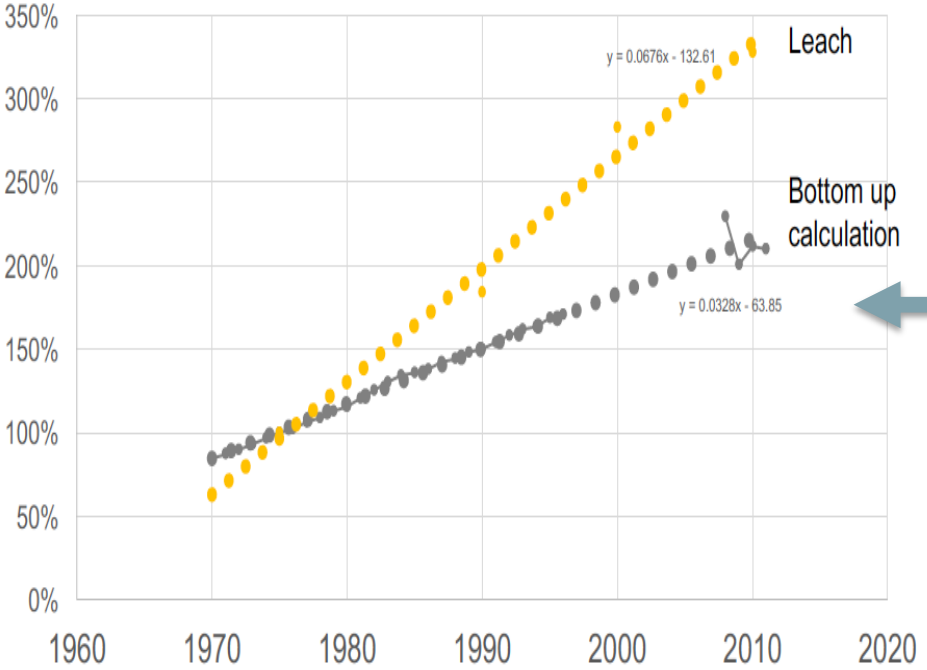
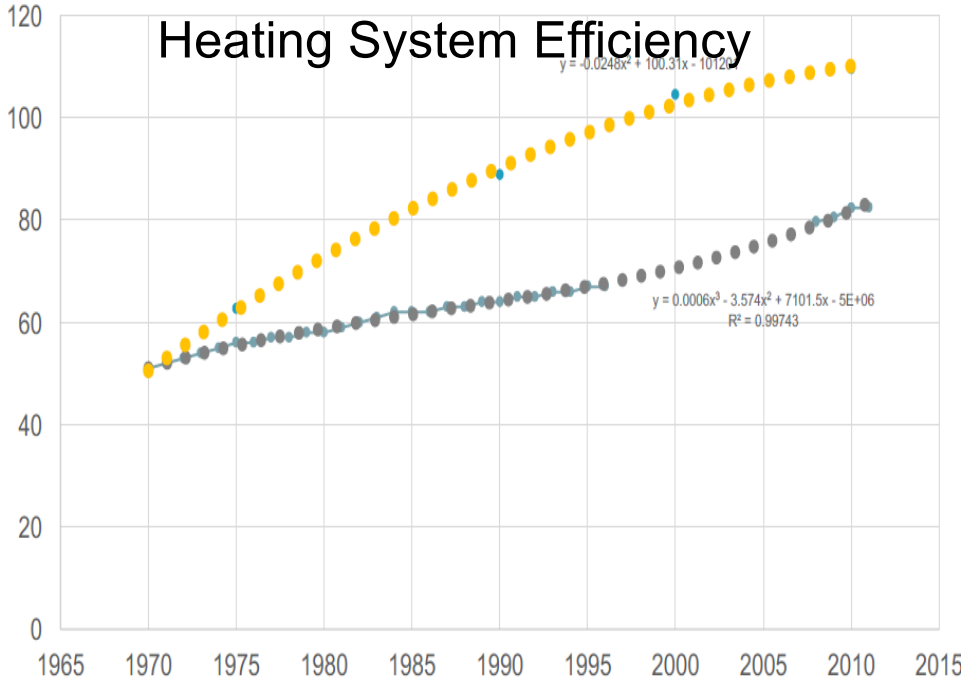
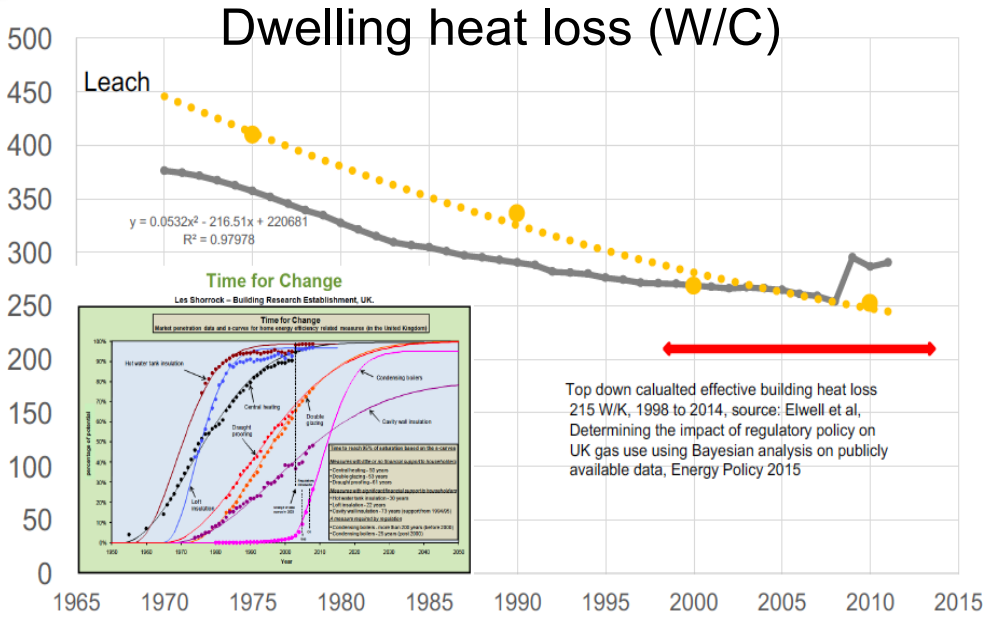
Efficiency (fabric & service)



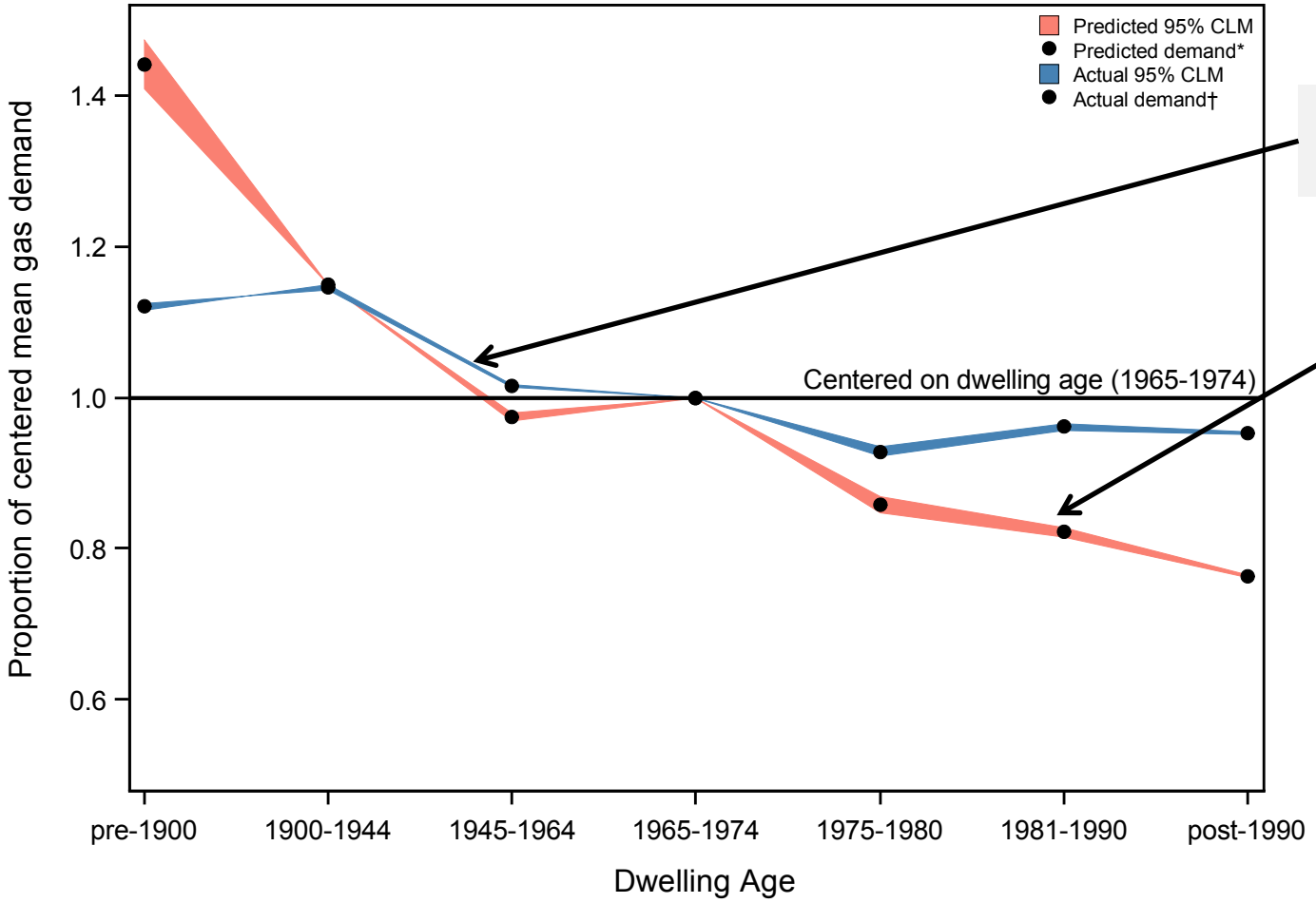
Efficiency (fabric & service)







Building age, and energy demand: how reality diverges from our model



Actual demand has a shallow slope

Predicted demand has a steep slope

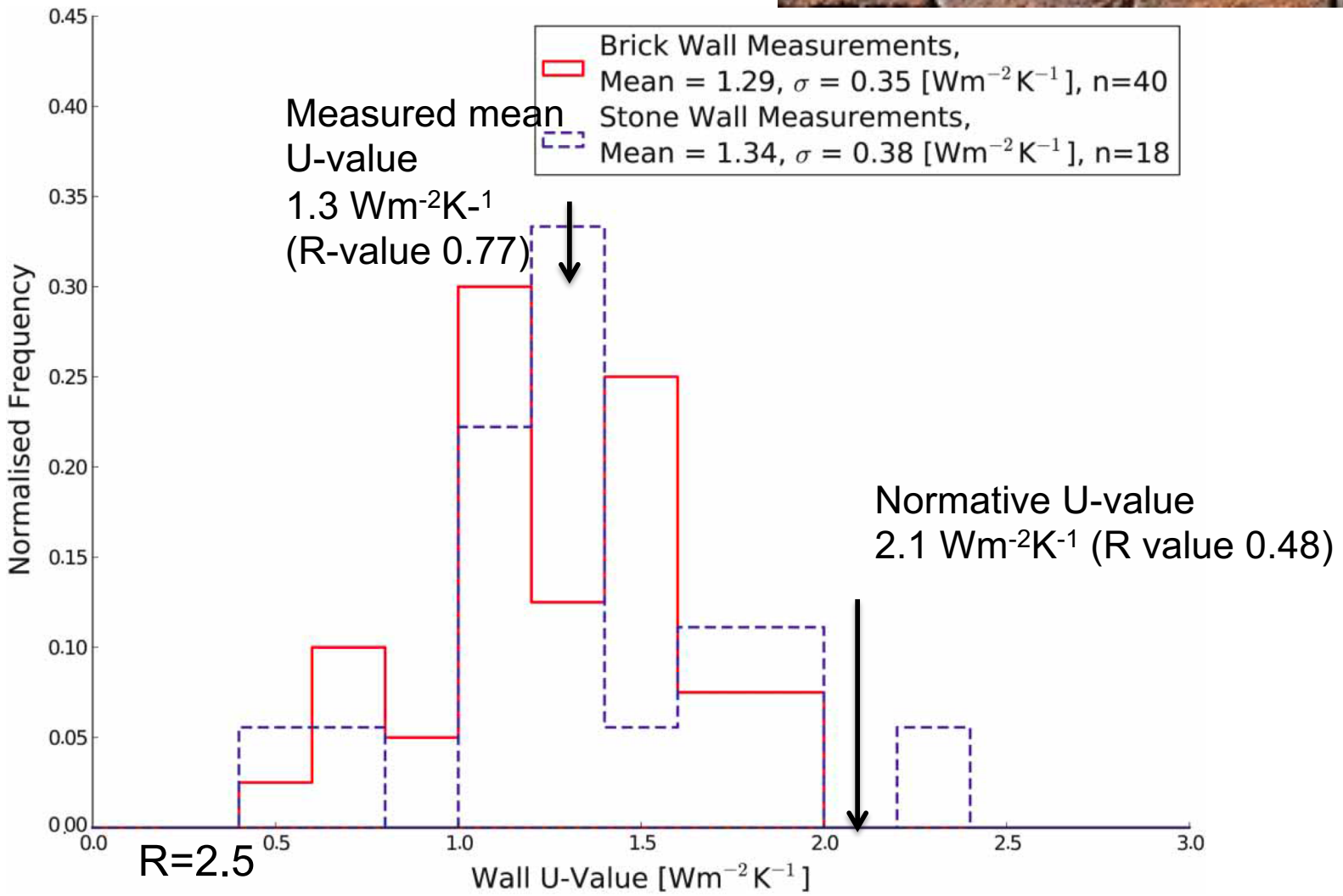
*Representative sample of British dwellings with predicted 2007 gas primary space and water heating N=13,000

†Representative sample of British dwellings with actual 2007 gas meter readings N=50,000

Diversity in U-values of solid wall

Solid walls are 27% of stock

To cite this article: Francis G. N. Li, A.Z.P. Smith, Phillip Biddulph, Ian G. Hamilton, Robert Lowe, Anna Mavrogianni, Eleni Oikonomou, Rokia Raslan, Samuel Stamp, Andrew Stone, A.J. Summerfield, David Veitch, Virginia Gori & Tadj Oreszczyn (2014): Solid-wall U-values: heat flux measurements compared with standard assumptions, Building Research & Information, DOI: 10.1080/09613218.2014.967977



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Multiple sources of performance gap evidence

Source: Jez Wingfield & Ian Hamilton

Loft Insulation

- Design depth 300mm
- Actual depth 150mm
- Subcontractor required to come back to make up difference

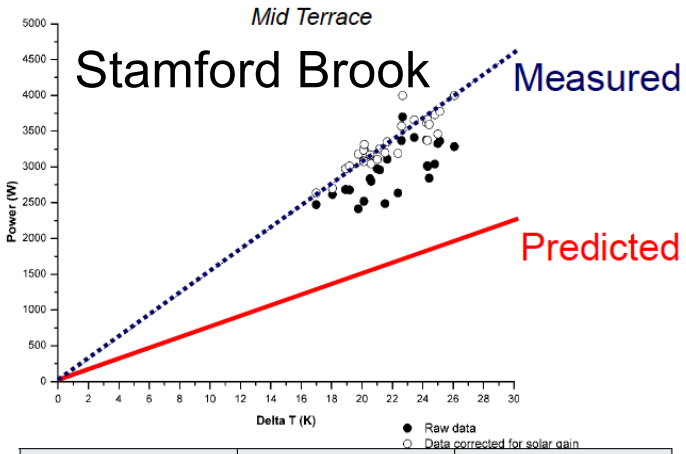
Calculated U = 0.29 W/m^{2}K

U in SAP = 0.35 W/m^{2}K

Measured U = 0.45 W/m^{2}K

Interventions	Average¥	Actual Change from 2005	Actual Savings (from trend)	Modelled Savings+
All 2005	17,567	-	-	-
No efficiency† 2007	16,243	-7.5%	-	-
Boiler only 2007*	14,501	-17.4%	-9.9%	-20.0%
Loft & Boiler only 2007*	14,494	-17.6%	-10.0%	-25.2%
Cavity & Boiler only 2007*	14,172	-19.4%	-11.8%	-41.1%

Case 1: Coheating test



Predicted Heat Loss (W/K)	Measured Heat Loss (W/K)	Heat Loss Discrepancy (W/K)
75.2	153.4	78.2 (+103%)

Regulation Works, if!

It is easy to police

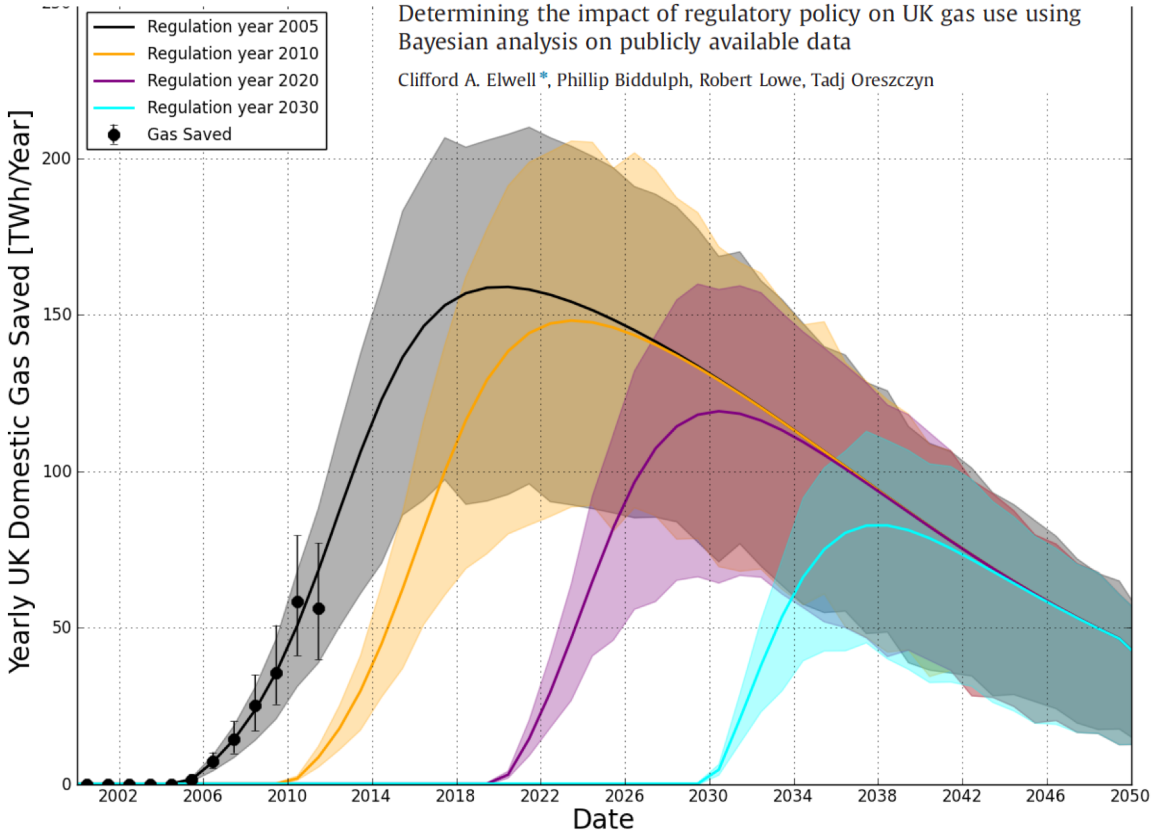
Impact of 2005 Condensing Boiler Regulation

Bayesian analysis of UK energy data

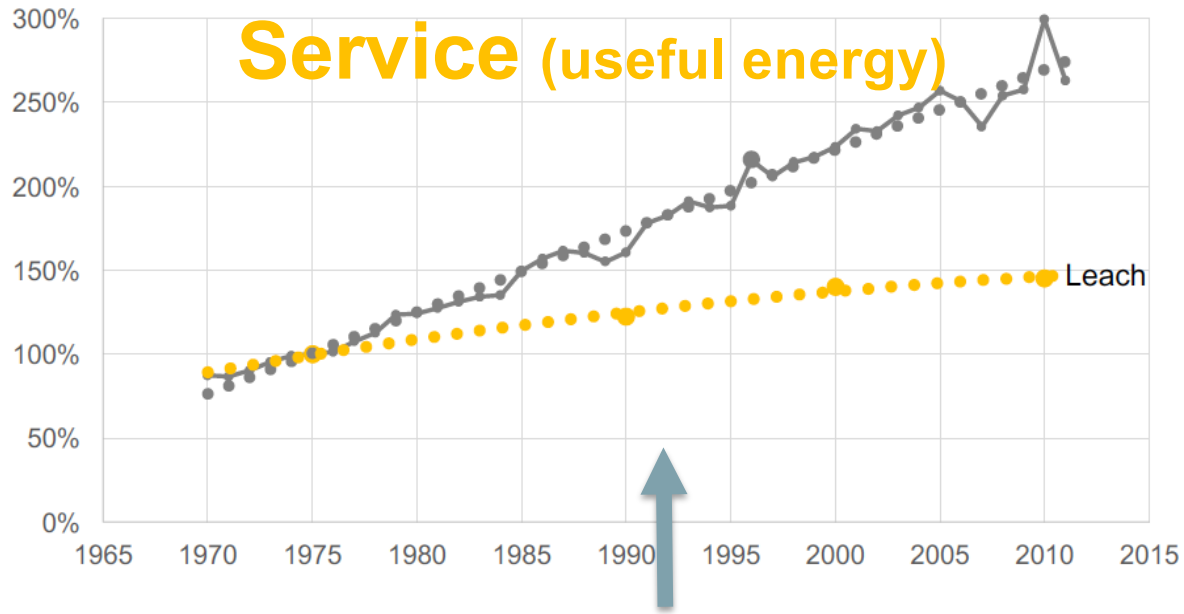
shows regulation impact

By 2050 savings equivalent to 6 years of CO2 emissions (370MT CO2)

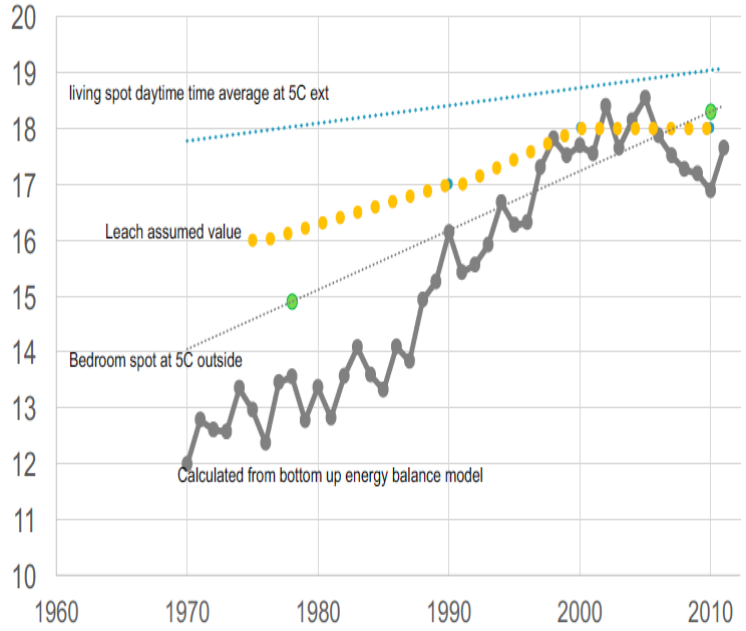
Energy Policy 86 (2015) 770–783



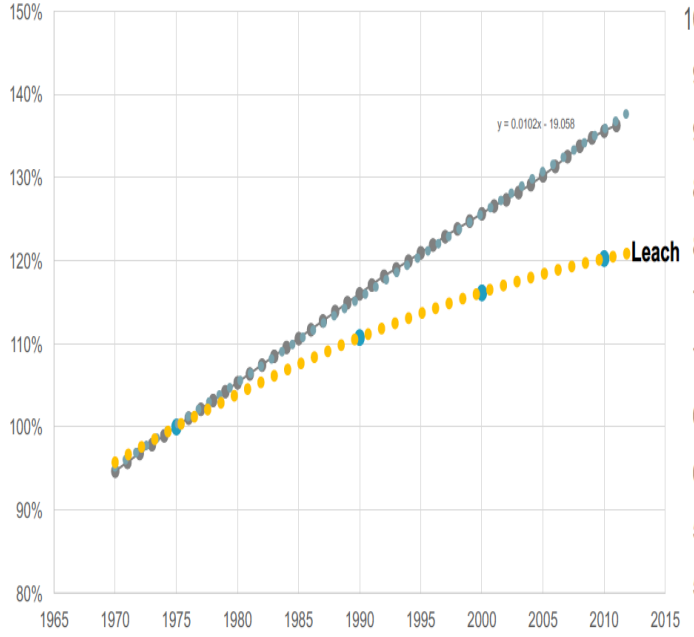
Old floor standing boiler and hot water tank (2m2 floor space) replaced with wall hung condensing combi boiler – value of floor space saved £4,400



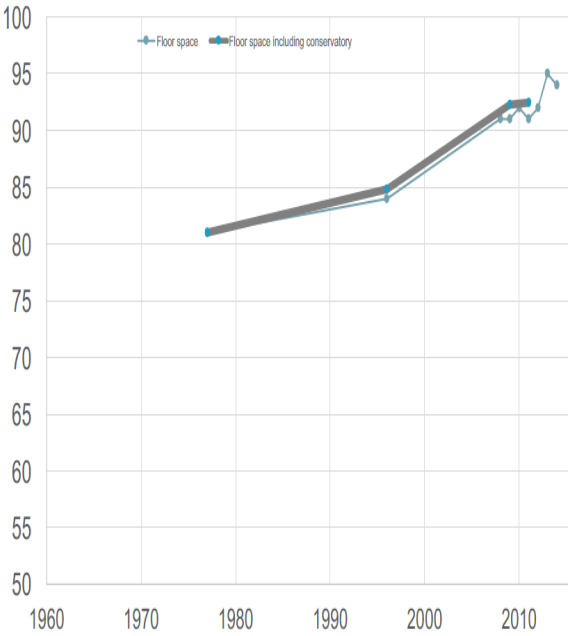
Mean Internal Temperature (C)

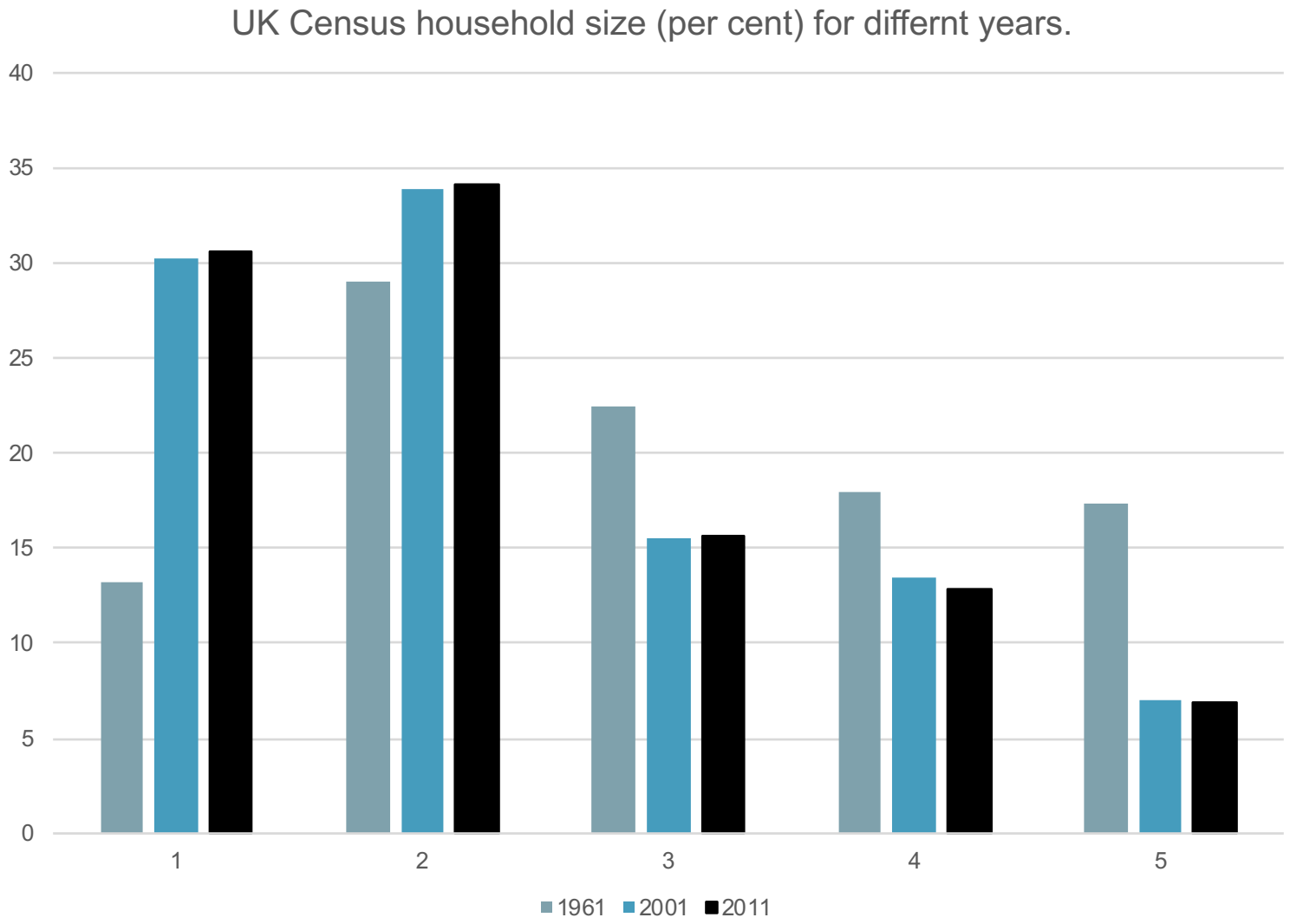


Number Dwellings



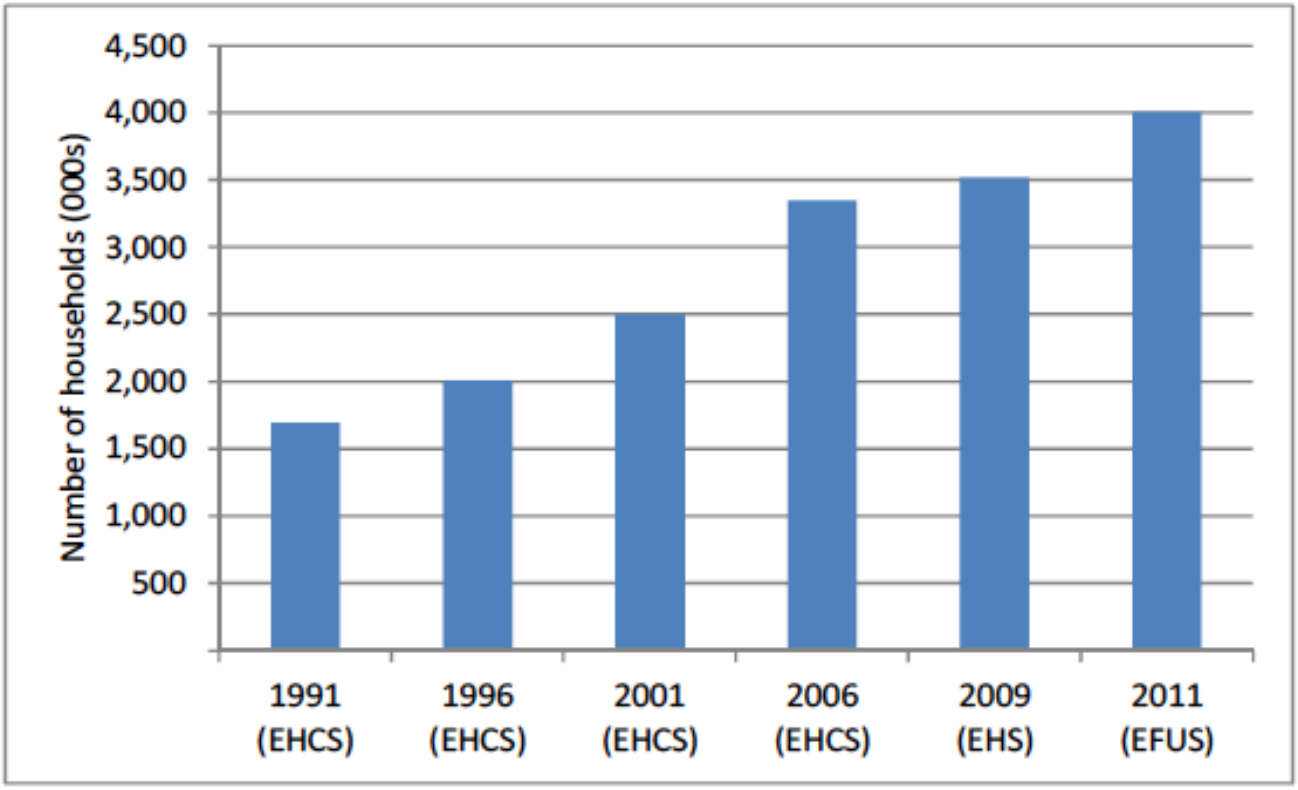
Floor Area (m^2)




UK Census household size (per cent) for differnt years.
40
35
30
25
20
15
10
5
0
1
2
3
4
5
1961
2001
2011

Increase in non-traditional spaces
Conservatory, Man Cave/Shed

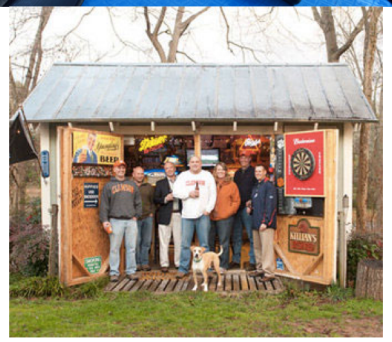
Figure 1: Number of conservatories by year (000's) using EHS and EFUS data



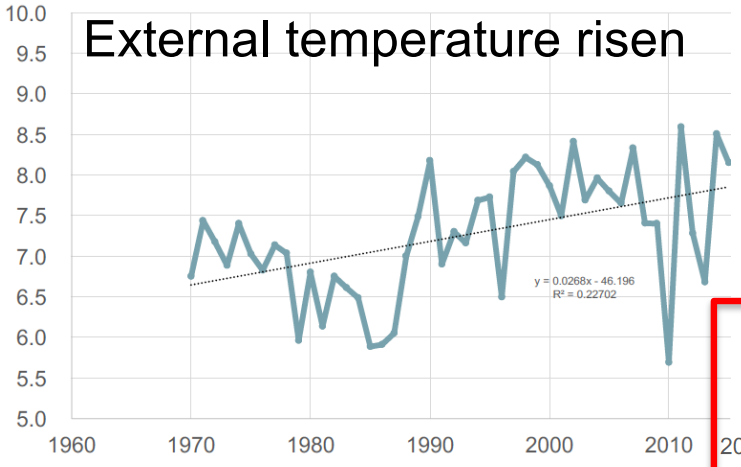
Base: All households in the EFUS Interview Survey

Sources: 2006 and earlier DCLG English House Condition Survey; 2009 DCLG English Housing Survey.

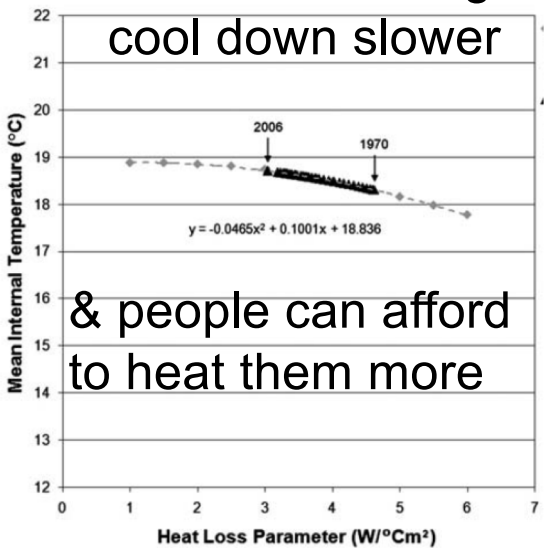
Figure from: Energy Follow-Up Survey 2011 Report 6: Conservatories, December 2013



External temperature risen

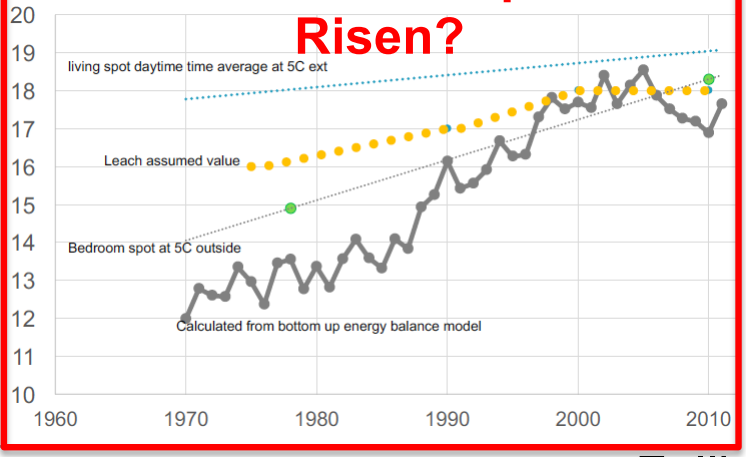


Insulated buildings cool down slower

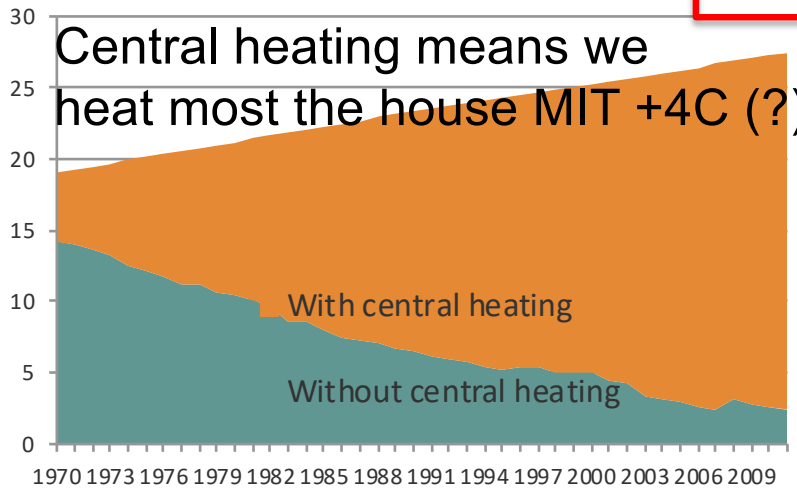


& people can afford to heat them more

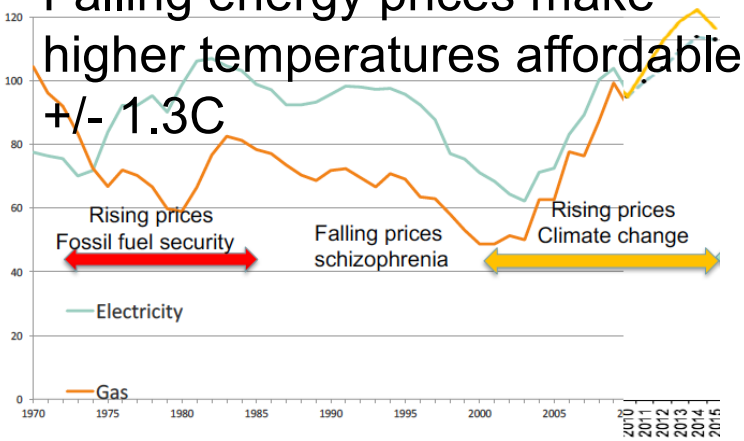
Why has Mean Internal Temperature Risen?



Central heating means we heat most the house MIT +4C (?)



Falling energy prices make higher temperatures affordable +/- 1.3C



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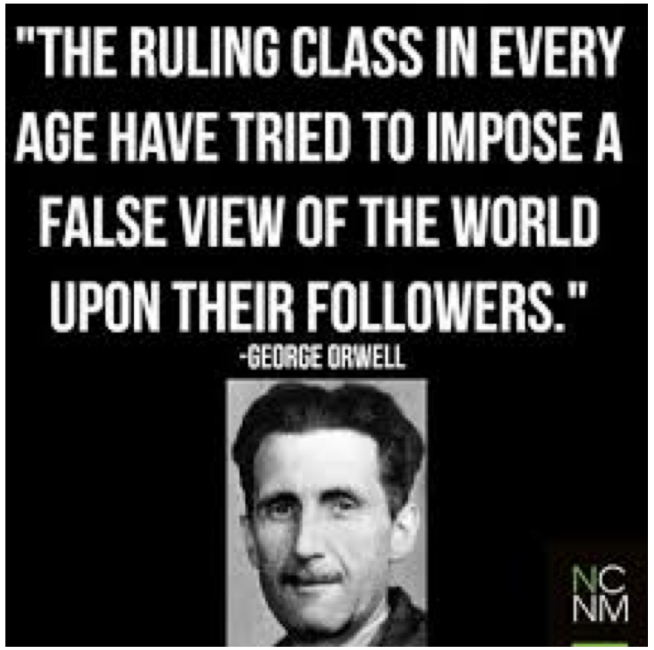
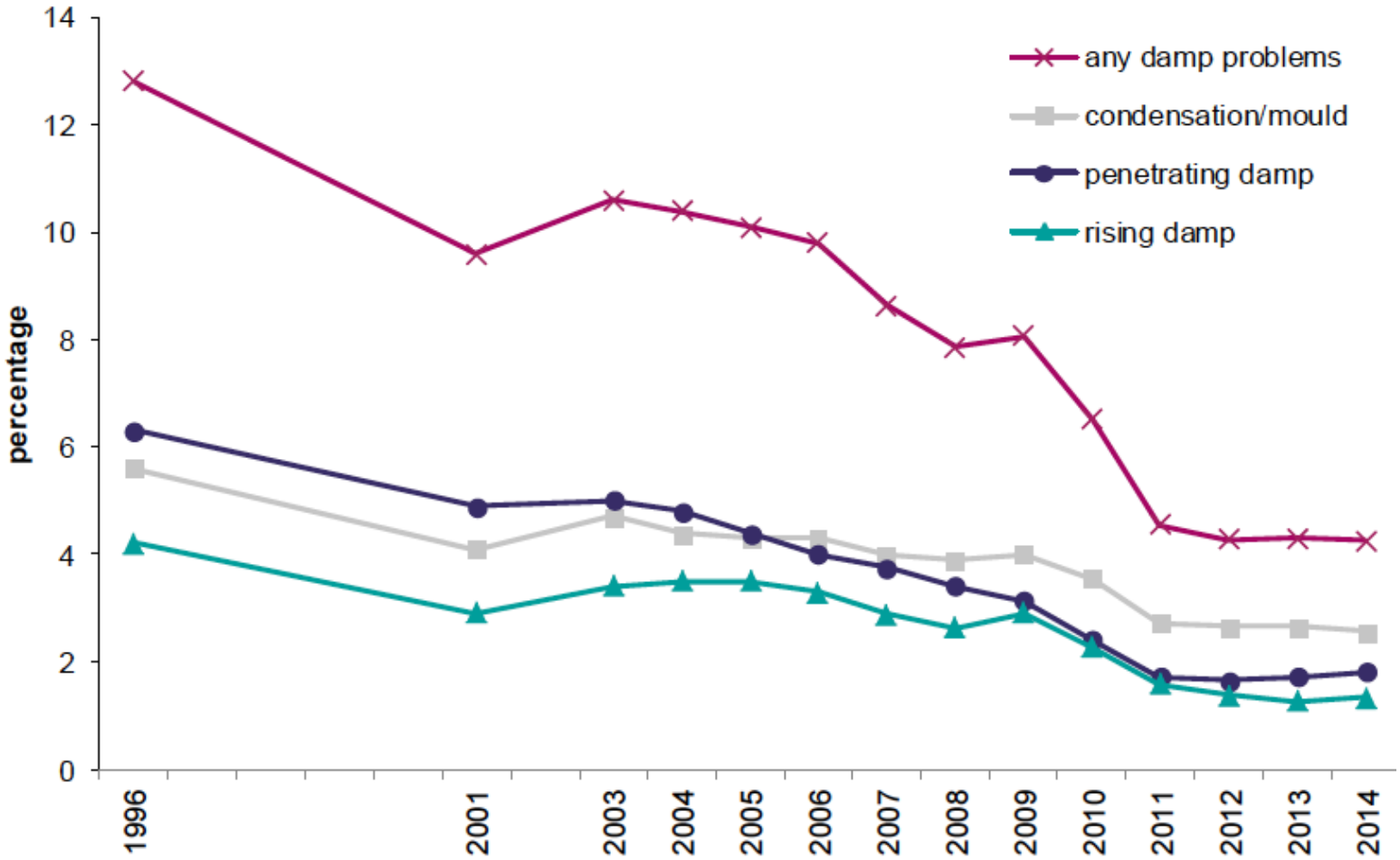


George Orwell
"The Case for the Open Fire"
Evening Standard, December 8, 1945

"To one side of the fireplace sits Dad, reading the evening paper. To the other side sits Mum, doing her knitting. On the hearthrug sit the children, playing snakes and ladders. Up against the fender, roasting himself, lies the dog. It is a comely pattern, a good background to one's memories, and the survival of the family as an institution may be more dependent on it than we realise."

Figure 2.6: Damp problems, 1996 to 2014



Base: all dwellings
Note: underlying data are presented in Annex Table 2.3
Sources:
1996-2007: English House Condition Survey, dwelling sample;
2008 onwards: English Housing Survey, dwelling sample

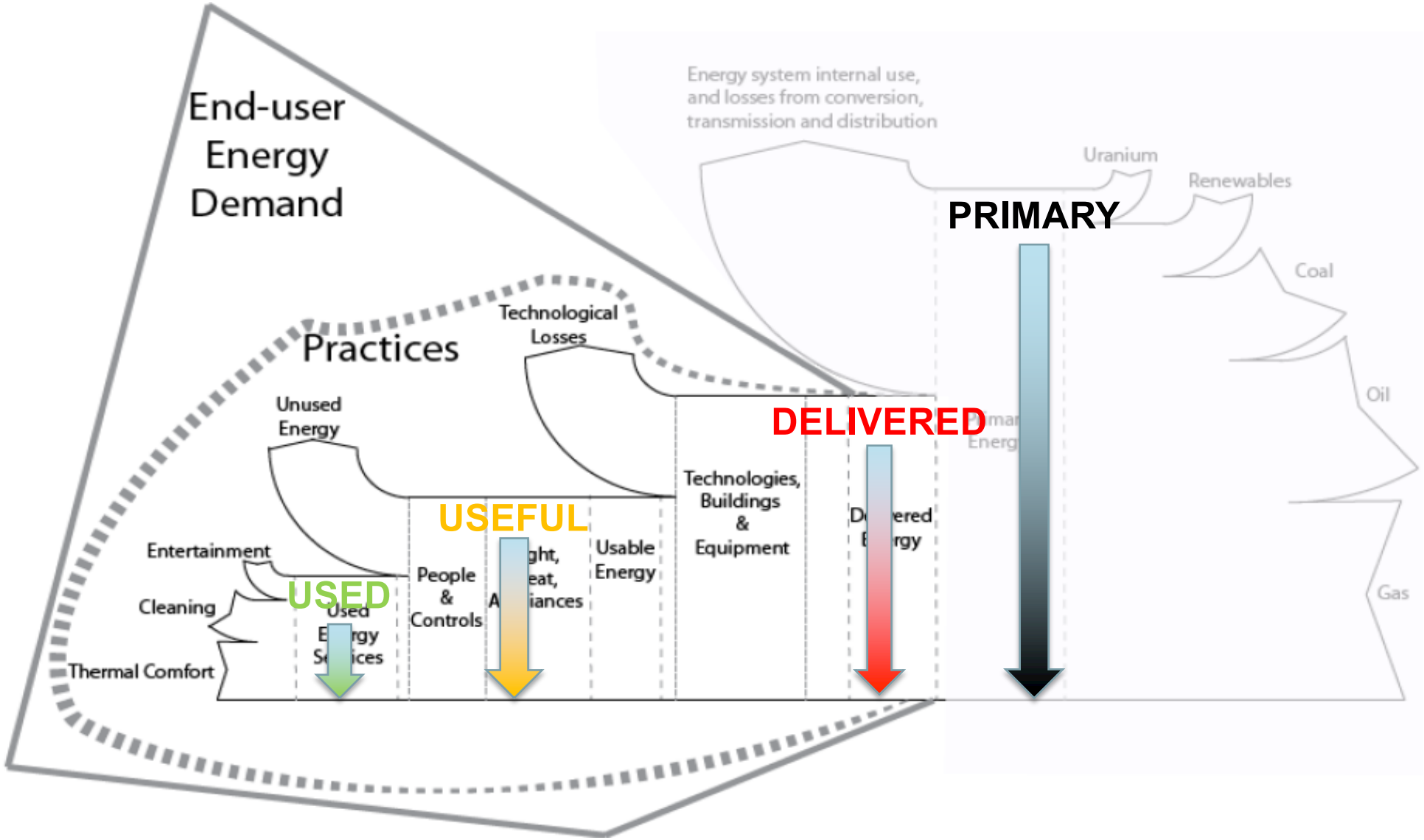
Source 2014-15 EHS headline report

Observations from history

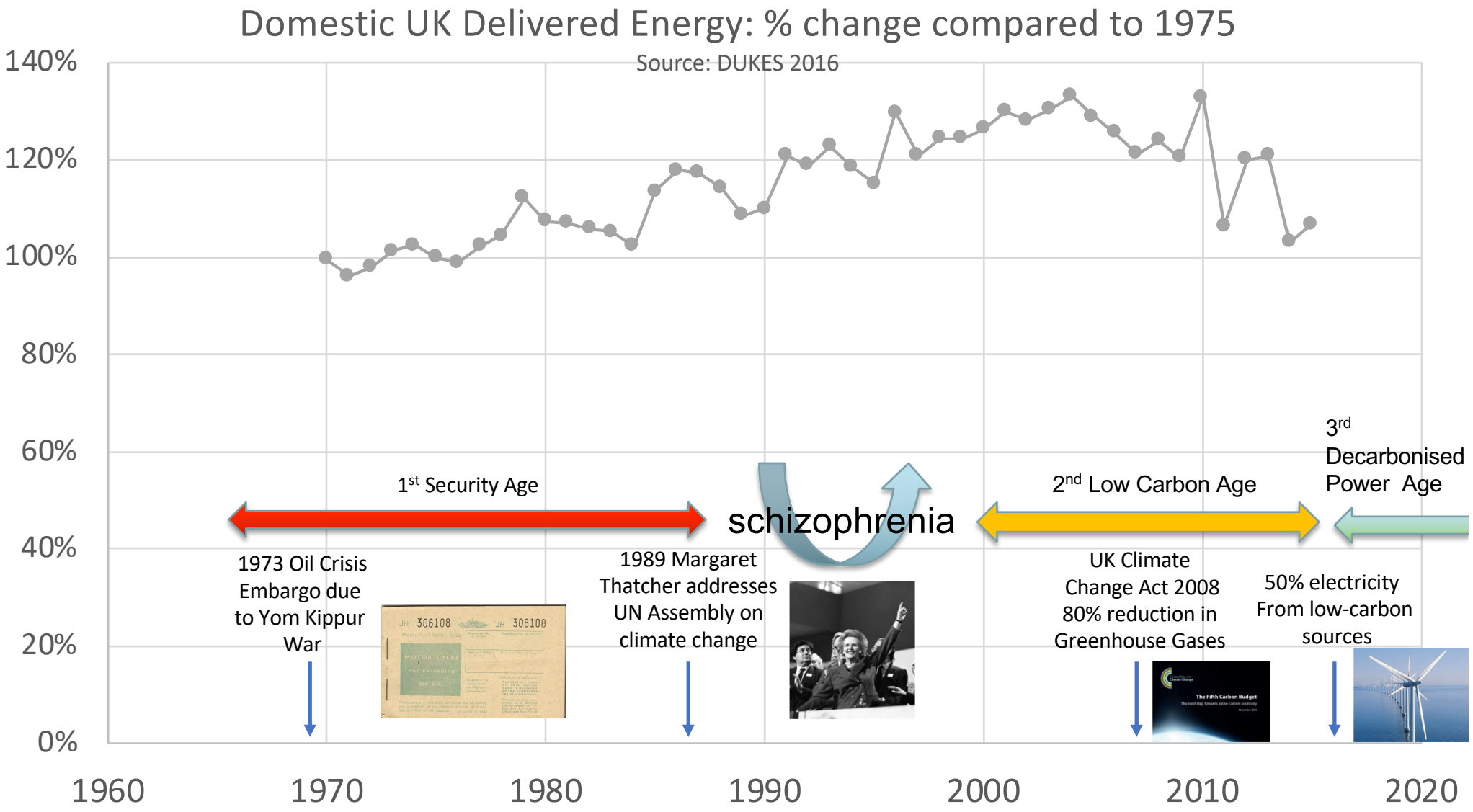
- The UK buildings and energy efficiency sector can and has moved at glacially slow paces.
- Little historic concern about systemic actual performance – theory is much more interesting
- Any energy efficiency problem is mostly going to be fixed over the next 30 years by the same technology we have now, the exception is controls and monitoring.
- Many new systems are more complex than existing

What are the known –unknowns

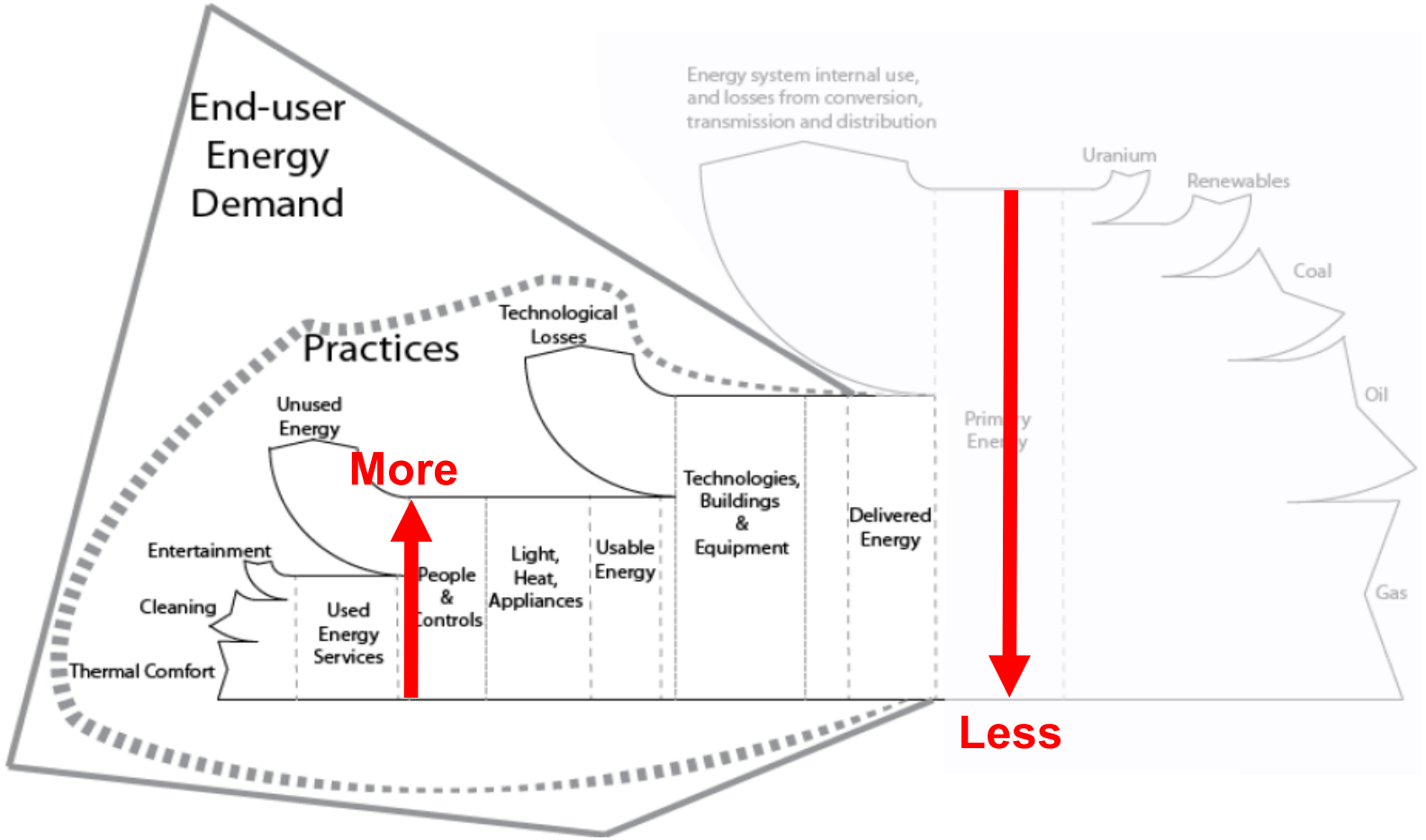
- Actual ventilation rates
- Size of domestic properties
- The percentage of floor area that is heated in a home
- The amount of wasted energy - heat generated but not used.


End-user
Energy
Demand
Practices
Technological
Losses
Unused
Energy
Entertainment
Cleaning
Thermal Comfort
USED
Used
Energy
Services
USEFUL
People
&
Controls
Light,
Heat,
Appliances
Usable
Energy
Technologies,
Buildings
&
Equipment
DELIVERED
Delivered
Energy
Energy system internal use,
and losses from conversion,
transmission and distribution
PRIMARY
Uranium
Renewables
Coal
Oil
Gas

What has happened to Domestic Energy Use over the last 40 years?

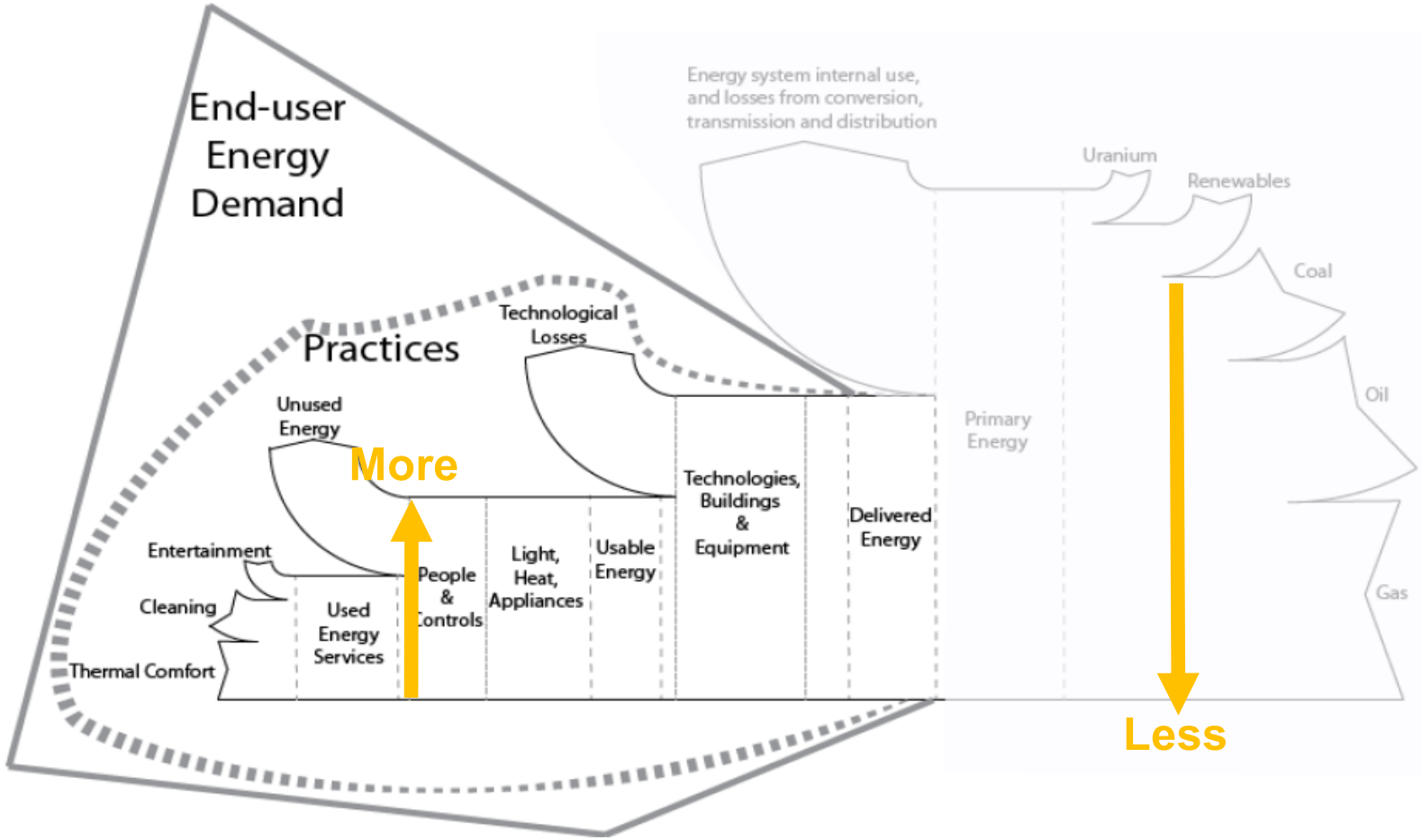


1st Age - More useful energy for less primary : SECURITY AGE



1st Age - More useful energy for less primary : SECURITY AGE

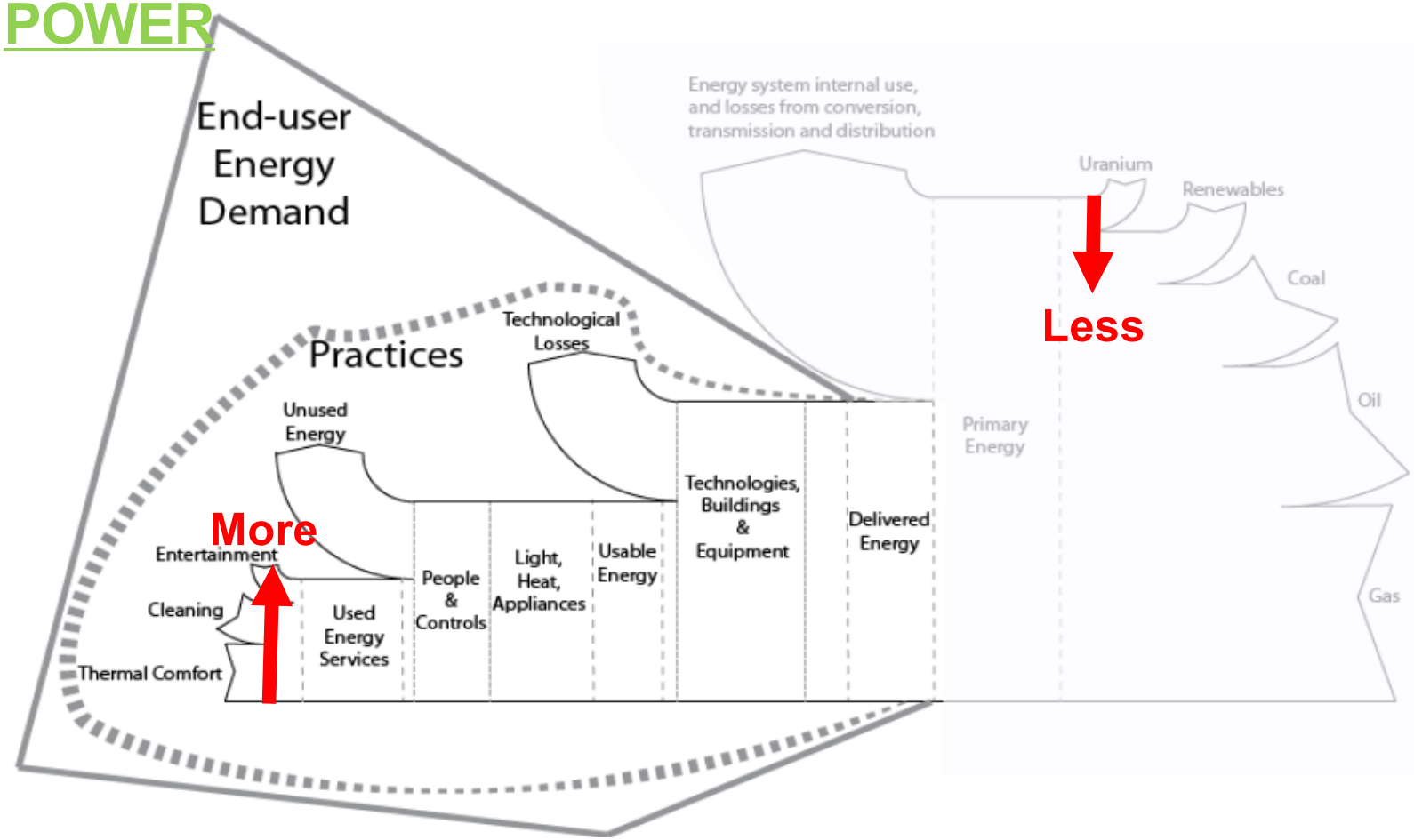
2nd Age – More useful energy for less carbon emissions: LOW CARBON AGE



1st Age - More useful energy for less primary : SECURITY AGE

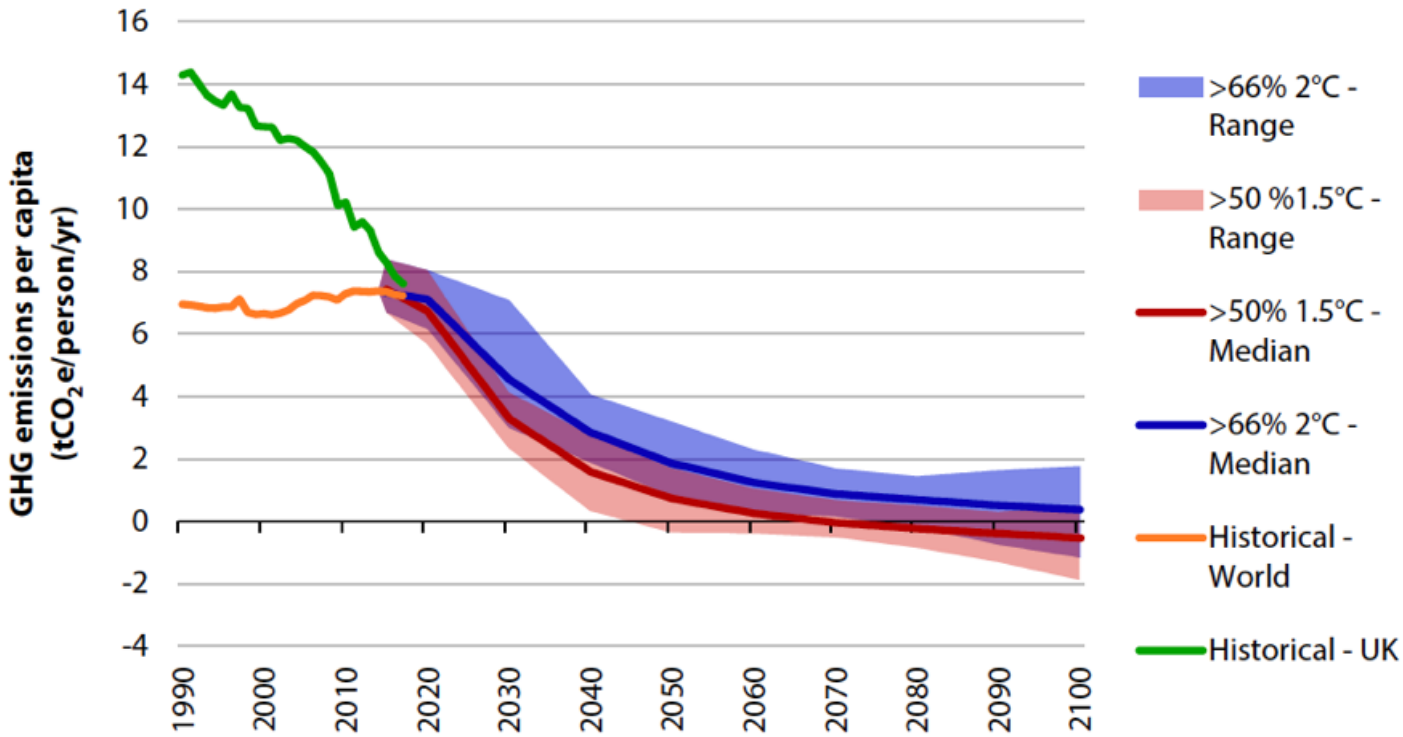
2ndAge – More useful energy for less carbon emissions

3rd Age – More used energy for less power: DECARBONISED POWER



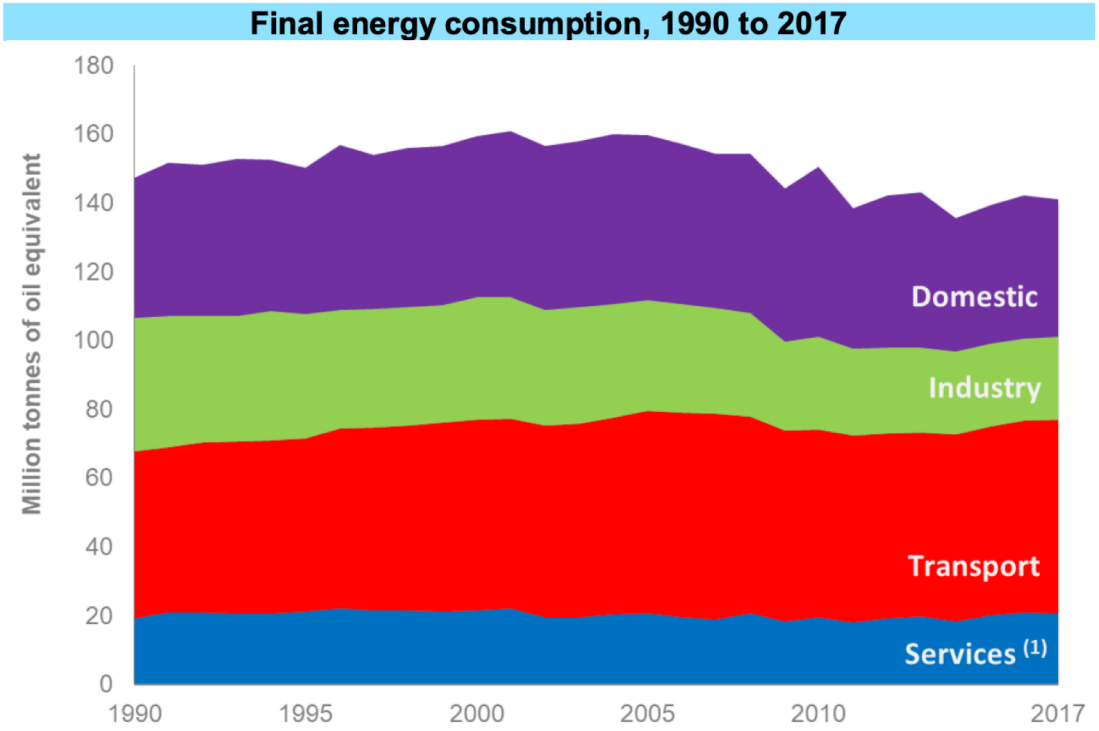
The Good News!

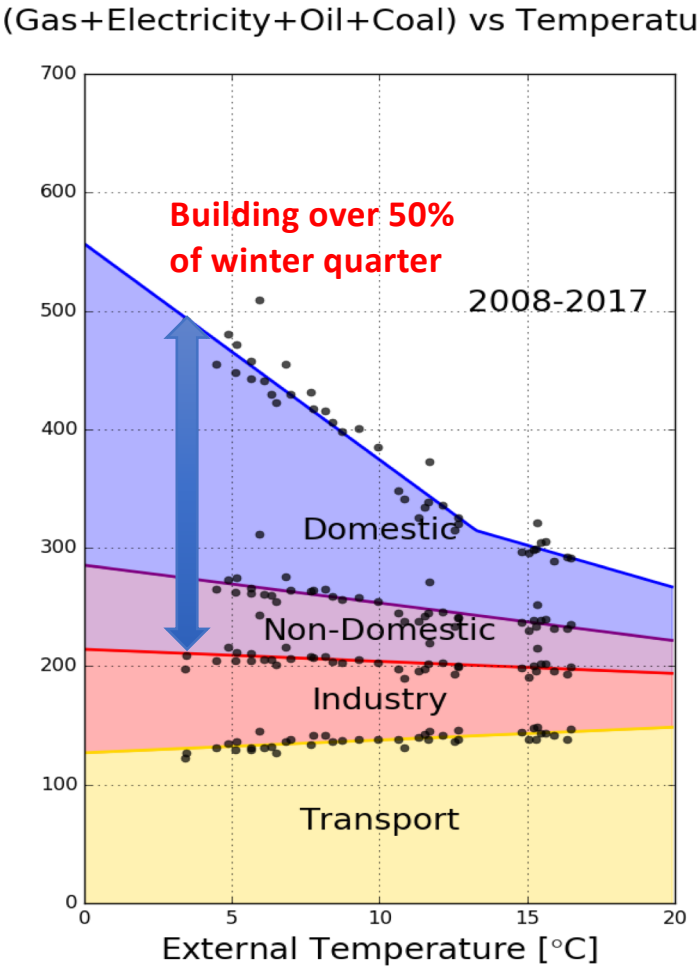
Figure 3.8. Evolution of global and UK per capita emissions over time



Source: CCC analysis; Huppmann, D. et al. (2018) A new scenario resource for integrated 1.5°C research. *Nature Climate Change*, 8 (12), 1027; Olivier, J. & Peters, J. (2018) *Trends in global CO_2 and total greenhouse gas emissions*.
Notes: UK GHG emissions per capita include land-use change emissions and emissions from international aviation and shipping. Land-use emissions from the Global Carbon Project are included in 'Historical - World'.

The importance of buildings



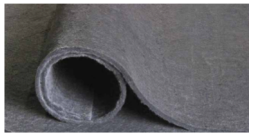


Thought experiment: What happens if we electrify all energy use?

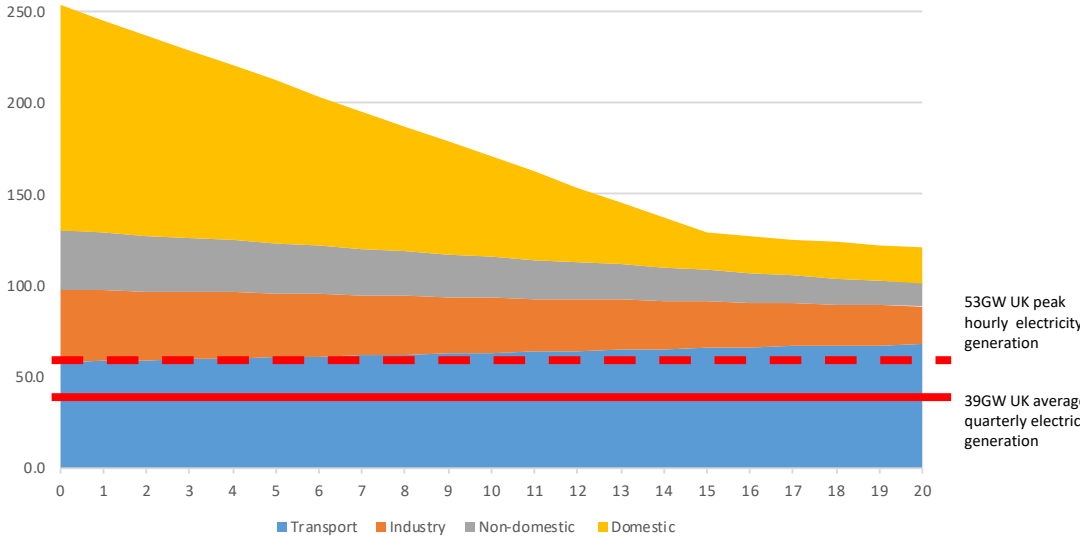
X 29

X14 +

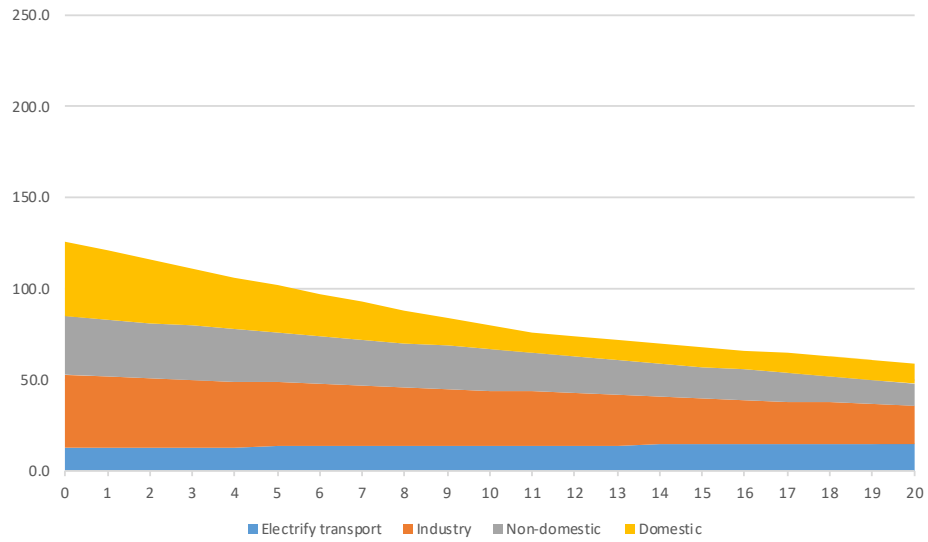
+



AS IS (Average quarterly energy demand in GW versus quarterly air temperature C) 29 x Wind



Domestic heat pumps (COP 4 to 2 versus Text), 20% reduction in fabric heat loss and efficient lights and appliances, 14 x Wind



Good news

- Many technical feasible routes to – net zero
- They are all challenging,
  - will cost more than people think
  - be slower to deploy then everybody hoped.
  - Many things will be changing at the same time. Everything needs to decarbonize!
- The optimum/best is unlikely to be the winning route

Should building energy efficiency be given the same support as nuclear, as we move from low hanging fruit to coconuts ?

- Costly, if done properly?
- Slow deployment, e.g. cars versus central heating?
- Not a mass produced component – but a tailored solution into a complex socio-technical system
- Long term unintended consequences, e.g. radon?
- Quality skills shortage?

Table 7.3. Average abatement costs by sector and measures (2050)

Sector or measure	Abatement cost (£/tCO$_2$e)	Sector or measure	Abatement cost (£/tCO$_2$e)
Power	**20**	**Agriculture**	**-55**
Variable renewables	-5	Agricultural soils	-80
Firm low carbon power	50	**Land use**	**85**
CCS for mid-merit generation	80 – 120	Tree planting	10
Residential buildings	**155**	Forestry management	-50
New homes	70	Peatland restoration	See note
Heat in space constrained homes	310	**Waste**	**10**
Heating in homes off the gas grid	-20	**Transport**	**-35**
Non-residential buildings	**95**	Cars	-40

"Heating buildings. ...*This must be fully-funded, following the Spending Review, and it is essential that the Treasury commits now to working with BEIS on this. Recent announcements on new build must be delivered."* CCC Net Zero report

Challenges facing future

- Law of diminishing return (many technologies are reaching laboratory theoretical performance limits)
- Coconut uptake – (5th Carbon Budget 13% uptake of heat pumps/DH and 1.5M solid walls) coconuts are more complex, less cost effective, bulkier, etc.
- Poor field efficacy and unintended consequences
- Thermal comfort saturation – limited co-benefits of further energy efficiency – although cooling is the elephant in the room
- Existing markets prevent upstream benefits of energy efficiency being valued
- Timescales challenging for significant deployment – historically 20 to 50 years
- Increased demand for service (more homes)