Our Renewable Future

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Energy flows in the United States

Estimated U.S. Energy Consumption in 2015: 97.5 Quads

Source: LLNL March, 2016. Data is based on DOE/EIA MGR (2013). 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. EIA reports consumption of renewable resources (i.e., hydro, wind, geothermal and solar) for electricity in Btu-equivalent values by assuming a typical fossil fuel plant heat rate. The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. End use efficiency is estimated as 65% for the residential sector, 65% for the commercial sector, 80% for the industrial sector, and 21% for the transportation sector. Totals may not equal sum of components due to independent rounding. LLNL-MI-415527
What energy do we use everyday?

U.S. Final Energy Consumption (2012): 1.5 billion metric tons oil equivalent

sources: IEA Energy Balances; U.S. EIA
China’s energy system is coal-based.

China Final Energy Consumption (2012): 2.1 billion metric tons oil equivalent

Electricity: 19% of Total

source: China National Bureau of Statistics
How energy is embodied in goods

- Embodied energy is the sum of all energy used to produce goods or services.
- It includes the various forms of energy (oil, coal, natural gas, electricity, etc.) used during the raw material extraction, transport, manufacturing, assembly, construction, and end-of-life phases.
- Embodied energy can account for a substantial proportion of the lifetime energy and emissions footprint of a produce or service.
- A fully renewable system requires consideration of the entire supply chain in which energy becomes “embodied” in a product.
Manufacturing

First Use of Energy for All Purposes in U.S. Manufacturing (Fuel and Nonfuel, 2010)

- Electricity: 12%
- Natural Gas: 28%
- LPG & NGL: 10%
- Coke & Breeze: 2%
- Coal: 7%
- Energy Produced Onsite: 4%
- Residual Fuel Oil: 1%
- Distillate Fuel Oil: 1%
- Other: 36%

China Manufacturing Energy Use (2012)

- Coke & Coke Gases: 26%
- Coal: 34%
- Natural Gas: 5%
- Petroleum: 10%
- Heat: 4%
- Other: 1%

source: U.S. Energy Information Administration, Manufacturing Energy Consumption Survey (MECS)
Cement is the foundation of modern civilization.
Buildings

Average Annual Household Final Energy Consumption for a Single-Family Detached Home (2009)

Annual Household Operational Energy Use: 31 MWh

- Electricity: 43%
- Natural Gas: 46%
- Kerosene: 0.1%
- Fuel Oil: 6%
- Propane: 5%

source: U.S. Energy Information Administration, Residential Energy Consumption Survey (RECS)
CO₂ emissions from one pair of jeans is equal to the carbon sequestered by six trees per year

Food System

Distribution of Energy Use in the U.S. Food System (2002)

- Out-of-Home: 18%
- Household: 28%
- Wholesale/Retail: 15%
- Agriculture: 13%
- Processing: 17%
- Packaging: 5%
- Transport: 3%

Caloric Inputs & Outputs per Capita in the U.S, Based on Food Type (2002)

- Input: 2,655
- Output: 31,711

12 times more calories expended than produced

- Food away from home
- Household
- Meat
- Beverages
- Frozen, canned, snack, other
- Cereals & Baking
- Eggs & Dairy
- Fruit & Vegetables
- Fats, oils, sugars, sweets

The high embodied energy of food reflects a long supply chain.

- All links of the chain connected by oil-based transportation.
- Prior to the perfection of the refrigerated cold-chain, international transport of fresh vegetables and fruits was limited; now 5% of global containers are refrigerated.
- Shortening the supply chain is likely easier than decarbonizing the supply chain.
Transportation and related energy requirements

Embodied Energy in Manufacture of a Typical Vehicle

- Natural Gas: 66%
- Electricity: 27%
- Oil: 1%
- Coal: 6%

What Energy Goes Into Driving a Prius 1 Mile?

1. **Operation**: 56%
   - Operation requires the largest share of the total lifecycle energy consumed in the act of operating a passenger vehicle.

2. **Manufacturing & Maintenance**: 27%
   - Energy is required in the production, maintenance, and disposal of any passenger vehicle.

3. **Fuel Production**: 14%
   - Putting a single gallon of gasoline in a car requires oil to be extracted and refined into gasoline, which has to be delivered through service stations.

4. **Infrastructure**: 2%
   - While the individual share of each vehicle mile traveled is low, an enormous amount of energy goes into constructing and maintaining the roads that we drive on.

4.43 megajoules (1.23 kWh)

Source: Chester, et al., *Conventional, hybrid, plug-in hybrid or electric vehicles?* (2015)
Embodied & Operational Energy Footprints (Suzhou, China)

- Embodied energy constitutes over two-thirds of a Suzhou resident’s energy footprint.

- Over 41% of the footprint is the embodied energy in daily consumption.

- Food alone accounts for 22% of the energy footprint.

Source: David Fridley, Lawrence Berkeley National Laboratory
All segments of the supply chain will require conversion to renewable energy.

“The societal consumption driven by the process of urbanization — our collective desire for iPads, Frappuccinos and the latest fashions — more than outweighs the ecological benefits of local mass transit.”
— Geoffrey West, “A Physicist Solves the City”

2014 U.S. Average Household Expenditures

Total average expenditures: $53,495

- Gasoline: 62%
- Electricity: 37%
- Natural gas: 1%
- Fuel oil and other: 1%
- Shelter: 20%
- Transportation: 13%
- Food at home: 9%
- Food away from home: 5%
- Health care: 8%
- Other: 21%
- Clothing: 3%
- Entertainment: 7%
- Household (furniture, appliances, phone, upkeep, etc.): 5%

source: Bureau of Labor Statistics
Prices reflect the relative value of energy forms

- The premium value of electricity reflects its high ‘exergy’, or useful work possible.

- Electrification is most feasible where an electric process is more efficient than a fuel process (e.g. motor vs engine; heat pump vs furnace).

- Using electricity directly for heat is an inferior use.

Sources: Pacific Gas & Electric; Sonoma Clean Power; GasBuddy.com; IATA
Summary Points

- The transition to renewable energy is inevitable, necessary, and in progress.

- Most attention is focused on how to supply renewable energy; little on how we use energy and the how to develop substitutes for complex production processes and how to restructure supply chains.

- Vast efforts will be required to decarbonize electricity, but the majority of work will be substitution of non-electrical energy uses.

- The cheapest first step is to use less energy, through increased efficiency of existing uses, as well as reduction in consumption, thus reducing upstream supply chain energy use.