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IMPROVING ENGINEERING EDUCATION

Domestic Energy Use and Sustainability

The Cambridge-MIT Institute

UNIVERSITY OF CAMBRIDGE

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- version 2. Modified by Dr. Tamás Bertényi

- October 27th, 2005

Energy Consumption Units

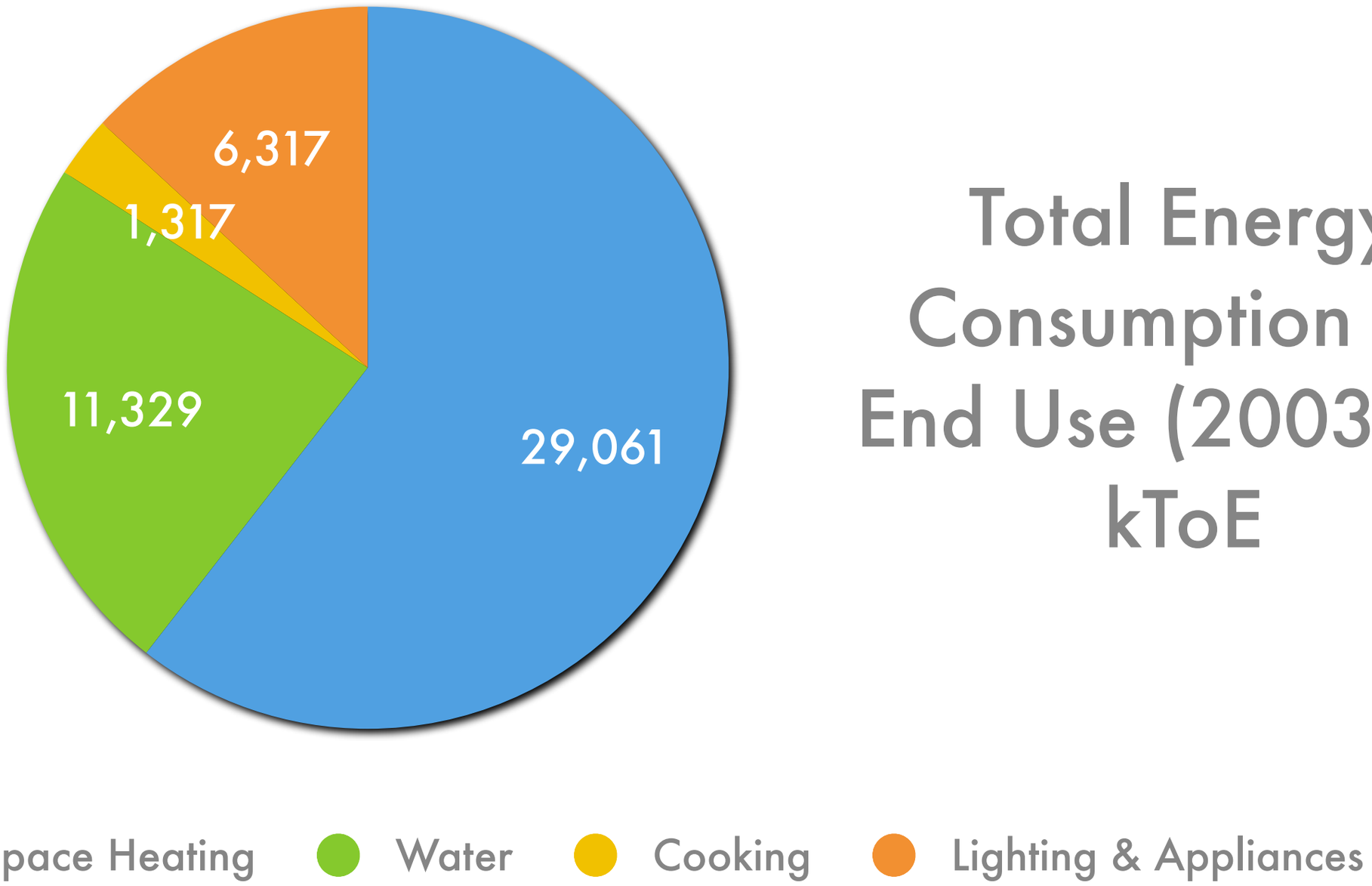
ToE = Ton of oil equivalent

- 1 ToE = 42 GJ = 11 630 kWhr
- 1 ToE = 32 full (4.5l) car petrol tanks
- 43 kToE = annual production of a medium (60MW) gas plant
- 3 mToE = annual consumption of a fluorescent light bulb

Notes

- ToE = Ton of oil equivalent. The ToE is commonly used for large amounts of energy, since it may be easier to understand in a practical context than the proper SI unit for energy, the joule.

Total UK Domestic Energy Consumption



Total Energy Consumption by End Use (2003), in kToE

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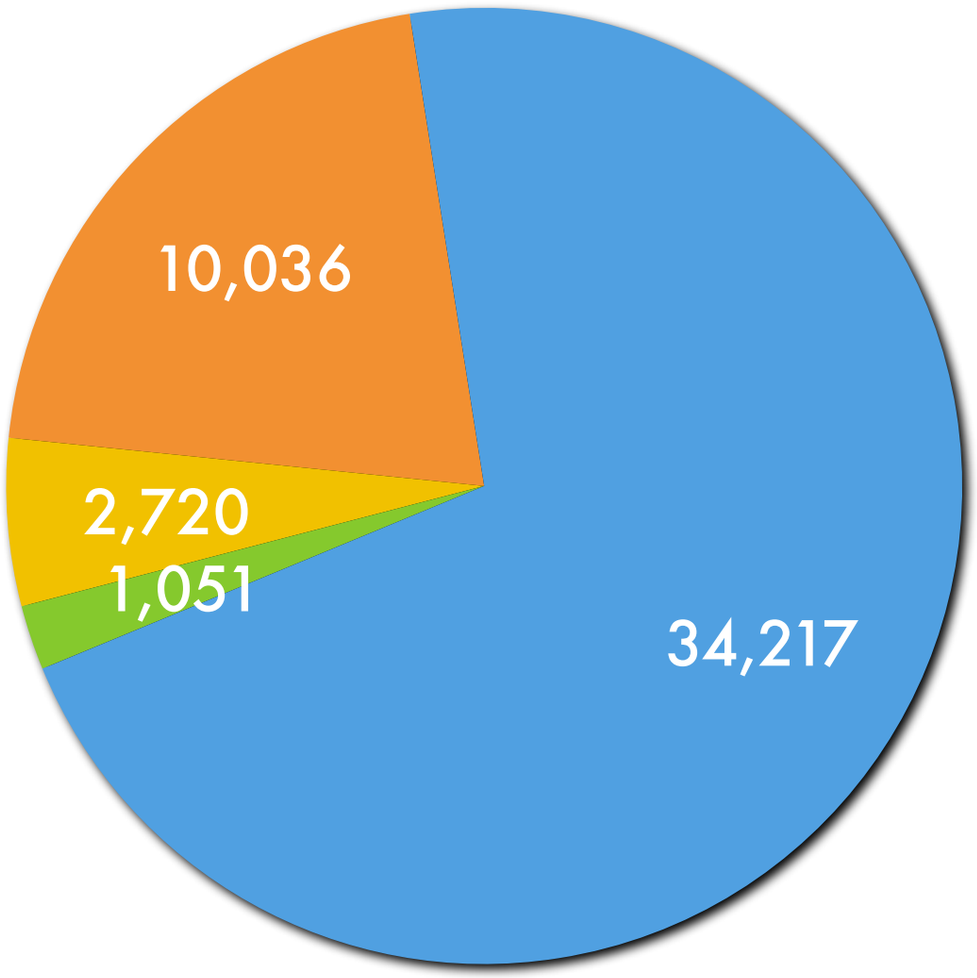
Notes

- Source: DTI http://www.dti.gov.uk/energy/environment/energy_impact/seib2005ch3.pdf
- This plot shows the total energy consumption (gas, oil, electricity etc. all included) by end use in the UK's domestic sector in 2003.
- The domestic sector accounts for 28% of all UK energy consumption.

Proportions of UK Domestic Fuels

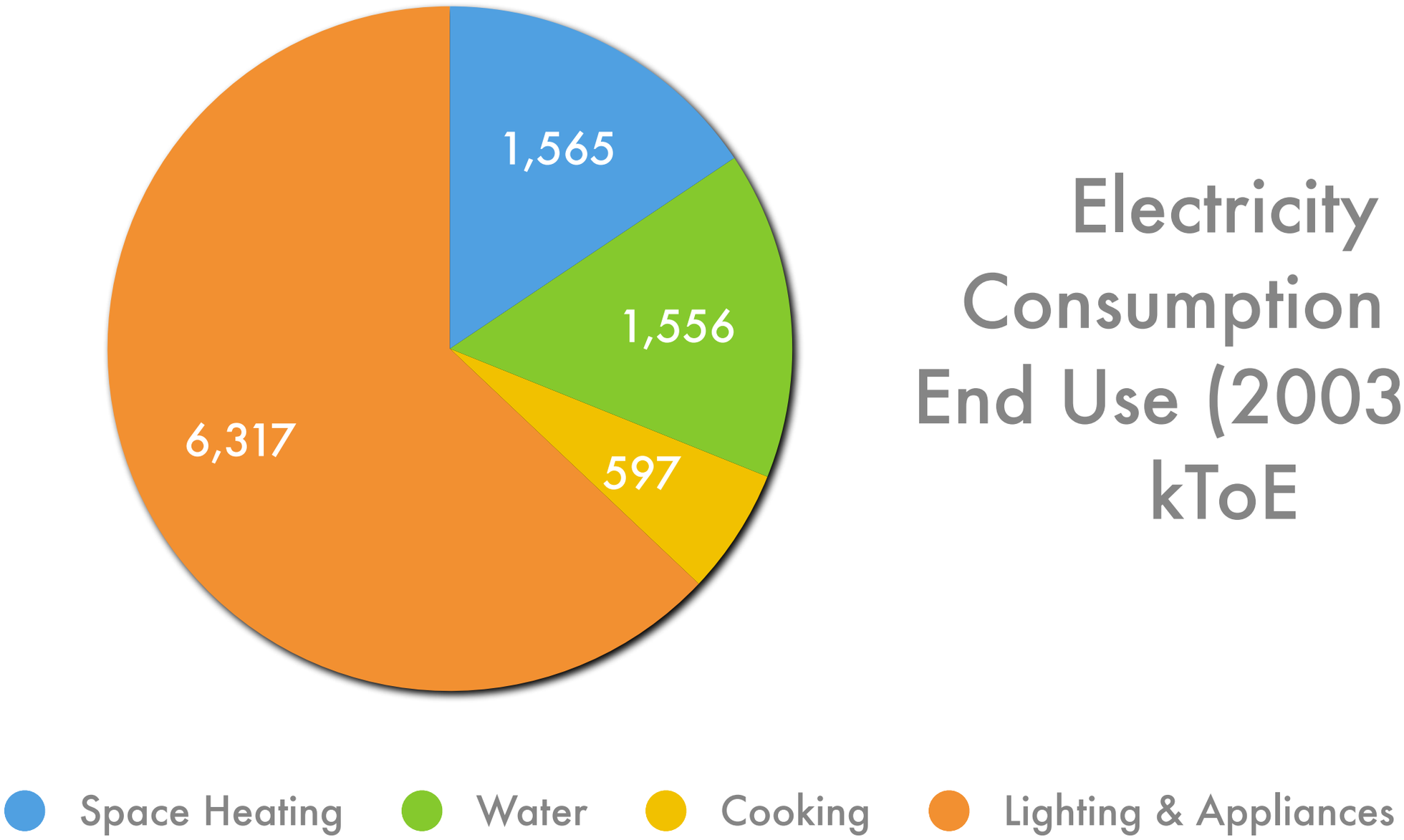
Proportions of Fuel Use (2003), in kToE



Notes

- Source: DTI
- Data derived from data supplied by the Building Research Establishment
- This plot shows the energy consumption by fuel from the UK's domestic sector in 2003.

Total UK Domestic Electricity Consumption



Electricity Consumption by End Use (2003), in kToE

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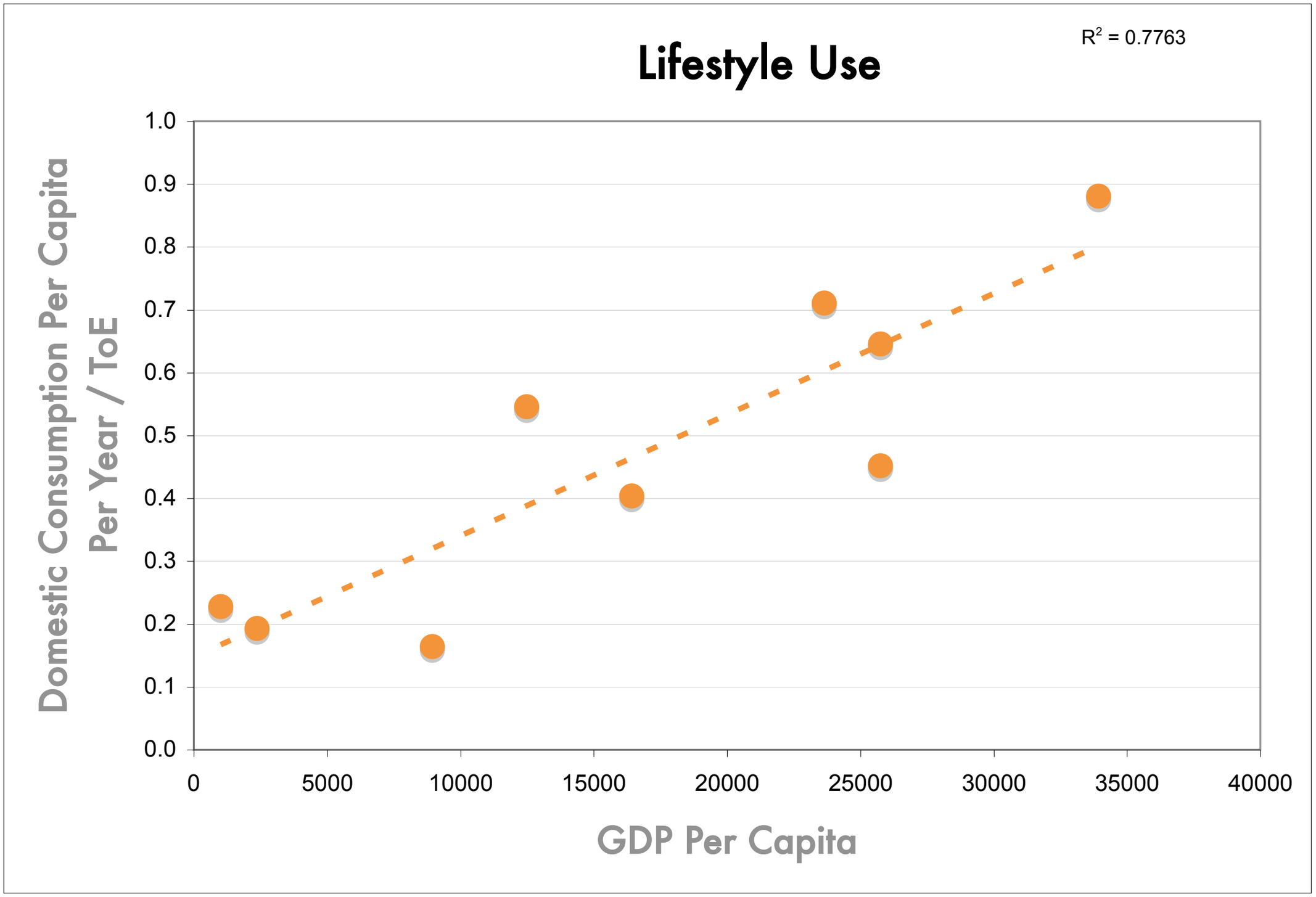
Notes

- Source: DTI
- This plot shows the total electricity consumption (gas, oil, electricity etc. all included) by end use in the UK's domestic sector in 2003.
- The domestic sector accounts for 28% of all UK energy consumption.

Lifestyle Use



Notes

- Source: World Resources Institute
- http://earthtrends.wri.org/country_profiles/index.cfm?theme=5
- http://earthtrends.wri.org/country_profiles/index.cfm?theme=6
- Illustrating the relationship between GDP per capita in dollars (a commonly used "living standards" indicator) and the domestic energy consumption in ToE per capita per annum.

Domestic Sustainability

	Total Energy Consumption / kToE	Domestic Energy Consumption / kToE	Population	Domestic Energy Consumption per capita / ToE
World	7 585 443	2 085 997	5 992 485 000	0.348
Australia	107 930	8 828	18 948 000	0.466
China	1 088 349	289 489	1 264 764 000	0.229
India	480 418	200 781	1 000 161 000	0.201
Kenya	14 690	7 283	29 991 000	0.243
UK	230 324	42 424	58 494 000	0.725
USA	2 269 985	254 209	281 975 000	0.902

Notes

- Source: World Resources Institute 1999 Data

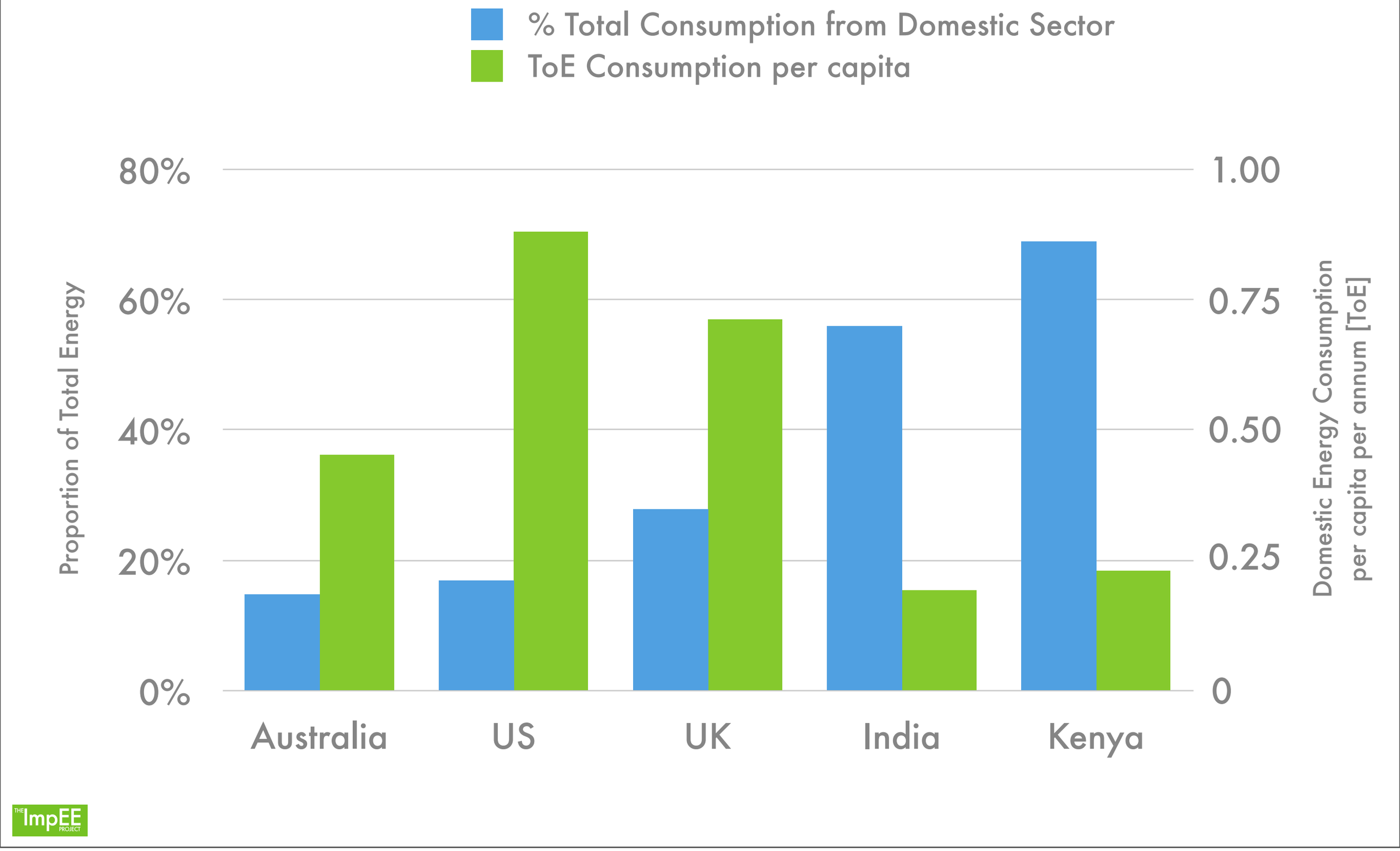
Domestic Sustainability

- 750 billion tonnes carbon dioxide in the atmosphere
- If a billion people – e.g. in developing China and India – adopt Western lifestyles, an extra 500 MToE/yr will be consumed.
- Using existing coal, oil, electricity and gas sources, this corresponds to 1.43 billion extra tonnes carbon dioxide released – just from the domestic sector!
- MUST tackle domestic energy issues before power-hungry technology and inefficient building and heating become available and are implemented worldwide

Notes

- Source: World Resources Institute
- Source: Cambridge University Earth Sciences Dept.

Domestic Sectors Worldwide



Notes

- Source: World Resources Institute http://earthtrends.wri.org/country_profiles/index.cfm?theme=6
- The plot shows figures for total energy, not electricity. The blue bars show the proportion of the country's total energy consumption resulting from the domestic sector. The green bars show the domestic energy consumption per person in the country.

Example 1: ZED Housing

- BedZED, a development of around 100 apartments in south London which emits no net carbon.
- A bottom-up approach to the problem of domestic energy consumption
- Design which maximises solar gain - the urban block is shaped to allow direct solar radiation in any season
- Thermal mass for internal heat retention in winter and external heat exclusion in summer.
- Passive ventilation with outgoing heat capture.
- Use of photovoltaic cells to generate zero emission power.
- A distributed heating system fired by carbon-neutral biomass (landscaping waste).
- Designed as a complete system, so all elements contributed to the zero emission performance.

Notes

- Further information from:
- BedZed
- Zero Emissions Development Website

Standby Power Wastage

- Also known as “vampire power”… arises from “always-on” components like clock displays, memory, remote sensing etc.
- Power converters, e.g. phone chargers, employ transformers that consume energy even when not charging.
- Inefficient technology like linear converters often couple with e.g. remote control sensing to increase impact.
- Entertainment and security appliances are particularly strong vampires.

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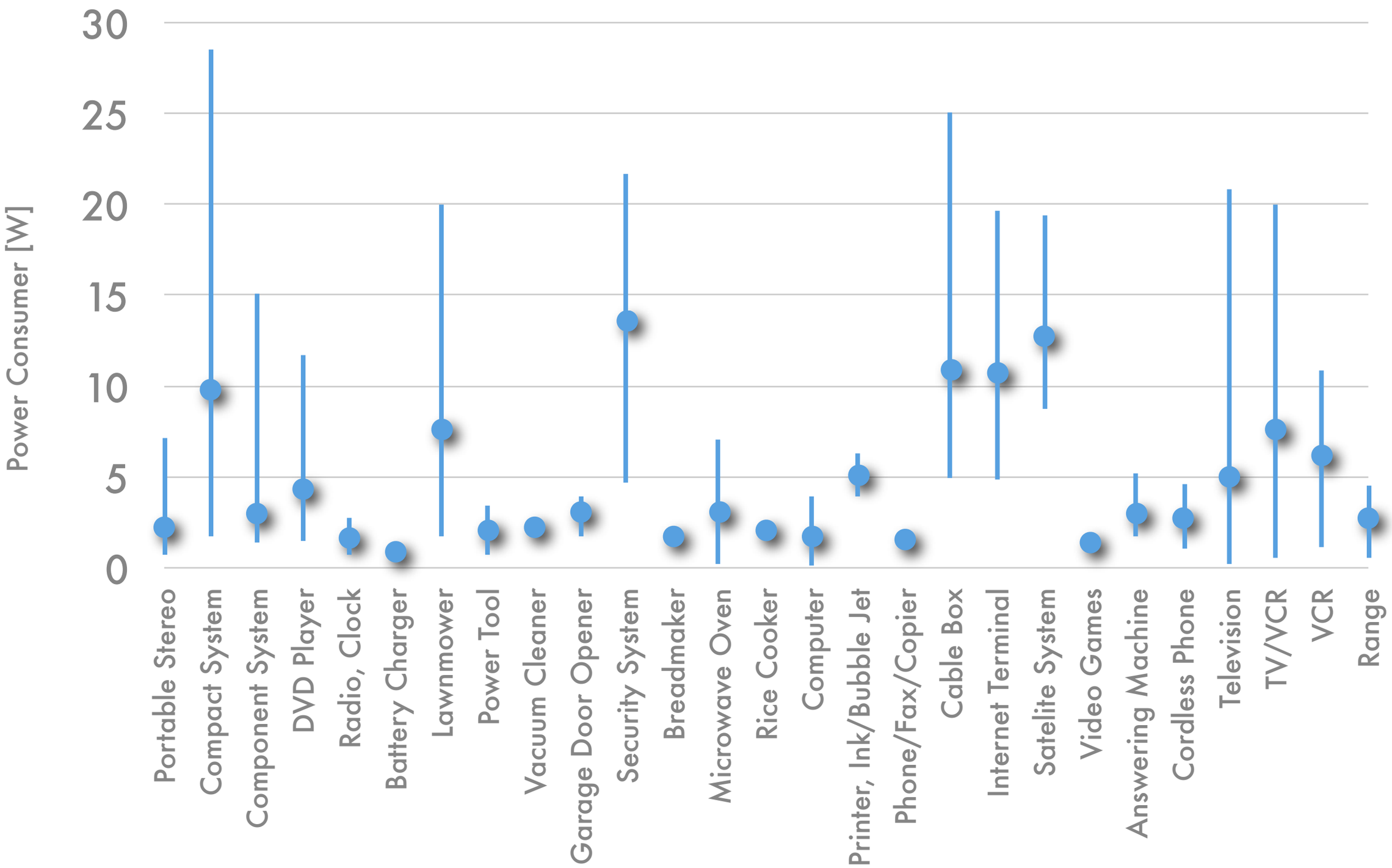
Notes

- An excellent reference document is the Report on Energy Efficiency published by the HOUSE OF LORDS Science and Technology Committee 2nd Report of Session 2005–06 Volume I Ordered to be printed 5 July and published 15 July 2005

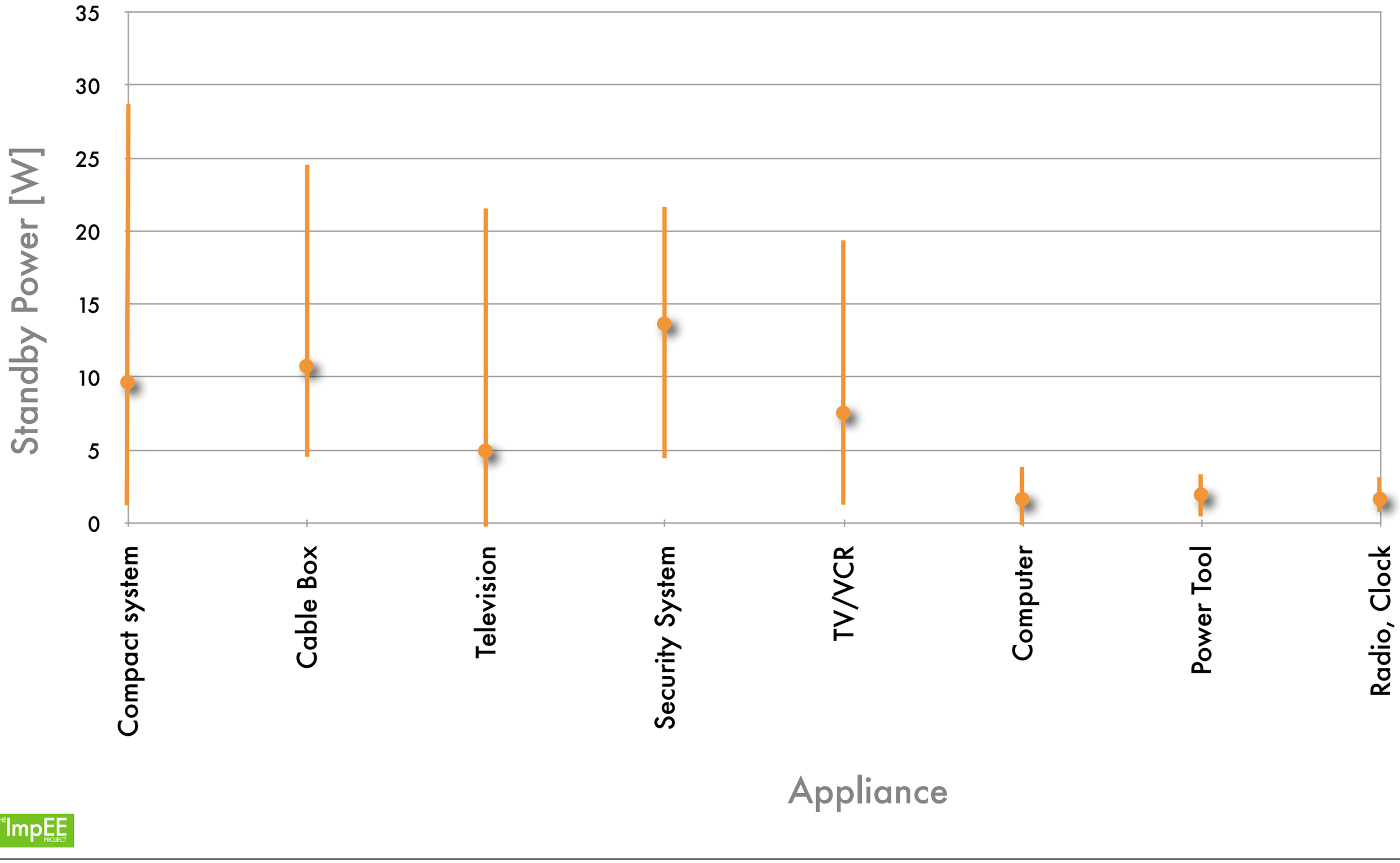
Standby Power Usage



Notes

- Source: http://standby.lbl.gov/Data/SummaryTable.html
- The worst offenders are those that combine complex circuitry with vampire components like remote control sensing: see compact system, security system and cable box.

Selected Standby Power Data



Notes

- Source: http://standby.lbl.gov/Data/SummaryTable.html

Case Study: Set-Top Vampire

- Standby power wastage or "vampire power" causes a significant impact on the environment from the domestic sector

- Average passive standby consumption of a digital set-top box is 7.5W, with highs of over 20W – active standby even higher.
- If this mode is used 70% of the time… 5000 hrs/yr…38 kWh are used annually.
- Corresponds to 25kg CO_2… just to avoid flicking the switch.
- …enough to fill the living room with the GHG.

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Notes

- http://www.energyrating.gov.au/library/pubs/sb200403-stbs.pdf
- "Leaking power tours"around some houses around the world.
- Leaking power accounts for ~80W (~10% of total household energy bill)

Appliance Efficiency

- Legislation and rating systems have made appliances like refrigerators much greener in the last decade
- BUT the lifetime of an appliance is > 10 years: inefficient appliances are still abundant
- And CHEAPER to buy second-hand

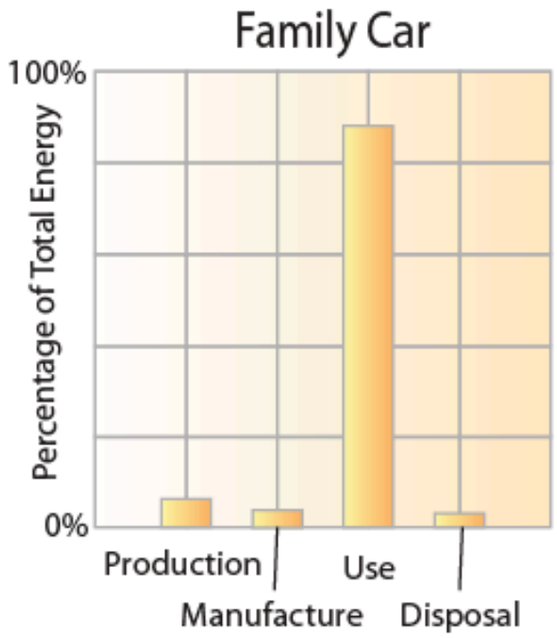
Case Study: Lighting The Domestic Sector

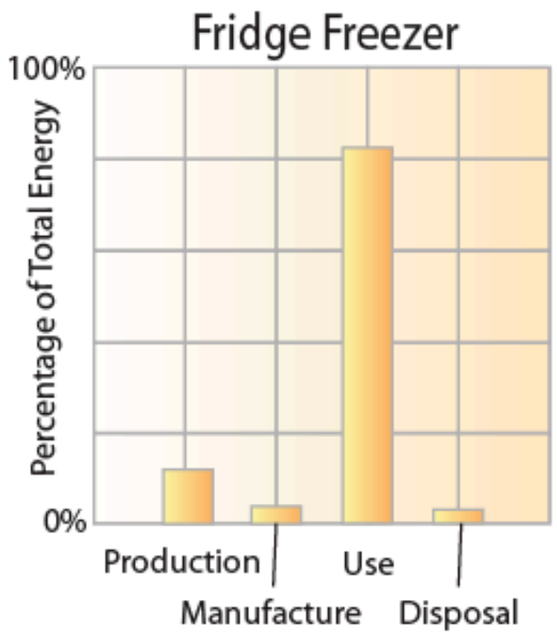
Bulb Type	100W Incandescent	23W Fluorescent	8W LED
Purchase Price	£0.45	£3.99	£5.95
Bulb Lifetime	750 hours	10 000 hours	50 000 hours
Hours on per day	4	4	4
Number of bulbs	~ 6 over 3 years	1 over ~ 7 years	1 over ~ 34 years
Total cost of bulbs	£2.70	£3.99	£5.95
Lumens Produced	1 690	1 500	120
Cost of Electricity	£13.14	£3.02	£1.05
Total cost over 3 yrs	£15.84	£7.01	£7.00

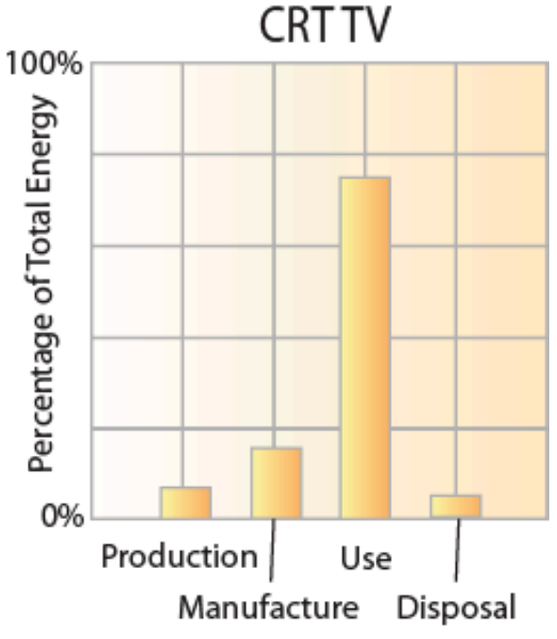
Notes

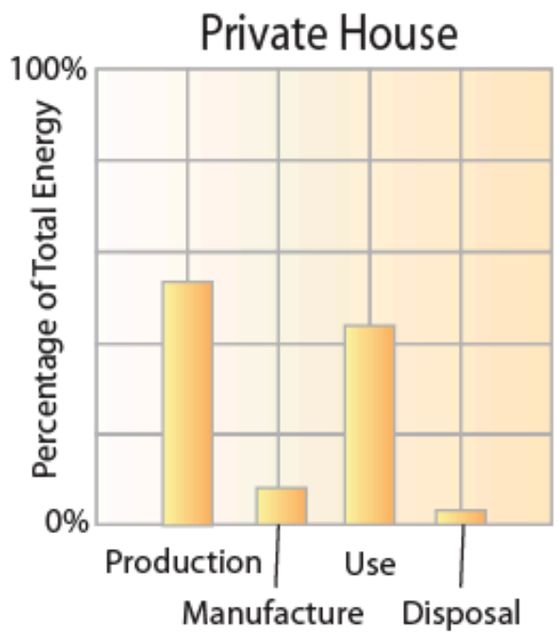
- Sources:
- Maplin Electronics
- Lamina Ceramics
- An illustration of the advantageous purchase of more efficient technology – initially more expensive but economic in the long-term. Electricity cost calculated at 3p/kWh.
- (Note that in 2005, the average unit price of electricity is nearer to 7p/kWh)
- Energy Saving Trust)

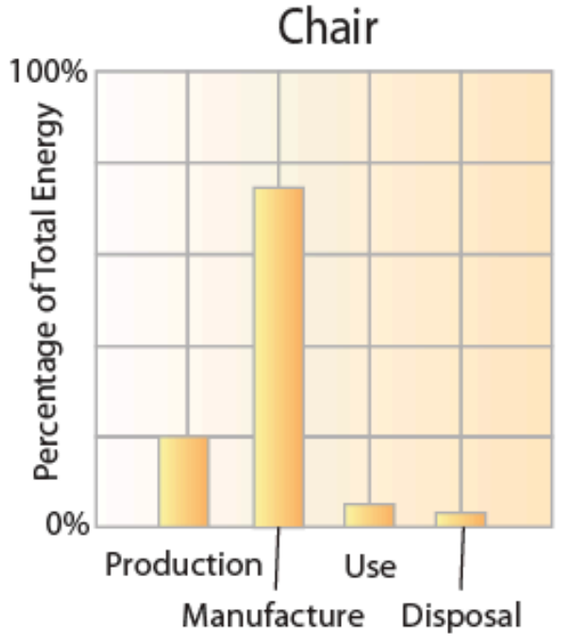
Energy Consumption of Products











Notes

- Which phase dominates the energy lifetime of the product?
- Usually "Use" in the case of appliances: but new technology can increase the energy costs associated with production and manufacture.
- Note that the slide indicating that the production of a new house is the dominant phase assumes a life time of 20 years. As the lifespan of a building increases, the proportions will change considerably, with use becoming dominant.

Case Study: Televisions

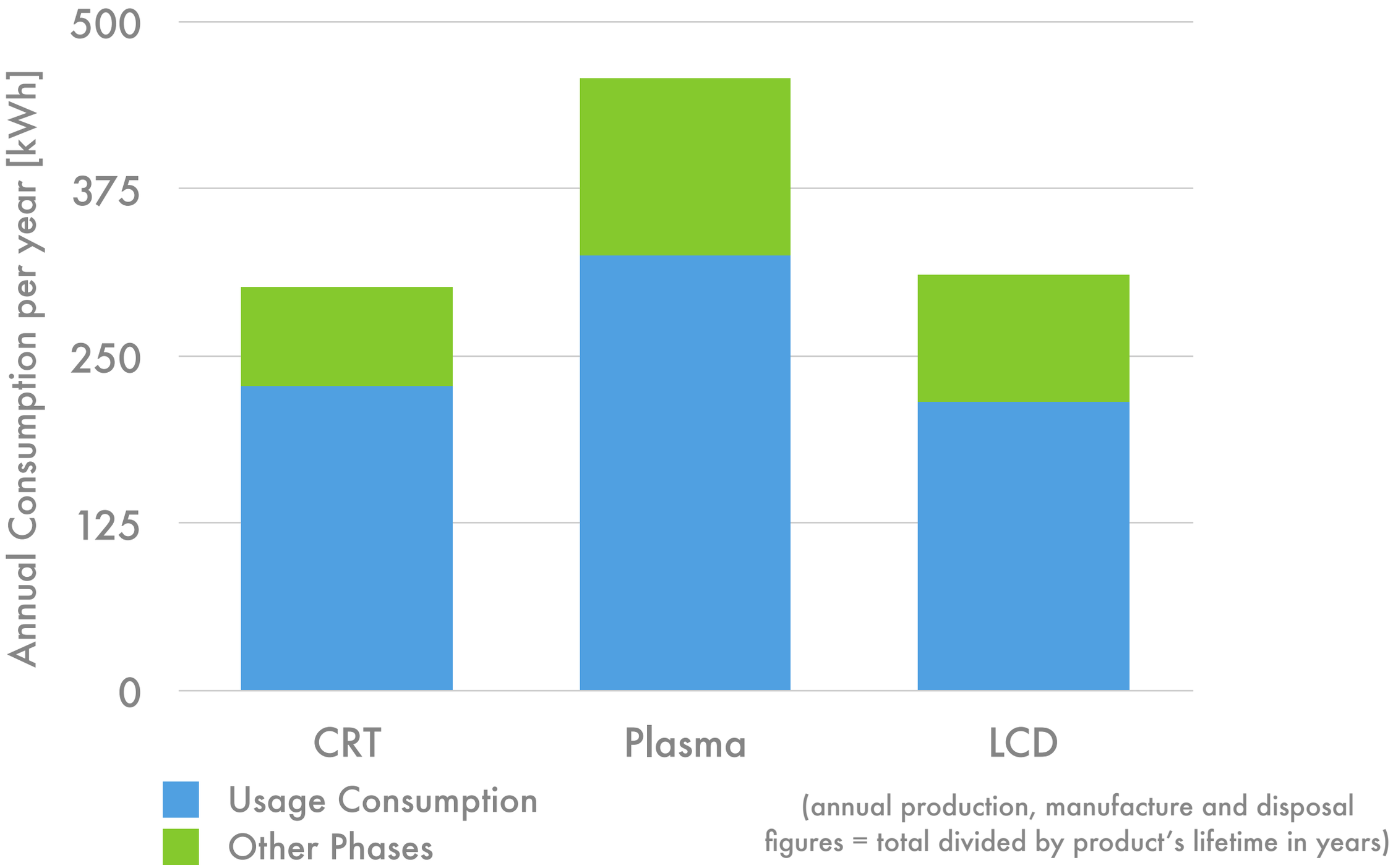
- LCD displays consume less power than CRTs and are generally regarded as the "greener" option.
- BUT construction of an LCD screen and set require a significant release of greenhouse gases…320 kg compared to 220 kg for a CRT…which forms a significant proportion of the overall appliance lifespan emission (~30%).
- Plasma screens are even worse: 430kg, and less efficient in the Use life phase than a CRT
- Also, although LCD screens are more efficient in the Use phase, they are considerably larger… very similar power consumption figures.

Notes

- Source: Panasonic (http://panasonic.co.jp/eco/factor_x/m_pdf/031208_2.pdf)

Television Consumption

All TVs 32-inch screen size.

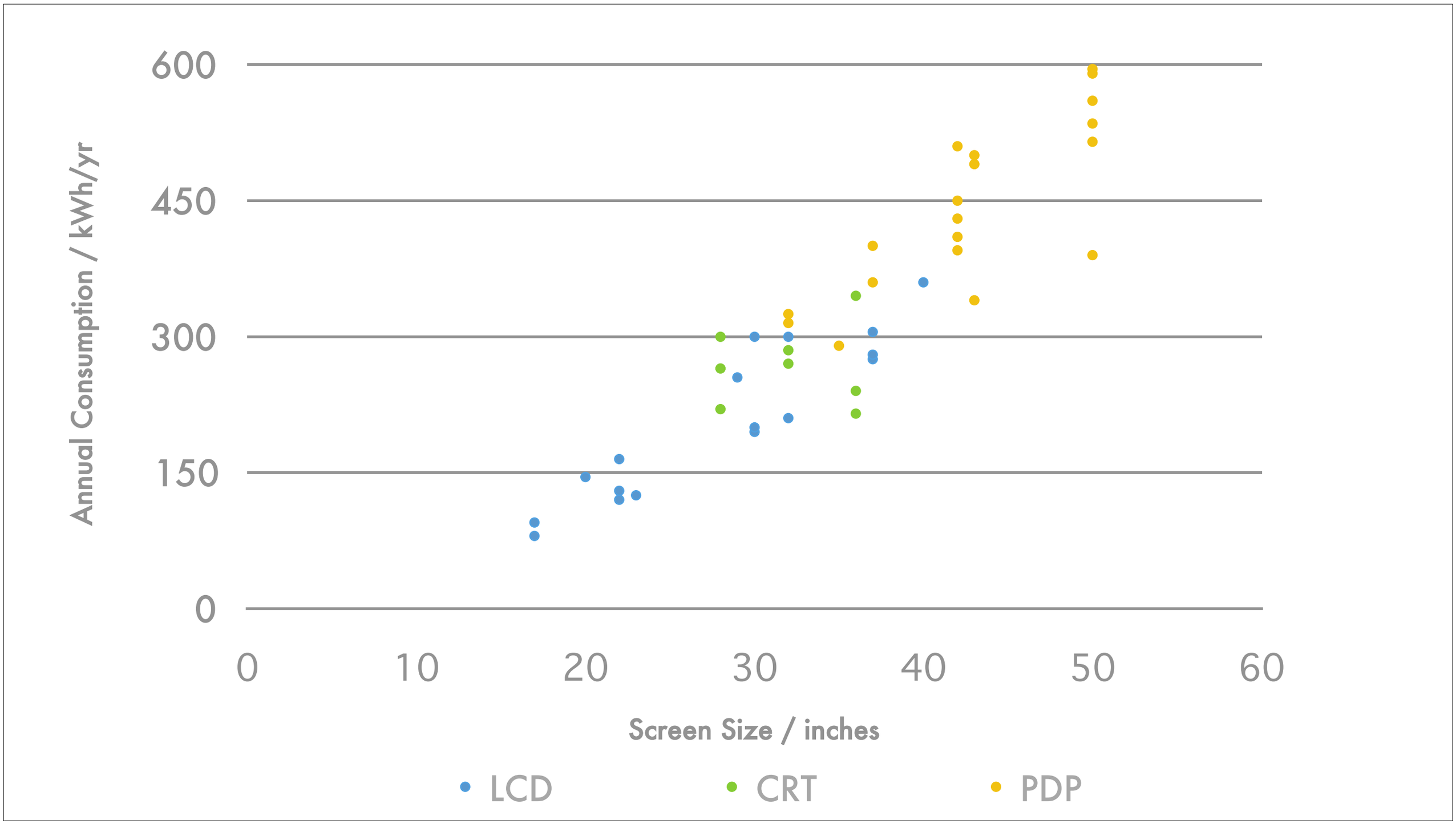


(annual production, manufacture and disposal figures = total divided by product's lifetime in years)

Notes

- Source: Panasonic (http://panasonic.co.jp/eco/factor_x/m_pdf/031208_2.pdf)
- The "Other Phases" data is obtained by first summing the energy costs involved in production, manufacture and disposal of the TV, then dividing this total by the product's lifetime.

Television Consumption by Size



Notes

- Source: Panasonic (http://panasonic.co.jp/eco/factor_x/m_pdf/031208_2.pdf)

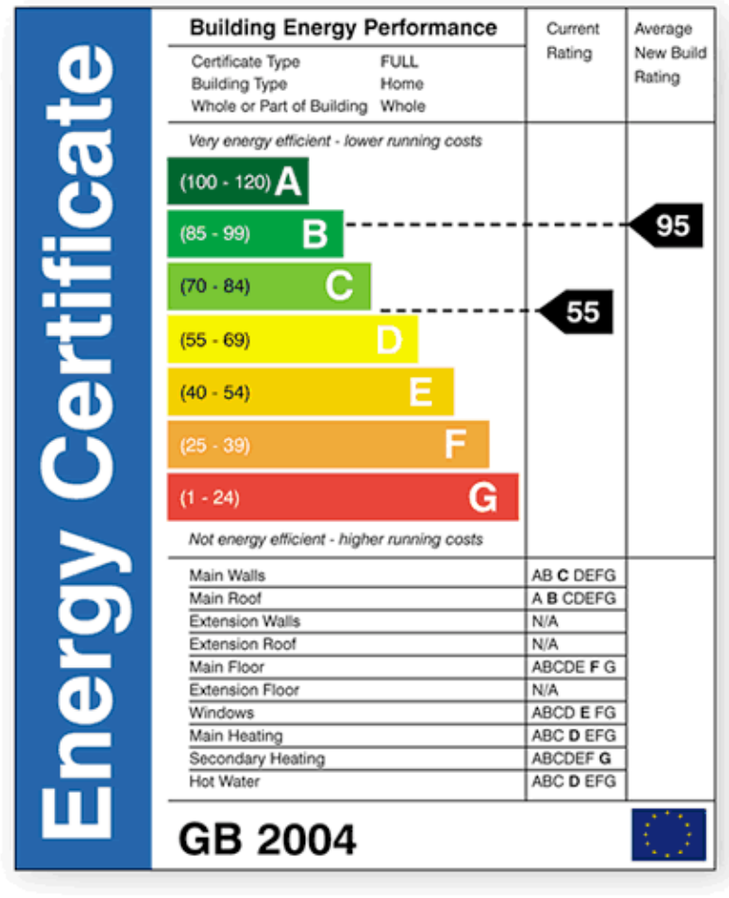
Legislation

Since 2000, all businesses pay Climate Change Levy.
Current rates (Spring 2004) are:

- 0.43p/kWh for electricity
- 0.15p/kWh for gas
- 1.17 p/kilogram for coal
- 0.96 p/kilogram for LPG
  similar arrangement for residential sector?

- Now environmentally sound solutions are economically encouraged…

- But legislation may not always work for the best…



Source - Energy Efficiency: The Government's Plan for Action 2004

Notes

- A fine line exists between positive legislation and inhibiting regulation, particularly in the case of newly-introduced technology.
- The energy rating can be misleading because it is based on the energy use per cubic metre of space inside. This approach favours bigger appliances because, as the size of a fridge increases, the additional energy required to cool the interior decreases. But extra energy is still extra energy, so an A-rated mega-fridge will use far more power than a B-rated under-counter fridge.
- http://money.independent.co.uk/property/homes/article325667.ece
- More information from: Report on Energy Efficiency published by the HOUSE OF LORDS Science and Technology Committee 2nd Report of Session 2005-06 Volume I
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Example 2: Non-linear Switching

- Linear low-dropout regulators (LDOs) frequently used in electronics
- Efficiency > 85% for e.g. 3.3V audio power amp supply from 3.6V single cell Li battery
- Efficiency < 25% when generating a sub-1V processor core voltage: energy dissipated as heat
- Non-linear switching involves using switch-mode dc/dc converters that exhibit high conversion efficiency.
- Recent advances in IC process and packaging technology now allow integration of dc/dc controllers with FETs into small chip-sized packages.
- Increased switching frequencies drive down inductor size and cost, a key factor for small price-sensitive applications.

Notes

- Source: Electronics Products (http://www.electronicproducts.com/ShowPage.asp?SECTION=3700&PRIMID=&FileName=TEXAS.feb2004.html)
- (Accessed August, 2005)

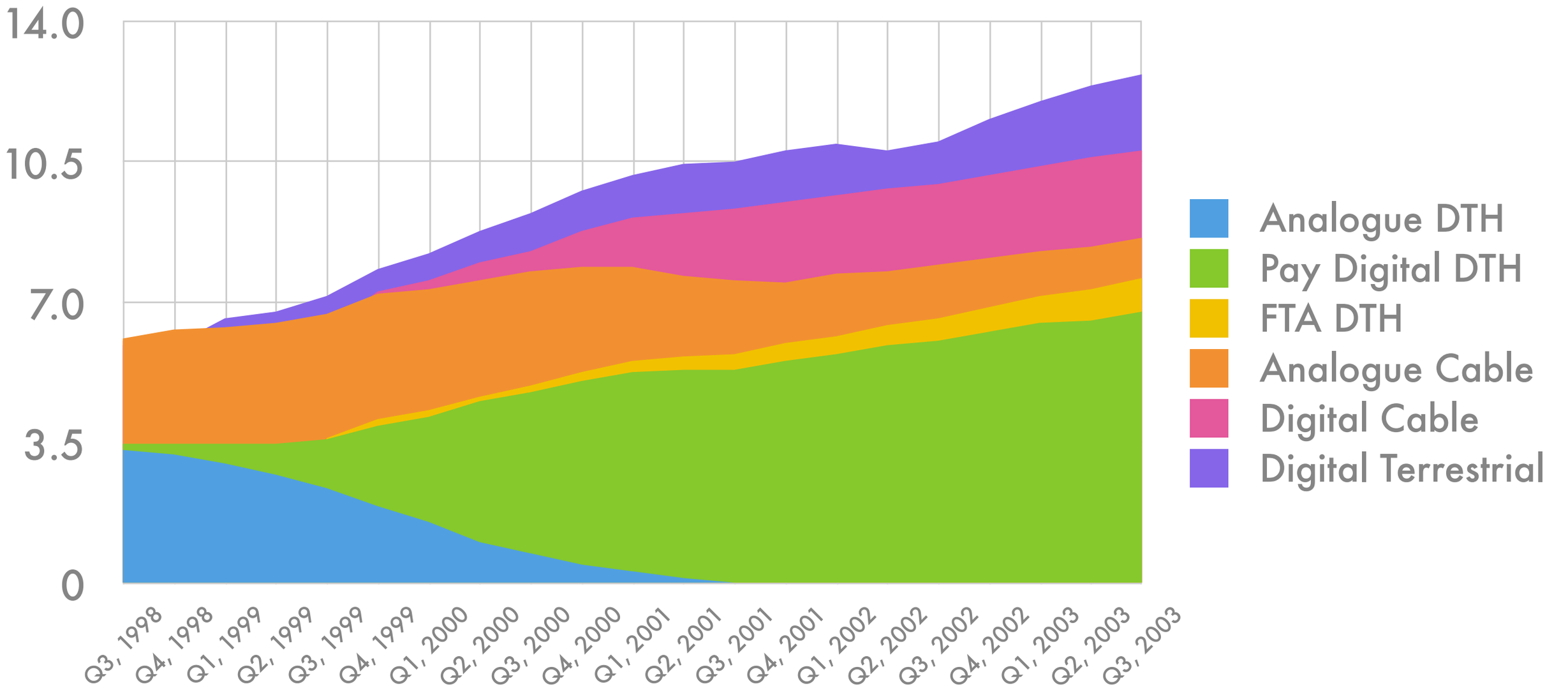
Digital Broadcasting

- Digital set-top boxes are large consumers of both standby and active power.
- Combined with larger, higher-tech TVs, digital penetration has large electricity consumption implications.
- The UK has a greater percentage of digital households than another country - 53% (more than 13 million) of UK households.

Notes

- (Source: Ofcom, figure by 31 March 2004; and Barry Cox, Free for All)
- Energy Conservation Centre, Japan www.eccj.or.jp
- Source: Electronics Products (Accessed August, 2005) ECJRC, http://energyefficiency.jrc.cec.eu.int/

Digital Penetration



- Compare 5W Standby power for a non-multichannel TV to 15W for digital TV and set-top box
- 6 million more households is 60MW more standby power
- This is equivalent to a medium gas power plant

Notes

- **DTH** = "Direct to Home"
- **FTA** = "Free to Air"
- Source: OFCOM *(Accessed August, 2005)*

http://www.ofcom.org.uk/research/tv/reports/dtv/dtv2003q3/#content

Perspective

- The USA uses standby power equivalent to 26 power plant's outputs.
- $1 million were spent in the US keeping "Exit" lights turned on last year.
- The UK uses enough standby power to power 400 000 homes.
- Tumble-dryers can use 38% of their power waiting at the end of a cycle.
- Turning lights off when not in use would save 375 000 tons CO_2 or £55m costs.

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Notes

- Statistics quoted in "The Independent", 23 June 2005
- The effect of standby consumption, at a national level, is breathtaking: in the United Kingdom television sets alone consume some 90 million kWh per month in standby mode. This is approximately equivalent to the continuous output of a small (120 MW) power station. It translates into greenhouse gas emissions approaching 150,000 tC/year. Moreover, these figures apply only to televisions, and fail to take account of all the other forms of equipment – audio equipment, video or DVD players, computers, photocopiers – which revert to standby mode when not in use. The Government estimate that overall no less than 760 million kWh per month of electricity are consumed by appliances not actually in use – the equivalent of 1 GW continuous output, or some 2.25 percent of total United Kingdom electricity consumption, producing of the order of 1.2 MtC per annum.
- More information from: Report on Energy Efficiency published by the HOUSE OF LORDS Science and Technology Committee 2nd Report of Session 2005–06 Volume I
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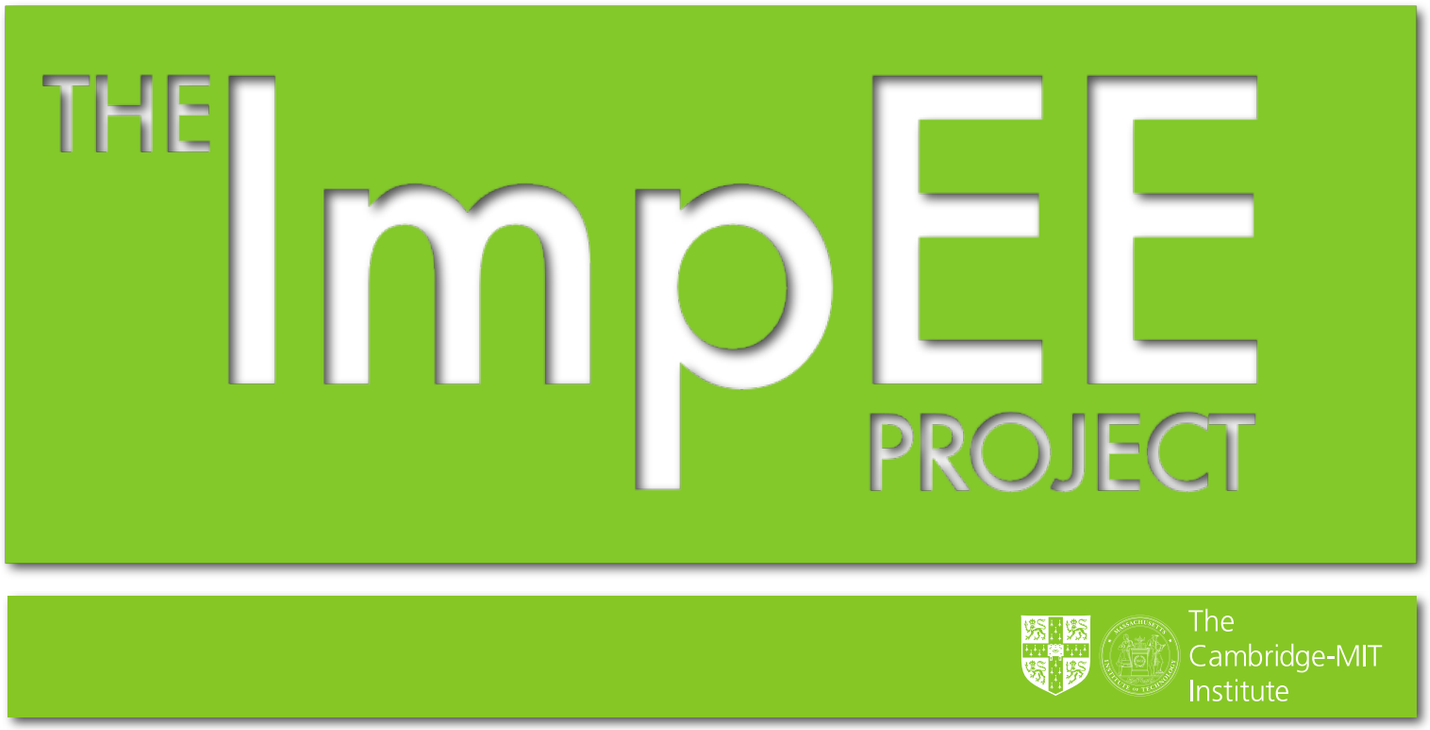

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