THE OXFORD INSTITUTE FOR ENERGY STUDIES

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Is Energy Efficiency Sustainable?

Malcolm Keay

Energy efficiency as motherhood and apple pie

“Energy efficiency is the **most cost effective** way to **reduce emissions**, **improve energy security and competitiveness**, make energy consumption **more affordable** for consumers as well as **create employment**, including in export industries ….. [It] can be seen as **Europe's biggest energy resource**”

(Commission – Energy 2020)

“Improving energy efficiency in all sectors of the economy is fundamental and urgent. It has the **greatest potential for CO_2 savings** and the **lowest cost** (in most cases negative costs)…..Energy efficiency can deliver results quickly.” (IEA Report to G8) Energy efficiency leads to 2/3 of emissions reductions in IEA alternative policy scenario.

“Increased **energy efficiency is the key** to reducing emissions” (Chris Huhne)

“**Energy efficiency must be the starting point** [for increased energy security]” (Malcolm Wicks)

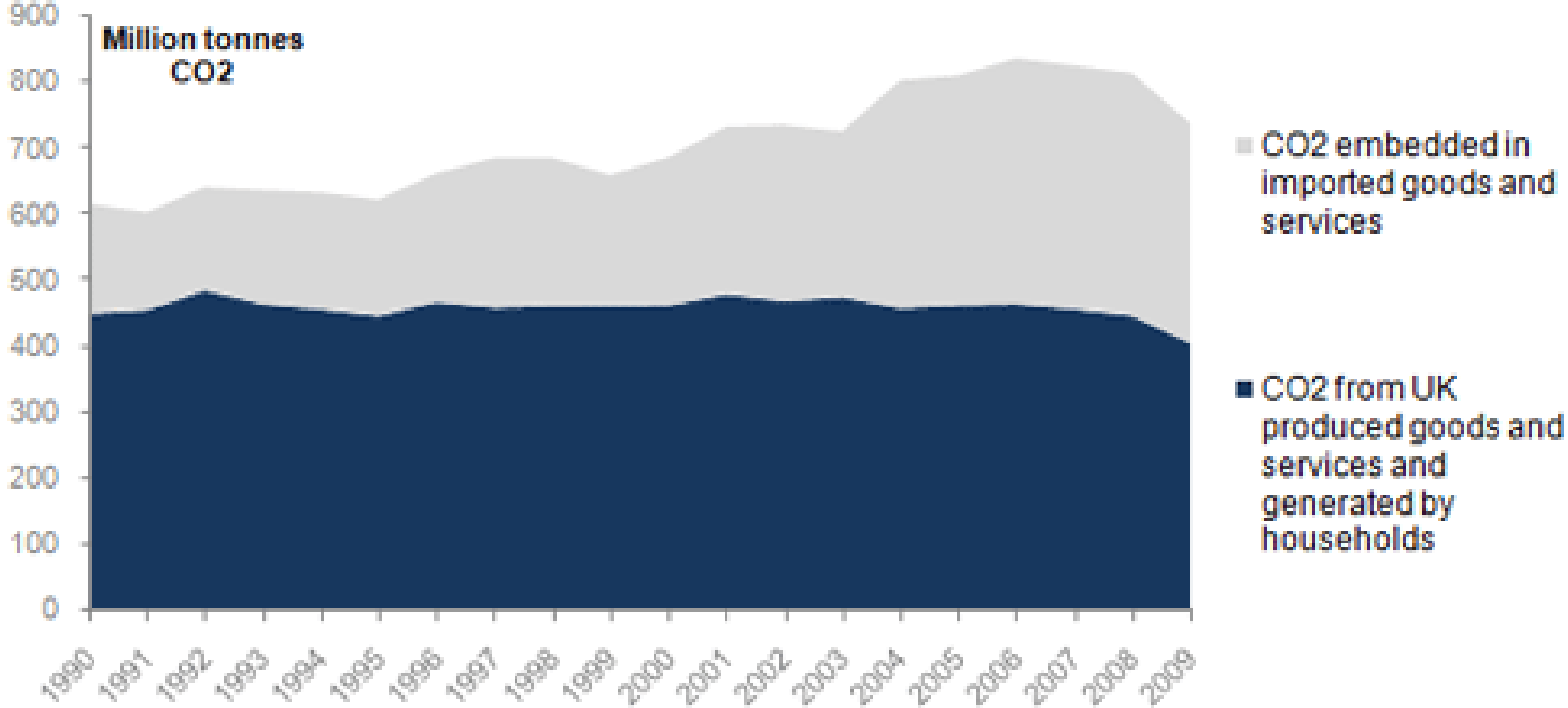
So why is there a question?

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

Sometimes outcomes are counter-intuitive. Energy efficiency can work against sustainability.

* Eg efficiency of international shipping has roughly doubled since 1990 but emissions have also doubled; in the UK, a reduction in emissions since 1990 becomes an increase when carbon embodied in trade is included; such emissions have risen from 25% to 50% of UK emissions since 1990.

Outsourcing emissions



Source: University of Leeds and Centre for Sustainable Accounting

What is the question?

In what circumstances does energy efficiency:

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

Definitions: what is energy efficiency?

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

Technical efficiency – some issues

Inputs:

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

Cost-effectiveness?

Outputs?

- Subjective or objective services (eg passenger/kilometres, speed or comfort)?

Question 1: when does technical efficiency reduce demand?

How does technical efficiency (productivity) affect demand?

Conventional wisdom is inconsistent:

- Labour productivity **increases** demand for labour (unless you're a Luddite) - so is a good thing
- Energy productivity **decreases** demand for energy (unless you're a Jevonsite) - so is a good thing

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 (new services, changing preferences)

(Greening et al 2000)

Measurement needs to cover all levels

"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."

(UKERC 2007)

Long term view - 1

"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 - 2

"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)

Long term view – 3 (Fouquet and Pearson 2012)

Year	Lighting cost (£/m. lumen hours)	Per capita income	Lighting consumption (blh)	Per capita Consumption (klh)
1711	15,000	1,500	6.4	1.2
1750	14,500	2,000	7.9	1.3
1800	8,000	1,750	18	1.1
1850	2,600	1,500	355	13
1900	250	3,200	10,500	255
1950	18	5,400	155,000	3,100
2000	2.5	17,000	775,000	13,000

Lighting elasticities

- To mid 19th C: income 0.7; price 1.2
- Second half 19th: income 3.5; price 1.7
- First half 20th: income 1; price 0.5-0.7
- Now: income 0.25-0.4; price 0.5-0.7

But don’t we at least measure the short term savings?

“In dealing with energy efficiency, 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?

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

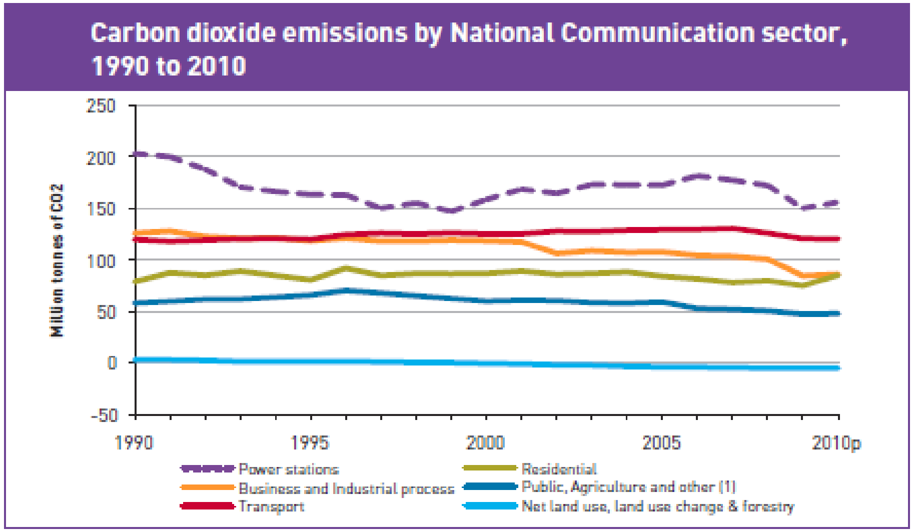
	Population (m)	TPES/GDP (toe/$,000)	TPES/cap (toe/person)	TPES (Mtoe)
Ethiopia	82.83	1.97	0.39	33
Switzerland	7.80	0.09	3.45	27

Measuring savings 2: bottom-up assessment of CERT

"By the end of the third year, suppliers had collectively delivered measures resulting in approximately **197 Mt CO2** (including EEC2 carryover), but excluding innovation uplifts. This equates to 67% of the overall target of 293 Mt CO2. 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)

…. uncertainty rules; weather (and prices?) may swamp other effects

Table 2: Sources of carbon dioxide emissions, 1990-2011 (provisional) (Mt)

	1990	1995	2000	2005	2007	2008	2009	2010	2011 (p)
Energy Supply	242	211	203	218	219	213	190	196	184
Transport	119	120	125	129	131	126	121	121	119
Business	111	104	104	94	89	87	76	76	70
Residential	79	81	87	84	78	80	75	87	67
Other	39	36	31	27	24	22	16	17	16
Total	590	552	550	551	542	529	478	496	456

(p) 2011 estimates are provisional.
All figures are for the UK and Crown Dependencies only, and exclude Overseas Territories.

Bottom-up programmes: some measurement issues

- Direct and indirect rebounds
- Persistence
- Free-riding
- Gaming
- Principal/agent slippage
- Appraisal optimism
- Behavioural changes, economy, prices, technology etc – what is the baseline?

What can be done about these issues: medical studies

- Randomised control groups (baseline, rebounds and free-riding)
- Double blind trials (Hawthorne effect)
- Long term longitudinal studies (persistence and long term rebounds)
- All impact measurement (indirect rebounds)
- Control for confounding factors
- Independent arbiter (principal/agent issues; appraisal optimism)

How is CERT quantified?

- Carbon saving score estimated for each measure, using BREDEM, EST and other models
- Suppliers report data on measure numbers
- Ofgem checks data
- Savings = number of measures X carbon saving score

[ie no controls, no baseline, no monitoring of outcomes, no wider impacts measure etc etc. Some of this being addressed by (unpublished) studies]

Meta 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)

Meta studies 2

"Estimates of the rebound are low to moderate. ….Rebound is not high enough to mitigate the importance of energy efficiency" (Greening 2000)

[The small print: the range is 0 – 100% for long run impacts, for which the meta analysis includes "Any number of studies with a variety of conclusions". Furthermore, "In the majority of end uses, data collection or end-use metering studies are lacking." Transformational effects have been ignored as too difficult to measure. In any event, the conclusion is "not definitive at the microlevel" and "even less work" has been done at the macro level. "Substantial additional research is needed". Energy efficiency needs reinforcement by other policies such as taxes.]

Meta Studies 3

"The key message is that promoting energy efficiency remains an effective way of reducing energy consumption and carbon emissions." (Sorrell)

[Small print: The evidence base is remarkably weak. Economy wide rebound effects may be larger than is conventionally assumed. Under some circumstances …. economy wide rebound effects may exceed 50% and could potentially increase energy consumption in the longer term. Time costs are an important but relatively unexplored issue. Policies to address market barriers may be insufficient, since rebound effects could offset much of the energy savings. Rebound effects may be mitigated through carbon pricing.]

More meta studies – savings maybe 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)

Latest research: 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?

In situations where there is:

- Demand saturation/incremental rather than fundamental change (difficult to gauge)
- No economic growth (rare)
- No new services (unlikely)
- Supportive policy context (taxes etc)
- Barriers are removed (see later)
- Rebounds less likely because energy is a low proportion of cost (though remember ICT – 13% of US electricity demand)

Examples of areas to focus on

- Upstream energy (power generation, refineries)
- System efficiency (storage, demand response)
- Facilitating switch to low carbon fuels (smart grids)
- 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 **and**
- efficiency policies do not conflict with other policies

Carbon intensity of power generation (IEA 2011)

Country	gCO_2/kWh
India	950
China	748
US	531
UK	480
Germany	447
France	89
Brazil	75
Switzerland	40
Iceland	1

Policy interactions

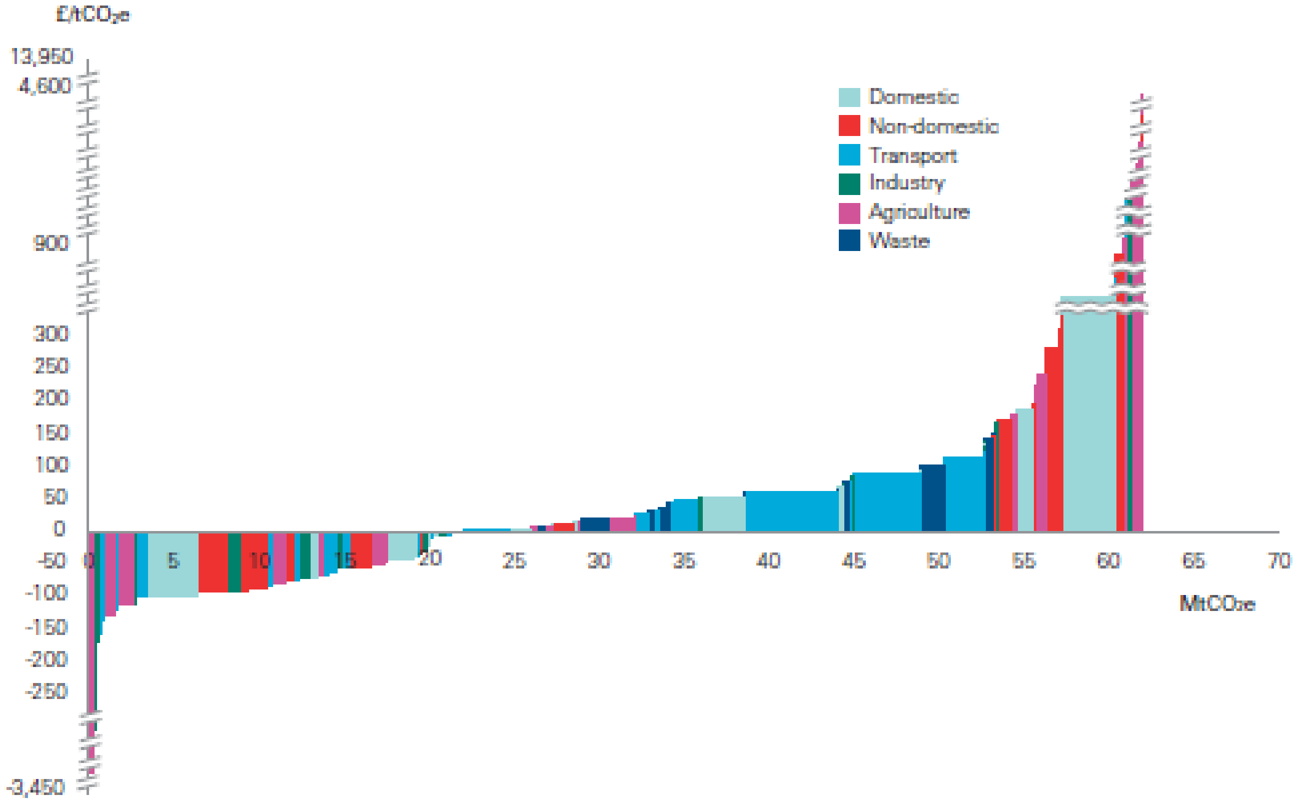
- Decarbonisation reduces (cost-effectiveness of) carbon savings
- Lower demand lowers ETS prices
- Could discourage fuel-switching (eg CHP)
- Energy efficiency is about energy – the problem is carbon

Question 3: when might energy efficiency reduce costs? Is there an efficiency gap for policy to fill?

A big MACC

Chart 12

A Marginal Abatement Cost Curve in the Non Traded Sector

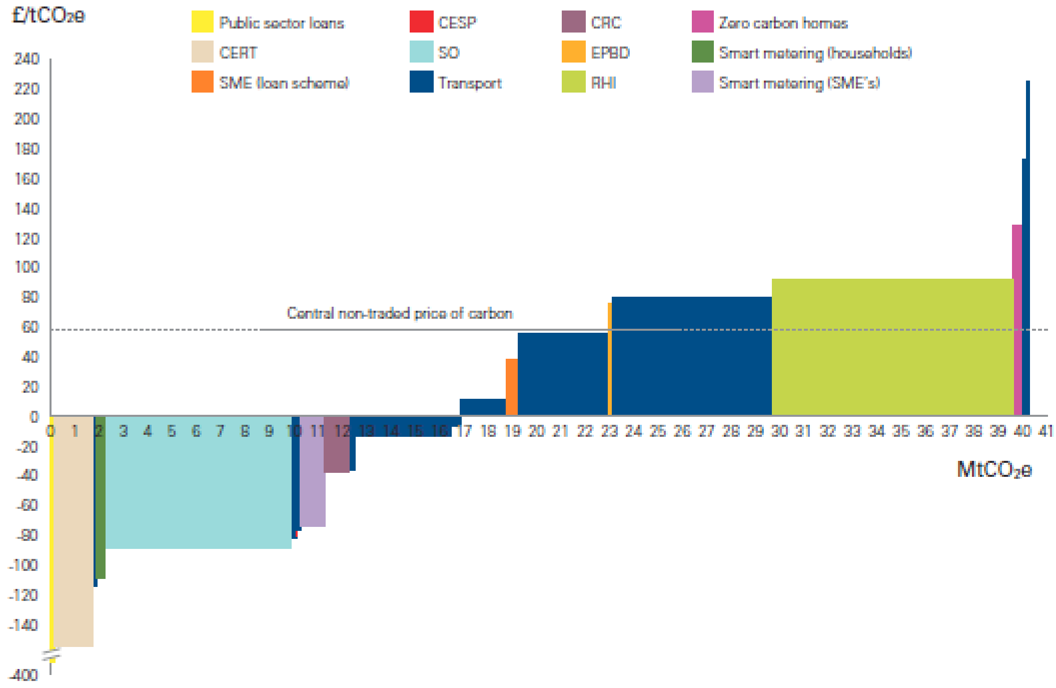


Source: Committee on Climate Change (2008)

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
- Normally consumer is best placed to make the judgement, not engineering models or the government

Conclusions 1: when does energy efficiency lead to sustainability?

- When it leads to reduced demand, emissions and costs
- This can happen, but is not automatic
- To ensure it does happen requires an integrated approach to the various systems issues

Conclusions 2: what does this mean for policy on energy efficiency and sustainability? Some thoughts

- Try to understand wider system; integrate energy efficiency and low carbon policies
- Monitor and measure properly; learn what works

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, facilitation of non-fossil sources