Energy, Environment and Sustainability

Lecture

The challenges of Energy Efficiency:

Rebound effects, Sufficiency and beyond

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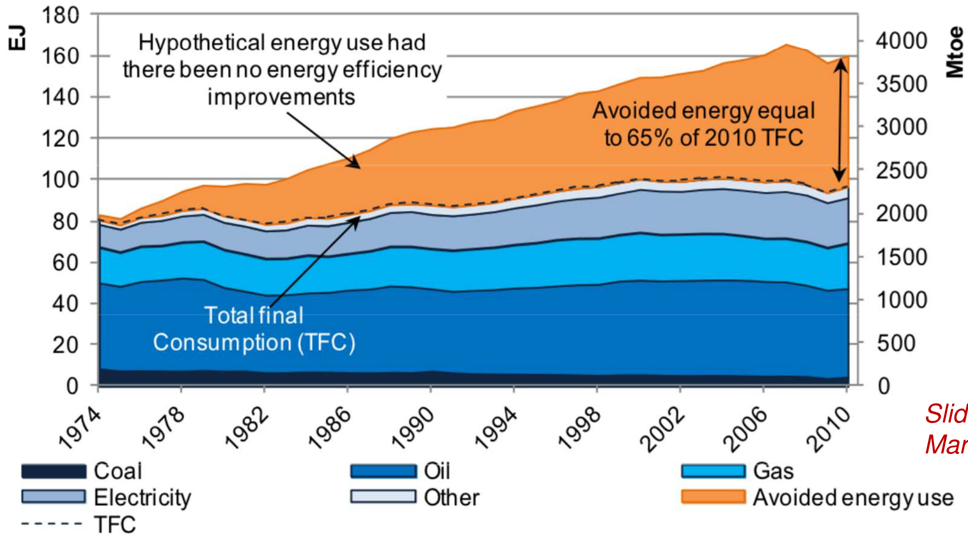
Vítor Leal | 2018.12.12 > 2019.10.30

An introduction

Between 1974 and 2010, energy efficiency was the largest energy resource

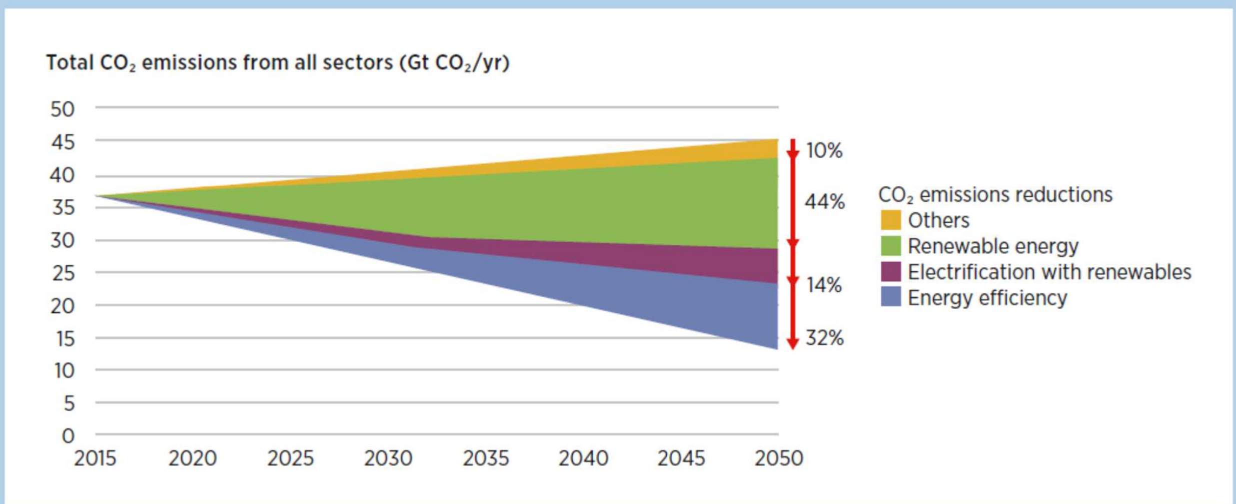
Cumulative avoided energy consumption due to energy efficiency in these IEA countries amounted to over 1 350 EJ (32 billion toe)



Slide by Prof.s Gomes Martins and M. Gameiro

Long-term improvements in energy efficiency in 11 IEA countries

Figure 1: CO_2 emission reduction potential by technology in the Reference Case and REmap, 2015–50



Based on IRENA analysis in the source: IEA and IRENA, 2017

Notes: CO_2 emissions include energy-related emissions (fossil fuel, waste, gas flaring) and process emissions from industry; if only fossil fuel emissions were displayed in this figure, CO_2 emissions in 2050 would be 40.5 Gt and 9.5 Gt per year in the Reference Case and REmap, respectively.

[A brief and simplified] History of my (main) TV's:

- 1999: CRT
- 2009: LCD
- 2011: LCD (A)
- 2015: LED (A+)

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Power Consumption Comparison Between LED, LCD, CRT & Plasma:

Screen Size	LED	LCD	CRT	Plasma
15 inches	15	18	65	---
17 inches	18	20	75	---
19 inches	20	22	80	---
20 inches	24	26	90	---
21 inches	26	30	100	---
22 inches	30	40	110	---
24 inches	40	50	120	---
30 inches	50	60	---	150
32 inches	55	70	---	160
37 inches	60	80	---	180
42 inches	80	120	---	220
50 inches	100	150	---	300

* Results may vary significantly, results assume displays are calibrated for energy saving performance.

LED = 1/3 CRT

A lot of energy savings, right ?]

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[A brief and simplified] History of my (main) TV's:

- 1999: CRT
- 2009: LCD
- 2011: LCD
- 2015: LED

- 1999: CRT 26´´ ~110 W
- 2009: LCD 32'' – 90 W
- 2011: LCD 48'' – 90 W
- 2015: LED 50''*– 50W

* but I actually wanted a bigger TV

** and still want [but I haven't]

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- Any other cases that resemble this ?

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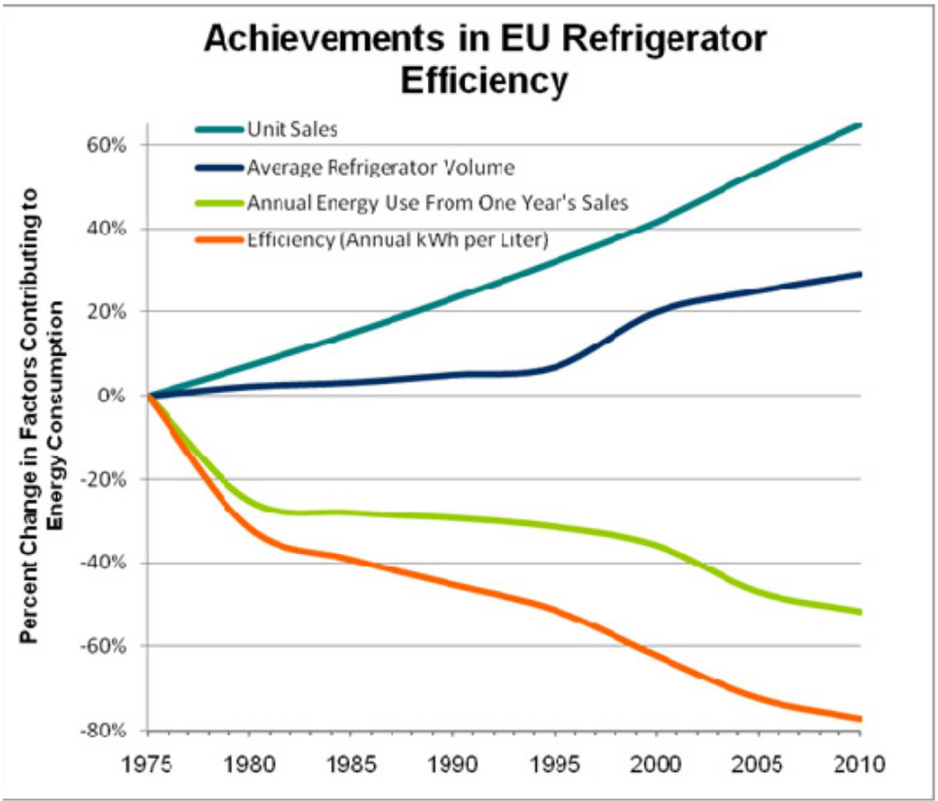

Figure 11: Attributes of new refrigerators in the EU (Bertoldi and Atanasiu)

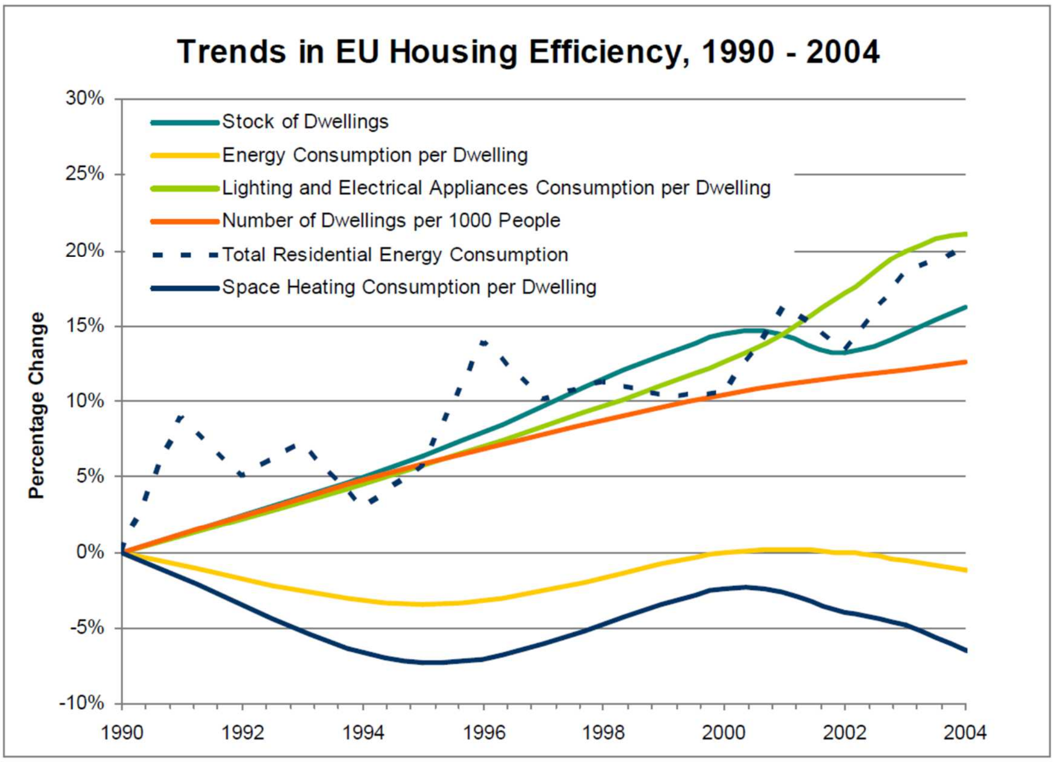

Figure 9: EU housing efficiency trends, 1990 – 2004 (Ecos analysis of EU data)

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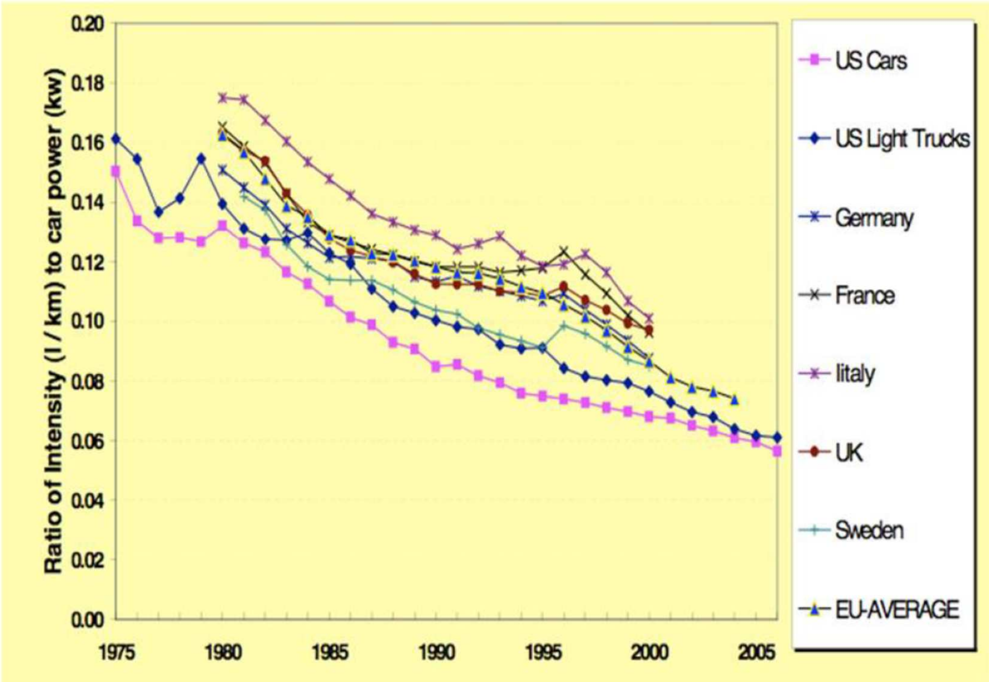
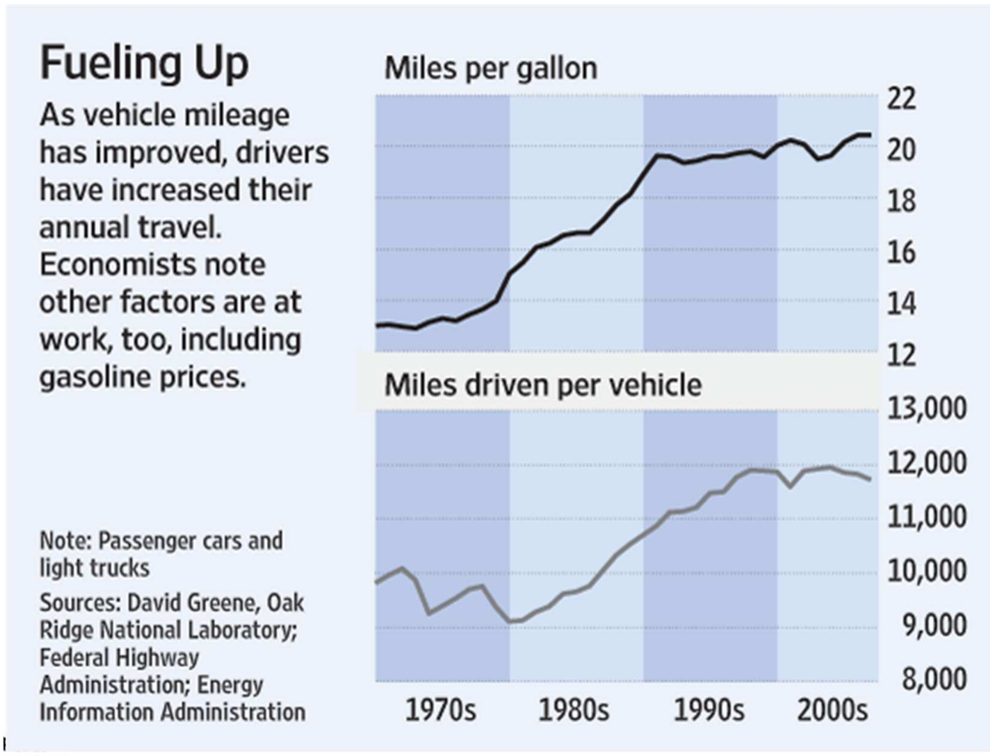
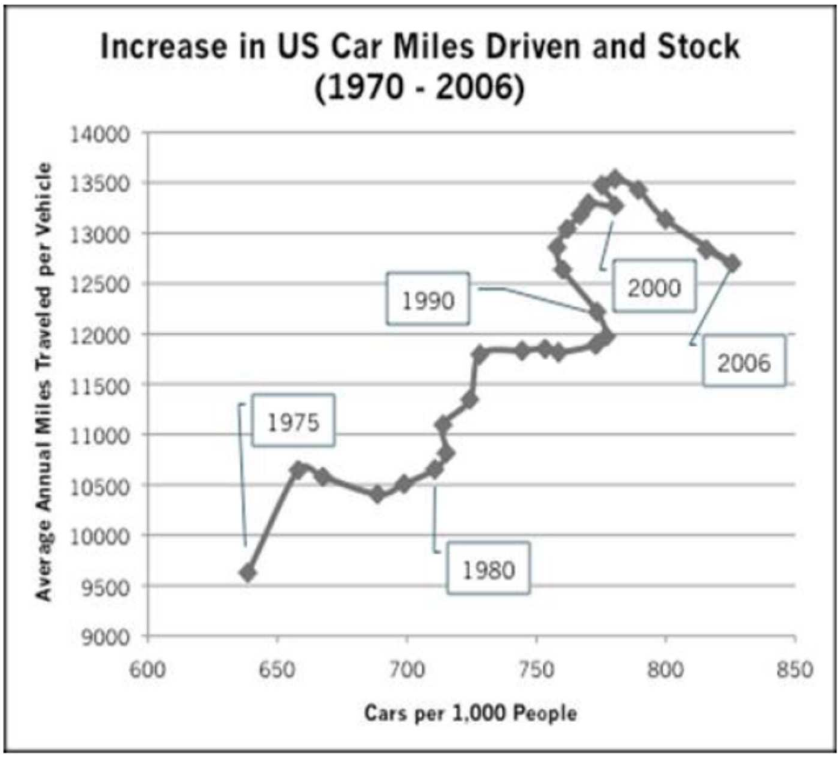


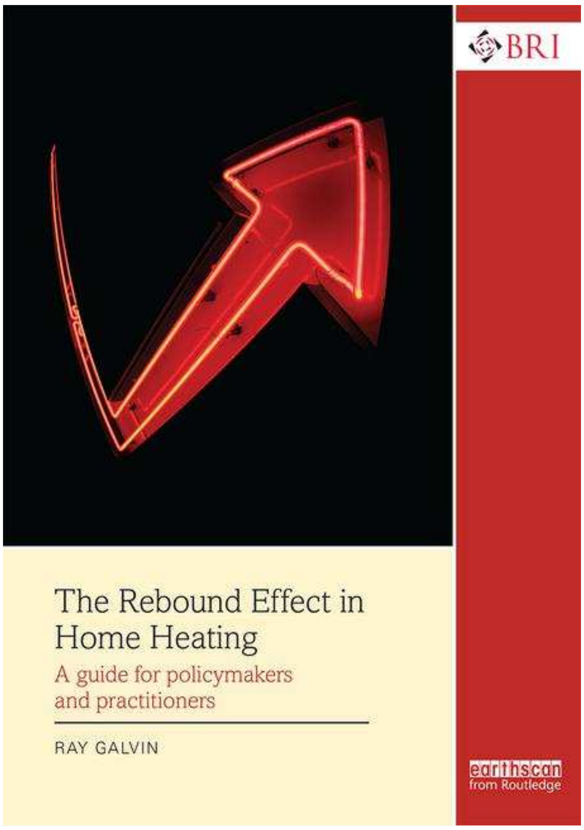
Figure 4: Vehicles in Europe and the US have increased engine power to a greater degree than they have reduced fuel consumption per kilometer traveled (UC Berkeley Transportation Center).

Direct rebound: increase thermostat temperature, travel more km etc.

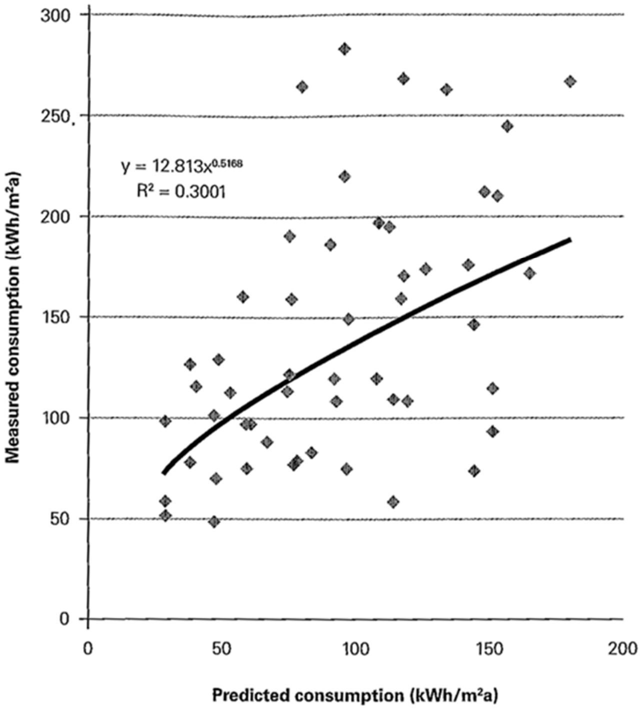




Increase in US Car Miles Driven and Stock (1970 - 2006)
Average Annual Miles Traveled per Vehicle
Cars per 1,000 People
14000
13500
13000
12500
12000
11500
11000
10500
10000
9500
9000
600
650
700
750
800
850
1975
1980
1990
2000
2006



BRI
The Rebound Effect in Home Heating
A guide for policymakers and practitioners
RAY GALVIN
earthscan from Routledge



Source: Galvin (2016)

Figure 5.5
Predicted and measured consumption, 52 buildings, showing rebound effect = 1 − 0.5168 = 0.4832 = 48.32%

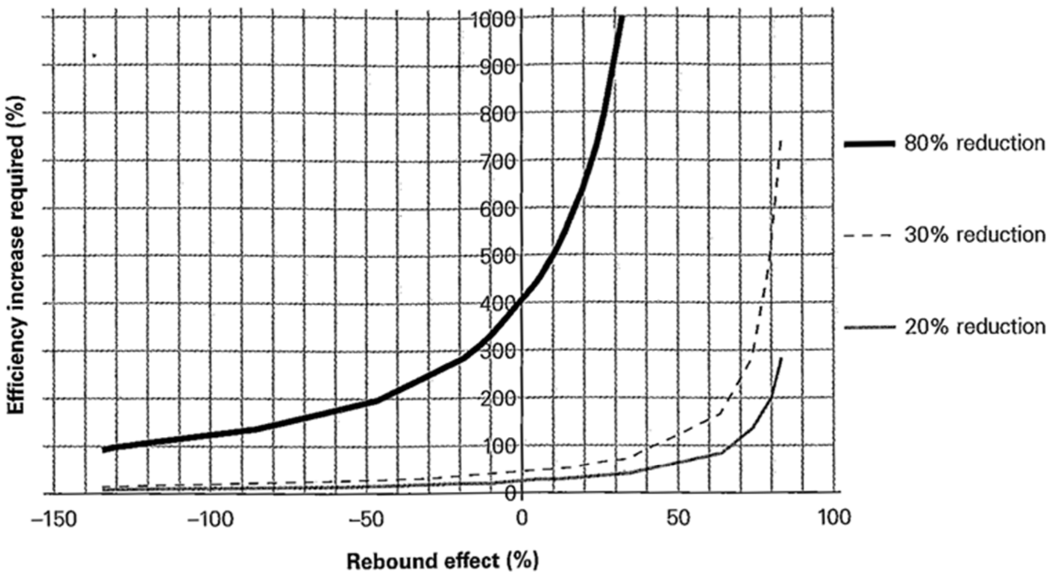


Figure 4.8
Efficiency increase required to reduce energy consumption by 20 per cent, 30 per cent and 80 per cent, for a range of rebound effects

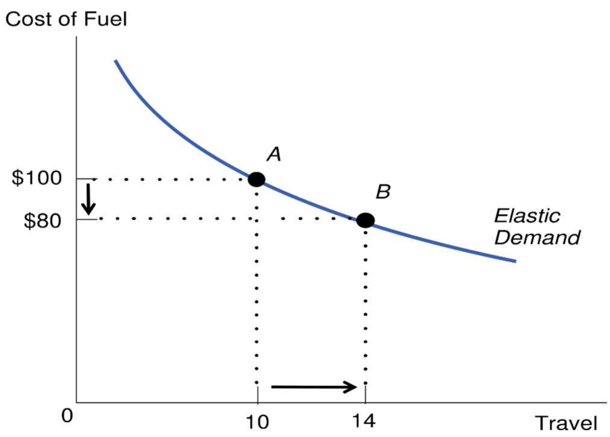
Source: Galvin (2016)

The concept(s)

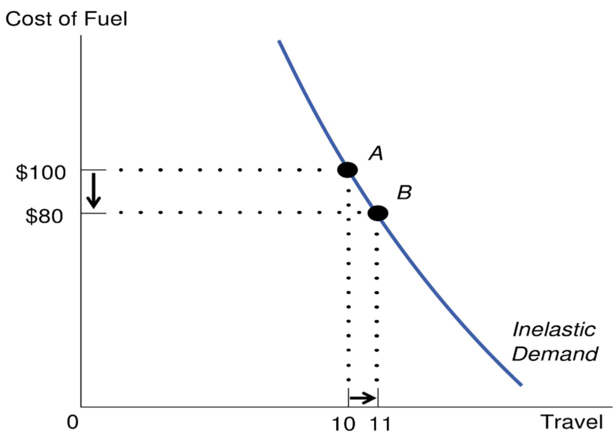
- In many cases, the growth of ownership of energy-using devices was even *accelerated* by the fact that they became more energy efficient.
- The increase(s) of Energy services due to improvements in the Energy efficiency receives the designation of Rebound Effect(s).
- Rebound Effects partially or totally cancel the intended effects of energy efficiency / the potential energy savings.

Jevons paradox

- English economist William Stanley Jevons
- 1865 book *The Coal Question*



Elastic demand: Rebound



Inelastic / low elastic demand: Rebound

- Many energy efficiency specifications (may) have unintentionally helped feed the trend toward conspicuous consumption by consistently choosing linear or categorized efficiency specifications.
- These specifications can make it no more difficult for extremely large, luxurious, high performance, or costly devices to earn an environmental “seal of approval” than their simpler, more utilitarian counterparts that yield far lower total consumption
- When the enormous restaurant-grade refrigerator or wall-spanning plasma TV or 10,000- square-foot (929 square meter) home bears the ENERGY STAR label without regard to its absolute consumption, it says to all the world that we can go on increasing material throughput and total energy consumption indefinitely without environmental consequence as long as we continue finding ways to reduce the amount of energy consumed per unit of volume or area of service provided.

- J. Daniel Khazzoom, Harry Saunders, Horace Herring, Mithra Moezzi, and J.S. Norgard, among others, brought renewed attention to this issue in the 1980s and 1990s in the academic literature and in various presentations at energy conferences.
- They used like "takeback," "the rebound effect," or "bounceback" to describe what happens when more energy efficient technologies lower the cost of using a particular device, allowing people to use it more extensively to gain additional comfort or amenity without increase financial outlay.
- *Some who hold this belief have reached the conclusion that energy efficiency efforts may make microeconomic sense for the particular end use to which are applied, but that their macroeconomic effect is to increase overall energy consumption, making the problem they originally intended to solve even worse.*

- Others believe the effect is real but modest in the face of other factors that are contributing to rising economic wealth generally.
- They conclude that well-designed efficiency programs still generate net savings in spite of the resulting takeback effects, which can sometimes amount to 5 to 30% of the anticipated total savings.
- As Sussex University's Steve Sorrell described the described the issue in a 2007 report, "It doesn't mean energy efficiency is a waste of time…
- [However,] standards on efficiency will not be sufficient by themselves."

A closer look

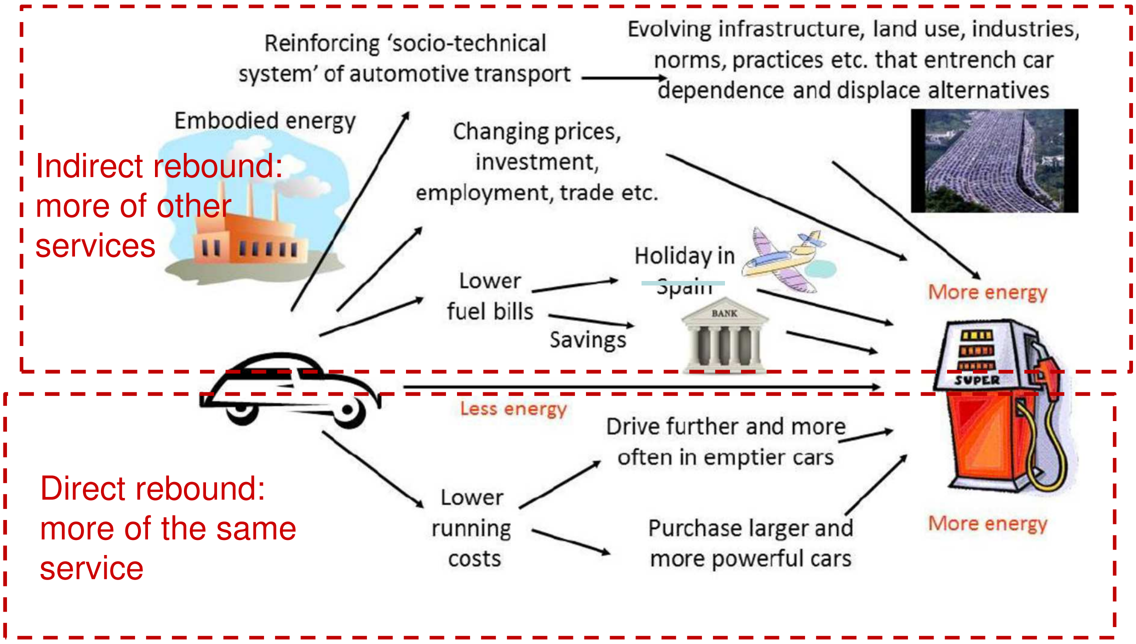


Figure 1. Rebound effects from more fuel-efficient vehicles

An even closer look

1. *Direct effects*: fuel-efficient cars make car travel cheaper, so people may be encouraged to buy more cars and to drive those cars further and/or more often [6];

2. *Indirect effects*: fuel-efficient cars may lead to reduced expenditure on road fuels, but the cost savings will be spent on other goods and services whose provision necessarily involves energy use and emissions at different stages of their global supply chains [7-9];

3. *Embodied effects*: fuel-efficient cars may embody technological improvements such as lightweight materials that can be more energy intensive to produce, with the result that the life-cycle energy savings may be less than the operational energy savings [7];

4. ***Service quality effects***: technical improvements such as better aerodynamics and more efficient engines may encourage the purchase of larger, heavier, more powerful and more comfortable cars, rather than more fuel-efficient cars [10,11];

5. ***Energy market effects***: widespread adoption of fuel-efficient cars may reduce fuel demand, thereby reducing fuel prices which in turn will encourage increased fuel consumption within national and global markets [12];

6. ***Secondary effects:*** widespread adoption of fuel-efficient cars will induce changes in prices, investment, production and trade in multiple markets, which will have corresponding impacts on energy consumption both within the national economy and along international supply chains [13,14];

- *7. **Transformational effects**:* widespread adoption of fuel-efficient vehicles may make car travel increasingly attractive relative to other transport modes, thereby deepening the 'lock-in' to the car-based transportation system and triggering associated and reinforcing changes in infrastructure, land use patterns, institutions, regulations, supply chains and social practices [5,15].

Direct rebound effects derive from increased consumption of the energy service, such as heating or lighting, whose effective price has fallen as a result of improved energy efficiency.

Indirect rebound effects derive from re-spending the cost savings from energy efficiency improvements on *other* goods and services (e.g. leisure, clothing) that also require energy to provide (e.g. from production of materials, manufacture of products, shipping, road freight, retail), and hence also lead to greenhouse gas (GHG) emissions.

The rebound effect (*R*) is commonly defined as the gap between the *potential* energy savings (*PES*) from an energy efficiency improvement and the *actual* energy savings (*AES*):

$$R = \left[1 - \frac{AES}{PES}\right]$$

'Energy market' rebound

- Initially, a quantity Q_1 of energy is sold at price P_1
- the potential energy saving is given by Q_1-Q_2
- The energy efficiency improvement shifts the demand schedule to the left, leading to new equilibrium of Q_3, P_3
- the actual energy saving is given by Q_1-Q_3

$$R = 1 - \left[\frac{(Q_1 - Q_3)}{(Q_1 - Q_2)}\right]$$

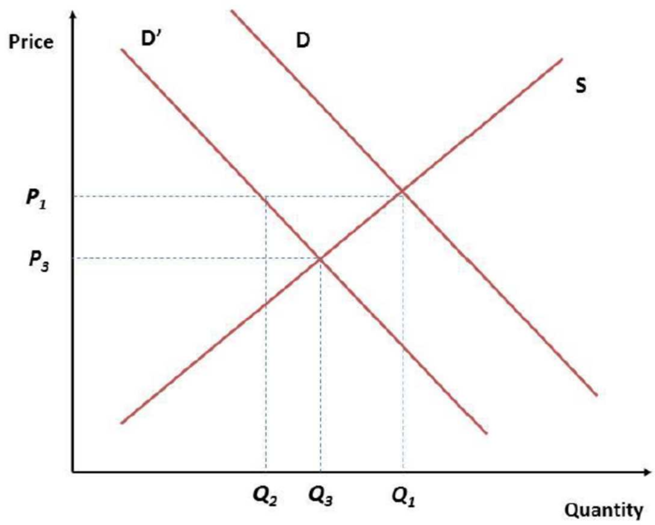
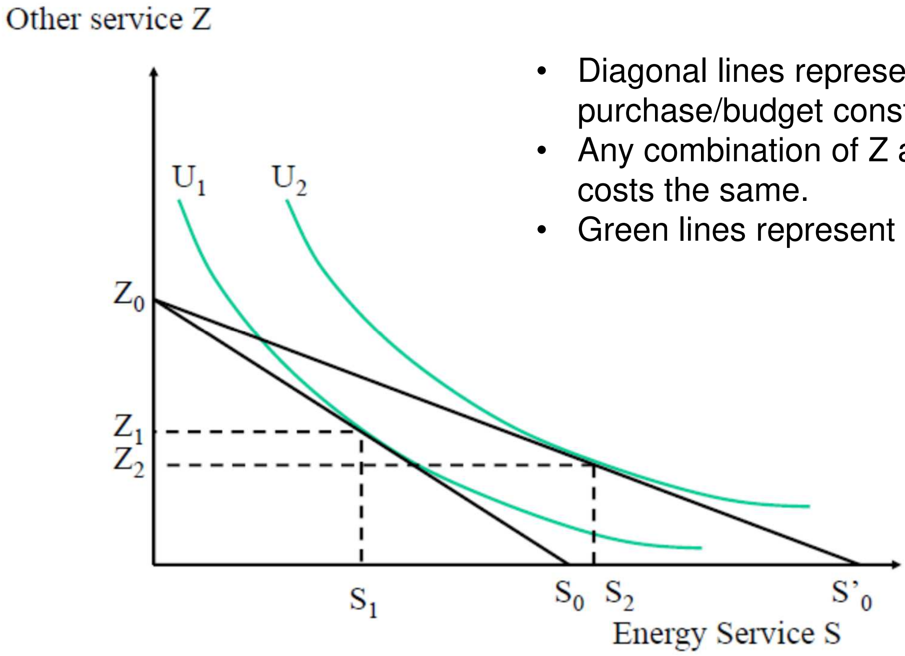


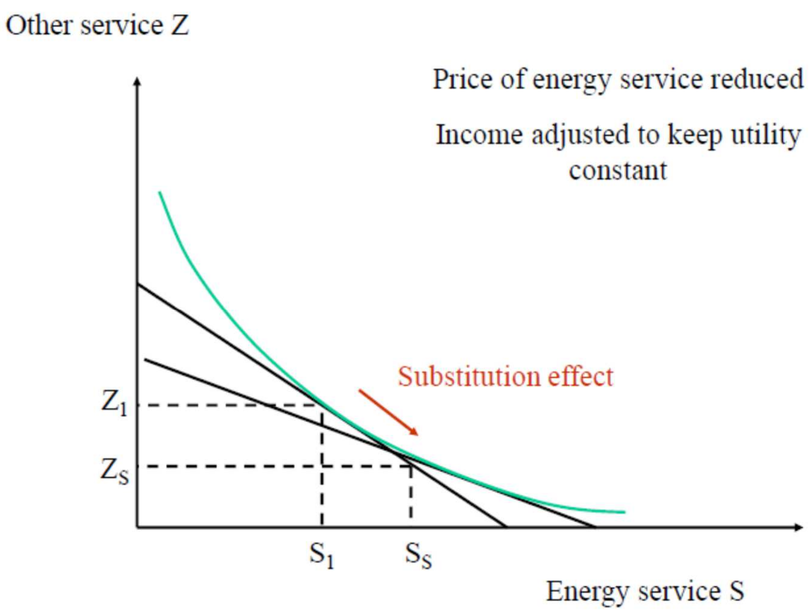
Figure 5. Energy market effect

Substitution vs income effects



- Diagonal lines represent the purchase/budget constraints.
- Any combination of Z and S along that line costs the same.
- Green lines represent the iso-utility.

The *substitution effect* is defined as the change in consumption that would result from the change in relative prices *if* income were adjusted to keep utility constant.



- But since the energy service is cheaper, the consumer's total purchasing power, or 'real income' has increased. This allows a shift from one indifference curve to another (higher utility).

- The *income effect* is defined as the change in consumption that would result exclusively from this change in real income, holding prices and nominal income constant.

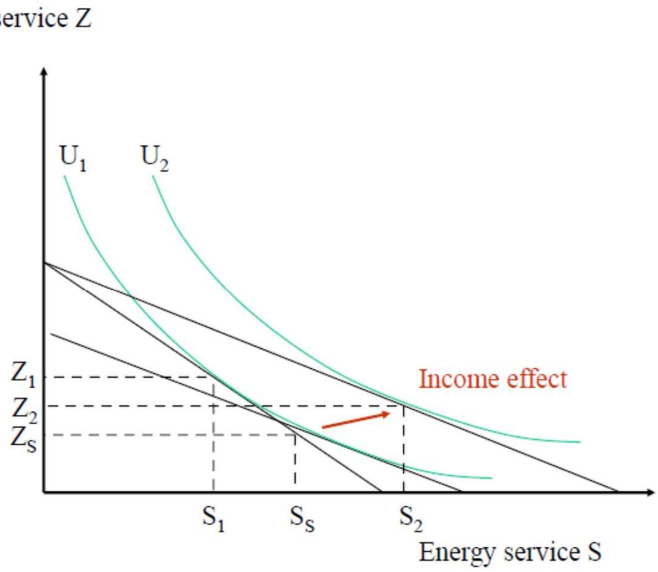


Table 2. Studies estimating combined direct and indirect rebound effects for households – income effects only

Author	Region	No. of expenditure categories	Measure	Area	Rebound metric	Estimated rebound effect (%)
Lenzen and Day [37]	Australia	150	Efficiency & Sufficiency	Food, heating	Energy & GHGs	45-123%
Alfreddson [38]	Sweden	300	Sufficiency	Transport, electricity, heating, food	CO_2	7-300%
Thomas and Azevedo [39]	US	428	Efficiency	Transport, electricity, heating	Energy and GHGs	15-27%
Murray [40]	Australia	36	Efficiency & Sufficiency	Transport, lighting	GHGs	4–24%
Chitnis *et al* [7]	UK	17	Efficiency	Electricity, heating	GHGs	5-15%
Freire-Gonzalez [41]	EU-27	163	Efficiency	Transport, electricity, heating	Energy	30-300%
Bjelle *et al* [42]	Norway	12	Efficiency & Sufficiency	Transport, electricity, heating, food, waste, other	GHGs	40-58%

Table 3. Studies estimating combined direct and indirect rebound effects for households – income and substitution effects

Author	Region	No. of commodity categories	Measure	Area	Rebound metric	Estimated rebound effect (%)
Brannlund *et al* [27]	Sweden	13	Efficiency	Transport; utilities	CO_2	120-175%
Mizobuchi [43]	Japan	13	Efficiency	Transport; utilities	CO_2	12-38%
Lin and Liu [44]	China	10	Efficiency	Transport; utilities	CO_2	37%
Kratena and Wuger [45]	Austria	6	Efficiency	Transport; heating; electricity	Energy	37-86%
Chitnis and Sorrell [46]	UK	12	Efficiency	Transport, heating, electricity	GHGs	41-78%

- the empirical evidence suggests that rebound effects are frequently large and therefore should not be ignored in either energy modelling studies or policy appraisals.
- It is common to find estimates of direct or combined direct and indirect rebound effects that exceed 30%, especially for energy efficiency improvements by low-income groups (prebound effect);
- However, since it is rare to find estimates of rebound effects that exceed 100%, the majority of energy efficiency improvements should still lead to some energy and emission savings.

(Towards) Solutions

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ECEEE 2010 – some proposals:

- Shift energy efficiency specifications away from categorical, discontinuous, or line approaches toward progressive and continuous ones that approach sufficiency limits and then cease to increase [ECEEE 2010].
- Make return and recycling of still-functional energy-using products a central feature of utility incentive programs on the sale of new, energy-efficient devices [ECEEE 2010].
- Institute a corresponding system of fees on the least efficient and most energy consumptive products sold, so that consumers understand that A-rated or 5 star products are financially beneficial to purchase and G-rated or 1 star products are financially disadvantageous to purchase.

- Eliminate declining block utility rates for residential and commercial customers. Shift toward progressively tiered rates instead, ensuring that those who purchase more electricity or natural gas than average pay more for each incremental unit of energy beyond the average.
- Institute macroeconomic “backstop” provisions that trigger rising taxes on energy consumption or greenhouse gas emissions if voluntary consumption targets are not met.

Sufficiency

Energy Sufficiency

european council for an energy efficient economy

Energy sufficiency and rebound effects

Concept paper

Energy sufficiency as a vision for the future

- Energy sufficiency as an outcome can be thought of as an 'energy safe space' where everyone's basic needs are met and we enjoy a range of energy services;

- Access to these energy services is more equitable than it is today, and total energy demand is no more than can be supplied within the limits of the environment's carrying capacity.

To move towards this energy safe space, a number of things can happen:

• increase access to energy services for those whose basic needs are not currently met

• decrease energy demand whilst maintaining the same energy services through energy efficiency improvements

• decrease energy demand through energy sufficiency actions

• meet energy demand through more sustainable supply options, thus increasing the level of demand that can be met within environmental limits.

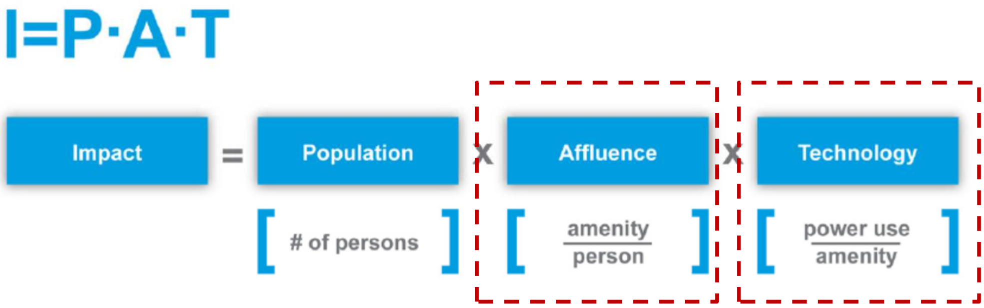


Figure 17: The IPAT formula

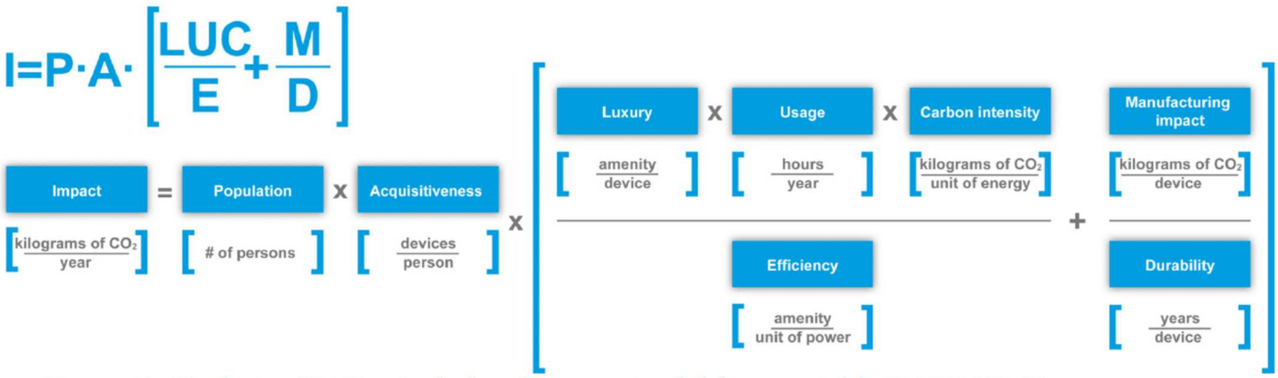


Figure 18: Updating IPAT to include other meaningful factors yields IPALUCEMD .

Restraint versus substitution:

- Many sufficiency actions are associated with some form of restraint.
- For example, in the travel domain, an action based on restraint might start by asking: ‘do I need to undertake this car journey’?
- True restraint would renounce the journey altogether.
- On the other hand, less energy-intensive substitutes might be considered, such as travelling by public transport, or replacing the journey with a video conference.

Personal Ethics (voluntary) vs Institutional measures (enforcement)

- Walking and cycling can be encouraged by policies: high-density land-use developments, dedicated cycle lanes and adequate cycle parking, whereas car travel can be discouraged by high parking charges and rising fuel taxes.
- It is misleading, therefore, to view sufficiency actions as solely an individual choice - they depend upon the broader infrastructural, technical, economic and social context and may be specifically incentivised or required by public policy.
- Prescriptive policies such as banning car use in city centres, or regulating floor areas tend to be unpopular and hence are rarely used - although there are exceptions.
- Most sufficiency actions are taken by individuals, but people are more likely to adopt such actions if they feel social pressure to do so, if they act in collaboration with others (e.g. neighbourhood groups) or if they identify with a broader social trend or social movement [72].

Downshifting

- Most people taking sufficiency actions will continue to work and to earn as much as before – and simply spend their money in a different way.
- But an alternative approach is to voluntarily reduce household income - commonly known as downshifting.
- For example, people may choose to work less, take a pay cut and reduce their aggregate consumption.
- It has been estimated that if everyone in the UK were to downshift to the Minimum Income Standard as defined by Bradshaw et al [74], then average household GHG emissions would fall by 37%

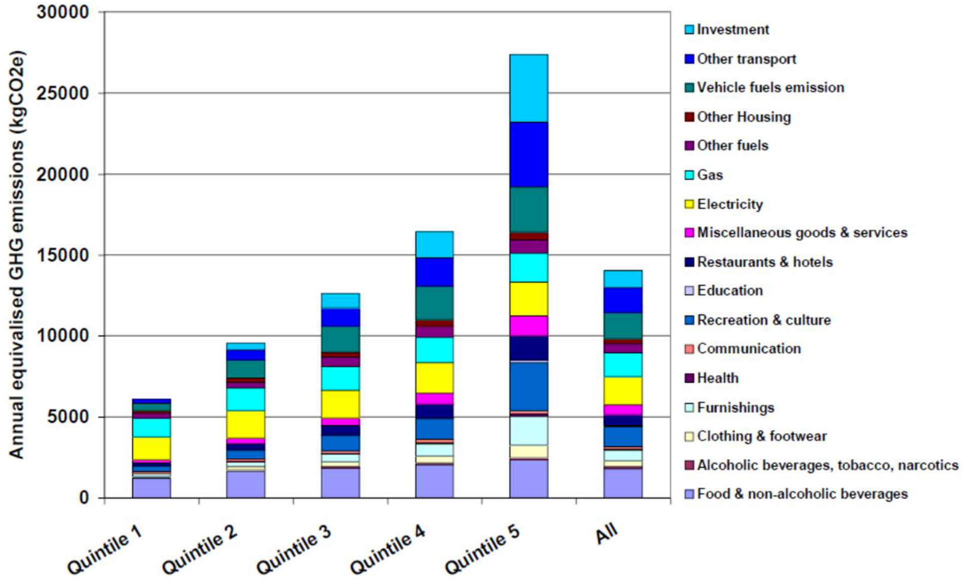
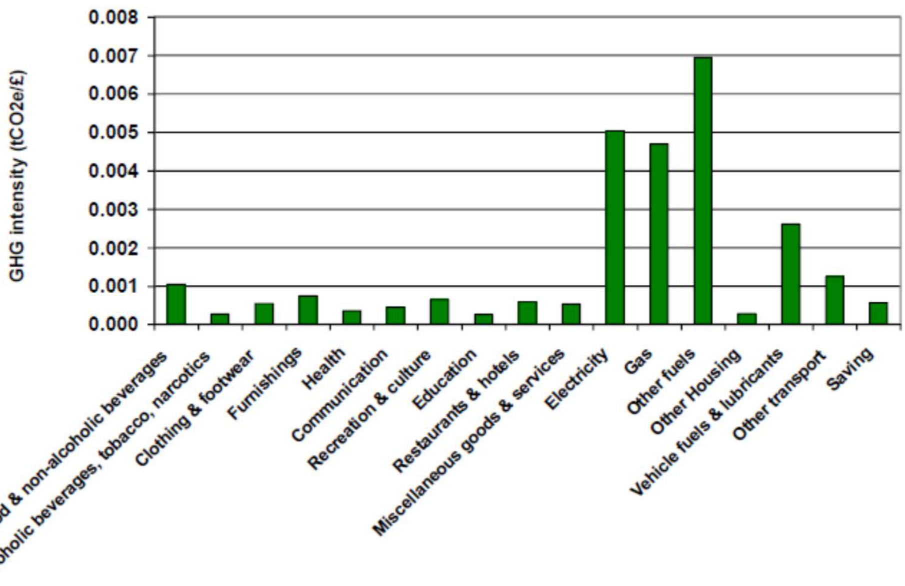


Figure 7. Estimates of GHG emissions for different income groups in the UK
Source: Chitnis et al Figure 4 [7].

Can Sufficiency create rebound effects too ?

- The savings in energy costs will be available for re-spending on other goods and services. Hence, sufficiency actions will lead to indirect rebound effects.
- *It is important (just like in Energy efficiency) to know in what re-spending occurs.*



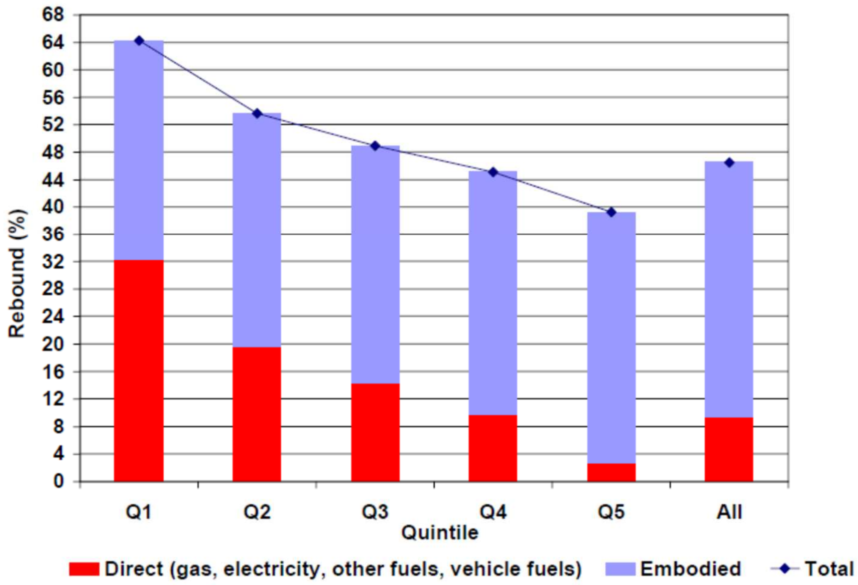
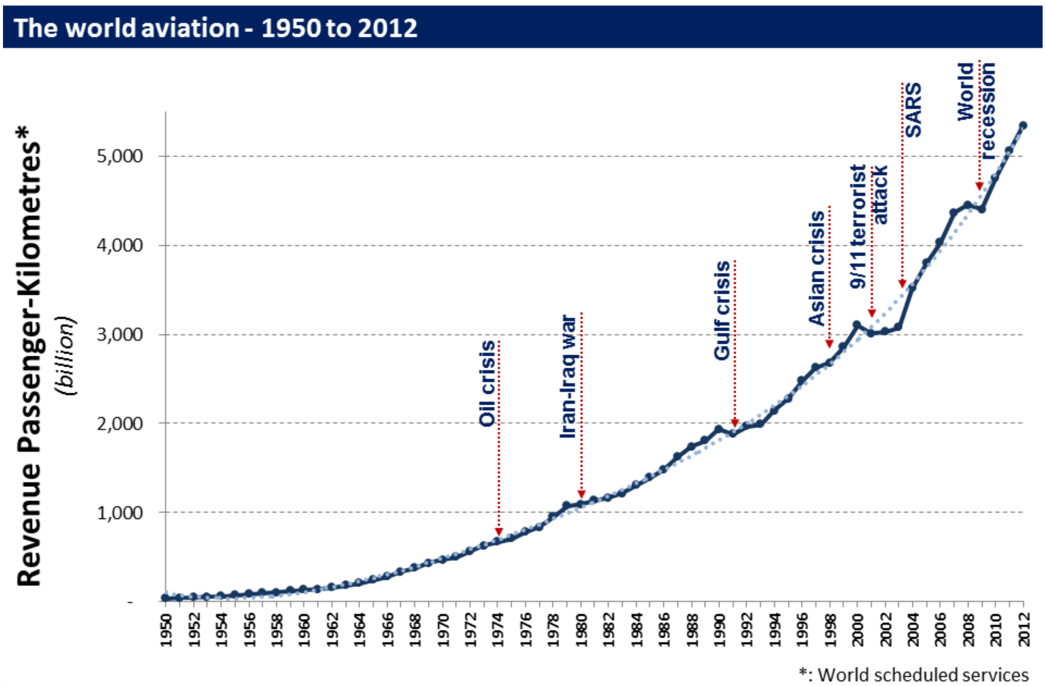


Figure 9. Estimates of the indirect rebound effect from reducing vehicle use for different income groups in the UK

Source: Chitnis et al [8].

Indirect rebound: use other energy-intensive energy services



- Evidence suggests that if people engage in environmentally responsible behaviour in one area (e.g. purchasing a fuel-efficient car) they may consider that they have 'moral licence' to engage in *less environmentally responsible behaviours in other areas* (e.g. more flying).

- These broader mechanisms are termed *negative spill-overs* by environmental psychologists and they both *overlap* with the mechanisms discussed above and provide an *additional* source of rebound.

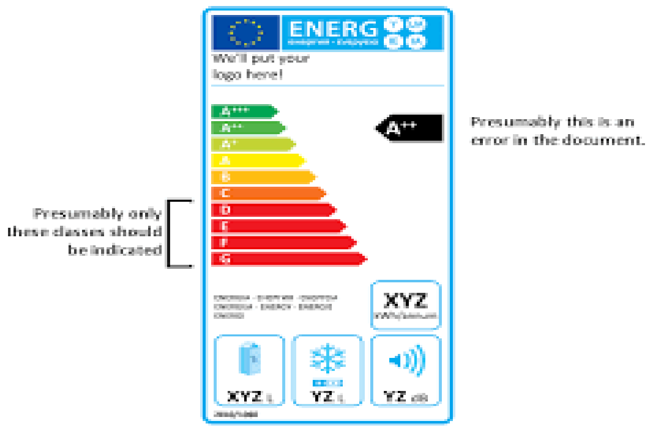
"Super-indirect" rebound:

You leave the saved money at bank, but bank lends it to finance energy-intensive business

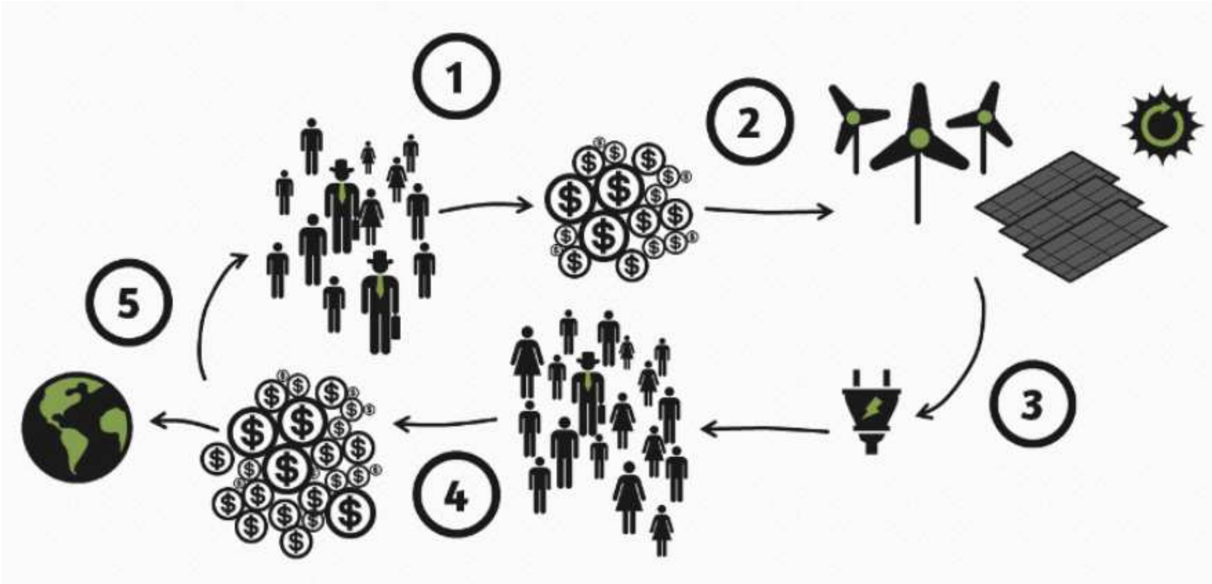
(i) Burn the savings ?

- Generates CO_2
- Ilegal in many countries

(ii) Keep improving "your" energy -efficiency



(iii) Invest in Renewables & Energy Efficiency funds



Source: citizenergy.eu / coopernico.org

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