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Energy efficiency and sustainability – what's the connection?

Malcolm Keay

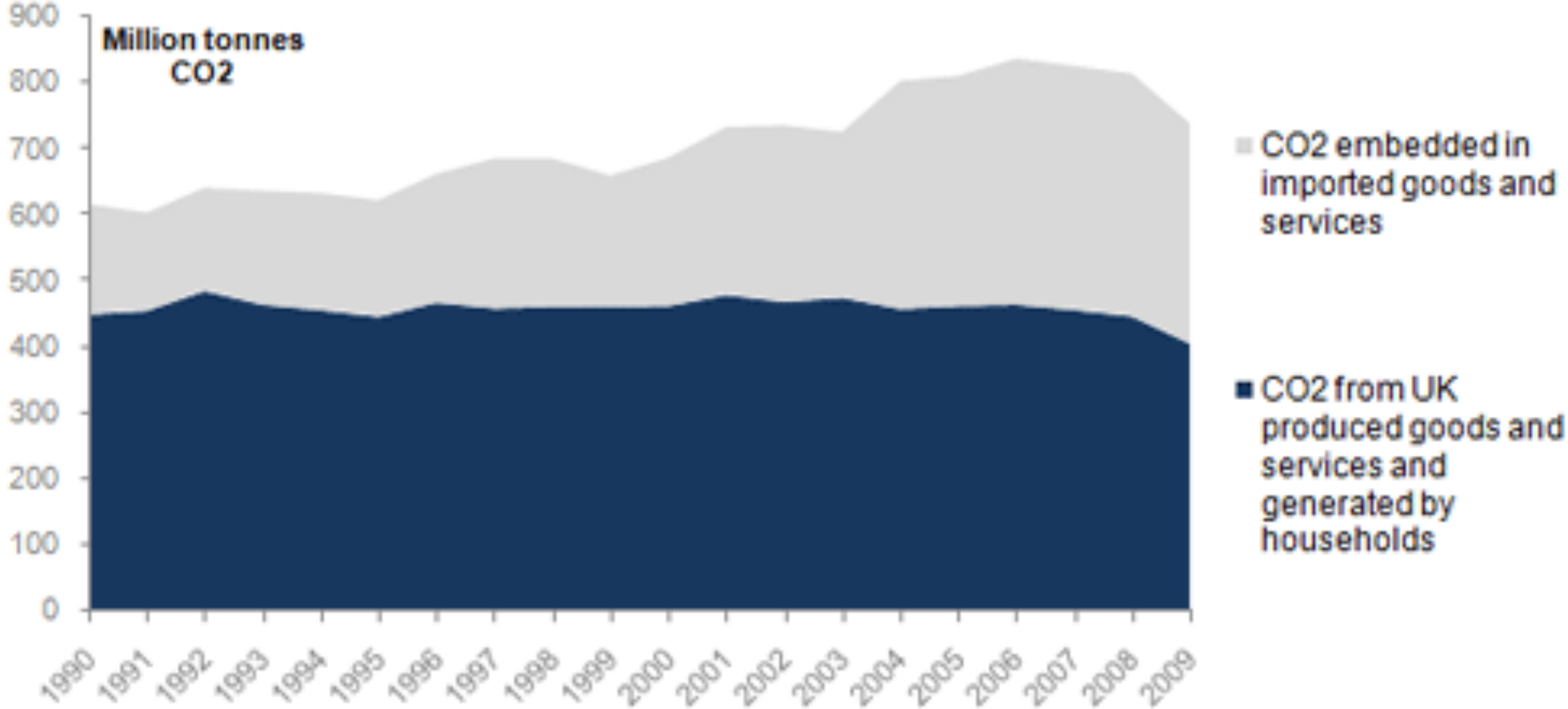
Why ask the question in the first place?

Because the answer is not as obvious as it might seem. Conventional wisdom is no guide.

2½ examples:

- International shipping and air freight
- Air conditioning in the US
- ICT ?

Outsourcing emissions



Source: University of Leeds and Centre for Sustainable Accounting

(Re)framing the question

In what circumstances does energy efficiency:

- reduce energy demand?
- reduce emissions?
- reduce costs?

What is energy efficiency?

- **Technical efficiency (energy productivity)** – reduction in physical energy input required for given energy services output.
- **Energy intensity** – improvement in PES/ output ratio (GJ/£ or GJ/t) at economy-wide or sectoral level.
- **Energy conservation (saving)** – reduction in absolute demand for energy (services).
- **Demand response** – shifting demand to improve system efficiency.
- **Energy efficiency policies**

Technical efficiency – some issues

Inputs:

- Primary or final energy?
- Energy quality (exergy)?
- Embodied energy?

Cost-effectiveness?

Services output:

- Physics or welfare? - eg passenger/kilometres or convenience/comfort/time saved?

Question 1: when does energy efficiency reduce demand?

Conventional wisdom (cognitive dissonance?)

Holds that:

- Labour productivity is a good thing because it **increases** demand for labour (unless you're a Luddite – or French*)
- Energy productivity is a good thing because it **decreases** demand for energy (unless you're a Jevonsite)

*74% of French people think that robots steal people's jobs. Eurobarometer 382 September 2012

Rebounds

- **Jevons paradox (1865)**: technological progress that increases the efficiency with which a resource is used tends to increase (rather than decrease) the rate of consumption of that resource
- **Khazzoom-Brookes postulate (1980)**: energy efficiency = cheaper energy services. It leads to income and substitution effects which tend to increase energy consumption

Rebounds updated

- Direct rebounds (comfort etc)
- Secondary effects (higher income, output growth, embodied energy etc)
- Economy-wide effects (new equilibrium at lower energy service price)
- Transformational (changing preferences and behaviour)

(Greening et al 2000)

You need to look at the (very) big picture - in time and space

"To capture the full range of rebound effects, the system boundary for the independent variable (energy efficiency) should be relatively narrow, while the system boundary for the dependent variable (energy consumption) should be as wide as possible."

(Sorrell 2007)

Long term view - 1 (Fouquet and Pearson 2012)

Year	Per capita real income £ 2000	Lighting efficiency (lh/kWh)	Per capita Consumption (klh)	Per capita lighting energy consumption (kWh)
1800	1,750	38	1.1	29
1850	1,500	160	13	81
1900	3,200	450	255	566
1950	5,400	11,660	3,100	266
2000	17,000	25,000	13,000	520

Long term view - 2

"Historical evidence is thus replete with examples demonstrating that substantial gains in …. efficiencies stimulated **increases of fuel ….use that were far higher than the savings**." (Smil)

" Dramatic declines in energy service prices certainly lead to **rising service consumption and often energy use**." (Fouquet)

Long term view - 3

"A basic conclusion of a stable long-run relationship between energy demand and price and income is that **the share of income spent on energy services is roughly constant**"

(Platchkov and Pollitt)

"Energy efficiency improvements appear to have been 'captured' by consumers to increase their well-being but not to reduce their energy consumption, as if **consumers were keeping their energy budgets as a constant share of their spending**, whatever the final energy price." (WEC)

The shorter term - can we measure savings?

"In dealing with energy efficiency, there is a sensation of standing on shifting sands due to the difficulty of producing reliable future forecasts and evaluating the impact of current policy measures"

(Environmental Audit Committee)

[We don't know the counter factual baseline so can't measure efficiency impacts; applies at both macro and micro level]

Measuring savings 1: top down intensity

“ At the world level there has been a continuous decline in primary energy intensity, by approx. 1.5% pa …. This reduction resulted in large energy savings; 4 Gtoe since 1980 (37% of total [current] consumption)”

(WEC)

An intensity comparison – where are the savings?

	Population (m)	TPES/GDP (toe/$,000)	TPES/cap (toe/ person)	TPES (Mtoe)
Ethiopia	82.83	1.97	0.39	33
Switzerland	7.80	0.09	3.45	27

Energy demand and efficiency increase with GDP growth – and may even cause it. (Sorrell)

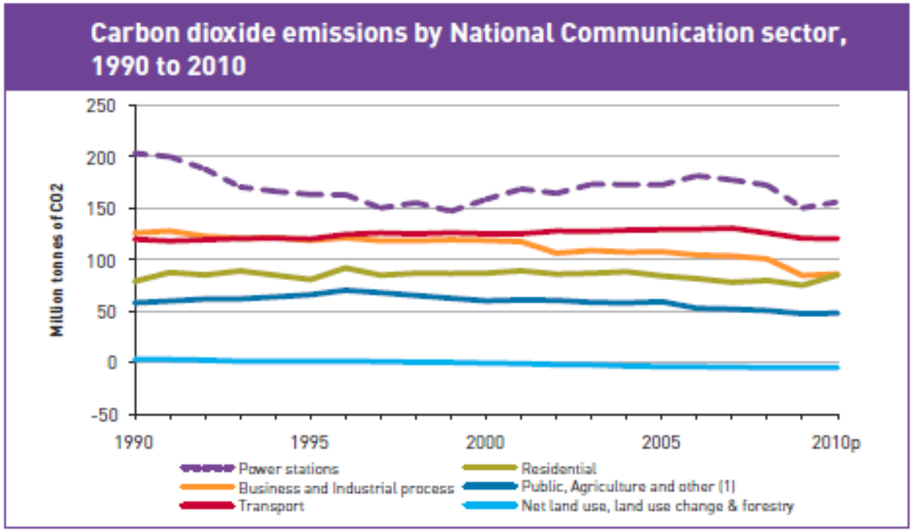
Measuring savings 2: bottom-up assessment

UK domestic energy saving scheme (CERT)

"By the end of the third year, suppliers had collectively delivered measures resulting in approximately **197 Mt CO_2** (including EEC2 carryover), but excluding innovation uplifts. This equates to 67% of the overall target of 293 Mt CO_2. Overall, energy suppliers are therefore on track to meet the target."

(Ofgem)

In the real world



(1) Includes emissions from Public, Agriculture, Waste Management and other Energy supply.

Million tonnes of carbon dioxide

	1990	1995	2000	2008	2009	2010p
Power stations	203.4	163.4	163.1	172.4	150.3	156.2
Residential	79.0	80.8	92.0	79.9	75.2	85.3
Public, Agriculture and other [1]	58.2	66.0	70.4	50.7	47.6	48.1
Business and Industrial process	126.0	118.8	121.3	100.8	84.7	86.3
Transport	120.0	120.2	124.6	126.0	120.8	120.6
NLULUCF	3.1	1.6	1.4	-4.7	-4.8	-4.8
Total CO_2 emissions	**589.7**	**550.8**	**549.4**	**525.1**	**473.7**	**491.7**

Source: AEA, DECC (2010 provisional figures)

Studies of rebounds – their size is uncertain

Domestic heating rebounds: 10-58% in short run

1.4-60% in long run

Personal transport: 5-87%

(Sorrell)

"Aggregate studies suggest that electric utility DSM programmes in the US …. have been between 50% and 100% as effective as utilities themselves have estimated…..However, there is significant uncertainty in these estimates" (Jaccard and Rivers)

Some meta studies – savings but not absolute reductions

"Energy efficiency may be reducing the rate of growth in consumption but is not reducing consumption so far" (Owen)

"There are few examples where the energy savings from …energy efficiency….have outstripped the growth in energy demand" (IEA)

Different approaches: econometric baseline study

"In aggregate DSM expenditures by Canadian electric utilities have had only a marginal effect on electricity sales" "The method we use … directly accounts for the net effect of free ridership, rebound effect and within-jurisdiction spill-over." (Rivers and Jaccard, 2011)

CGE Studies

"All of the studies find economy-wide rebound effects to be greater than 37% and most studies show either large rebounds (>50%) or backfire" [ie >100%]. (In fact, fully half of the studies show backfire). "However the studies have a number of flaws." (Sorrell)

So when might efficiency lower demand?

Potentially, in these situations:

- Demand saturation (difficult to gauge)
- No economic growth (rare)
- No new demands (unlikely)
- Energy is a low proportion of cost (but then savings are also small)
- Supportive policy context (taxes etc)
- Barriers are removed (see later)

Examples of areas to focus on

- Upstream energy (power generation, refineries)
- System efficiency (storage, demand response)
- Facilitating switch to low carbon fuels (smart grids; transmission)
- Passive measures (controls)

Question 2: when might energy efficiency reduce emissions?

When it reduces demand for energy **and**

- the energy saved is carbon intensive **and**
- is not offset by more carbon intensive demand elsewhere

Carbon intensity of power generation (IEA 2011)

Country	gCO_2/kWh
India	950
China	748
US	531
UK	**480 (2030 – 100?; 2050 <50?)**
Germany	447
France	89
Brazil	75
Switzerland	40
Iceland	1

Some interactions

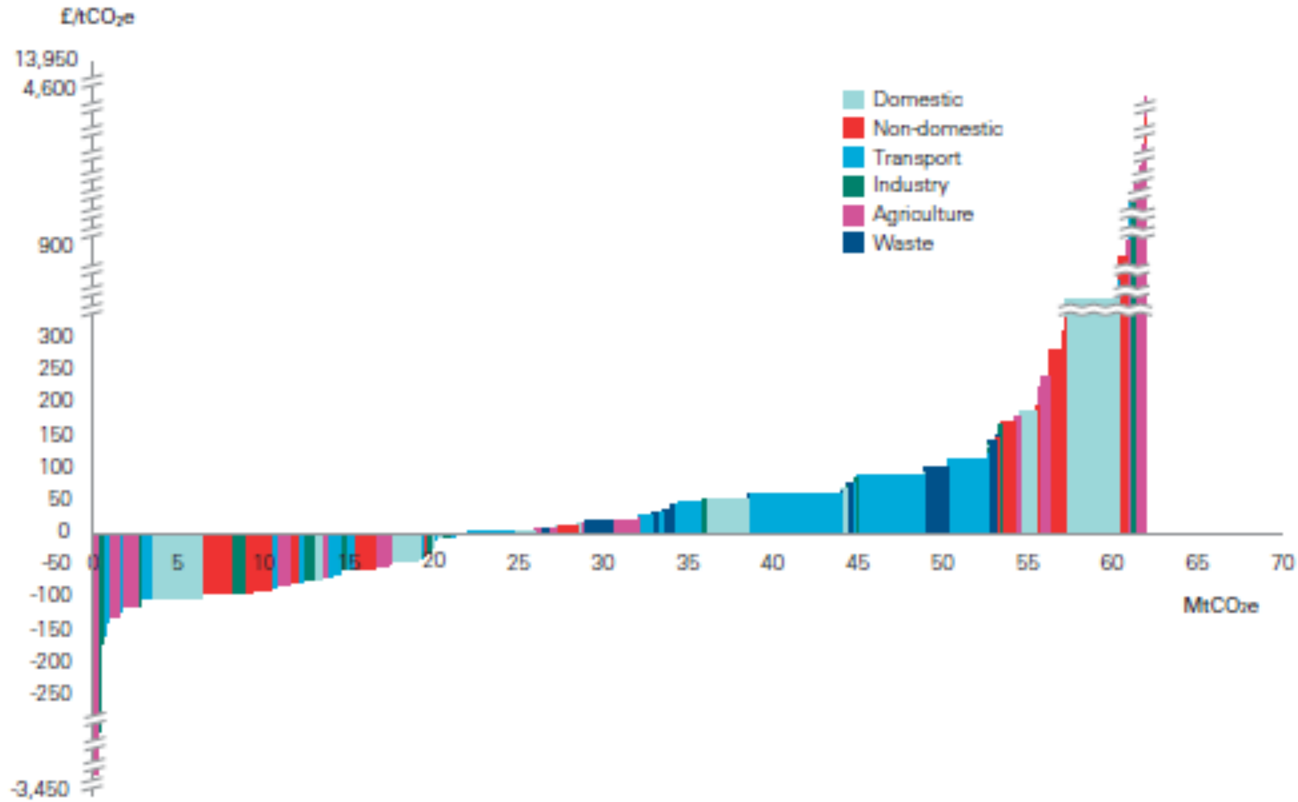
- Decarbonisation reduces (cost-effectiveness of) carbon savings
- Lower demand lowers carbon and energy prices
- Some efficiency measures could discourage fuel-switching (eg CHP) or perpetuate use of high carbon energy (eg vehicle efficiency)
- Energy efficiency is about energy – the main sustainability issue is carbon

Question 3: when might energy efficiency reduce costs?

A big MACC

Chart 12

A Marginal Abatement Cost Curve in the Non Traded Sector

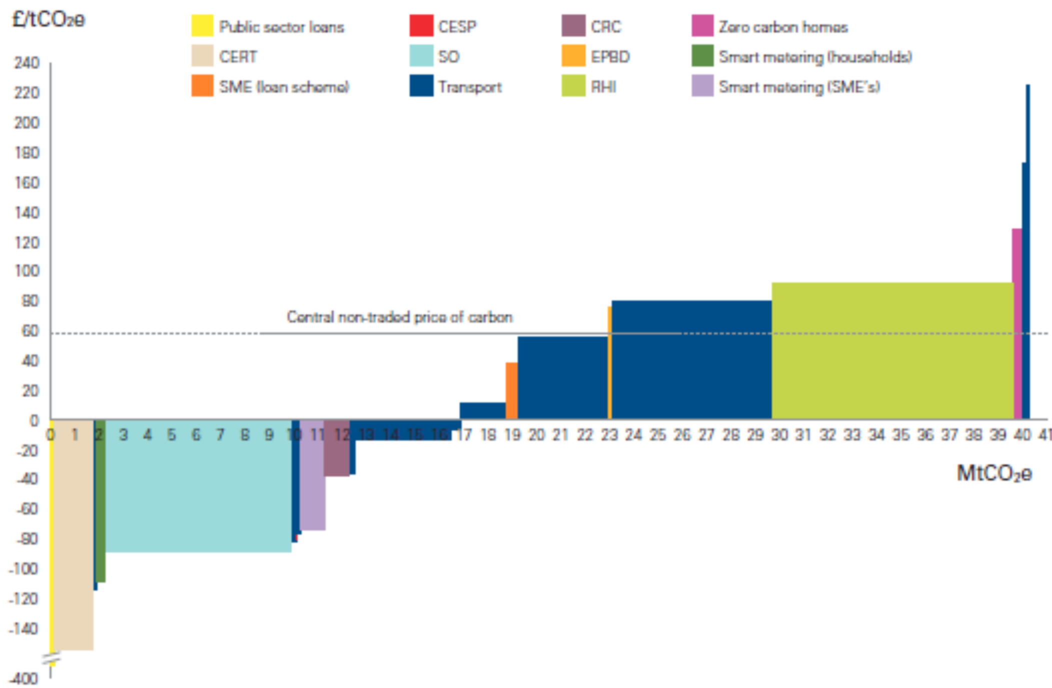


Source: Committee on Climate Change (2008)

Saving Money and Carbon

Chart 15

Policy MAC curve for policies that deliver savings in the non-traded sector



Source: Department of Energy and Climate Change (2009)

But there are hidden costs

"There are real and substantial time and financial costs associated with domestic energy efficiency and carbon saving measures that existing cost-effectiveness analysis neglects."

(DECC – referring to Ecofys study)

And factors not in models

For example, in relation to home insulation:

- Nature of housing, orientation, ventilation
- Behavioural differences
- Technical factors (eg how effectively insulation is installed)
- Changing environment (energy prices, weather, new energy services etc)

How is it supposed to work – market failure/barriers (Adapted from Haney et al)

1 **Environmental externalities:** Significant and major

2 Imperfect information Absence of markets Split incentives Capital constraints	Not so different from most markets; soluble; relatively minor
3 Bounded rationality Low priority Risk aversion	People don't agree with experts – but who's right?
4 Transaction costs:	Real costs, not barriers

Barriers aren't very significant – apart from CO_2

"The available evidence …. suggests that …. the actual magnitude of the energy efficiency gap is small". (Allcott and Greenstone 2012)

So when does energy efficiency reduce costs?

- Obviously depends on situation
- Has to be assessed empirically, not a priori

Conclusions 1: when does energy efficiency lead to sustainability?

- When it leads to reduced demand, emissions and costs
- This can happen, but only in certain circumstances
- To ensure it does happen requires an integrated and informed approach to the various systems issues

Conclusions 2: what does this mean for the physics of energy efficiency? Some thoughts

- Try to understand wider system
- Work with colleagues from other disciplines

Focus on areas where

- rebounds are less likely to be significant – eg storage, demand response, conversion efficiency
- contribution to sustainable systems likely to be greatest – eg smart grids, controls and communication, non-fossil sources