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Conceptualizing urban household energy use: Climbing the "Energy Services Ladder"

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A B S T R A C T

This article begins by defining energy services and identifying how they differ according to sector, urban and rural areas, and direct and indirect uses. It then investigates household energy services divided into three classes: lower income, middle income, and upper income. It finds that the primary energy technologies involved with low-income households involve a greater number of fuels and carriers, ranging from dung and fuelwood to liquefied petroleum gas and charcoal, but a fewer number of services. Middle-income households throughout the world tend to rely on electricity and natural gas, followed by coal, liquefied petroleum gas, and kerosene. These homes utilize energy to produce a much broader range services. The upper class or rich have access to the same energy fuels, carriers, and technologies as middle-income homes and families, but consume more energy (and more high luxury items). The study highlights how focusing on energy services reorients the direction of energy policy interventions, that energy services are neither uniform nor innate, and by noting exciting areas of potential research.

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1. Introduction

The late biologist Stephen Jay Gould (2007: 324) once remarked that how a zebra gets its stripes is culturally determined. Predominately Caucasian scientists will argue that it is a white animal with black stripes, proven by its white underbelly. Yet most African people regard it as a black animal with white stripes, proven by the tendency for newly born zebras to be mostly black and grow their stripes later. Gould says that in actuality the Zebra is both white and black, but that one's cultural background and institutional training will shape perception of it.

Energy studies, energy policymaking, and energy reporting seem similarly ensnared in sharing the perception that the most important elements of the energy system are fuels and technologies. We in the community frequently discuss coal, oil, natural gas, and uranium, and even "fuels" such as sunlight and wind, along with complex technologies such as hydrogen fuel cells, carbon capture and storage, advanced nuclear reactors, and superconducting transmission lines, to name a few. But shift the perspective to energy uses and services, and the most serious issues become achieving mobility (rather than purchasing barrels of oil) or light (rather than delivering kWh of electricity). This shift raises a whole set of different issues that energy policy analysis has only begun to explore.

To help aid in that exploration, this article examines how three different types of urban households—lower income, middle income, and upper income—consume and use energy services. While it draws from data from many specific countries, the central goal of the study is to produce a general theory of how urban households of various classes use energy. The article begins by defining energy services and identifies the heterogeneity of such services by sector, urban and rural areas, and direct and indirect uses. It then creates a grounded theory stating that the primary fuels and technologies involved with low-income households involve a greater number of fuels and carriers, ranging from dung and fuelwood to liquefied petroleum gas and charcoal, but a fewer number of services. The primary fuels and energy carriers in middle-income households throughout the world tend to be electricity and natural gas, followed by coal, liquefied petroleum gas, and kerosene. These homes utilize these carriers to produce a much broader range services. The upper class or rich have access to the same energy fuels, carriers, and technologies as middle-income homes and families, but consume more energy (and more high luxury items). The study concludes that shifting to focus on energy services reorients the direction of energy policy interventions, that energy services are neither uniform nor innate, and by noting new areas of potential research.

2. Defining energy services

It is necessary to begin with some definitions and caveats. First is that the author collected data for this article using what

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methodological theorists B.G. Glaser and A.L. Strauss called a "grounded" approach (Strauss, 1987; Glaser and Strauss, 1967). That is, the author collected as many relevant peer-reviewed studies on energy services that he could locate but had no preconceptions about what he would find. The household energy services ladder discussed below is thus built from the "ground up," forming itself around the data, which makes it complicated and unstructured, but also more complex and (the author hopes) accurate. A grounded approach works exceptionally well when few relevant theories yet exist to explain what is being studied, as was the situation with urban household energy services. The author also focused primarily on qualitative data, rather than quantitative data, to paint a sufficiently rich narrative to describe how different households use energy. Shortcomings to this approach include the somewhat subjective nature of synthesizing and coding qualitative data, the limited sample size of articles (the author searched only major energy studies journals with articles written in English), and the messiness of trying to fit a theory around such a large amount of information.

The term "primary energy" means the energy "embodied" in natural resources, such as coal, crude oil, natural gas, uranium, and even falling water, which may be mined, stored, harnessed or collected but not yet converted into other forms of energy (Pachauri et al., 2004). "End-use energy," refers to the energy content of primary energy supplied to the consumer at the point of end-use, such as kerosene, gasoline, or electricity, delivered to homes and factories. "Useful energy," "useful energy demands," and "energy services" are what we are most interested with in this study, and refer to what "end-use energy" is transformed into: heat for a stove or mechanical energy for air circulation (Howells et al., 2005). Energy services are often measured in units of heat, or work, or temperature, but these are in essence surrogates for measures of satisfaction experienced when human beings consume or experience them (Reister and Devine, 1981). Energy services can thus be regarded as the "benefits that energy carriers produce for human well being" (Modi et al., 2005: 9).

Making matters more complicated, however, is the multi-dimensional aspect of energy services. Many services can be multifunctional or dynamic. A hot shower not only cleans human bodies, it can also provide warmth to a room, or steam and humidity when one is sick to cure a cough. A wood brazier can provide cooking, space heating, hot water, or all three. Mechanical energy from a rural microhydro system can be utilized to husk rice, separate mustard seed oil, grind cereals, or move water for irrigation. When modeled, Fig. 1 exhibits the complex networked aspect of one energy service, heat.

Salient differences in energy services occur between sectors, urban and rural areas, and direct versus indirect attributes. Fig. 2 breaks down typical final energy end uses by six basic sectors. The most significant differences appear to be between residential, commercial, agricultural, transport, and industrial needs, as well as between particular countries. Reister and Devine (1981), for example, looked at the key energy services being consumed in the United States and documented space heating and passenger transport at the top of their list in Table 1, yet Fig. 3 shows that the bulk of commercial energy needs in a developing country such as Kenya are related to cooking, metal forging, and casting. Mobility and freight may be the predominate needs for the transport sector, but farmers need water pumping and irrigation whereas industrial firms require process heating or mining and milling (International Atomic Energy Agency, 2005: 156; Karekezi and Majoro, 2002; Barnes and Floor, 1996; International Energy Agency, 2004).

Urban regions, which tend to have higher population density and constraints on space, require and also make easier the delivery of higher-density energy fuels and electricity. Table 2 shows how sectoral energy service needs display variation according to urban and rural contexts. Rural regions, due to their lower population density and comparatively less demand for energy, tend to have limited access to electricity grids and well established distribution systems for modern fossil fuels. In rural markets in the developing world, energy equipment and electric appliances may also be lacking, systems of barter exchange are common, and cash is in limited supply (Pachauri and Jiang, 2008; Habtetsiona and Tsighe, 2002; Karekezi and Majoro, 2002).

Third, and lastly, energy services can differ by direct versus indirect use. Direct energy services involve things such as lighting, heating, cooking, cooling, washing, drilling, sawing, and so on. Indirect uses, however, include the embodied energy in particular goods and services. They can include things like exchange of information, communication, shoes and clothing, buildings, and items purchased at the local supermarket (Haas et al., 2008).

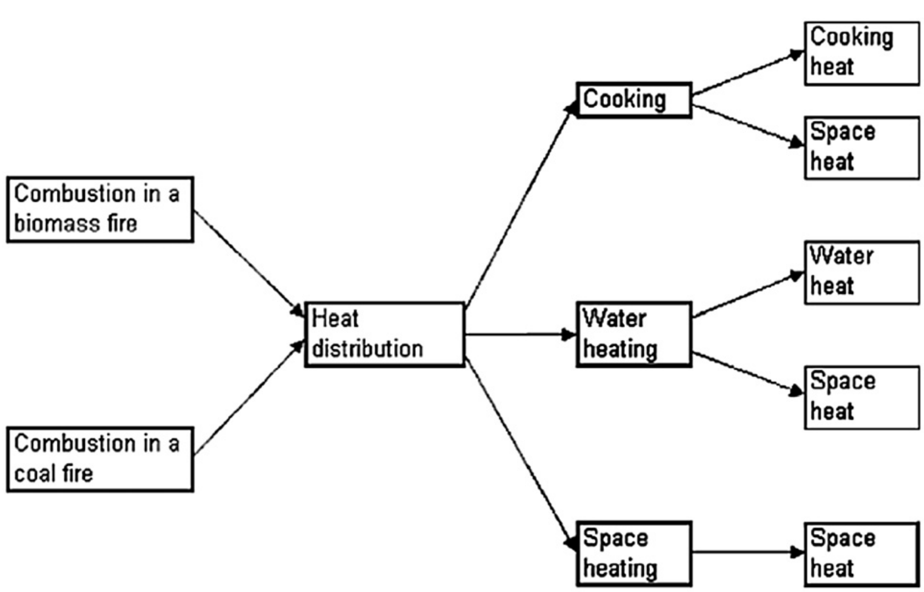

Fig. 1. Model of heating energy services.
Source: Howells et al. (2005: 1840).

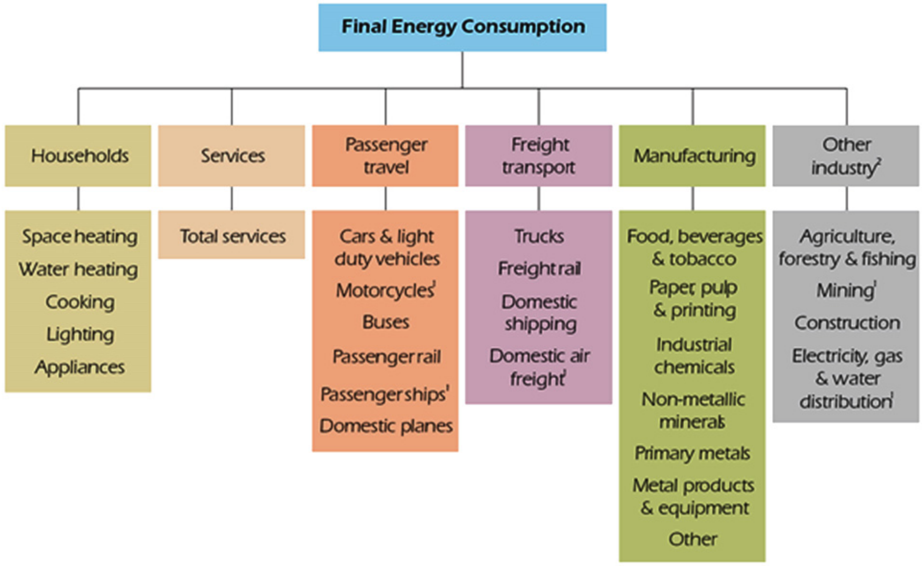

Fig. 2. Six types of final energy consumption.
Source: International Atomic Energy Agency (2005).

Table 1
Fifteen energy services in the United States..
Source: Reister and Devine (1981)

Category	Type	Measure of energy service	Use (% compared to others)	Cost (% compared to others)
General energy services	Space heating	Heat provided to rooms	22.8	10.8
	Water heating	Heat provided to water	3.3	1.2
	Space cooling	Heat removed from rooms	1.7	4.7
	Refrigeration	Electricity consumed	1.2	2.1
	Cooking	Heat provided to cookware	1.1	0.8
	Drying	Heat provided to drying spaces	0.5	0.6
	Lighting	Electricity consumed	1.6	2.5
	Electronic Services	Electricity consumed	0.6	3.4
	Appliance services	Electricity consumed	0.4	2.3
Industrial process energy services	Process heat	Heat provided to manufacturing processes	18.3	2.5
	Mechanical drive	Electricity consumed	1.9	1.1
	Electro processes	Electricity consumed	1.2	2.2
Mobile equipment services	Mobile machinery and service vehicles	Equipment kilometers traveled	2.9	9.1
	Passenger and freight transport	Passenger kilometers traveled	29.0	55.6
Feedstocks	Various manufacturing processes	Heat equivalent of quantity consumed	13.6	1.1

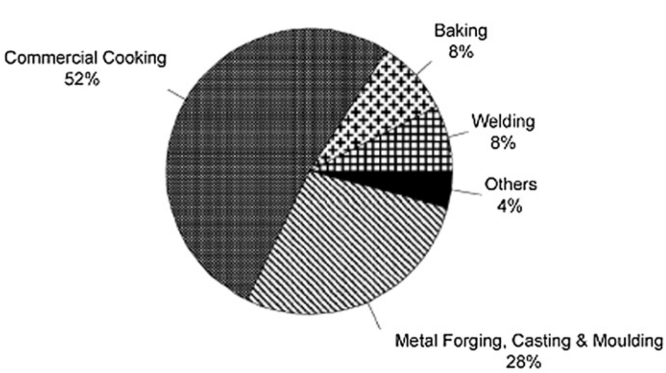

Fig. 3. Commercial activities for small and medium enterprises in Africa.
Source: Karekezi and Majoro (2002).

This study has decided to focus on direct energy services and uses at the urban scale involving the residential and household sector. It does so not only for the sake of simplicity (and the obvious limitations of space), but also because households are where most energy consumption occurs. Moll et al. (2005) estimate that 70–80% of national energy use in the United Kingdom are related to household activities directly, required to deliver goods and services to households, or to manage waste flows that they create. Similarly, Vandenbergh and Steinemann (2007) found that energy use at private homes and vehicles accounted for one-third of annual carbon dioxide emissions in the United States. When aggregated, such emissions are greater than those from the entire industrial sector for the country and are also larger than the total emissions from countries such as Canada, South Korea, and the United Kingdom, as well as the global chemical manufacturing and petroleum refining industries.

The focus on energy services may seem quite banal to some, but it has two unique benefits.

First, emphasizing services underscores the complexity of the demand-side for energy. Energy services cut across inputs, outputs, domains, technologies, fuels, and users (Haas et al., 2008). They can be categorized based on sector, e.g. transport services are different from household services which differ still from

Table 2
Urban and rural distinctions in energy services.

Sector	Energy service	Fuel for urban areas	Fuel for rural areas
Households	Cooking	Wood, charcoal, coal	Kerosene, wood, dung, residents, biogas
	Lighting	Kerosene, electricity, LPG	Candles, kerosene, or none
	Space heating	Wood, residues, coal, kerosene, LPG	Dung, wood, residents, coal
	Appliances	Electricity	Solar, batteries, or none
Agriculture	Plowing	–	Diesel, animate
	Irrigation	–	Diesel, electricity
	Food processing		Diesel, electricity
Industrial	Mechanical	Diesel, electricity	Manuel, animate
	Process heating	Electricity, natural gas, coal	Charcoal, coal, wood

Table 3
Fuels and technologies involved in providing five energy services.
Source: Girardet and Mendonca (2009: 105).

Energy service	Sector/scale	Conventional fuel(s)	Renewable fuel(s)
Cooking	Homes, restaurants, commercial stoves and ovens	Liquefied petroleum gas, kerosene	Direct biomass combustion, biogas from digesters, solar cookers
Lighting	Homes, schools, street lighting	Candles, kerosene, batteries, diesel generators	Hydroelectric power, biogas and biomass gasification, wind and solar minigrids
Refrigeration	Homes, hospitals	Diesel generators	Hydroelectric power, biogas and biomass gasification, wind and solar minigrids
Water pumping	Agriculture, drinking water	Diesel pumps	Mechanical wind pumps, solar photovoltaic pumps
Heating and cooling	Crop drying, agricultural processing, hot water	Liquefied petroleum gas, kerosene, diesel generators	Biomass combustion and biogas, solar crop dryers, solar water heaters

Table 4
Energy services, fuels, and technologies for commercial enterprises in Africa.
Source: Karekezi and Majoro (2002).

Activity	Fuel	Technology	Alternative technology
Food kiosks	Charcoal, kerosene	Stove	LPG, biofuel stove
Small restaurants	Charcoal, kerosene, electricity, natural gas	Stoves, electric cookers	Biofuel stoves, more efficient electric stoves
Small shops	Kerosene, electricity	Refrigerators, stoves, lanterns	More efficient devices
Laundry	Charcoal, electricity, sunlight	Flat iron, washing board	
Tailoring	Animate, electricity	Sewing machines, flat irons	More efficient electric motors
Beer halls	Kerosene, electricity	Refrigerators	More efficient devices
Video halls	Electricity	Televisions, VCRs, DVD players	More efficient devices
Taxis	Petroleum	Petroleum and diesel engines	More efficient automobiles
Vehicle repair	Electricity, gas	Welding equipment, grinders, lathe machines, compressors	More efficient motors
Electrical repair	Electricity	Soldering equipment	
Butcheries	Electricity	Lightbulbs	Tubes and CFLs
Tire repair	Kerosene	Heaters, compressors	More efficient motors and devices
Health clinics	Electricity	Sterilizers, water boiling equipment, refrigerators	Solar water heaters, tubes and CFLs, more efficient equipment
Churches and mosques	Electricity	Incandescent lightbulbs	Tubes and CFLs
Metal household items	Electricity, charcoal	Heaters	More efficient devices
Pottery	Animate, wood	Rollers	Solar dryers, electric rollers
Woodwork and furniture	Animate, electricity	Cutting and planning equipment	More efficient motors
Grain milling	Diesel, electricity	Electric motors	More efficient motors
Paint manufacturing	Animate, electricity	Mixers, incandescent lightbulbs	Efficient motors, tubes and CFLs
Bakeries	Electricity, animate	Mixers, ovens	More efficient devices
Coffee processing	Firewood, electricity	Heaters, blowers, motors	More efficient devices

commercial or industrial needs. They can be categorized by fuel, e.g. electricity can get you light and refrigeration, gasoline can get you mobility and convenience, and fuelwood can get you heat. They can even be categorized by the service itself, such as motive power, status, convenience, entertainment, and so on, although such a list could possibly extend for many pages. Tables 3 and 4 depict the complexity of energy services nicely, showing how a particular service such as cooking can encompass multiple sectors, fuels, and technologies. Energy services therefore offer a rich terrain to explore the complications of how humans use energy.

Second, energy services and uses emphasize the role of culture and social values in driving energy consumption. To use an analogy to computers, our bodies are like genetic hardware where culture is the software (Wilk, 2002). Culture determines how we learn, where we live, the languages we use to communicate, the philosophical systems we develop, and the technologies we design. It is not innate, but learned individually and in groups over time. Culture's influence on energy consumption is multigenic, affecting how and why we use energy. To cite three examples, Fouquet (2008) looked at the history of energy and noted that energy choices have long been intimately tied up with intangible elements like status or comfort; medieval lords proudly burnt coal to encourage guests to attend festivals and modern day environmentalists place solar panels on their roof to make an ethical statement. Agbemabiese et al. (1996) explored the growing use of air conditioning and found that comfort levels and the desire for cooler temperatures differed between industrialized countries and tropical developing countries. When residents from such tropical developing countries visited Western countries the lower temperature comfort levels were "transmitted" so that they returned home and adopted air conditioning. Wilhite et al. (1996) investigated household energy use in Japan and Norway and documented that despite average dwelling size, similar levels in standards of living, and economic activity, culture played a significant role differentiating energy needs. The Japanese and Norwegians all had different practices for space heating, lighting, clothes washing, dish washing, cooking, and hot water. Because energy services are intimately tied to human behavior, focusing on them helps reveal the meaningful ways in which energy using behavior differs.

3. Energy services for three types of households

To investigate residential energy services it is useful to divide urban households into three rough classes: lower income, middle income, and upper income. For this study middle income refers to people living within four member households with a purchasing power of about $10,000–$20,000 per year in PPP terms. These households make up 12–56% of population in developing countries and 61–96% of the population in industrialized countries (Myers and Kent, 2003: 4963). Lower income households are those with a purchasing power below that range and upper income households are those above that range in PPP terms. As Table 5 summarizes, the fuels and energy carriers, primary energy services, and driving factors for each category of household differs markedly, creating a sort of "generic" or "universal" energy services ladder. The remainder of this section explains why.

3.1. Lower-income households

The primary fuels and technologies involved with energy services for low-income households involve (perhaps curiously) a greater number of carriers but a fewer number of services than their middle- and upper-income counterparts. One study of energy use in a broad range of developing countries identified two primary services—cooking and lighting—as well as two secondary services (sometimes running appliances and space heating), with the two primary fuels of wood and animal dung (Barnes and Floor, 1996). Other studies have shown that without access to modern energy carriers, women and children are typically forced to spend significant amounts of time searching for firewood, and then burning wood and charcoal indoors to heat their home or prepare meals (United Nations Development Programme, 1997), and that such households rarely have access to electricity and instead depend on wood, charcoal, agricultural waste, and animal dung for energy (Malyshev, 2009). Another survey identified lighting, television, radio, and telephony as predominant services in low-income households along with cooking and hot water (Dutschke et al., 2006). Howells et al. (2005) looked at energy services in Africa and found that the majority of energy use centered on cooking and space heating dominated followed by water heating, lighting, refrigeration, and televisions and radios.

The prevailing driving force behind this energy use is subsistence. Poor households use energy to survive, to cook food and keep warm. Women and children in such homes, for example, spend several hours each day indoors cooking and outdoors searching for fuel. In some countries more than 90% of households rely exclusively on solid fuel, directly combusted inside the home, to meet their energy subsistence needs (Malyshev, 2009). Even television, when watched, is often done so for educational purposes or to keep up to date with pertinent business news.

3.2. Middle-income households

The primary fuels in middle-income households throughout the world tend to be electricity and natural gas, followed by coal, liquefied petroleum gas, and kerosene. These homes utilize these carriers to produce a much broader range of end uses and services. One international comparison of how homes utilized energy in Australia, Canada, Denmark, Finland, France, Germany, Italy, Japan, Norway, Sweden, United Kingdom, and the United States found that the top five energy services for households were (in order)

Table 5
The urban household energy services ladder.
Source: Modified from Sovacool (2010).

Household type	Primary fuels/energy carriers	Primary technologies	Primary energy services	Broader driving factor(s)
Low income	Wood, dung, kerosene, charcoal, coal, biomass, liquefied petroleum gas, paraffin, candle wax, biogas, agricultural waste, diesel, coconut oil, sunlight	Cookstoves, open fires, candles, solar cookers, small solar home systems	Cooking and lighting, occasionally television, telephony, radio, mobile phone charging, space heating, refrigeration, and hot water	Satisfying subsistence needs
Middle income	Electricity, natural gas, coal, liquefied petroleum gas, kerosene, fuel oil	Large solar home systems, televisions, radios, DVD players, air conditioners, refrigerators, water heaters, dishwashers, clothes washing machines, computers, printers, other modern appliances	All low-income services plus space heating and cooling, hot water, cooking, entertainment, and lighting, refrigeration and freezing, clothes washing and drying, computing and surfing the internet, watching television, advanced telecommunication	Convenience, comfort, and cleanliness
High income	Electricity, natural gas, fuel oil	Multiple air conditioners, refrigerators, water heaters, dishwashers, clothes washing machines, other advanced appliances	All of the middle-income services above plus luxury practices such as swimming in a heated pool, going to the bathroom with a heated toilet to the sound of music, and watching television while one cooks	Conspicuous consumption and social signaling

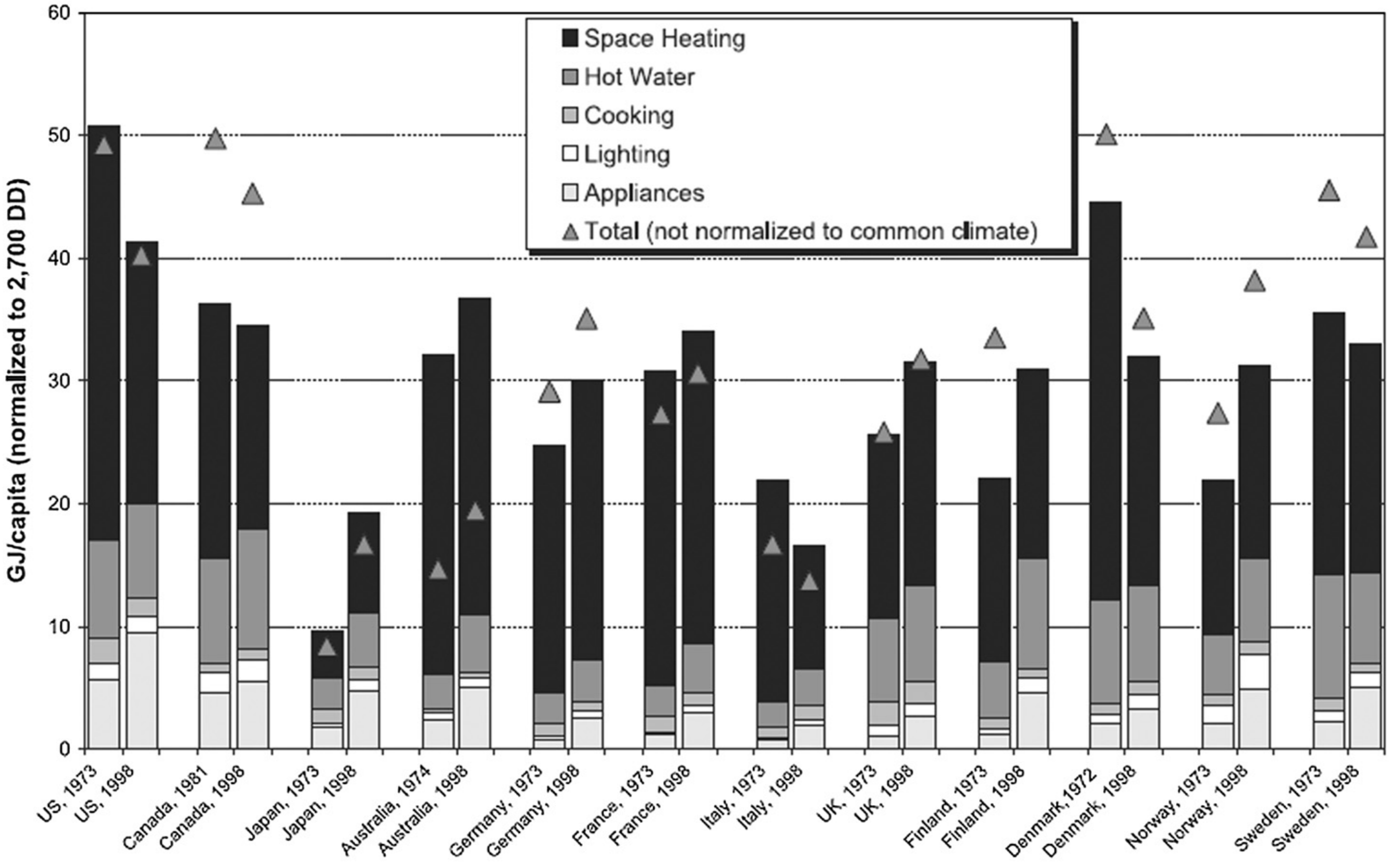

Fig. 4. Residential energy use in twelve industrialized countries.
Source: Unander (2005).

Table 6
Energy end uses at American homes.
Source: Gardner and Stern (2008).

Energy service	End-use	Percent
Transportation		**43.4**
	Private motor vehicles	38.6
	Air travel	3.4
	Mass transportation	1.4
Heating and cooling		**35.8**
	Space heating	18.8
	Air conditioning	6.2
	Water heating	6.5
	Refrigeration and freezing	4.3
Other appliances and lighting		**20.8**
	Lighting	6.1
	Other electric appliances	3.9
	Clothes washing and drying	2.5
	Color televisions	2.5
	Cooking	1.5
	Computers	0.6
	Propane and natural gas (swimming pool heaters, grills, and lamps)	0.5
	Dishwashers	0.2
	Other	3.0

space heating, hot water, cooking, entertainment, and lighting (Unander, 2005). Fig. 4 presents the study's results. Such households also have access to informational services such as computing and telecommunication. A study on household energy use in the United States documented that the majority of energy consumed by an average American household was directed at two purposes: running a private motor vehicle and heating and cooling a home, depicted in Table 6 (Gardner and Stern, 2008).

Table 7
Prices of end-use energy in Britain, 1300–2000 (1900 = 100).
Source: Fouquet (2008).

	1300	1500	1700	1750	1800	1850	1900	1950	2000
Heat		225	275	300	140	110	100	80	28
Power	85	155	160	165	185	150	100	50	12
Transport	390	360	690	790	330	260	100	75	20
Lighting		950	1115	1170	570	300	100	6	1

The driving factors behind "middle class" energy consumption are both economic and social. Economically, the growing demand for energy services has been motivated by substantial reductions in cost coupled with improvements in quality. Fouquet (2008) assembled data on fuel use and prices from the years 1300–2000 for four main energy services in the United Kingdom: heating, power, transport, and lighting. Table 7 presents his findings, and it shows that since 1750 the cost of lighting has fallen by a thousand, transport a factor of 40, and heating a factor of ten. In each case, Fouquet notes that as the cost of energy services has fallen, consumption has increased. Candles have been replaced by oil and gas lamps and then electric ones, making light so abundant some discuss "light pollution."

Socially, the forces behind energy consumption have been aptly described by Anthropologist Elizabeth Shove (2003, 2004) as convenience, comfort, and cleanliness. Comfort refers to one's satisfaction with the immediate physical environment, strongly associated with the ability to control indoor climate (a factor which explains the recent global rise of air conditioning). Cleanliness refers to more than removal of dirt and is a relational or umbrella concept that encompasses the distinctive ideas of display, disinfection, and deodorization. Shove's paradigmatic example is the washing machine, which transforms soiled clothing into a fresh, scented, fluffy, and ready to wear experience. Convenience involves helping save or shift time, either by helping one coordinate their lifestyles or by keeping one on schedule. Convenience can also refer to reducing the effort needed to do a job as well as improving the quality of an experience, such as watching color television instead of black and white (Spreng, 1993; Sovacool, in press).

Convenience, when it involves saving time by speeding things up, can be especially deleterious on efficient energy use. Illich (1974: 3) once quipped that beyond a certain speed no one can save time without forcing another to lose it. Aluminum smelters, for example, reach maximum thermodynamic efficiency by performing the process incredibly slowly. Efficient smelting, though, would never meet the rapid demands of the economy, so its production results in essential efficiency losses (Spreng, 1993). The optimal energy efficiency for a moving automobile is something like 40 miles per hour, taking into account the rolling resistance of tires, engine, friction, aerodynamics, and gears, yet hurried drivers will go twice as fast to save time (Spreng, 1993).

Even Fouquet (2008) notes that throughout history the demand for new energy services was *not* always inevitable; in many cases it resulted from demand creation. Clever entrepreneurs and marketers used advertising to convince people to switch to new forms of energy use, from gas lamps to electric light bulbs, and from the stagecoach to the automobile. Moreover, Fouquet found that for transitions from one energy carrier or technology to the next, substitute fuels need not be cheaper than the originals, they must only possess improved characteristics in terms of comfort, convenience, or cleanliness.

These twin culprits—lower costs, enhanced services—have overwhelmed recent improvements in household energy efficiency. Loveday et al. (2008) noted that in the Western world, consumers want everything "now." Convenience has become paramount, with even nighttime no longer reserved for sleeping, making it the "new playtime." People demand around the clock, continuous access to healthcare, television and radio programming, satellite services, high speed connections to the internet, banking, mail order shopping, and supermarkets. While the efficiency of heating systems and electric appliances as a whole has improved by about 2% every year since 1970, increased use and changing preferences and tastes (such as warmer homes in the winter) have more than offset these gains. Loveday et al. (2008: 4642) document that where residential consumption of electricity has grown 32% in the United Kingdom from 1970 to 2005, the electricity consumed by domestic household appliances and lights has jumped 70%.

A similar transition is occurring in developing countries such as China and India. There, the share of residential energy use met from the centralized grid jumped significantly over the past few years, with increases in income, urbanization, and lower energy prices all driving a shift away from solid and liquid fuels (Pachauri and Jiang, 2008). One recent assessment of household energy use in China found that household electricity demand grew at an average rate of 6.2% the past three years, and that almost every home surveyed put energy to use for lighting, cooling, heating, and household appliances. As Table 8 describes, the average Chinese household in Liaoning Province has two wall-mounted air conditioners, two fans, an electric water heater, nine lights and lamps, two televisions, a laptop computer, one refrigerator, and a variety of other appliances (Dianshu et al., 2010).

3.3. Upper-income households

While a bit more difficult to distinguish, the upper class or rich have access to the same energy fuels, carriers, and technologies as middle-income homes and families, they just consume more energy (and have more high luxury items such as multiple kitchens, multiple sets of the same appliance, heated swimming pools, and elaborate outdoor grills).

This point is best illustrated with a Gini coefficient or Lorenz curve, which looks at the degree of income concentration related to energy (varying between 0 for perfect equality and 1 for maximum inequality). Jacobson et al. (2005) analyzed the equity of energy use in El Salvador, Kenya, Norway, Thailand, and the United States. The study found that in every country the rich consumed more energy than the poor, and that even the "best" country was still prone to this trend. The top 38% of homes in Norway (classified by income), which was the most equal, consumed 50% of the country's residential electricity; the richest 25% of homes in the United States, which came second, consumed 50% of its electricity. Other studies have confirmed similar trends at the national level in Greece (Rapanos and Polemis, 2006), Mexico (Rosas-Flores et al., in press), and the United Kingdom (Hunt et al., 2003), as well as at the village and household level in India (Fernandez et al., 2005) and the technological level (for things like clothes washers, clothes driers, refrigerators, and freezers) (Druckman and Jackson, 2008). Papathanasopoulou and Jackson (2009) looked at fossil fuel consumption in the United Kingdom from 1968 to 2000 and found

Table 8
Typical household appliances at a Chinese home in Liaoning Province, China.

Lighting			**Cooling**		
Energy-saving circline lamp	1	32 W	Air-conditioner	1	1600 W
Energy-saving circline lamp	1	22 W	Air-conditioner	1	815 W
Energy-saving Ubent lamp	2	18 W	Fan	1	60 W
Compact fluoresecent bulb	2	32 W	Fan	1	45 W
Fluorescent lamp	3	30 W			
Heating					
Electric heater	1	2200 W	Fan for heating	1	1200 W
Water heater	1	1200 W	Bathroom heater	1	1100 W
Household appliances					
TV set	1	150 W	PC	1	250 W
TV set	1	255 W	Laptop	1	300 W
Cooker	1	600 W	Vacuum cleaner	1	1400 W
Micro-oven	1	800 W	Washing machine	1	200 W
Range hood	1	250 W	Induction cooker	1	2100 W
Water dispenser	1	500 W	Refrigerator	1	0.77 kWh/24 h

that higher incomes result in greater inequality related to the consumption of fuel and light, car use, recreation, and travel. Sovacool and Brown (2010) found a nearly perfect monotonic relationship between carbon footprints and per capita national income for a sample of 12 large metropolitan areas spread across the developed and developing world. Myers and Kent (2003) looked at "middle class" consumption patterns in 14 countries and found extreme asymmetries in wealth. In India, the upper middle class account for less than one-eighth of the population, but have two-fifths of the country's purchasing power and account for 85% of private spending. Put another way, per capita energy consumption from these more affluent homes is 15 times greater than those of the rest of India's population (Myers and Kent, 2003: 4963). In Australia, middle and upper income households consumed as much as four times the amount of fuel, light, power and transport services than lower income homes (Van Hoa, 1985).

Apart from consuming more, wealthier homes are more resilient and can better withstand increases in the price of energy fuels and services. Lutzenhiser (1993) demonstrated that when faced with scarcity or increases in price, low-income households often cutback consumption and make lifestyle changes. Middle and higher income homes, however, maintain consumption or purchase more efficient equipment such as newer appliances or cars that use less fuel or energy.

The end result is that upper income households can extravagantly use energy. The affluent will do things like turn up the thermostat during the winter because it is more convenient than putting on extra clothing (Loveday et al., 2008). In the United Kingdom, affluent families are reputed to heat their outdoor swimming pools to bath temperature all year round so they can lie in the pool at winter and look up at the stars, costing them £3000 on fuel per month (Monbiot, 2009). Wealthier homes in Japan feature toilets that can warm and wash one's bottom, "whisk away odors" with built-in fans, produce water noises to drown out sounds, and play relaxation music. They can be installed with automatic sensors to detect when someone enters or leaves the bathroom and raise or lower their lids accordingly, and most have "learning modes" to record and adjust to the lavatory schedules of different household members. Such toilets use more electricity than dishwashers or clothes dryers, and accounted for about 4% of Japanese household energy consumption in 2008 (Harden, 2008).

The primary driver behind such luxurious energy use appears to be what anthropologists, sociologists, and economists have termed "conspicuous consumption" and "social signaling" (Jackson, 2005). Human beings may consume more energy as a form of communication, signaling to others that they have the affluence and financial resources to waste energy; or as an act of socializing into a group, such as belonging to a class of people that own a swimming pool. Anthropologists Douglas and Isherwood (1979) have shown how affluent groups can consume material goods and energy to cement and maintain social relations; such consumption can extend beyond the mere need to "display" one's affluence and serve a vital psychological purpose in helping the individual maintain and improve their sense of self and identity. In his meta-survey of the literature, Lutzenhiser (1993: 171) concludes that the "status-marking attributes of buildings and equipment, and the residential segregation of persons by social status, are seen in this analysis as particularly relevant to the macro-patterning of energy use. Regardless of theoretical preference, we find that income is strongly associated with the consumption of resources, such as water and the indirect energy embodied in goods and services, as well as with housing characteristics, electricity use and rate structure preferences, and attitudes toward and access to conservation."

In the United States, for instance, Wilk (2002) noted that multiple trends were driving increased energy use among the affluent. The breakdown of families and communities, and the rise of the individual, promotes greater per capita use since smaller families mean less people use the same water heater, refrigerator, space heater, and electric appliances. Such social changes also fuel the need for services once provided by friends and family, such as child care, cooking, and home repair, to now be provided by technology. Status competition, and conspicuous energy consumption, has become a way to mark people as belonging to a certain class; such values can be emulated and copied by others. The need for identity in an insecure world means that the wealthy become attached to material objects and possessions, which can influence their decision to purchase larger homes with greater floor space that in turn result in greater heating and cooling needs and demand for more electric appliances. Wilk commented that such a trend is worsened by pressures induced by marketing for new gadgets and devices. As societies grow in wealth, they become more obsessed with comfort and convenience. Once basic needs, such as food and shelter are satisfied, people focus more on leisure and entertainment. All of these threads—individualism, smaller families, status competition and emulation, materialism, leisure and luxury—weave together a tapestry of values and norms predisposed towards greater energy use.

In China, Feng et al. (2009) looked at variations in household energy use and discovered considerable variation between southeast and northwest regions of the country, and urban and rural households. The authors state that both correlate to affluence or levels of income. When disaggregated according to lifestyle and consumption patterns, fuel consumption and electricity use grow almost lineally with income. The consumption level of wealthier urban Chinese residents is twice as much as poorer rural residents. Or, as the authors conclude, "affluence is by far the strongest driving force behind the increase in CO_2 emissions" (Feng et al., 2009: 150). With growth in income, newly affluent Chinese spend more on recreational and educational activities, consume more meat and fish, spend more on transport, education, and medical services, all which use more energy. Rich urban residents move out of their tiny bungalows and apartments that they often shared with family to new blocks alone, increasing the need for more beds, sofas, washing machines, refrigerators, air conditioners, mobile phones, and automobiles.

Conversely, energy efficiency and consuming less energy can be affiliated with lower classes and households, convincing the wealthy to intentionally *ignore* suggestions to cutback consumption. Efforts to distribute evaporative coolers, weatherization techniques, and geothermal heat pumps in the Pacific Northwest of the U.S. were functionally "stigmatized" for their association with poorer households. Surveys with builders and real estate agents found that many perceived the more efficient technologies as "low-class" and "trashy" after a successful energy program had distributed these technologies primarily to low-income areas (Sovacool, 2008).

4. Conclusion

First, examining energy services rather than energy technologies and fuels reorients the direction of energy policy interventions. Proper policy no longer becomes about acquiring barrels of oil or tons of coal as an end in and of itself, but the mobility and comfort those fuels engender. An energy policy dedicated only towards securing oil or coal would tend to limit the range of options towards those two fuel chains, but a policy aimed at mobility or comfort would include a diffuse array of options such as walking, cycling, and running (for mobility) and altering conceptions of luxury and promoting more efficient electric appliances (for comfort).

Second, energy services are neither uniform nor innate. The poorest families in the world rely on energy carriers to survive; the bulk of us in the expanding middle rely on energy to thrive; the very rich use energy to signal their affluence. Energy may be

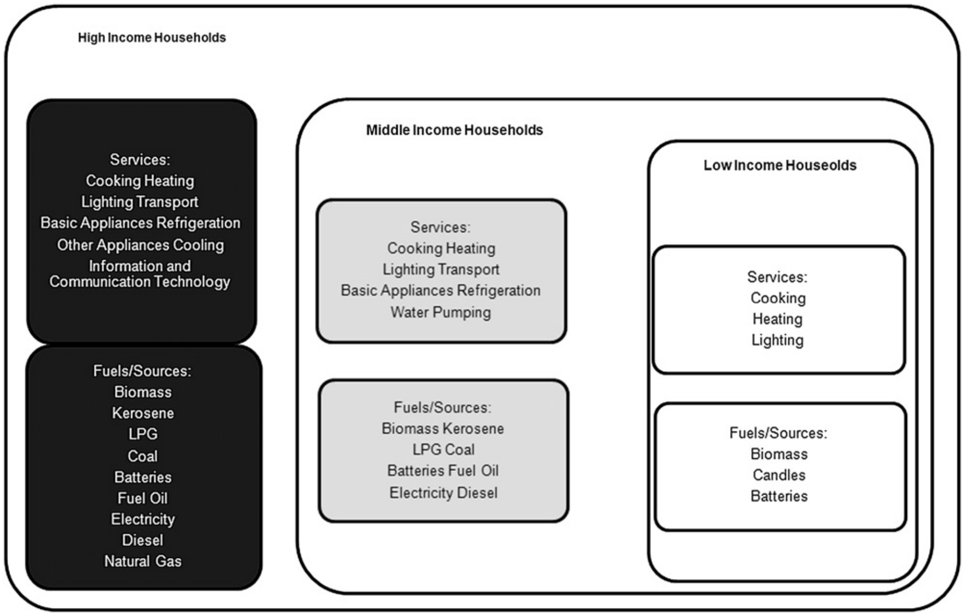

Fig. 5. Energy services and fuels according to household income.
Source: D'Agostino (2010).

consumed and harnessed to symbolize advancement in lifestyle as much as to cook food or light a room. A poorer household in Bangladesh may have to rely on wood for cooking and candles for lighting while a middle-income home in Boston will use natural gas to heat a warm bath and electricity to power their laptop computer while an upper class mansion in Brazil uses energy to heat a pool and operate televisions in every room. The lesson here is that the use and security of energy services is not ingrained; instead it is conditioned strongly by income and relative wealth within societies. The energy services ladder is also not a strictly vertical ascent; as one rises, there is a convergence not towards any single energy source, with multiple fuels used simultaneously, depicted in Fig. 5. Fig. 5 also shows how higher income groups "subsume" the services available to lower income groups as they move up from traditional to advanced fuels.

Third, an emphasis on energy services yields the potential for exciting new areas of research. This study has conceptualized energy services for three types of urban households, but the entire class of rural uses along with commercial, industrial, and agricultural energy services could be explored. Some initial evidence, for instance, suggests that a small number of services can cover most industrial needs, especially low temperature heat used for drying, washing, boiling, bleaching, distilling, and sterilizing in manufacturing processes as diverse as food and beverage making, textiles, and chemicals, which all need heat primarily below 150 °C (Weiss 2010). Primary data on energy services could be compiled and collected in the same way that statisticians and analysts currently track fuel use and energy prices. An exhaustive database or taxonomy of energy services could be engineered. These possibilities, and the dozens of others not mentioned, hold great promise for all of those wishing to better understand human behavior and the things we need energy fuels and carriers for.

References

Agbemabiese, Lawrence, Berko, Kofi, du Pont, Peter, 1996. Air conditioning in the tropics: cool comfort or cultural Conditioning? Proceedings of the 1996 ACEEE Summer Study on Energy Efficiency in Buildings, pp. 8.1–8.9.

Barnes, Douglas F., Floor, Willem M., 1996. Rural energy in developing countries: a challenge for economic development. Annual Review of Energy and Environment 21, 497–530.

D'Agostino, Anthony, 2010. Energy insecurity for ASEAN's BoP: the un-electrified 160 million. Presentation to the ESI-MINDEF Workshop, Singapore, October 5.

Dianshu, Feng, Sovacool, B.K., Minh Vu, Khuong, 2010. The barriers to energy efficiency in China: assessing household electricity savings and consumer behavior in Liaoning Province. Energy Policy 38 (2), 1202–1209.

Douglas, M., Isherwood, B., 1979. The World of Goods—Towards and Anthropology of Consumption. Penguin Books, London.

Druckman, A., Jackson, T., 2008. Measuring resource inequalities: the concepts and methodology for an area-based Gini coefficient. Ecological Economics 65, 242–252.

Dutschke, Michael, Kapp, G., Lehmann, A., Sschafer, V., 2006. Risks and chances of combined forestry and biomass projects under the clean development mechanism. Riso National Laboratory, United Nations Environment Program, and Hamburg Institute of International Economics, Riso.

Feng, Kuishuang, Hubacek, Klaus, Guan, Dabo, 2009. Lifestyles, technology and CO_2 emissions in China: a regional comparative analysis. Ecological Economics 69, 145–154.

Fernandez, E., Saini, R.P., Devadas, V., 2005. Relative inequality in energy resource consumption: a case of Kanvashram Village, Pauri Garwal District, Uttranchall (India). Renewable Energy 30, 763–772.

Fouquet, Roger, 2008. Heat, Power and Light: Revolutions in Energy Services. Edward Elgar, Cheltenham.

Gardner, Gerald T. and Paul C. Stern. 2008. The short list: the most effective actions U.S. households can take to curb climate change. Environment (September/ October).

Girardet, Herbert, Mendonca, Miguel, 2009. A Renewable World: Energy, Ecology, Equality. Green Books, London.

Glaser, B.G., Strauss, A.L., 1967. The Discovery of Grounded Theory. Aldine, ChicagoAldine, Chicago.

Gould, Stephen Jay, 2007. How the zebra gets its stripes. In: McGarr, Paul, Rose, Steven (Eds.), The Richness of Life: The Essential Stephen Jay Gould. Vintage Books, London, pp. 324–332.

Haas, Reinhard, Nakicenovic, Nebojsa, Ajanovic, Amela, Faber, Thomas, Kranzl, Lukas, Muller, Andreas, Resch, Gustav, 2008. Towards sustainability of energy systems: a primer on how to apply the concept of energy services to identify necessary trends and policies. Energy Policy 36, 4012–4021.

Habtetsiona, Semereab, Tsighe, Zemenfes, 2002. The energy sector in Eritrea—institutional and policy options for improving rural energy services. Energy Policy 30, 1107–1118.

Harden, Blaine, 2008. In energy-stingy Japan, an extravagant indulgence: posh privies. Washington Post, June 25.

Howells, M.I., Alfstad, T., Victor, D.G., Goldstein, G., Remme, U., 2005. A model of household energy services in a low-income rural African village. Energy Policy 33, 1833–1851.

Hunt, L.C., Judge, G., Ninomiya, Y., 2003. Underlying trends and seasonality in UK energy demand: a sectoral analysis. Energy Economics 25, 93–118.

Illich, Ivan, 1974. Energy and Equality. Freeman Press, New York.

International Atomic Energy Agency, 2005. Energy Indicators for Sustainable Development: Guidelines and Methodologies. IAEA, Vienna.

International Energy Agency, 2004. World Energy Outlook 2004. OECD, Paris.

Jackson, Tim., 2005. Live better by consuming less? Is there a 'double dividend' in sustainable consumption?. Journal of Industrial Ecology 9 (1–2), 19–36.

Jacobson, Arne, Milman, Anita, Kammen, Daniel M., 2005. Letting the (energy) Gini out of the bottle: Lorenz curves of cumulative electricity consumption and Gini coefficients as metrics of energy distribution and equity. Energy Policy 33 (14), 1825–1832.
Karekezi, Stephen, Majoro, Lugard, 2002. Improving modern energy services for Africa's urban poor. Energy Policy 30, 1015–1028.
Loveday, Dennis L., Bhamra, T., Tang, T., Haines, V.J.A., Holmes, M.J., Green, R.J., 2008. The energy and monetary implications of the 24/7 always on society. Energy Policy 36, 4639–4645.
Lutzenhiser, Loren, 1993. Social and behavioral aspects of energy use. Annual Review of Energy and Environment 18, 247–289.
Malyshev, Teresa, 2009. Looking Ahead: Energy, Climate, and Pro-Poor Responses. Rockefeller Foundation, Bellagio.
Modi, Vijay, McDade, Susan, Lallement, Dominique, Saghir, Jamal, 2005. Energy Services for the Millennium Development Goals. The International Bank for Reconstruction and Development/The World Bank and the United Nations Development Programme, Washington and New York.
Moll, H.C., Noorman, K.J., Kok, R., Engstrom, R., et al., 2005. Pursuing more sustainable consumption by analyzing household metabolism in European countries and cities. Journal of Industrial Ecology 9 (1), 259–275.
Monbiot, George, 2009. Stop blaming the poor: it's the wally yachters who are burning the planet. The Guardian September, 28.
Myers, Norman, Kent, Jennifer, 2003. New consumers: the influence of affluence on the environment. Proceedings of the National Academies of Science 100 (8), 4963–4968.
Pachauri, S., Mueller, A., Kemmler, A., Spreng, D., 2004. On measuring energy poverty in Indian households. World Development 32 (12), 2083–2104.
Pachauri, Shonali, Jiang, Leiwen, 2008. The household energy transition in India and China. Energy Policy 36, 4022–4035.
Papathanasopoulou, E., Jackson, T., 2009. Measuring fossil resource inequality—a longitudinal case study for the UK: 1968–2000. Ecological Economics 68, 1213–1225.
Rapanos, Vassilis T., Polemis, Michael L., 2006. The structure of residential energy demand in Greece. Energy Policy 34, 31–37.
Reister, David B., Devine Jr., Warren D., 1981. Total cost of energy services. Energy 6, 305–315.
Rosas-Flores, Jorge Alberto, David Morillon, Galvez, Jose Luis Fernandez, Zayas, in press. Inequality in the distribution of expense allocated to the main energy fuels for Mexican households: 1968–2006. Energy Economics.
Shove, Elizabeth, 2003. Comfort, Cleanliness, and Convenience: The Social Organization of Normality. Berg Publishers, Oxford.
Shove, Elizabeth, 2004. Efficiency and consumption: technology and practice. Energy and Environment 15 (6), 1053–1065.
Sovacool, Benjamin K., 2008. The Dirty Energy Dilemma: What's Blocking Clean Power in the United States. Praegar, Westport, CT.
Sovacool, Benjamin K., in press. Security of energy services and uses within different households. Current Opinion in Environmental Sustainability 2(5).
Sovacool, Benjamin K., Brown, Marilyn, 2010. Twelve metropolitan carbon footprints: a preliminary global comparative assessment. Energy Policy 38 (9), 4856–4869.
Spreng, Daniel, 1993. Possibilities for substitution between energy, time, and information. Energy Policy 21 (1), 13–23.
Strauss, A.L., 1987. Qualitative Analysis for Social Scientists. Cambridge University Press, Cambridge.
Unander, Fridtjof, 2005. Energy indicators and sustainable development: the International Energy Agency approach. Natural Resources Forum 29, 377–391.
United Nations Development Programme, 1997. Energy and Major Global Issues. Prospects and Challenges, Energy After Rio.
Van Hoa, Tran, 1985. Quality of consumption: some Australian evidence. Economics Letters 19, 189–192.
Vandenbergh, Michael P., Steinemann, Anne C., 2007. The carbon-neutral individual. New York University Law Review 82 (2007), 1673–1745.
Weiss, Werner, 2010. The challenge to exploit the solar thermal potential. Invited presentation to the 48th Annual Conference of the Australian Solar Energy Society "Solar 2010", Parliament House Great Hall, Canberra, Australia.
Wilhite, Harold, Nakagami, Hidetoshi, Masuda, Takashi, Yamaga, Yukiko, Haneda, Hiroshi, 1996. A cross-cultural analysis of household energy use behavior in Japan and Norway. Energy Policy 24 (9), 795–803.
Wilk, Richard B., 2002. Culture and energy consumption. In: Bent, Robert, Orr, Lloyd, Baker, Randall (Eds.), Energy: Science, Policy, and the Pursuit of Sustainability. Island Press, Washington, pp. 109–129.