YONSEI UNIVERSITY

Strategies for Sustainable Energy

Lecture 4. Consumption Part II

ENG2110-01
College of Engineering
Yonsei University
Fall, 2010

Prof. David Keffer

Strategies for Sustainable Energy

Lecture 4. Consumption Part II

Section 1: Contributions to Consumption
Section 2: Opportunities for Improvement

7. Consumption: Heating/Cooling

Estimating Energy Consumption by Heating and Cooling

Device	power	time per day	energy per day
Cooking			
– kettle	3 kW	⅓ h	1 kWh/d
– microwave	1.4 kW	⅓ h	0.5 kWh/d
– electric cooker (rings)	3.3 kW	½ h	1.6 kWh/d
– electric oven	3 kW	½ h	1.5 kWh/d
Cleaning			
– washing machine	2.5 kW		1 kWh/d
– tumble dryer	2.5 kW	0.8 h	2 kWh/d
– airing-cupboard drying			0.5 kWh/d
– washing-line drying			0 kWh/d
– dishwasher	2.5 kW		1.5 kWh/d
Cooling			
– refrigerator	0.02 kW	24 h	0.5 kWh/d
– freezer	0.09 kW	24 h	2.3 kWh/d
– air-conditioning	0.6 kW	1 h	0.6 kWh/d

- bath = 5 kWh
- shower = 1.4 kWh

Total usage:

heating water = 12 kWh/day
heating air = 24 kWh/day
cooling = 1 kWh/day (no AC needed in the UK)
total = 37 kWh/day

7. Consumption: Heating/Cooling

YONSEI UNIVERSITY

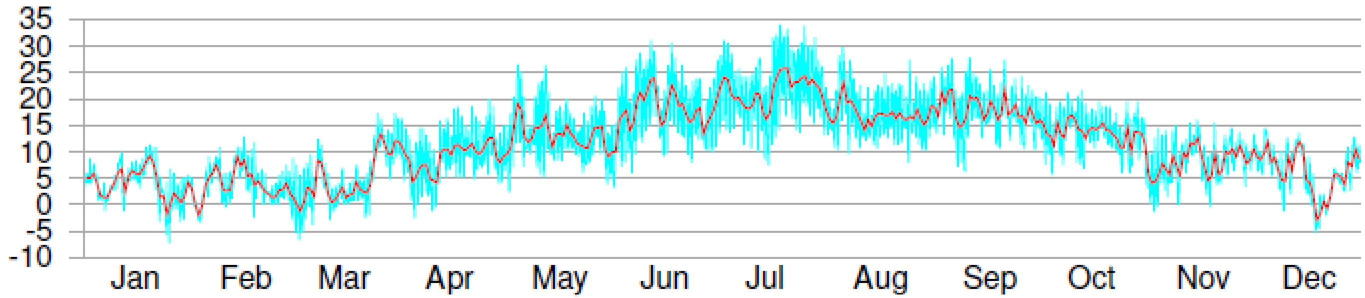
Estimating Energy Consumption by Heating and Cooling

Other types of heating:

- patio heater = 30 kWh
- electric blanket = 0.14 kWh

Air conditioning:

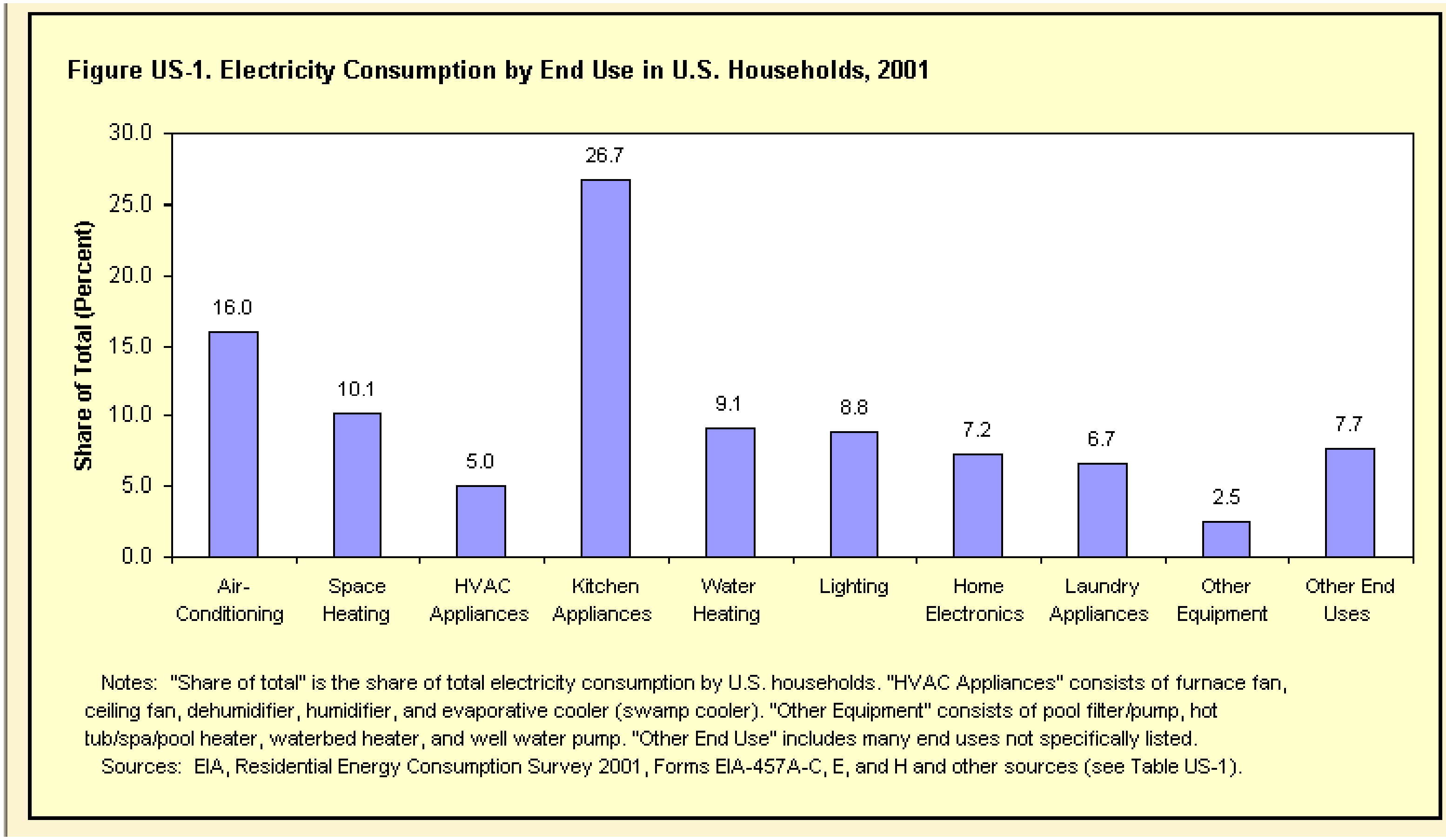
heating water = 0.6 kWh/day
(no AC needed in the UK)



7. Consumption: Heating/Cooling

Estimating Energy Consumption by Heating and Cooling

In the United States, heating and cooling of home is about 30% of total energy usage.



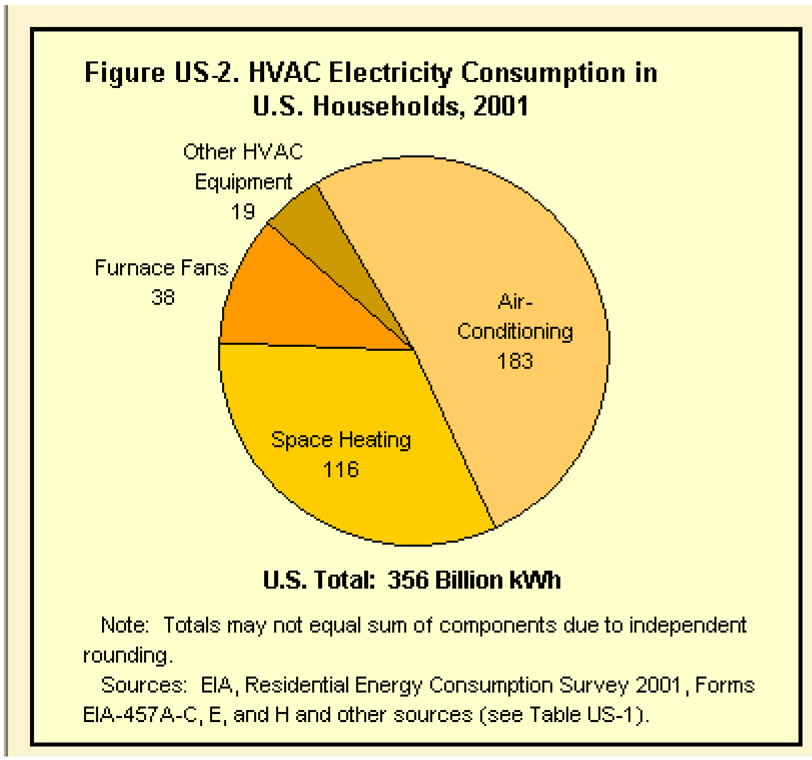
http://www.eia.doe.gov/emeu/reps/enduse/er01_us_figs.html

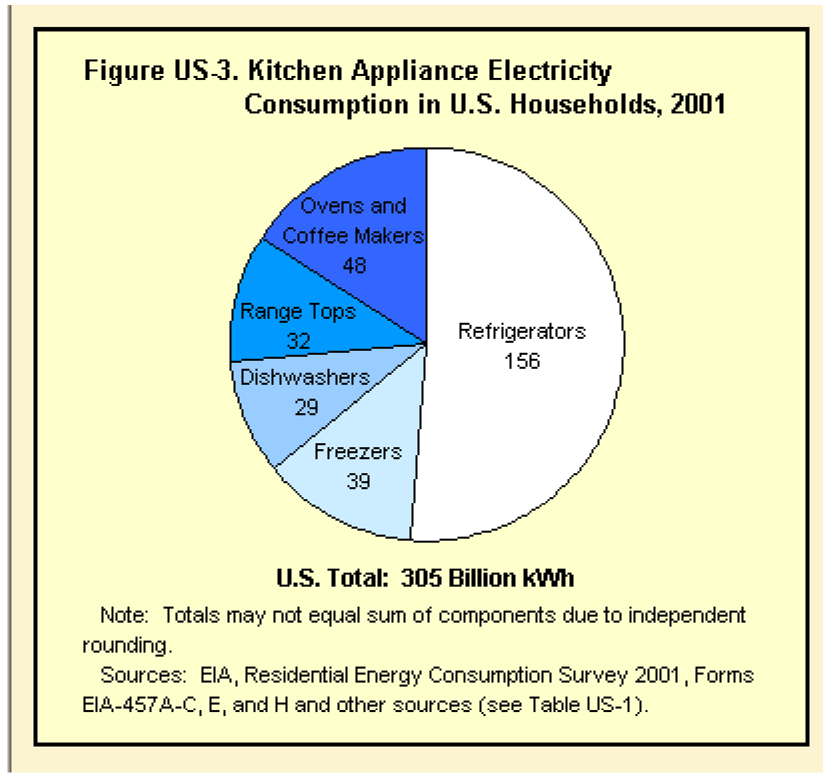
7. Consumption: Heating/Cooling

YONSEI UNIVERSITY

Estimating Energy Consumption by Heating and Cooling

Air conditioning is responsible for more than half of the energy usage used in heating/cooling the house. Refrigerators are responsible for more than half the energy usage used for heating/cooling with kitchen appliances.





http://www.eia.doe.gov/emeu/reps/enduse/er01_us_figs.html

9. Consumption: Light

Estimating Energy Consumption by Lighting

total = 4 kWh/day

Incandescent vs compact fluorescent light bulbs

- incandescent = 10 lumens per W
- compact fluorescent = 55 lumens per W

> *Should I wait until the old bulb dies before replacing it?*
>
> It feels like a waste, doesn't it? Someone put resources into making the old incandescent lightbulb; shouldn't we cash in that original investment by using the bulb until it's worn out? But the economic answer is clear: *continuing to use an old lightbulb is throwing good money after bad*. If you can find a satisfactory low-energy replacement, replace the old bulb now.

Light: 4 kWh/d

Heating, cooling: 37 kWh/d

Jet flights: 30 kWh/d

Car: 40 kWh/d

9. Consumption: Light

YONSEI UNIVERSITY

Estimating Energy Consumption by Lighting

Economic analysis

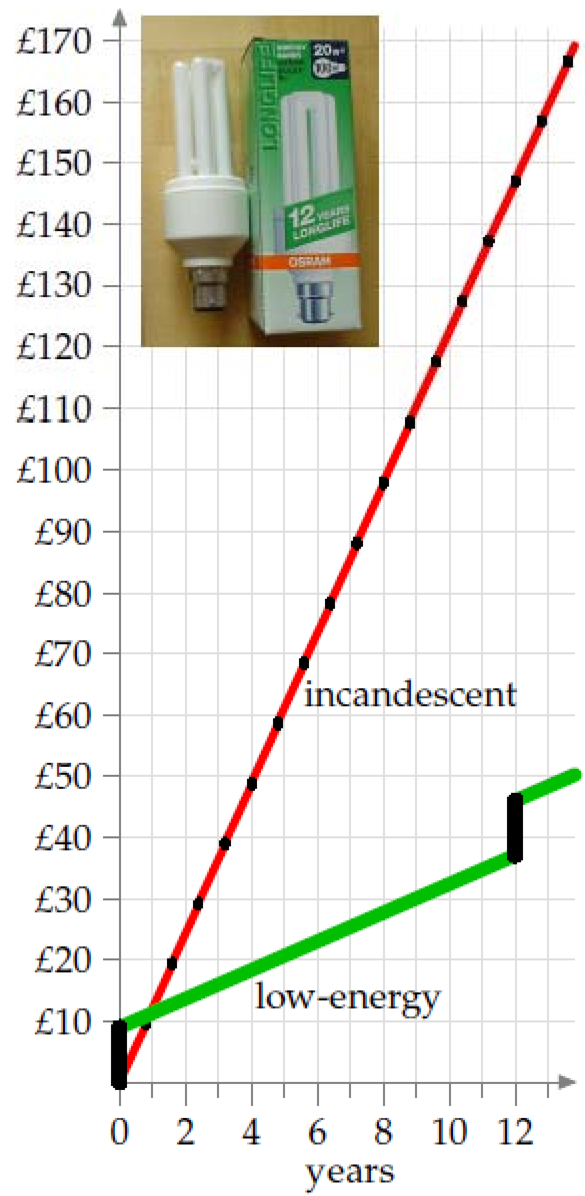


Figure 9.3. Total cumulative cost of using a traditional incandescent 100 W bulb for 3 hours per day, compared with replacing it *now* with an Osram Dulux Longlife Energy Saver (pictured). Assumptions: electricity costs 10p per kWh; replacement traditional bulbs cost 45p each; energy-saving bulbs cost £9. (I know you can find them cheaper than this, but this graph shows that even at £9, they're much more economical.)

11. Consumption: Gadgets

Estimating Energy Consumption by Gadgets (electronics)

total = 5 kWh/day

Table 11.4. Power consumptions of various gadgets, in watts. 40 W is 1 kWh/d.

Laptop: 16 W Computer: 80 W

LCD 31 W CRT 108 W Printer: 17 W (on, idle)

Projector: 150 W Digital radio: 8 W

Gadget	Power consumption (W)			
	on and active	on but inactive	standby	off
Computer and peripherals:				
computer box	80	55		2
cathode-ray display	110		3	0
LCD display	34		2	1
projector	150		5	
laser printer	500	17		
wireless & cable-modem	9			
Laptop computer	16	9		0.5
Portable CD player	2			
Bedside clock-radio	1.1	1		
Bedside clock-radio	1.9	1.4		
Digital radio	9.1		3	
Radio cassette-player	3	1.2		1.2
Stereo amplifier	6			6
Stereo amplifier II	13			0
Home cinema sound	7	7	4	
DVD player	7	6		
DVD player II	12	10	5	
TV	100		10	
Video recorder	13		1	
Digital TV set top box	6		5	
Clock on microwave oven	2			
Xbox	160		2.4	
Sony Playstation 3	190		2	
Nintendo Wii	18		2	
Answering machine		2		
Answering machine II		3		
Cordless telephone		1.7		
Mobile phone charger	5	0.5		
Vacuum cleaner	1600			

Gadgets: 5

Light: 4 kWh/d

Heating, cooling: 37 kWh/d

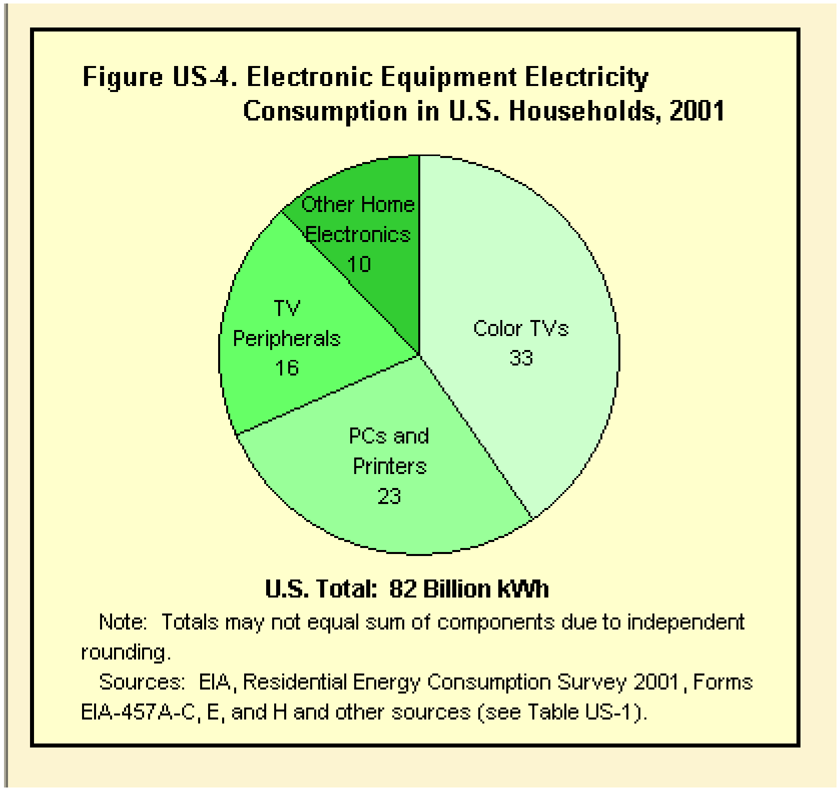
Jet flights: 30 kWh/d

Car: 40 kWh/d

7. Consumption: Gadgets

Estimating Energy Consumption by Heating and Cooling

In the United States, energy usage among electronic components is devoted to TVs and computers.



http://www.eia.doe.gov/emeu/reps/enduse/er01_us_figs.html

7. Consumption: Gadgets

YONSEI UNIVERSITY

Plasma TVs vs. LED TVs vs. LCD TVs

Model	HDTV type	Screen size	Default settings (watts)	Default setting (watts per square inch)	Default setting (cost per year)	Calibrated setting (watts)	Calibrated setting (watts per square inch)	Calibrated setting (cost per year)
Vizio VF552XVT	LED	55	191.14	0.148	$42.54	103.72	0.080	$23.37
Samsung UN55C8000	LED	55	129.46	0.100	$28.44	111.64	0.086	$24.53
Samsung LN52B750	LCD	52	191.15	0.165	$41.90	128.86	0.112	$28.25
Sony KDL-52XBR9	LCD	52	237.52	0.206	$52.07	159.97	0.138	$35.07
Samsung PN50B650	plasma	50	252.04	0.236	$55.39	290.46	0.272	$63.82
Panasonic TC-P50V10	plasma	50	255.61	0.239	$56.14	294.42	0.276	$64.65

LED televisions are really just LCD televisions that use LED lights for back lighting instead of the flourescent CFL lighting traditionally used for LCDs. Both employ the liquid crystal diode (LCD) technology front panel containing the “twisting crystals” which define LCD technology. --http://www.lcdtvbuyingguide.com/hdtv/led-vs-lcd.html

http://www.eia.doe.gov/emeu/reps/enduse/er01_us_figs.html

13. Consumption: Food & Farming

YONSEI UNIVERSITY

Estimating Energy Consumption by Food & Farming

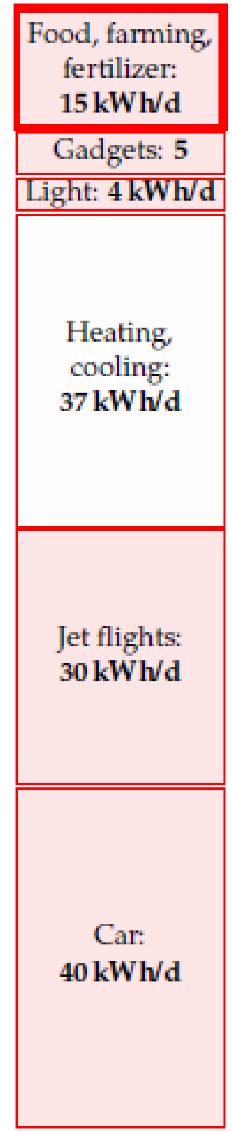
The minimum energy required by an active human being is on average about 2600 calories or 3 kWh/day

- vegetables = 1.5 kWh/d
- milk = 1.5 kWh/d (includes feeding the dairy cow)
- 2 eggs = 1 kWh/d (includes feeding the chicken)
- meat = 8 kWh/d (includes feeding the chicken, pig, cow)
- fertilizer = 2 kWh/d
- energy on the farm = 1 kWh/d (tractors, heating greenhouses)

total = 15 kWh/day

Pets

- pet cat = 2 kWh/d
- pet dog = 9 kWh/d
- pet horse = 17 kWh/d



Estimating Energy Consumption by Food & Farming: Meat

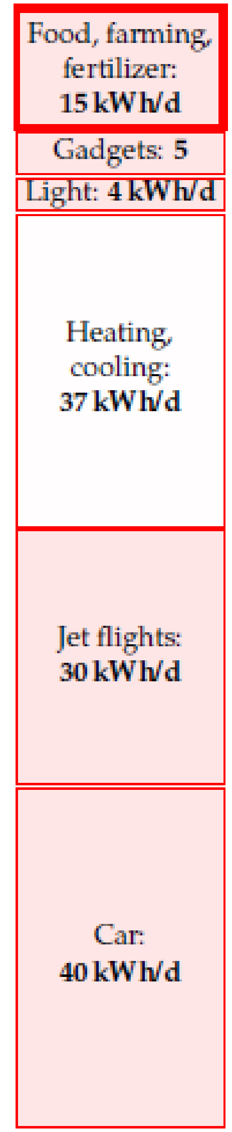
Chicken, sir? Every chicken you eat was clucking around being a chicken for roughly 50 days. So the steady consumption of half a pound a day of chicken requires about 25 pounds of chicken to be alive, preparing to be eaten. And those 25 pounds of chicken consume energy.

Pork, madam? Pigs are around for longer – maybe 400 days from birth to bacon – so the steady consumption of half a pound a day of pork requires about 200 pounds of pork to be alive, preparing to be eaten.

Cow? Beef production involves the longest lead times. It takes about 1000 days of cow-time to create a steak. So the steady consumption of half a pound a day of beef requires about 500 pounds of beef to be alive, preparing to be eaten.

To condense all these ideas down to a single number, let's assume you eat half a pound (227 g) per day of meat, made up of equal quantities of chicken, pork, and beef. This meat habit requires the perpetual sustenance of 8 pounds of chicken meat, 70 pounds of pork meat, and 170 pounds of cow meat. That's a total of 110 kg of meat, or 170 kg of animal (since about two thirds of the animal gets turned into meat). And if the 170 kg of animal has similar power requirements to a human (whose 65 kg burns 3 kWh/d) then the power required to fuel the meat habit is

$$170\,\text{kg} \times \frac{3\,\text{kWh/d}}{65\,\text{kg}} \simeq 8\,\text{kWh/d}.$$



The Sustainable Diet

Diets heavy in meat and dairy have a major impact on greenhouse gas emissions; it is estimated that livestock production is responsible for 18 percent of worldwide greenhouse gas emissions.[16]

http://en.wikipedia.org/wiki/Low_carbon_diet

SCIENTIFIC AMERICAN™

Winner of the 2011 National Magazine Award for General Excellence

Search ScientificAmerican.com

News & Features | Blogs | Multimedia | Education | Citizen Science | Topics

Home » Special Editions » March 2009

Departments | Environment

Sustainable Eating--The Low-Carbon Diet

A California chef and a climate scientist present a recipe for a sustainable diet

By Christine Soares | March 17, 2009 | 15

Share Email Print 1 2 Next >

Can we save the earth one stir-fry at a time? I was certainly dubious when I first saw the book, *Cool Cuisine: Taking the Bite Out of Global Warming*. Still, the lush cover photography of a verdant table setting and a bowl of farm-fresh eggs drew me in. As I flipped through the pages, I was a bit surprised to see they were packed with clean, colorful graphics and sidebars explaining everything from the atmospheric

I heard that the energy footprint of food is so big that "it's better to drive than to walk."

Whether this is true depends on your diet. It's certainly possible to find food whose fossil-fuel energy footprint is bigger than the energy delivered to the human. A bag of crisps, for example, has an embodied energy of 1.4 kWh of fossil fuel per kWh of chemical energy eaten. The embodied energy of meat is higher. According to a study from the University of Exeter, the typical diet has an embodied energy of roughly 6 kWh per kWh eaten. To figure out whether driving a car or walking uses less energy, we need to know the transport efficiency of each mode. For the typical car of Chapter 3, the energy cost was 80 kWh per 100 km. Walking uses a net energy of 3.6 kWh per 100 km – 22 times less. So if you live entirely on food whose footprint is greater than 22 kWh per kWh then, yes, the energy cost of getting you from A to B in a fossil-fuel-powered vehicle is less than if you go under your own steam. But if you have a typical diet (6 kWh per kWh) then "it's better to drive than to walk" is a myth. Walking uses one quarter as much energy.

15. Consumption: Stuff

Estimating Energy Consumption by Stuff
stuff = material goods

The Life Cycle of stuff

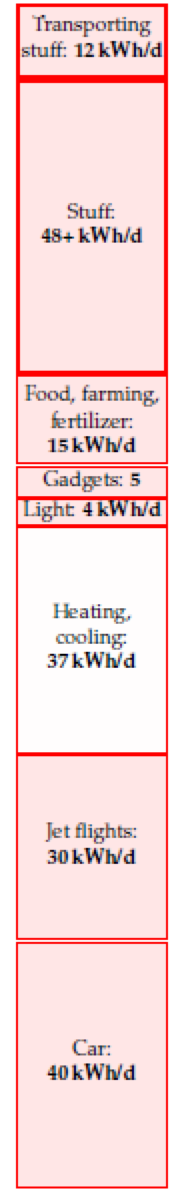
- extraction of raw materials
- production: processing of raw materials into products
- use by the consumer
- disposal (landfill, recycling)

This chapter focuses on the first two phases.

Examples

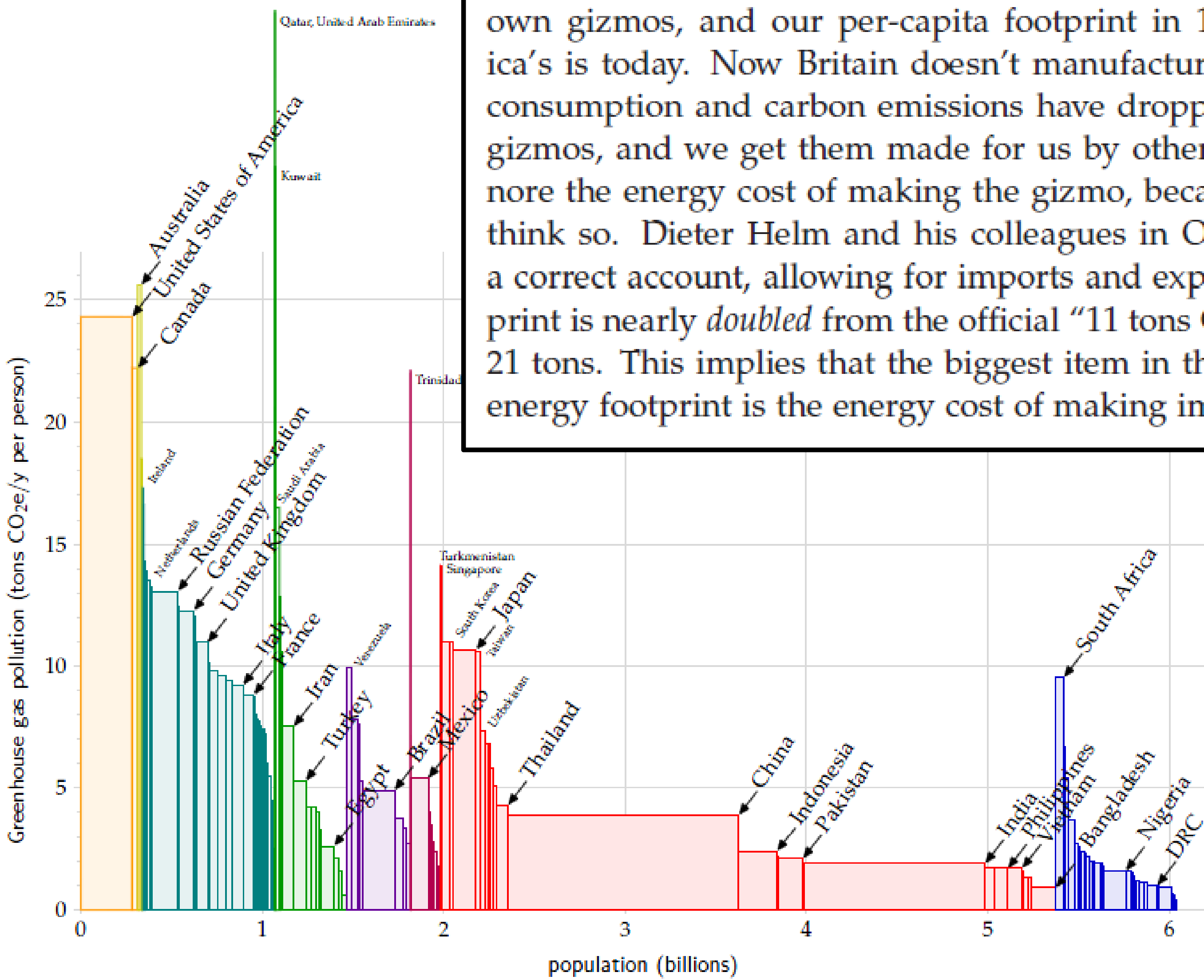
- 1 aluminum can = 0.6 kWh/d
- 400 g of packaging = 4 kWh/d
- new computer every two years = 2.5 kWh/d
- 200 g of newspaper/mail per day = 2 kWh/d
- 1 house (used for 100 years) = 1 kWh/d/person
- new car every 15 years = 14 kWh/d
- roads = 2 kWh/d/person
- television, furniture, clothes, shoes, etc.
- imported stuff = 1.3 tons stuff/person/year @ 10 kWh/kg = 40 kWh/d

Total = 48 kWh/d



15. Consumption: Stuff

In standard accounts of "Britain's energy consumption" or "Britain's carbon footprint," imported goods are *not* counted. Britain used to make its own gizmos, and our per-capita footprint in 1910 was as big as America's is today. Now Britain doesn't manufacture so much (so our energy consumption and carbon emissions have dropped a bit), but we still love gizmos, and we get them made for us by other countries. Should we ignore the energy cost of making the gizmo, because it's imported? I don't think so. Dieter Helm and his colleagues in Oxford estimate that under a correct account, allowing for imports and exports, Britain's carbon footprint is nearly *doubled* from the official "11 tons CO_2e per person" to about 21 tons. This implies that the biggest item in the average British person's energy footprint is the energy cost of making imported stuff.



15. Consumption: Stuff

Estimating Energy Consumption by Stuff
stuff = material goods

Transporting stuff

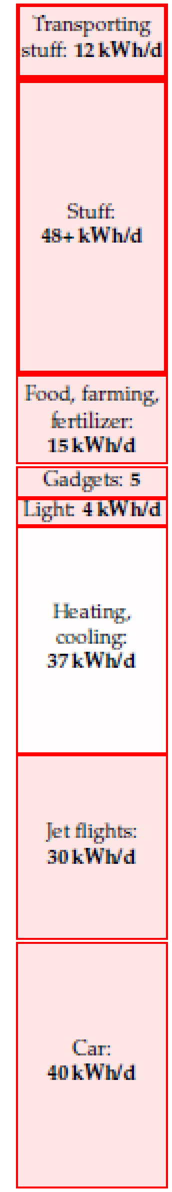
- 1 kWh will transport one ton of freight one kilometer on the road
- 0.015 kWh will transport one ton of freight one kilometer by ship

In the UK in 2006, 156 billion t-km of freight on the road shared between 60 million people comes to 7 t-km/day/person = 7 kWh/d/person

560 million tons of freight in British ports = 4 kWh/d/person

pumping water/treating sewage = 0.4 kWh/d/person

Transportation of stuff total = 12 kWh/d



17. Consumption Public Services

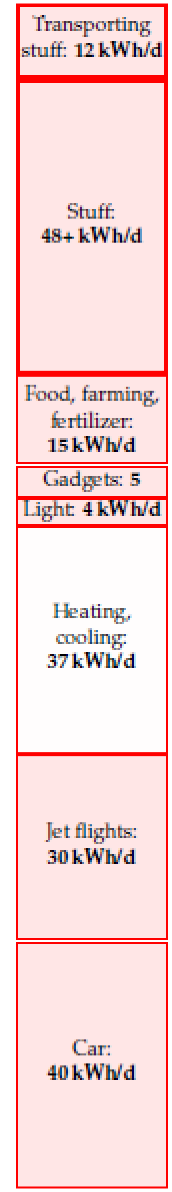
Estimating Energy Consumption by Public Services

6% of the British government expenses went to the military = 33 billion pounds
6% of the gross domestic product (GDP) went to energy

If 6% (fraction of energy) of the 6% (fraction of military) is billed at 2.7p/kWh,
Then we have 80 TWh per year in the military. This is 4 kWh/d/person.

Total = 4 kWh/d/person, ignoring everything except the military!

universities = 0.24 kWh/d/person



18. Total Consumption

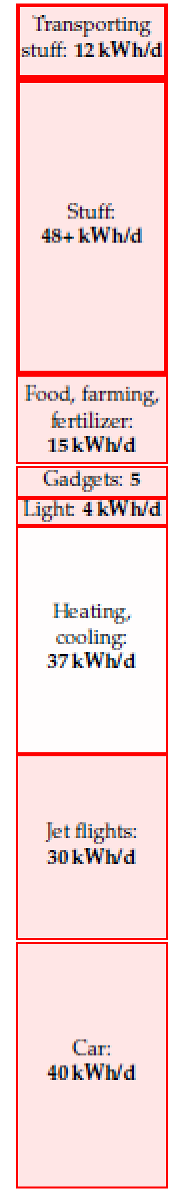
Consumption Grand Total = 195 kWh/day/person

Official consumption in the UK is 125 kWh/day/person.

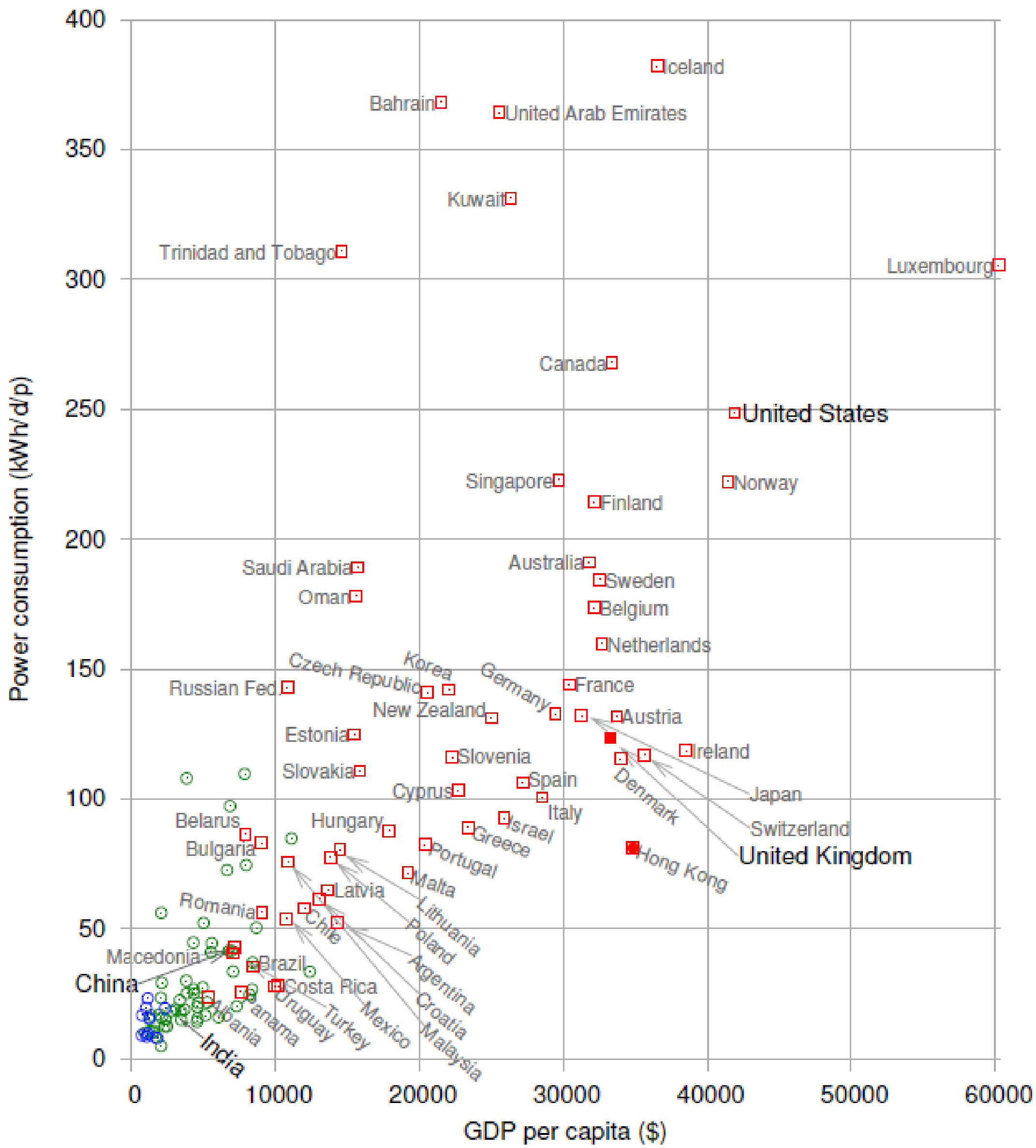
What is the difference?

If you don't count the energy to make imported stuff, you lose 40 kWh/d/p.

The resulting 155 kWh/day/person is higher than the UK average. (Perhaps the average UK citizen doesn't take 1 transcontinental flight each year—subtract another 30 kWh/day/person.)



18. Total Consumption



Strategies for Sustainable Energy

Lecture 4. Consumption Part II

Section 1: Contributions to Consumption
Section 2: Opportunities for Improvement

18. Improvements: Heating

Comparison: Knoxville, Tennessee, USA 3 new homes

Home 2:
Built by Contractor
w/ conventional materials
w/ conventional design
immediately retrofit to be energy efficient

Home 1:
Built by Contractor
with conventional materials
with conventional design

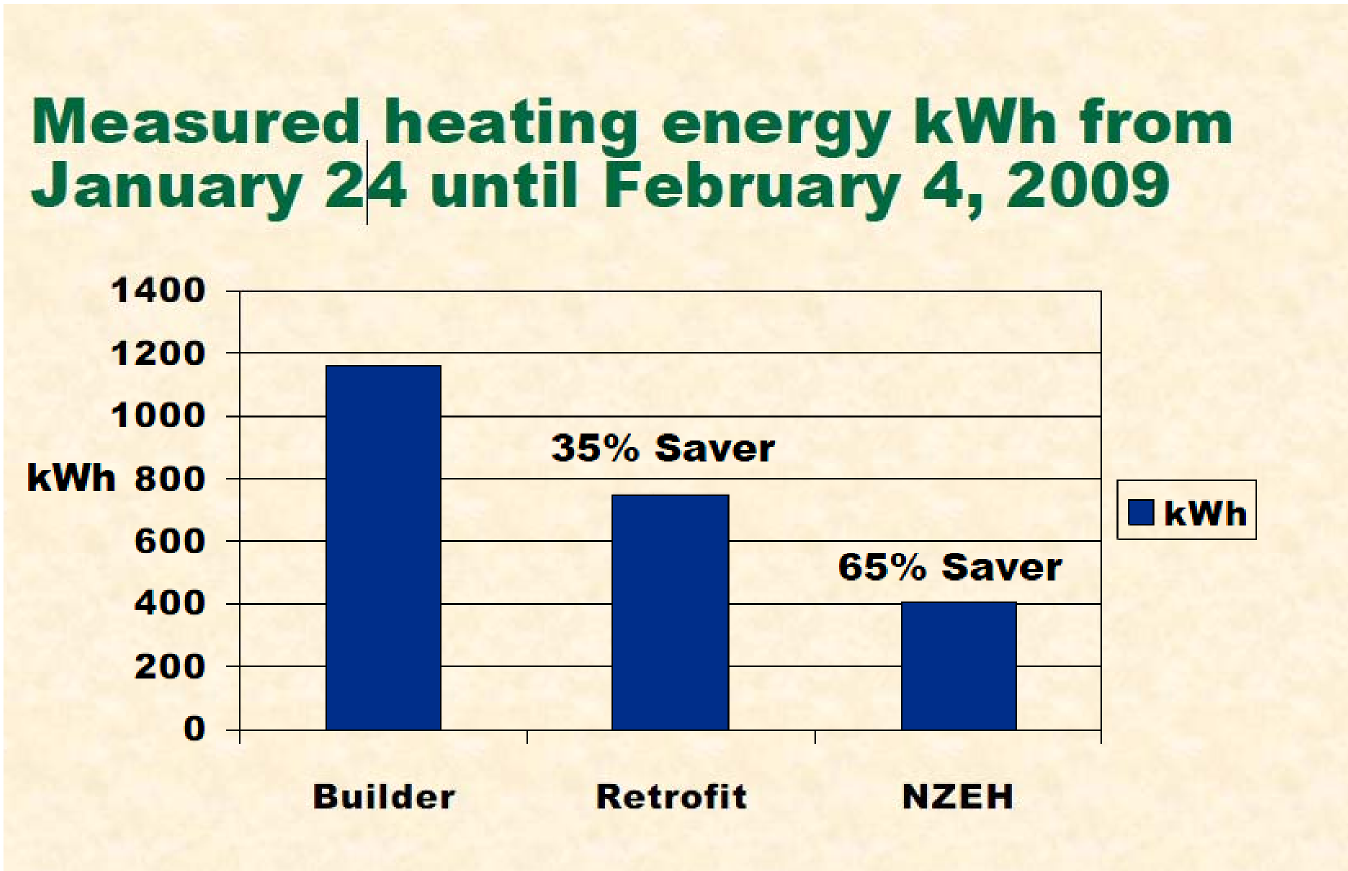
Home 3:
Built by from the beginning to be energy efficient
Energy efficient design
Energy efficient materials

Images & Slides:
Jeff Christian
Oak Ridge
National Laboratory

18. Improvements: Heating

YONSEI UNIVERSITY

Comparison: Knoxville, Tennessee, USA 3 new homes

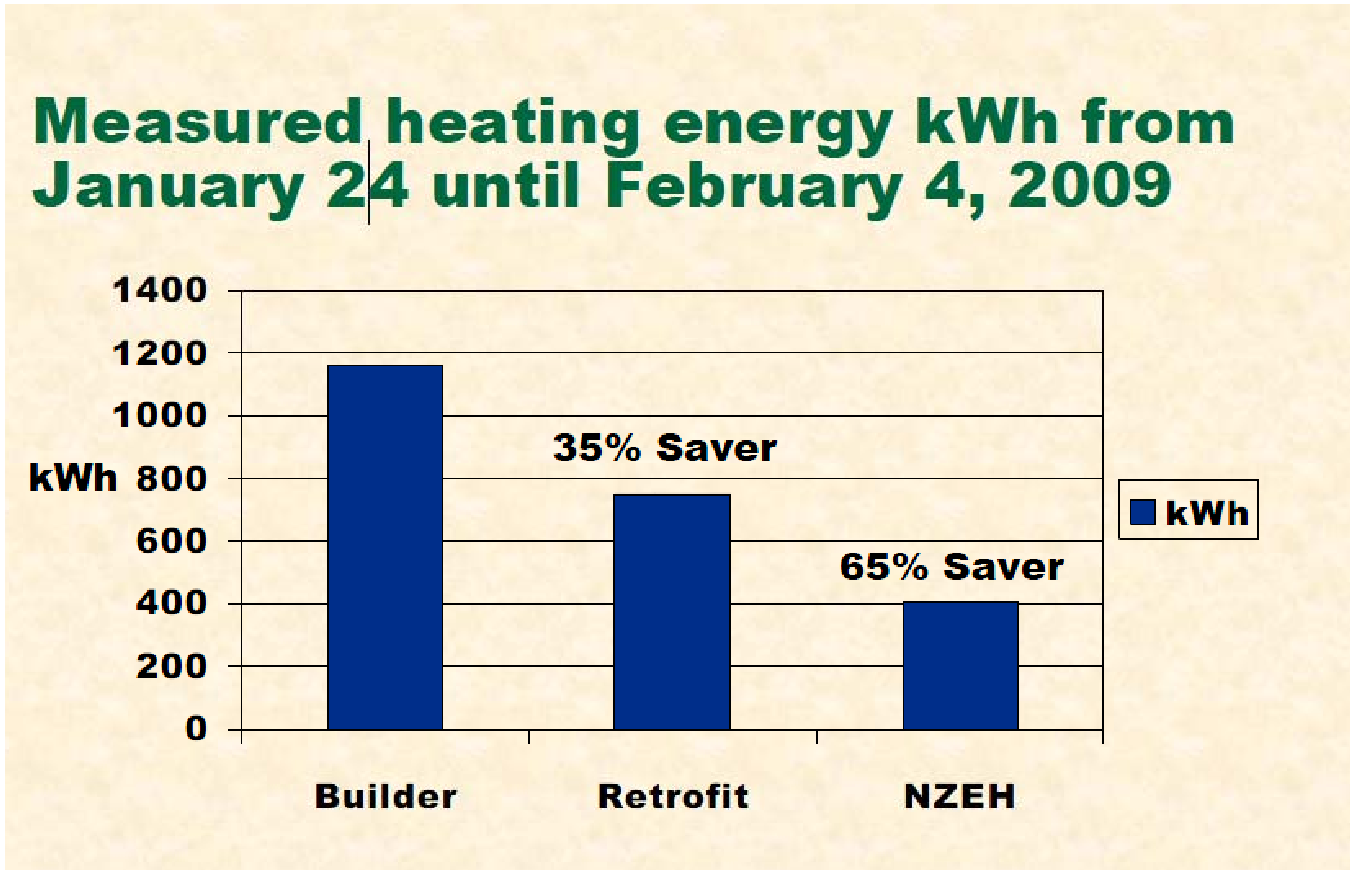


Images & Slides:
Jeff Christian
Oak Ridge
National Laboratory

Note: NZEH = near zero energy house

18. Improvements: Heating

Comparison: Knoxville, Tennessee, USA 3 new homes



Images & Slides:
Jeff Christian
Oak Ridge
National Laboratory

Note: NZEH = near zero energy house

18. Improvements: Heating

Comparison: Knoxville, Tennessee, USA 3 new homes

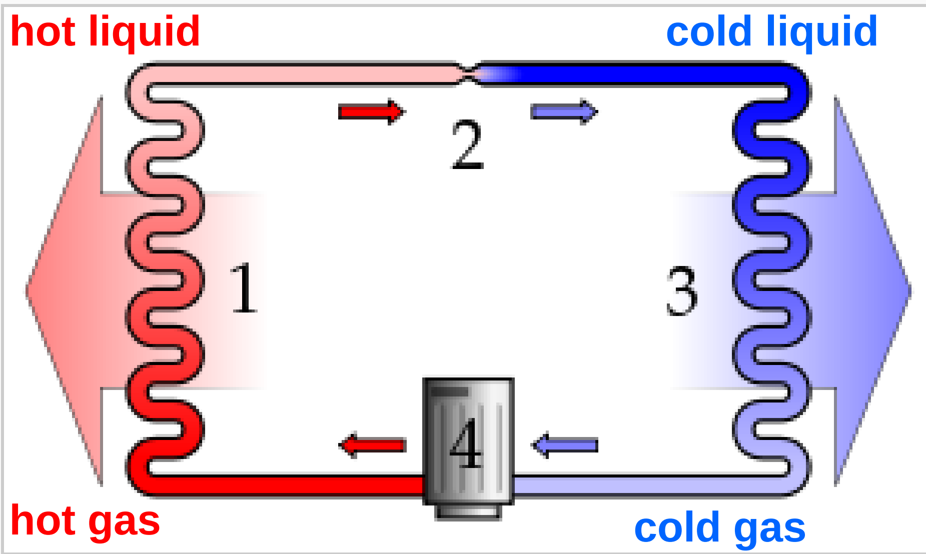
- **Builder house, HERS Index = 85**
  - Standard framing package R-13 walls, R-30 Ceiling
  - 2 Heat Pumps, SEER 13, HSPF 7.7, totaling 4.5 tons tons
- **Retrofit house, HERS Index = 66**
  - Sealed insulated attic
  - One 3 ton heat pump, HSPF= 9.5, SEER 16, zone control
  - 100% CFL
  - Energy star appliances
  - Single-hung LowE, gas filled windows
  - Heat pump water heater in the garage
  - 35-45% heating savings compared to the Builder house

Images & Slides:
Jeff Christian
Oak Ridge
National Laboratory

Note: HERS = home energy rating system

18. Improvements: Heating

All modern houses use heat pumps
- with electrical heating, 1 kWh electricity creates 1 kWh of heat
- with a heat pump, 1 kWh of electricity creates 3-4 kWh of heat



A simple stylized diagram of a heat pump's vapor-compression refrigeration cycle: 1) condenser, 2) expansion valve, 3) evaporator, 4) compressor.

Heat pumps use energy from an outside source (air or ground).
Heat pumps are reversible (heat in winter, cool in summer).
Heat pumps become less efficient as the temperature difference becomes greater.

18. Improvements: Heating

YONSEI UNIVERSITY

Comparison: Knoxville, Tennessee, USA 3 new homes

TVA Near Zero Energy House, HERs Index = 32

- Advanced 2 X 6 Framing with DOWsis
- R-49 attic with LP Techshield radiant barrier sheathing
- R-7. Triple layer windows from Serious Materials
- R-10 vertical slab stem wall insulation
- One Amana 2-ton HP, SEER 16, HSPF=9.5, zone control
- Fantech Energy Recovery Ventilator
- Advanced GE appliances
- Energy Star pin based High performance lighting design
- Solar drain-back water heater
- 2.5 kWh Solar PV system
- Greywater waste heat recovery
- Appliance waste heat recovery
- 65-70% heating energy savings

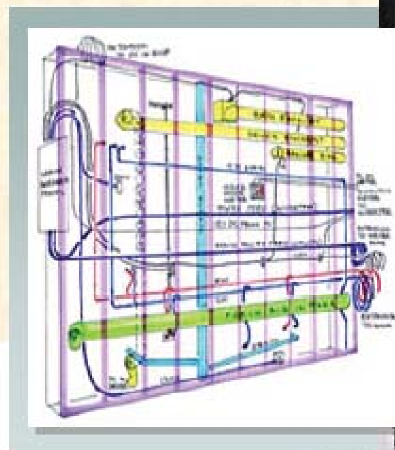
Images & Slides:
Jeff Christian
Oak Ridge
National Laboratory

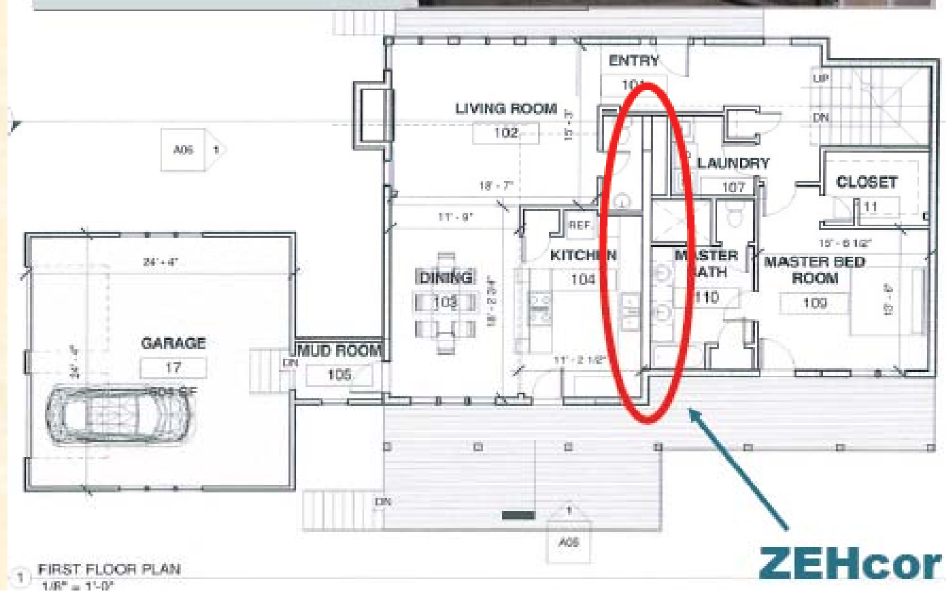
18. Improvements: Heating

Improvements In Design

ZEHcor Interior Utility Wall

- Saves energy
  - Imposes floor plan discipline
  - Reduces hot water distribution losses
  - Enables integration that could never be done reliably on-site
    - ERV-to-FHX
    - Appliances & grey water to FHX
- Reduces cost
  - Pre-fabrication in a controlled environment
  - Greater labor productivity
  - Less materials waste





Images & Slides:
Jeff Christian
Oak Ridge National Laboratory

18. Improvements: Heating

YONSEI UNIVERSITY

Improvements
In Materials

Triple layer windows R-6.7

Images &
Slides:
Jeff Christian
Oak Ridge
National
Laboratory

YONSEI UNIVERSITY

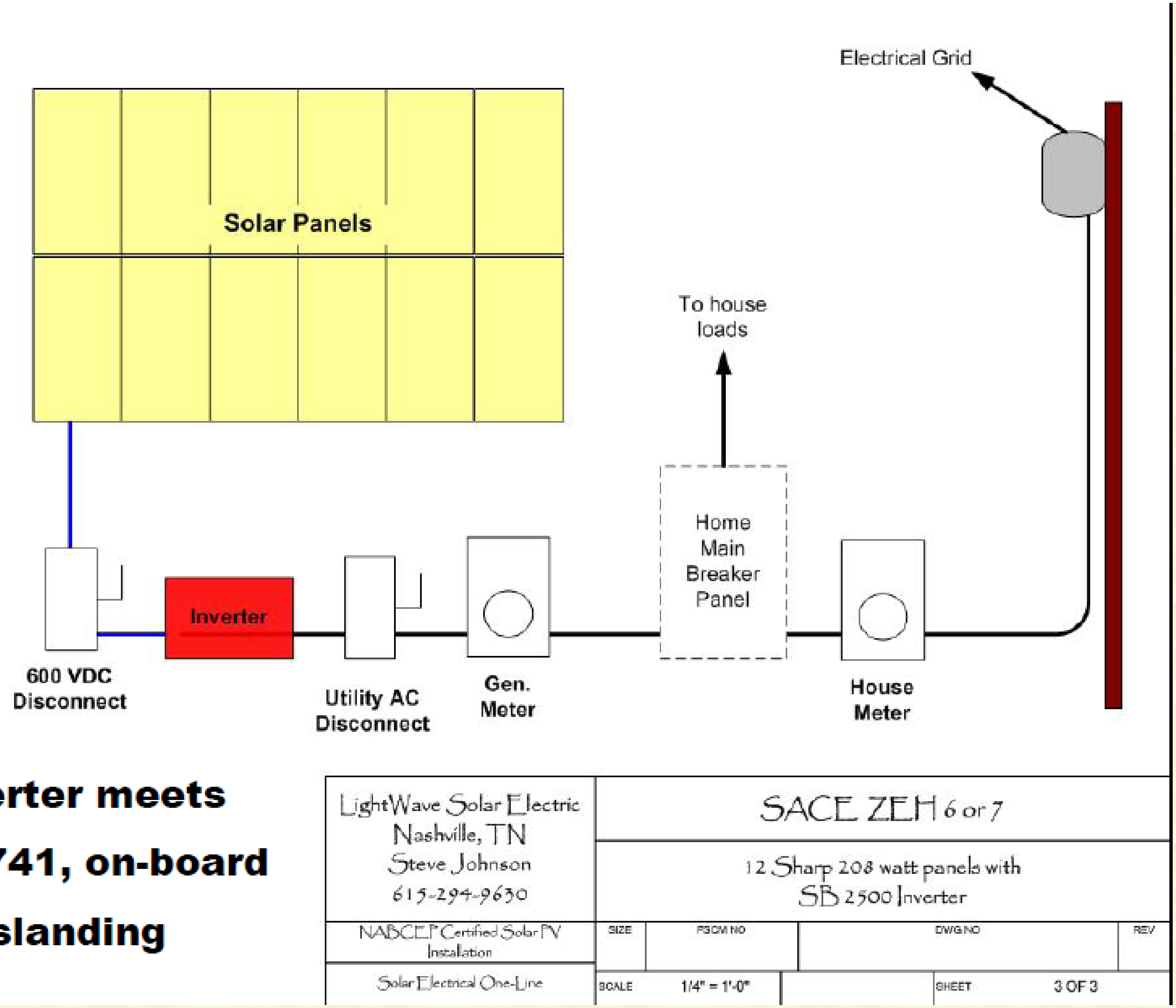
Ducts all inside the conditioned space, except 6 ft run out to bonus

Images & Slides:
Jeff Christian
Oak Ridge National Laboratory

18. Improvements: Heating

YONSEI UNIVERSITY

Improvements in energy generation



Inverter meets UL 1741, on-board islanding

Images & Slides:
Jeff Christian
Oak Ridge National Laboratory

18. Improvements: Heating

YONSEI UNIVERSITY

Improvements in economics due to local policy on green energy

First TVA Solar Generation Partner collecting $0.12/kWh above residential rate

New TVA feed-in tarriff

Images & Slides:
Jeff Christian
Oak Ridge National Laboratory