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Estimated United States Residential Energy Use in 2005

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Estimated United States Residential Energy Use 2005

United States

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Estimated United States Residential Energy Use: 2005

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Abstract

A flow chart depicting energy flow in the residential sector of the United States economy in 2005 has been constructed from publicly available data and estimates of national energy use patterns. Approximately 11,000 trillion British Thermal Units (trBTUs) of electricity and fuels were used throughout the United States residential sector in lighting, electronics, air conditioning, space heating, water heating, washing appliances, cooking appliances, refrigerators, and other appliances. The residential sector is powered mainly by electricity and natural gas. Other fuels used include petroleum products (fuel oil, liquefied petroleum gas and kerosene), biomass (wood), and on-premises solar, wind, and geothermal energy. The flow patterns represent a comprehensive systems view of energy used within the residential sector.

Introduction

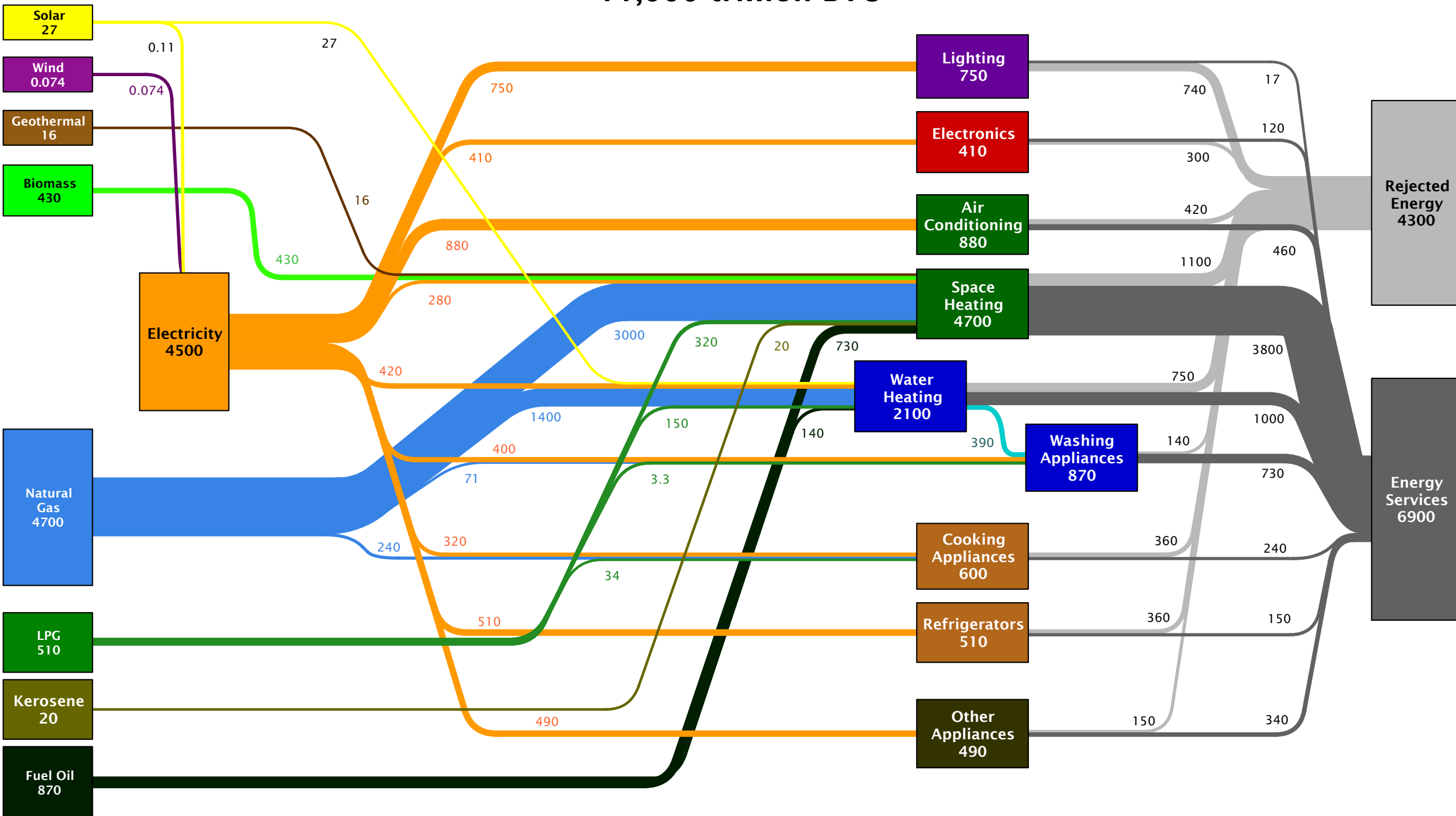
Lawrence Livermore National Lab (LLNL) has published flow charts (also referred to as “Sankey Diagrams”) of important national commodities since the early 1970s. The most widely recognized of these charts is the U.S. energy flow chart (Livermore, 2011). LLNL has also published charts depicting carbon (or carbon dioxide potential) flow and water flow at the national level as well as energy, carbon, and water flows at the international, state, municipal, and organizational (i.e. United States Air Force) level. Flow charts are valuable as single-page references that contain quantitative data about resource, commodity, and byproduct flows in a graphical form that also convey structural information about the system that manages those flows.

Data on residential energy use is reported on national and regional levels. Data on residential energy use is compiled by the U.S. Department of Energy’s Energy Information Administration (U.S. EIA) in the Residential Energy Consumption Survey (RECS) which can be considered a subset of data covered by the Annual Energy Outlook and the Annual Energy Review. RECS is updated every four years and reports data from 4 years prior to the year of the update. RECS served as the main data source for this flow chart. Where necessary, RECS data was augmented with appliance efficiency and energy consumption from the literature (see References).

This is the first detailed visualization of residential energy use for the United States by LLNL. This report, including the flow chart, explanations and assumptions used, can be found at <http://flowcharts.llnl.gov>.

Estimated United States Residential Energy Use in 2005

~11,000 trillion BTU



Source: LLNL 2011. Data is based on DOE/EIA-RECS, 2009. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and does not include self-generation. All quantities are rounded to 2 significant digits and annual flows of less than 0.01 trBTUs are not included. Totals may not equal sum of components due to independent rounding. LLNL-TR-520271

Analysis

This visualization of energy use in the residential sector is based upon a “bottom-up” calculation of energy consumption in U.S. homes. In this report, specific energy flows which were calculated from RECS and other data are listed first, followed by flows and quantities which are calculated as residuals or summations. Every effort has been made to group flows logically by fuel and end use.

Residential Energy Resources:

Individual households and communities produce some electricity and other energy services from energy resources present on their property. These resources include solar, wind and geothermal energy.

Solar

Solar-> Electricity

While *Solar* power is a source of *Electricity* for all sectors in the United States economy, this flow solely represents the solar power generated by local residential solar systems using photovoltaic cells. The residential *Solar* installations are estimated to produce 0.11 trBTUs of *Electricity* in 2005 (BEDB, 2007).

Solar->Water Heating

This flow represents the *Solar* energy used directly in *Water Heating* activities on the residential sector. The amount of *Solar* energy used in *Water Heating* is estimated at 27 trBTUs in 2005 (BEDB, 2007).

Wind

Wind-> Electricity

The amount of residential electricity generated by on-site *Wind* sources is estimated at 0.074 trBTUs in 2005 (AWEA, 2008).

Geothermal

Geothermal->Space Heating

This flow represents the *Geothermal* energy used directly in *Space Heating* activities on the residential scale. The amount of *Geothermal* energy used in *Space Heating* is estimated at 16 trBTUs in 2005 (BEDB, 2011).

Biomass

Biomass -> Space Heating

Energy generated from combustion of *Biomass* is reported as 430 trBTUs in 2005 (RECS, 2009). It is assumed that *Biomass* used in the residential sector is exclusively used in *Space Heating*.

Consumption of Energy Carriers by Residential Devices:

The majority of energy used in U.S. homes is derived from commodity energy carriers such as electricity, natural gas, fuel oil and other petroleum products. This energy is used for lighting, electronics, heating, ventilation and air conditioning, water heating, cooking, refrigeration and other appliances.

Electricity

Electricity -> Lighting

The primary energy consumed by *Lighting* in the Residential sector was reported as 2,400 trBTUs in 2005 (BEDB: Table 7, 2007). As the site-to-source electricity conversion is 3.18 (BEDB: Table 1.2.1, 2007), 1 / 3.18 or 31.5% of the primary energy is delivered as *Electricity* to *Lighting*. Therefore, the energy from *Electricity* used by *Lighting* in the residential sector is calculated to be 750 trBTUs. The remaining 1,650 trBTUs are attributed to Rejected Energy located outside the scope of this analysis.

Electricity -> Electronics

The category of *Electronics* includes televisions, receivers, computers, and fax machines. Energy use is expected to increase in this category as users purchase and use more *Electronics* or replace units with those with higher energy demands. The types of equipment and statistics of their energy usages are shown in Table 1.

Total annual energy use for each appliance is calculated as follows:

$$E_{App} = \frac{\#_{App} \times E_{unit} \times t_{use} \times CF}{F_{pop} \times 24 \text{ hrs/day}}$$

The number of appliances ($\#_{App}$) present in each surveyed household is used as reported for 2005 (RECS, 2009). This is scaled to include the entire population as 4,382 households surveyed in 2001 represent the 111.1 million households in the United States residential economy sector present in 2005 (F_{pop}). Annual energy consumption by one unit of each of these appliances (E_{unit}) is estimated using the unit energy consumption previously reported for 2001 (End-Use: Table 2, 2005). The hours of use (t_{use}) are estimated for each appliance and the fraction of the day ($t_{use}/24$ hours/day) is included in the energy use estimate. The conversion factor (CF) converts the units of energy from kWh to trBTUs.

Using this methodology, the energy flow from *Electricity* used in *Electronics* is estimated at 410 trBTUs in 2005.

Table 1: Electronics energy use estimation

Electronics	Appliances in survey (# _{App})	Equivalent appliances (#)	Energy Use (E _{unit}) ¹	Hours of Use (t _{use})	Total Annual Energy (E _{App})
	#	million	kWh/unit-yr	hr/day	trBTUs
Color TV	11,003	278.97	460	12	220
VCR/DVD	10,284	260.74	70	6	16
Cable Box	3,912	99.18	120	24	41
Personal Desk Top	3,192	80.93	262	24	72
Personal Lap Top	1,278	32.40	77	24	8.5
Printer w/ Fax/copier	1,063	26.95	216	24	20
Printer without Fax/copier	1,477	37.45	45	24	5.7
Compact Stereo	1,342	34.02	81	8	3.1
Component Stereo	1,608	40.77	55	8	2.6
Portable Stereo	1,071	27.15	19	8	0.59
Other Stereo	125	3.17	55	8	0.20
Answering Machine	2,458	62.32	35	24	7.4
Cordless Telephone	3,337	84.61	26	24	7.5
Cell phone	3,301	83.69	26	24	7.4
Fax machine	483	12.25	71	24	3.0
Copier	360	9.13	45	24	1.4
Total					410

Electricity ->Air Conditioning

The energy from *Electricity* used in *Air Conditioning* (both central systems and window/wall units) is reported at 880 trBTUs in 2005 (RECS, 2009).

Electricity ->Space Heating

The energy from *Electricity* used in *Space Heating* is reported at 280 trBTUs in 2005 (RECS, 2009).

Electricity -> Water Heating

The energy from *Electricity* used in *Water Heating* is reported as 420 trBTUs in 2005 (RECS, 2009).

¹ For energy use of *Electronics* not listed in the reference, the following assumptions were made: a cell phone is uses the same energy as a cordless telephone, the copier uses the same energy as a printer without a fax or copier, and a fax machine uses the same energy as both a cordless phone and a printer without a fax or copier. The energy use per unit television is revised from the 2001 representation of 137 kWh/unit-yr to a weighted average of 460 kWh/unit-yr calculated from 48% of televisions having plasma screens using 680 kWh/unit-yr and 52% having cathode-ray tube or liquid crystal displays using 250 kWh/unit-yr (RECS, 2009 and ENERGY STAR, 2008).

Electricity -> Washing Appliances

Washing Appliances include laundry machines, clothes dryers, and dishwashers. The *Electricity* use for these appliances is calculated using energy estimates for each appliance reported in 2001 (Table-US-1, 2005) and scaling these numbers for the portion of 111.1 million households in the United States in 2005 that reported using the machines (RECS, 2009). Direct electricity use for laundry machines, clothing dryers, and dishwashers are calculated as 38 trBTUs, 250 trBTUs, and 110 trBTUs, respectively. Therefore, the total energy from *Electricity* used in *Washing Appliances* is 400 trBTUs in 2005.

Electricity-> Cooking Appliances

Cooking Appliances include ranges, ovens, coffee makers, toasters, and microwaves. The *Electricity* use for these appliances is calculated using energy estimates for each appliance reported in 2001 (End-Use, 2005) and scaling these numbers for the portion of 111.1 million households in the United States in 2005 who use the machines (RECS, 2009). Direct electricity use in one year for ranges, ovens, coffee makers, toasters, and microwaves is 120 trBTUs, 98 trBTUs, 27 trBTUs, 6.4 trBTUs, and 70 trBTUs, respectively (RECS, 2009). Therefore, the total energy from *Electricity* used in *Cooking Appliances* is estimated at 320 trBTUs.

Electricity-> Refrigerators

The energy from *Electricity* used in *Refrigerators* is reported at 510 trBTUs in 2005 (RECS, 2009).

Electricity -> Other Appliances

Other Appliances are defined as the appliances that use *Electricity* in the residential sector not accounted for in the previous sections. This category includes, but is not limited to, the use of vacuum cleaners, ceiling fans, well water pumps, and dehumidifiers. Energy use is reported as 2,740 trBTUs for a category of "Other Appliances and Lighting," which includes the categories *Lighting*, *Electronics*, *Washing Appliances*, *Cooking Appliances*, and *Other Appliances* defined elsewhere in this report. *Electricity* use by *Other Appliances* is estimated by subtracting the energy use from all other categories over all energy carriers from the energy used by "Other Appliances and Lighting" in the residential sector. The *Electricity* use by *Other Appliances* is 490 trBTUs in 2005 (RECS, 2009).

Natural Gas

Natural Gas -> Space Heating

The amount of *Natural Gas* used in *Space Heating* is reported as 3,000 trBTUs in 2005 (RECS, 2009).

Natural Gas -> Water Heating

The amount of *Natural Gas* used in *Water Heating* is reported as 1,400 trBTUs in 2005 (RECS, 2009).

Natural Gas -> Washing Appliances

The amount of *Natural Gas* used in *Washing Appliances* such as laundry machines, laundry dryers, and dishwashers is estimated using the natural gas usage factor for clothing dryers of 3.7×10^{-6} trBTUs per household in a year (Table US-1, 2005) and the 19.4 million households estimated to use natural gas-fueled clothing dryers (RECS, 2009), for a total of 71 trBTUs in 2005.

Natural Gas -> Cooking Appliances

The amount of *Natural Gas* used in *Cooking Appliances* such as cooking ranges and ovens is estimated at 240 trBTUs in 2005 (RECS, 2009).

LPG

LPG ->Space Heating

The amount of *LPG* used in *Space Heating* is reported as 320 trBTUs in 2005 (RECS, 2009).

LPG -> Water Heating

The amount of *LPG* used in *Water Heating* is reported as 150 trBTUs in 2005 (RECS, 2009).

LPG -> Washing Appliances

The amount of *LPG* used in *Washing Appliances*, specifically laundry dryers, is estimated using the *LPG* usage factor for clothing dryers of 3.7×10^{-6} trBTUs per household in a year (Table US-1, 2005) and the 0.9 million households estimated to use *LPG*-fueled clothing dryers (RECS, 2009), for a total of 3.3 trBTUs in 2005.

LPG -> Cooking Appliances

The amount of *LPG* used in *Cooking Appliances*, specifically ranges and ovens, is estimated at 34 trBTUs in 2005 (RECS, 2009).

Kerosene

Kerosene -> Space Heating

The amount of *Kerosene* used in *Space Heating* is reported as 20 trBTUs in 2005 (RECS, 2009).

Fuel Oil

Fuel Oil -> Space Heating

The amount of *Fuel Oil* used in *Space Heating* is reported as 730 trBTUs in 2005 (RECS, 2009).

Fuel Oil -> Water Heating

The amount of *Fuel Oil* used in *Water Heating* is reported as 140 trBTUs in 2005 (RECS, 2009).

Water Heating

Water Heating -> Washing Appliances

The Consumer Energy Center estimates that heating water for a dishwashing cycle uses up to 80% of the energy used by a dishwasher (CECCEC, 2011). The same percentage is estimated for clothes washers. Assuming that all dishwasher cycles used hot water in 2005, 80% of the energy used by dishwashers and clothes washers comes from water heating. As described previously, 150 trBTUs of electricity are used in dishwashers and clothes washers for the remaining 20% of the equipment's energy needs. Therefore, $150 / 20\%$ or 750 trBTUs represent the total energy used by these *Washing Appliances* in 2005.

The sum of *Energy Services* and *Rejected Energy* in *Water Heating* by *Washing Appliances* is then calculated as the difference between the total energy (750 trBTUs) and electricity use (150 trBTUs) or 600 trBTUs in 2005. To account for the use of energy at its location, 600 trBTUs of energy are accounted for use by *Washing Appliances* in the *Water Heating* sector. As discussed below, *Water Heating* is estimated to be 65% efficient. Therefore, the flow from *Water Heating* to *Washing Appliances* is 65% of the total 600 trBTUs or 390 trBTUs, with the remaining 210 trBTUs attributed to *Rejected Energy* from *Water Heating*.

Energy Disposition:

Not all energy consumed by the residential sector is put to its intended use. Some energy is rejected to the indoor or outdoor environment as waste heat because motors, electronics and heaters are not 100% efficient. Nevertheless, all energy can be accounted for by apportioning some fraction of device input energy to its intended service and assigning the remainder to energy rejection. The ratio of energy service to energy consumption is equal to the device efficiency.

The thermodynamic value of residential energy services is, in some cases, hard to define. We have made every effort to explain our assumptions in the following sections.

Energy Services

Lighting -> Energy Services

The efficiency in *Lighting* is assumed to be dominated by the efficiency of light output from light bulbs. Incandescent light bulbs have an efficiency ranging from 1.6 - 2.8% while compact fluorescent light (CFL) bulbs have an efficiency ranging from 7.8 - 9.7% (NREL, 2010). From 2001 - 2005, the sales of compact fluorescent lamps in the United States total 98 million, in comparison to 6.3 billion incandescent lamps, compact fluorescent lamps representing 1.5% of the market (Itron: Table 1, 2007). Therefore, the efficiency of *Lighting* is estimated as 1.5% of the CFL average (8.75%) and 98.5% of the incandescent average efficiency (2.2%), for a total weighted energy efficiency of 2.3%. The flow from *Lighting* to *Energy Services* is calculated as 2.3% of the electricity consumed by lighting, or 17 trBTUs.

Electronics -> Energy Services

The *Energy Services* delivered by *Electronics* in homes are estimated by measuring the increase in electricity use by these devices above their energy use in “idle” mode. In this analysis, a typical desktop computer (from 2005) is used as representative of all home electronics. The computer, a Dell GX 280, uses 144 Watts while in Full/Loaded mode ($W_{F/L}$), 85 Watts while in On/Idle mode ($W_{O/I}$), 73 Watts while in On/Powersave mode ($W_{O/P}$), and 1 Watt while in Off/Standby mode ($W_{O/S}$) (Vanhorn, 2005). The computer is estimated to be in Full/Loaded mode for 7 hours per day ($t_{F/L}$) completing “useful work” based on survey data (RECS, 2009), 1 hour spent in On/Idle mode ($t_{O/I}$), 5 hours spent in On/Powersave mode ($t_{O/P}$), and 11 hours in Off/Standby mode ($t_{O/S}$). The efficiency of the computer is calculated using the following equation.

$$\text{Efficiency} = \frac{t_{F/L} \times W_{F/L} - t_{F/L} \times W_{O/I}}{(t_{F/L} \times W_{F/L}) + (t_{O/I} \times W_{O/I}) + (t_{O/P} \times W_{O/P}) + (t_{O/S} \times W_{O/S})}$$

During the 7 hours of “Full/Loaded” use, the computer uses 1.0 kWh of electricity, whereas it would have used 0.60 kWh if it were in On/Idle during that time. Therefore, the computer has performed 0.41 kWh of work. The computer’s total daily electricity consumption is 1.5 kWh, resulting in an efficiency of 28%.

Therefore, of the 410 trBTUs consumed by *Electronics*, 28%, or 120 trBTUs, are delivered as *Energy Services*.

Air Conditioning -> Energy Services

Two types of air conditioners are in use in the United States: central systems and window/wall units which used a total of 760 and 120 trBTUs in 2005, respectively (RECS, 2009).

Central systems have Seasonal Energy Efficiency Ratios (SEER) which range from 6 – 21 BTUs/Wh (NREL, 2010), with a maximum available SEER of 19 in 2005 (AtoZ, 2004). The average SEER rating on central air conditioning systems in service in 2005 is estimated to be 11. However, field examinations of residential air conditioners found the average performance to be at least 17% below its original design (Downey, 2002). Therefore, the average effective SEER is calculated as $11 \times 83\%$, or 9.1. The “fleet” efficiency is defined as the average effective SEER divided by the Best Available Technology (BAT) rated SEER; in 2005 that is $9.1 / 19$, or 48%. The Energy Service provided by central air conditioning systems from Electricity is 370 trBTUs.

Window/wall air conditioning units have Energy Efficiency Ratios (EER) which range from 8 - 11.8 BTUs/Wh and capacities that range from 6 - 21 kBtu/h (NREL, 2010 and CEE, 2003). The average EER of a window/wall air conditioning unit in use is estimated to be 9 in 2005. The BAT room air conditioner is a Super-Efficient Home Appliance rated air conditioner that has an EER of 11.8 available in 2003 (CEE, 2003), which is assumed to be the BAT in 2005 as well. We define the efficiency of window air conditioners to be the average EER divided by the BAT EER, which is $9 / 11.8$ or 76% in 2005. Therefore, 91 trBTUs are apportioned to *Energy Services*.

The total energy flow from *Air Conditioners* to *Energy Services* is 460 trBTUs.

Space Heating -> Energy Services

The efficiency of space heaters varies by the fuel used in heating. Electric heaters are 100% efficient, while those fueled by natural gas, LPG, kerosene, and fuel oil are about 80% efficient (EIA, 2010). Wood/Biomass fueled space heaters are about 55% efficient (EIA, 2010). As the definition of efficiency differs for geothermal space heaters with coefficients of performance reported to be over 400% (GEO, 2011), geothermal space heaters are assumed to have the same efficiency as electric heaters in this analysis for consistency, or 100%. *Space Heating* is therefore calculated to have a weighted average energy efficiency of 77% overall. Of the 4,700 trBTUs appropriated to *Space Heating*, 3,800 trBTUs are delivered as *Energy Services*.

Water Heating -> Energy Services

Water Heating is accomplished using electricity, LPG, fuel oil, and natural gas. Efficiencies of electric water heaters have been reported of about 90% while natural gas water heaters have efficiencies of about 60% (ACEEE, 2011). LPG and fuel oil-fueled water heaters are assumed to have the same efficiencies as those fueled by natural gas. . Using those efficiencies weighted by consumption of each fuel by water heaters, the overall *Water Heating* efficiency is 65%. Of the 2,100 trBTUs, 750 trBTUs are rejected and 1,400 trBTUs remain for use by *Washing Appliances* and *Energy Services* such as the hot water delivered by faucets and showers. Removing the 390 trBTUs used by *Washing Appliances*, *Water Heating* uses 1,000 trBTUs for *Energy Services*.

Washing Appliances -> Energy Services

The efficiency of *Washing Appliances* varies based on the fuel and type of use of energy. Electricity use in dishwashers (E_{e-dish}) and laundry machines ($E_{e-laundry}$) is estimated to have an energy efficiency of 90% based on an analysis report of electric motor energy and reliability (Penrose, 2011). The energy use in the form of hot water ($E_{HW-dish, laundry}$) is assumed to be 100% efficient because energy losses during the heating of water are accounted for in the *Water Heating* sector.

The energy efficiency standard for clothes dryers is 0.73 kWh/kg-clothes (electric) and 0.82 kWh/kg-clothes (gas) (these standards are expressed in English units as 3.01 lbs clothes per kWh-electric and 2.67 lbs clothes per kWh-gas) (EERE, 2011). This same standard specifies 70% Residual Moisture Content, indicating 0.7 kg water must be evaporated for each kg of clothes that are dried. Assuming that the minimum energy of drying is equivalent to the latent heat of vaporization of the moisture content (2425 kJ/kg-water), the minimum drying energy per kg-clothes is 0.47 kWh/kg-clothes. By this standard, electric dryers have an efficiency of 64% and natural gas and LPG-fueled dryers have an efficiency of 57%. As these standards went into effect in 1994, it is assumed the average clothing dryer in 2005 has these same efficiencies.

The overall useful energy for washing appliances ($Energy\ Services_{WA}$) is calculated as follows:

$$\begin{aligned} Energy\ Services_{WA} = & (90\%) * (110\ trBTUs\ E_{e-dish}) \\ & + (90\%) * (38\ trBTUs\ E_{e-laundry}) \\ & + (100\%) * (230\ trBTUs\ E_{HW-dish, laundry}) \\ & + (64\%) * (250\ trBTUs\ E_{e-dryer}) \\ & + (57\%) * (71\ trBTUs\ E_{NG-dryer}) \\ & + (57\%) * (3.3\ trBTUs\ E_{LPG-dryer}) \end{aligned}$$

The flow from *Washing Appliances* to *Energy Services* is calculated to be 730 trBTUs, or 84% of the sum of all energy inputs (*Water Heating*, *Electricity*, *Natural Gas*, and *LPG*).

Cooking Appliances -> Energy Services

The efficiency of *Cooking Appliances*, which include stoves, ovens, microwave ovens, toasters, and coffeemakers, depends on the appliance and the fuel used. Electric stoves, ovens, and microwave ovens

are estimated to have an energy efficiency of 74%, 13%, and 55%, respectively (EERE, 2008). Natural gas-fueled ranges and ovens are estimated to have an energy efficiency of 40% and 7%, respectively (EERE, 2008). LPG-fueled stoves and ovens are estimated to have the same efficiencies as the natural gas-fueled appliances. Toasters are assumed to have the same efficiency as electric ovens, and coffee makers are assumed to have the same efficiencies as microwaves.

The flow from *Cooking Appliances* to *Energy Services* is calculated as percentages of all energy inputs (*Electricity, Natural Gas, and LPG*) as shown below:

$$\begin{aligned}
 \text{Energy Services} &= (74\%) * E_{e\text{-stove}} \\
 &+ (13\%) * (E_{e\text{-oven}} + E_{\text{toaster}}) \\
 &+ (55\%) * (E_{m\text{-oven}} + E_{c\text{-maker}}) \\
 &+ (40\%) * E_{NG\text{-stove}} + (7\%) * E_{NG\text{-oven}} \\
 &+ (40\%) * E_{LPG\text{-stove}} + (7\%) * E_{LPG\text{-oven}}
 \end{aligned}$$

The overall energy efficiency of *Cooking Appliances* is estimated to be 40% and the flow of energy from *Cooking Appliances* to *Energy Services* is calculated to be 240 trBTUs.

Refrigerators -> Energy Services

The energy efficiency of *Refrigerators* is calculated as the ratio of the best available efficient refrigerator energy use to that of the average estimated refrigerator energy use in 2005. The Department of Energy Efficiency Standard was 486 kWh/yr for a refrigerator with 18 cubic feet of capacity, with a 25% more energy efficient refrigerator available with an energy use of 364 kWh/year (EERE, 2005). The average annual energy use for a refrigerator reported in 2001 is 1239 kWh (End-Use, 2005) and the average refrigerator is estimated to be 10% more efficient in 2005, using 1120 kWh/yr. Therefore, the energy efficiency of *Refrigerators* is calculated to be 364 kWh/year / 1120 kWh/year, or 30%, and the energy flow from *Refrigerators* to *Energy Services* is calculated to be 150 trBTUs.

Other Appliances -> Energy Services

The category of *Other Appliances* includes vacuum cleaners, waterbed heaters, rechargeable tools, and ceiling fans. As these energy efficiencies vary depending on the equipment, a few types are listed here to demonstrate the range. Vacuum cleaners are reported to have an average airflow efficiency of 30% (AEA, 2009). Corded power tools are assumed to have efficiencies ranging between 70% - 90% due to the use of electric motors, with penalties due to on/off cycling, while cordless power tools would be less efficient within a range of 60-80% due to battery charging and discharging. The energy efficiencies of portable and ceiling fans are estimated to be 90%, similar to electric motors.

Here, we estimate that *Other Appliances* have an overall energy efficiency of 70% and the flow from *Other Appliances* to *Energy Services* is calculated to be 340 trBTUs.

Rejected Energy

Lighting -> Rejected Energy

As described above, the flow from *Lighting* to *Energy Services* is calculated as 2.4% of the 750 trBTUs from *Electricity*. Therefore, the flow from *Lighting* to *Rejected Energy* is 740 trBTUs.

Electronics -> Rejected Energy

As described above, *Electronics* are assumed to have an energy efficiency of 28%. The flow from *Electronics* to *Rejected Energy* is calculated as 72% of the energy from *Electricity*, or 300 trBTUs.

Air Conditioning -> Rejected Energy

As described above, *Air Conditioners* consumed 880 trBTUs in 2005, and delivered 460 trBTUs as *Energy Services*. The remainder, or 420 trBTUs, is considered *Rejected Energy*.

Space Heating -> Rejected Energy

As described above, *Space Heating* is estimated to have an overall energy efficiency of 77%. The flow from *Space Heating* to *Rejected Energy* is calculated as 23% of the sum of all energy inputs (*Geothermal*, *Biomass*, *Electricity*, *Natural Gas*, and *Fuel Oil*), or 1,100 trBTUs.

Water Heating -> Rejected Energy

As described above, the weighted average efficiency for *Water Heating* is 65%. Therefore, of the 2,100 trBTUs consumed by *Water Heating*, the flow to *Rejected Energy* is 750 trBTUs.

Washing Appliances -> Rejected Energy

As described previously, *Washing Appliances* are estimated to have an energy efficiency of 84% in 2005. The flow from *Washing Appliances* to *Rejected Energy* is calculated as 16% of the sum of all energy inputs (*Water Heating*, *Electricity*, *Natural Gas*, and *LPG*), or 140 trBTUs.

Cooking Appliances -> Rejected Energy

As described above, *Cooking Appliances* are estimated to have an overall energy efficiency of 40% and the flow of energy from *Cooking Appliances* to *Rejected Energy* is estimated to be 360 trBTUs in 2005.

Refrigerators -> Rejected Energy

As described above, *Refrigerators* are estimated to have an energy efficiency of 30%. The flow from *Refrigerators* to *Rejected Energy* is calculated as 70% of the energy from *Electricity*, or 360 trBTUs in 2005.

Other Appliances -> Rejected Energy

As described above, *Other Appliances* are assumed to have an energy efficiency of 70% in 2005. The flow from *Other Appliances* to *Rejected Energy* is calculated as 30% of the energy from *Electricity*, or 150 trBTUs.

Conclusion

The flow chart described in this report is a compact depiction of the national energy use in the residential sector in 2005. This diagram is available at: <http://flowcharts.llnl.gov>

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Appendix

Glossary

Energy Inputs:

Solar:

Solar is the energy flow from *Solar* to *Electricity* and *Water Heating*. This energy resource represents the solar power collected in residential installations such as photovoltaic cells and used locally. It does not represent large commercial solar power plants.

Wind:

Wind is the energy flow from *Wind* to *Electricity*. This energy resource represents the electricity generated from residential installations of wind turbines and does not include power generated from large commercial wind farms.

Geothermal:

Geothermal is the energy flow from *Geothermal* to *Space Heating*. This energy resource represents the electricity generated from residential installations of geothermal power plants and does not include power generated from large commercial geothermal power plants.

Biomass:

Biomass is the energy flow from *Biomass* to *Space Heating*, representing energy used in the combustion of biomass in the residential sector.

Electricity

The residential sector of the United States economy is credited with using 4,600 trBTUs of *Electricity* from the grid, or 37% of the total United States *Electricity*, as estimated by the U.S. EIA in 2005.

Natural Gas:

Natural Gas is the energy flow from *Natural Gas* to *Space Heating*, *Water Heating*, *Washing Appliances*, and *Cooking Appliances*.

Liquefied Petroleum Gas (LPG):

LPG is the energy flow from *LPG* to *Washing Appliances* and *Cooking Appliances*.

Fuel Oil:

Fuel Oil is the energy flow from *Fuel Oil* to *Space Heating* and *Water Heating*.

Energy Using Device Classes:

Lighting

The energy used in *Lighting* is represented by the flow from *Electricity* to *Lighting*. *Lighting* is assumed to use 750 trBTUs of *Electricity* in 2005.

Electronics

The energy used by *Electronics* is represented by the flow from *Electricity* to *Electronics*. *Electronics* include the use of audio/visual equipment, computers, and printers. In 2005, 410 trBTUs of energy is used by *Electronics*.

Air Conditioning

The energy used by *Air Conditioners* is reported as 880 trBTUs in 2005 (RECS: Table AC3, 2009). It is assumed that all *Air Conditioners* are fueled by *Electricity*.

Space Heating

The energy used in *Space Heating* is reported as 4,700 trBTUs in 2005 (RECS: Table SH4, 2009). It is assumed that fuels used in *Space Heating* are *Geothermal*, *Biomass*, *Electricity*, *Natural Gas*, *LPG*, *Kerosene*, and *Fuel Oil*.

Water Heating

The energy used for *Water Heating* is reported as 2,100 trBTUs in 2005 (RECS: Table WH4, 2009). It is assumed that *Solar*, *Electricity*, *Natural Gas*, *LPG*, and *Fuel Oil* are the only sources of fuel in *Water Heating*.

Washing Appliances

The energy used in *Washing Appliances* is represented by the flow from *Water Heating*, *Electricity*, *Natural Gas*, *LPG*, and *Fuel Oil* to *Washing Activities*. *Washing Appliances* include the use of dishwashers, laundry machines, and clothes drying machines for a total energy used in 2005 of 870 trBTUs.

Cooking Appliances

The energy used in *Cooking Appliances* is represented by the flow from *Electricity*, *Natural Gas*, and *LPG* to *Cooking Appliances*. *Cooking Appliances* include the use of stoves, ovens, coffeemakers, toasters, and microwave ovens. In 2005, the energy used by *Cooking Appliances* totaled 600 trBTUs.

Refrigerators

The energy used by *Refrigerators* is reported as 510 trBTUs in 2005 (RECS: Table AP3, 2009). It is assumed that all *Refrigerators* are fueled by *Electricity*.

Other Appliances

The energy used in *Other Appliances* is represented by the flow from *Electricity to Other Appliances*. In 2005, *Other Appliances* include the use of vacuum cleaners, ceiling fans, well water pumps, and dehumidifiers for a total of 490 trBTUs of energy used.

Energy Disposition Totals:

Energy Services

Energy Services is estimated as the sum of all useful energy used in *Lighting, Electronics, Air Conditioning, Space Heating, Water Heating, Washing Appliances, Cooking Appliances, Refrigerators, and Other Appliances*. In 2001, 6,900 trBTUs were used in the United States residential sector as *Energy Services*.

Rejected Energy

This is estimated as the sum of all *Rejected Energy* from *Electricity, Lighting, Electronics, Air Conditioning, Space Heating, Water Heating, Washing Appliances, Cooking Appliances, Refrigerators, and Other Appliances*. In 2005, 4,300 trBTUs were rejected to the environment through the energy use in the residential sector of the United States as *Rejected Energy*.