Introduction to Commercial Building Audits

Course No. ENRG 50

Outline

A. Introduction to concept of commercial building energy auditing
1. Why energy efficiency (EE) is important
2. Energy use and waste in commercial building operations
3. Prioritizing energy efficiency over renewable energy generation

B. Ordinances, policies and standards governing commercial building audits
1. San Francisco Existing Commercial Buildings Performance Ordinance
2. State of California energy goals
3. ASHRAE standards, including Building Energy Assessment Professional (BEAP)
4. Other audit standards

C. Three ASHRAE audit levels
1. Level 1, Basic energy analysis
2. Level 2, Intermediate, walk through and energy analysis
3. Level 3, Detailed analysis of capital-intensive modifications

D. Developing the scope of work in a commercial building audit
1. Objectives of the audit, including needed data and resources
2. Assessment management
3. Responsibilities of audit team members

E. Elements in preliminary analysis of building performance data
1. Engineering and architectural document review
2. Geographical and climatic review
3. Review and analysis of current energy use and costs
4. Benchmarking procedures

F. Factors in on-site building assessment
1. Common safety hazards and field safety techniques
2. Occupant interviews and assessment of building operations
3. Building envelope
4. Electrical systems
5. HVAC&R systems
6. Lighting systems and use
7. Miscellaneous other energy use systems
8. Domestic water systems and use
9. Indoor environmental quality

G. Analysis of data collected
1. Identify opportunities for efficiency improvement
2. Calculate value of efficiency improvements and return on investment
3. Prioritize options based on client criteria

H. Audit completion activities
1. Prepare and present written report
2. Assist with development of implementation plan

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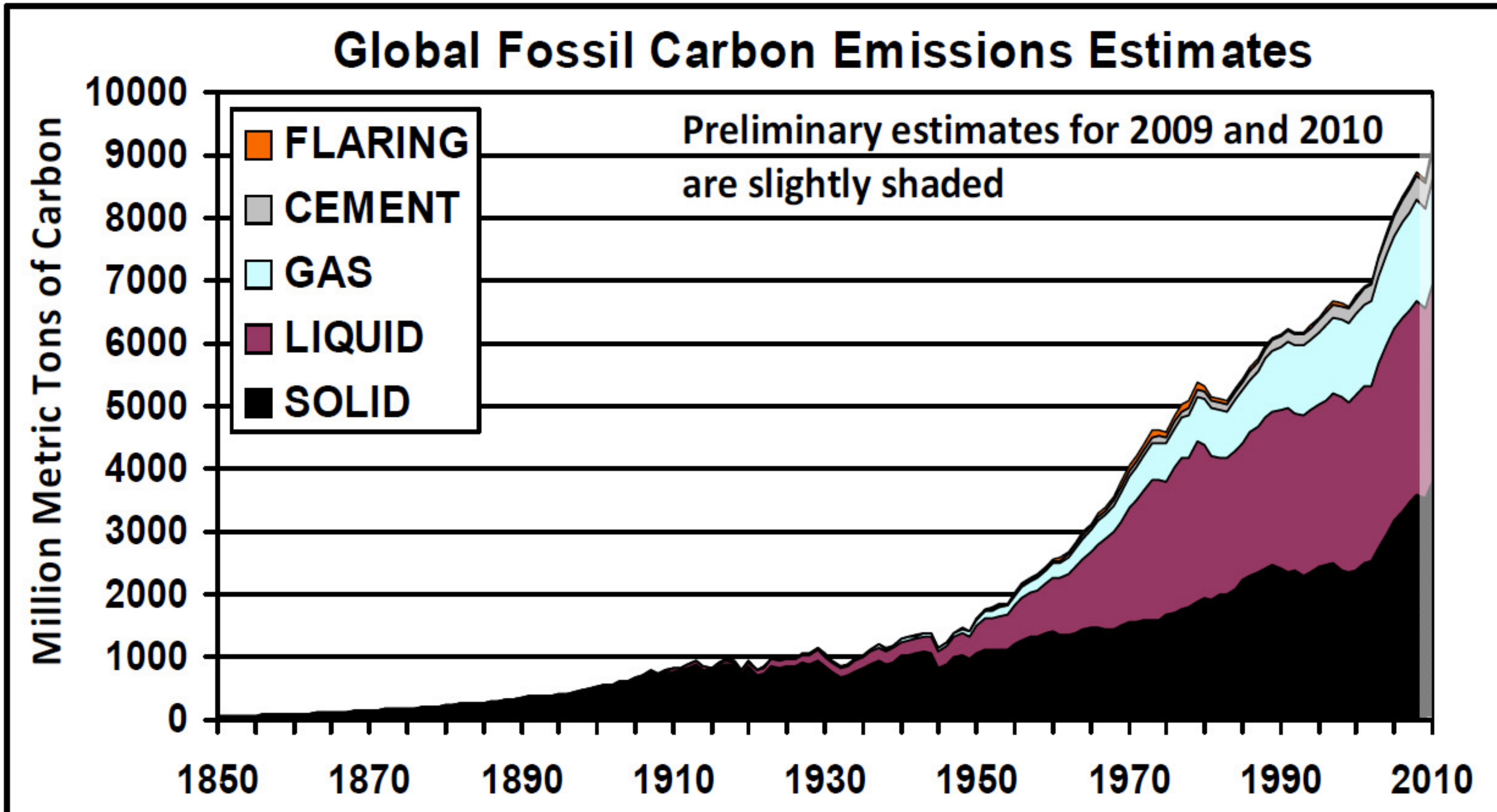
What is energy efficiency (EE)

- Using less energy to provide the same service.
- The goal of efforts to reduce the amount of energy required to provide products and services.
- Energy efficiency and renewable energy are the twin pillars of sustainable energy policy.

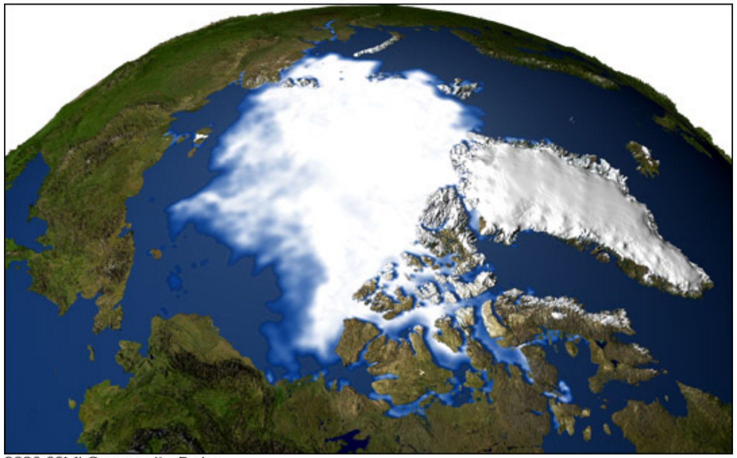
CO2/GHG emission getting worse, faster



http://envirolaw.com/ghg-worse-faster/

Climate change


1979 SSMI Composite Data

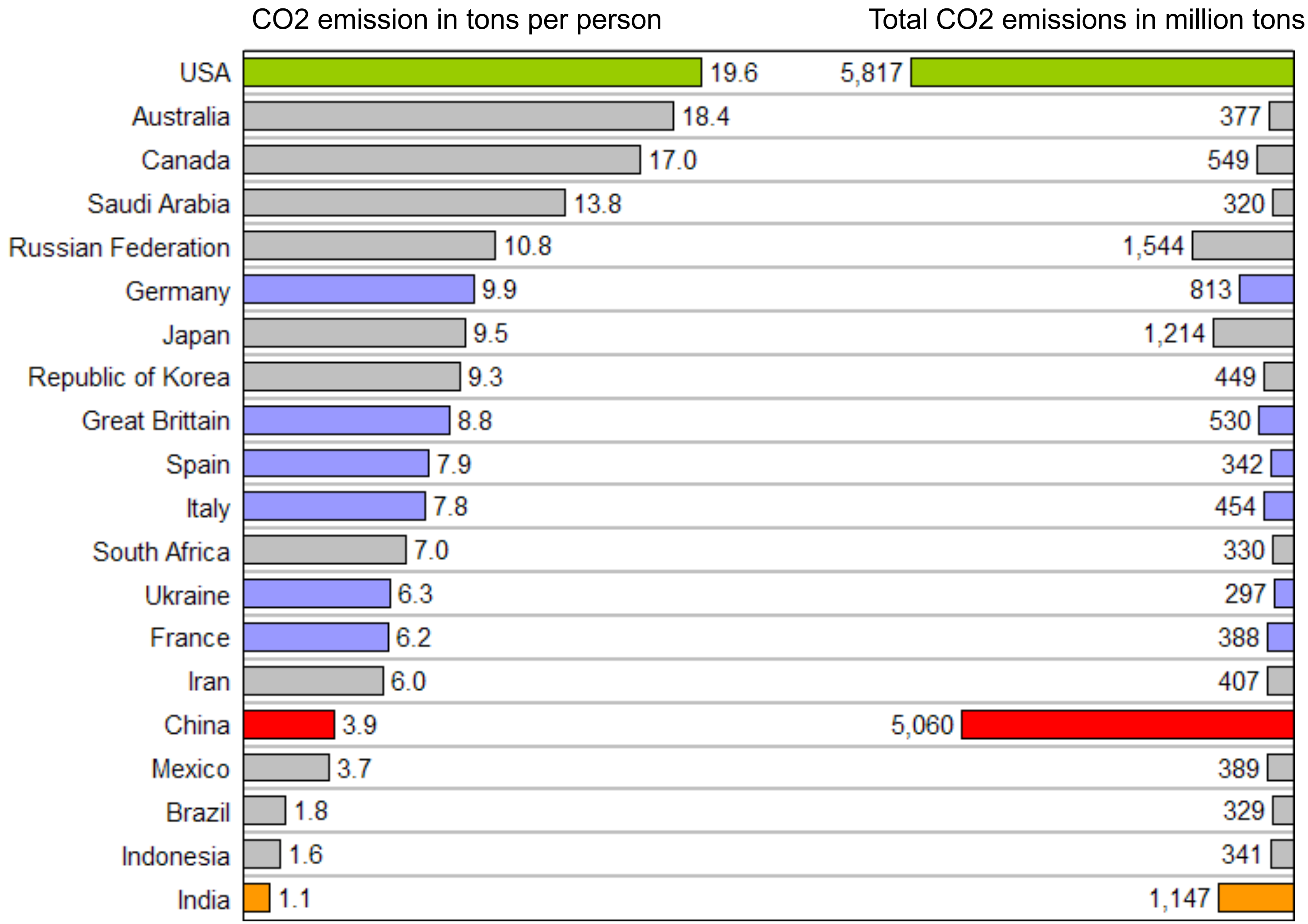

2003 SSMI Composite Data

Arctic Climate Change Assessment
http://amap.no/acia/

More reading materials:
http://iefworld.org/climate_what.html

http://www.sflorg.com/ear/

Per Capita and Total Carbon Dioxide Emissions, 2005



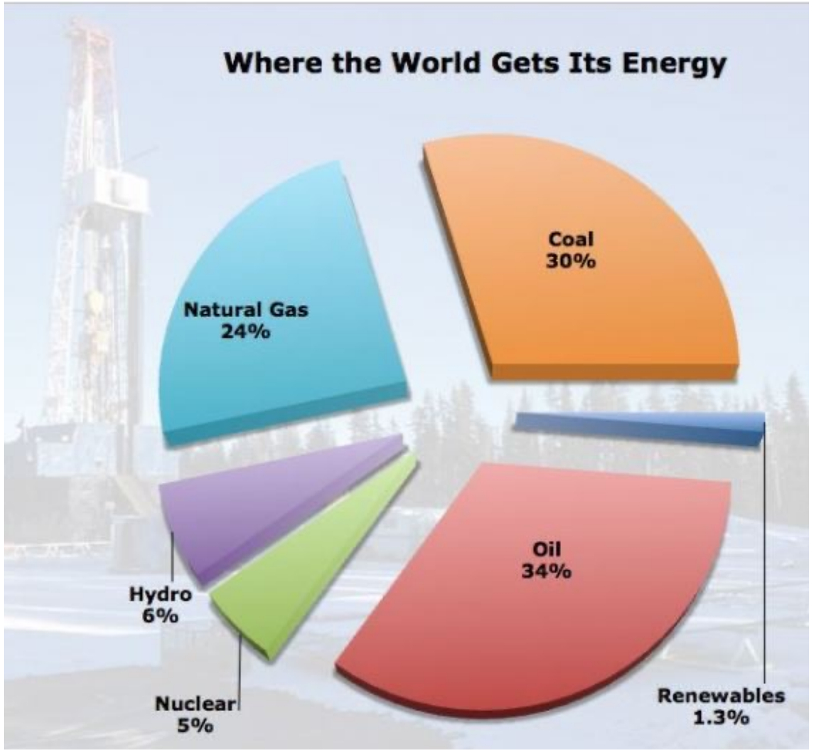
http://www.china-profile.com/data/fig_co2-emissions_3.htm

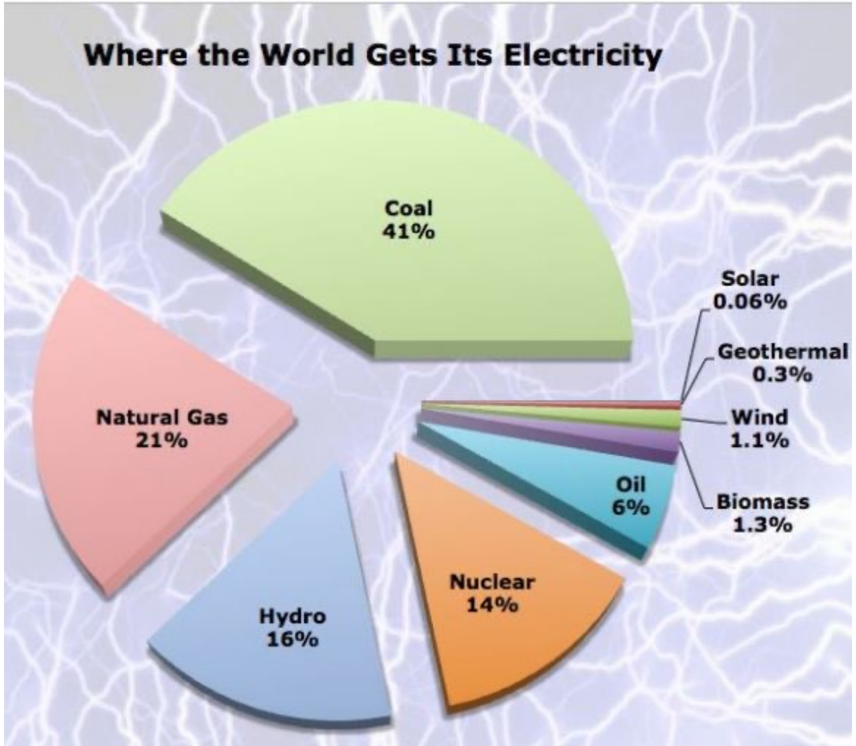
Carbon Footprint Calculators

http://www.carbonfund.org/business/calculator

http://www.pge.com/about/environment/calculator/

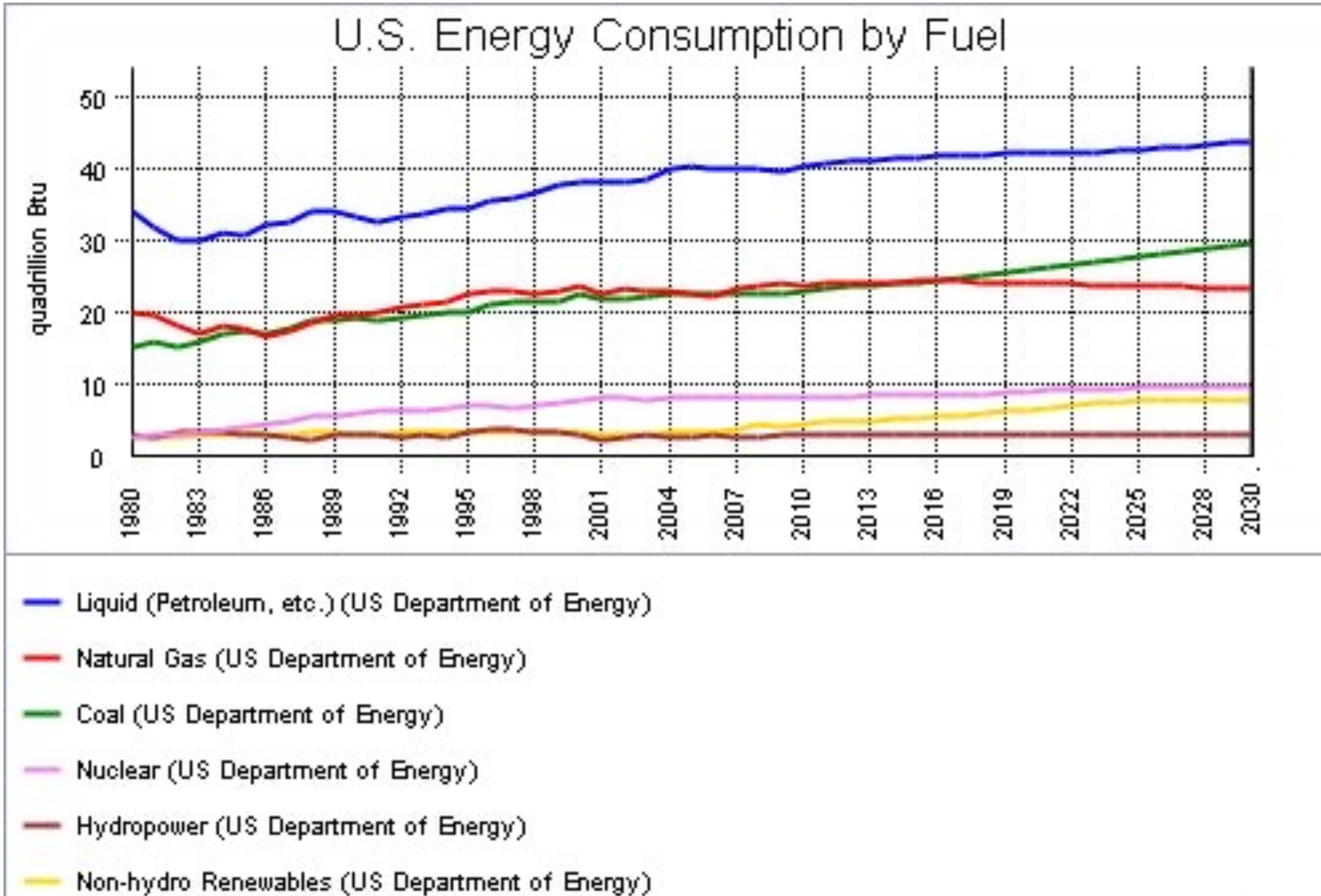
Energy sources





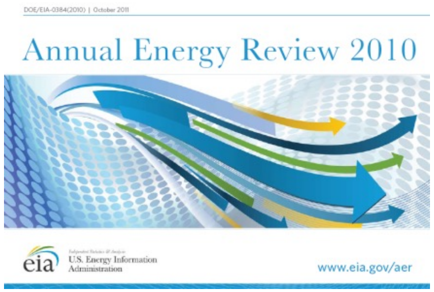
http://wattsupwiththat.com/2011/11/18/make-29-on-your-money-guaranteed/

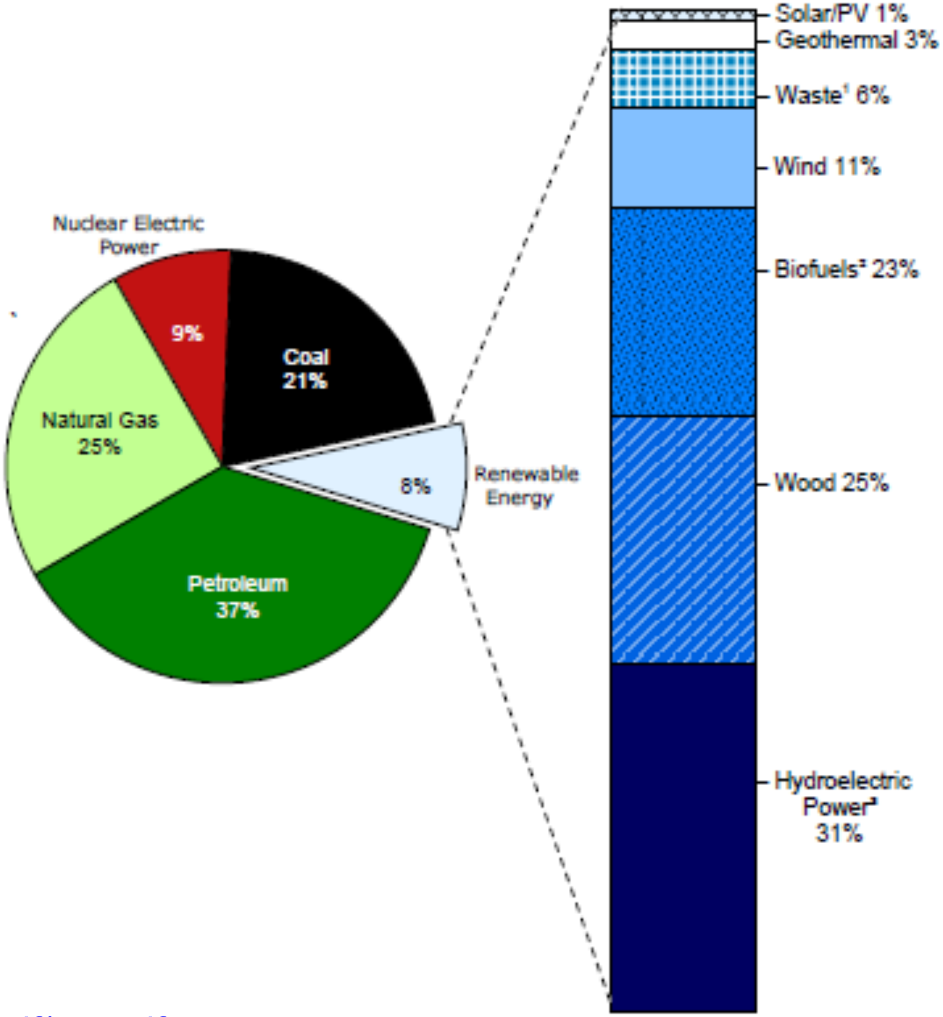
Energy sources



http://www.data360.org/dsg.aspx?Data_Set_Group_Id=611

US Energy sources

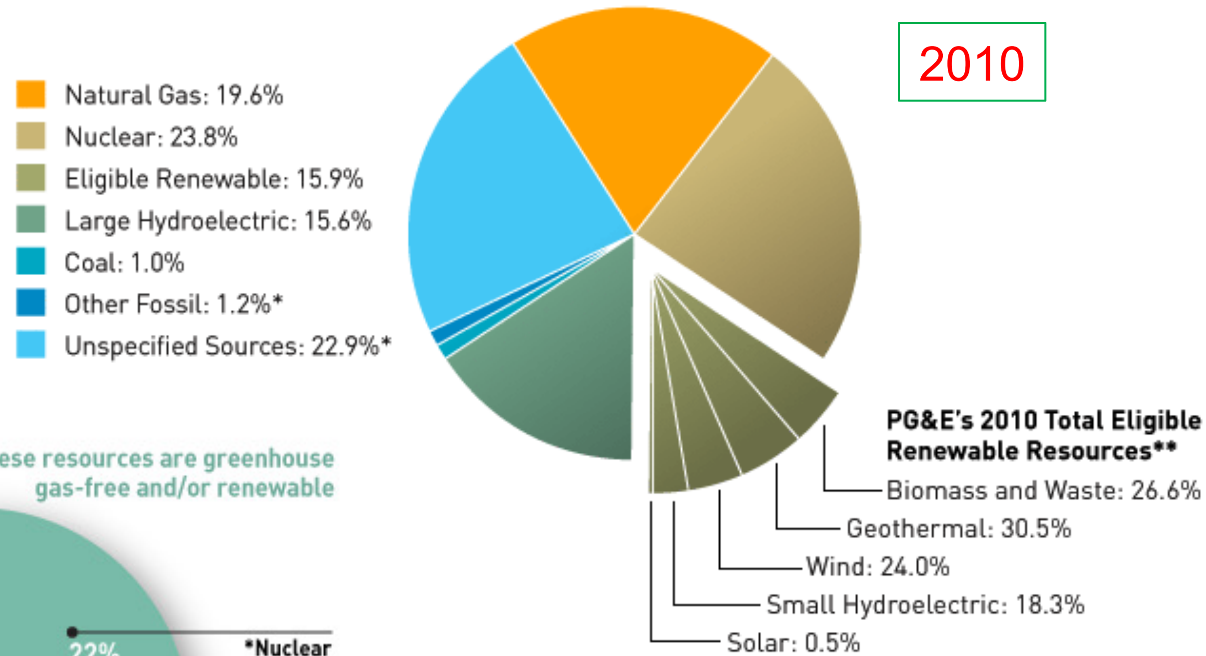


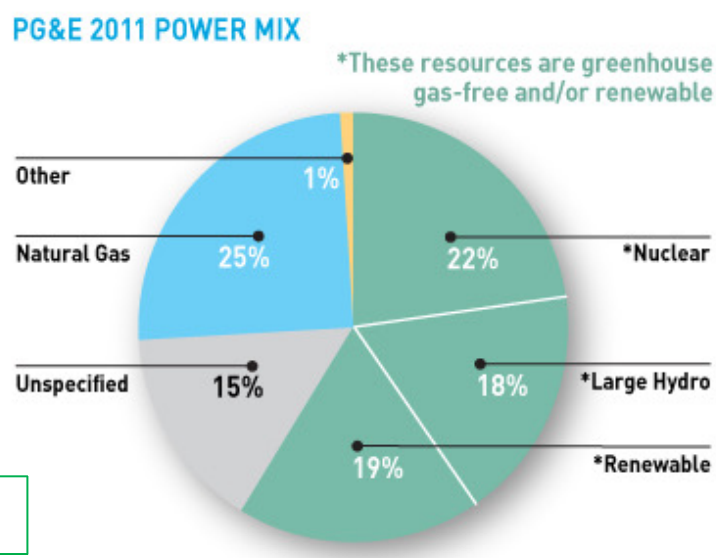


More readings:
http://www.eia.gov/totalenergy/data/annual/pdf/aer.pdf

PG&E Energy sources

2010





2011

Note: Power mix includes all PG&E-owned generation plus PG&E's power purchases.

http://www.pge.com/mybusiness/myaccount/explanationofbill/billinserts/

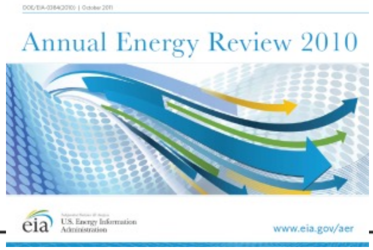
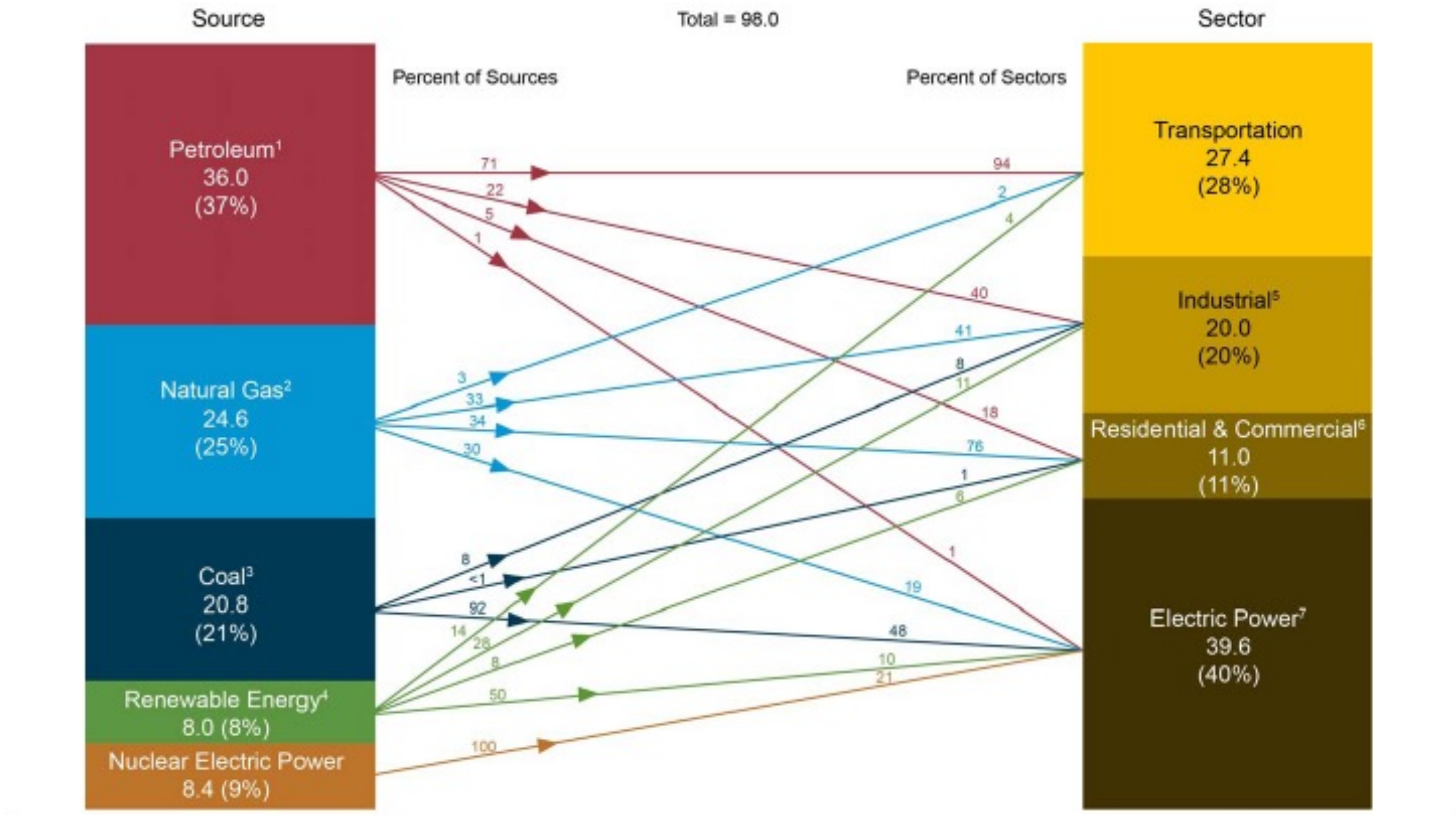


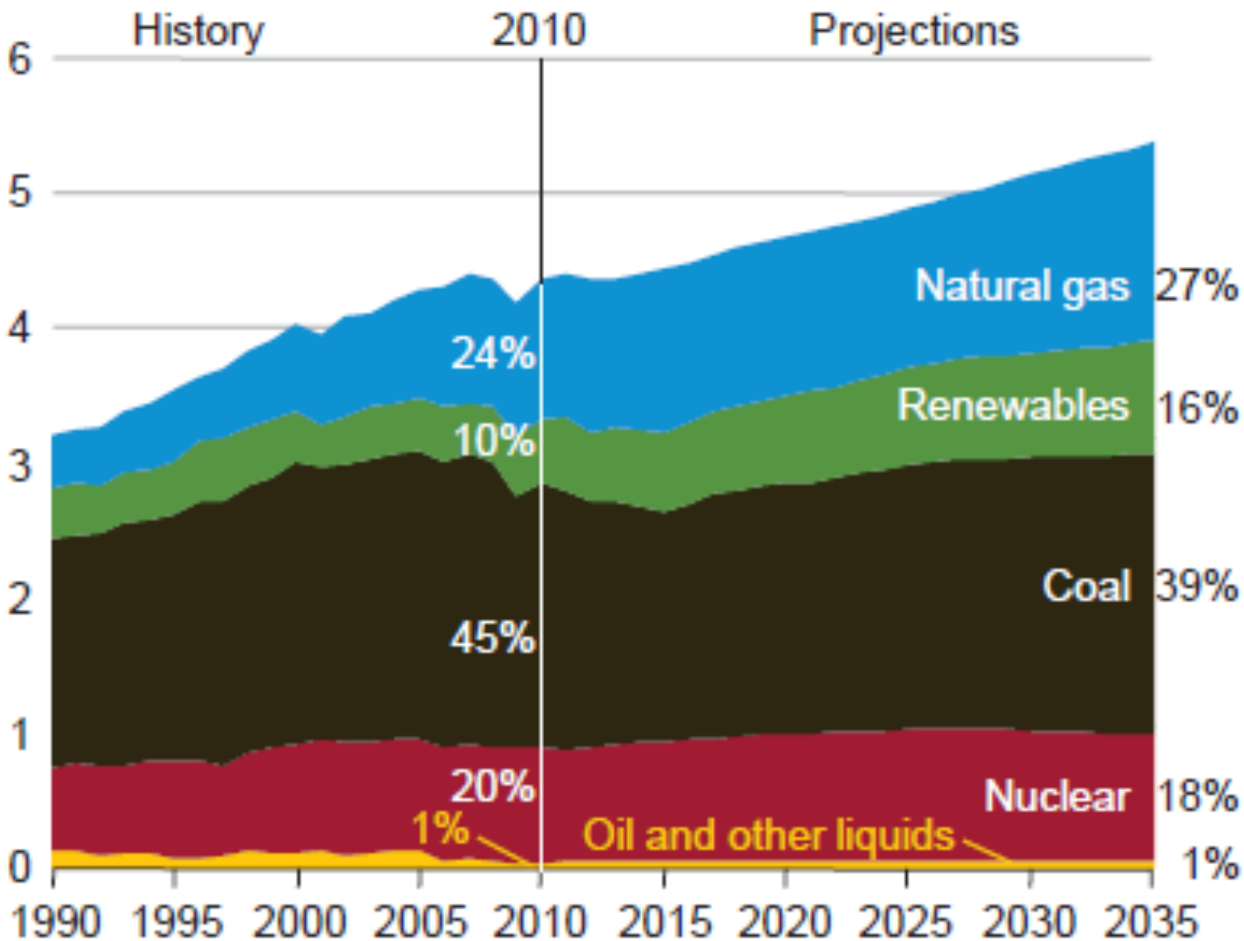
Figure 2.0 Primary Energy Consumption by Source and Sector, 2010
(Quadrillion Btu)

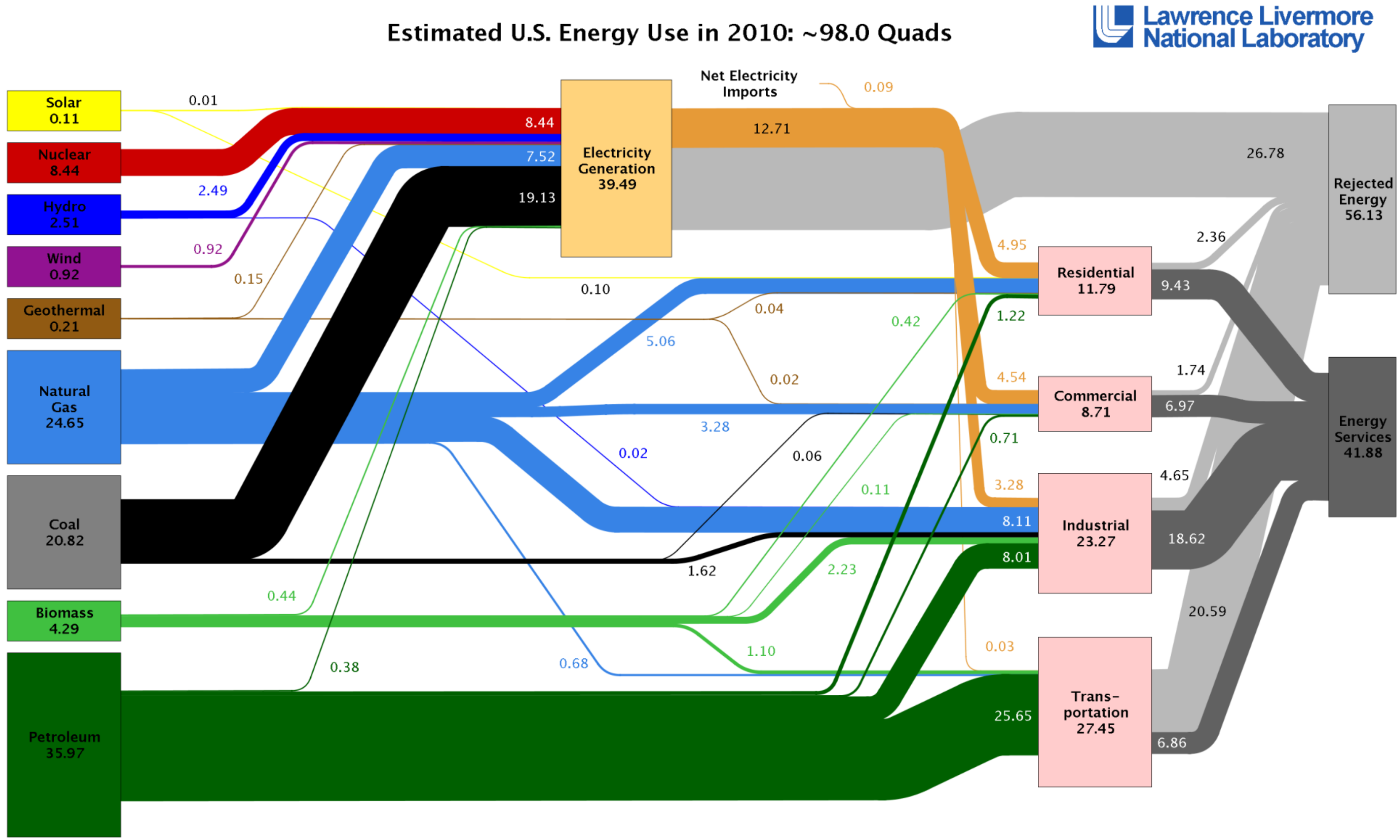


1. Why energy efficiency (EE) important

http://www.eia.gov/forecasts/aeo/er/pdf/0383er(2012).pdf

Figure 3. Electricity generation by fuel, 1990-2035 (trillion kilowatthours per year)





Source: LLNL 2011. Data is based on DOE/EIA-0384(2010), October 2011. 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 flows for hydro, wind, solar and geothermal in BTU-equivalent values by assuming a typical fossil fuel plant "heat rate." (see EIA report for explanation of change to geothermal in 2010). 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 80% for the residential, commercial and industrial sectors, and as 25% for the transportation sector. Totals may not equal sum of components due to independent rounding. LLNL-MI-410527

https://flowcharts.llnl.gov/

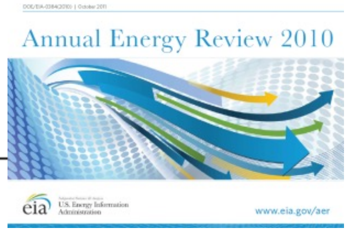
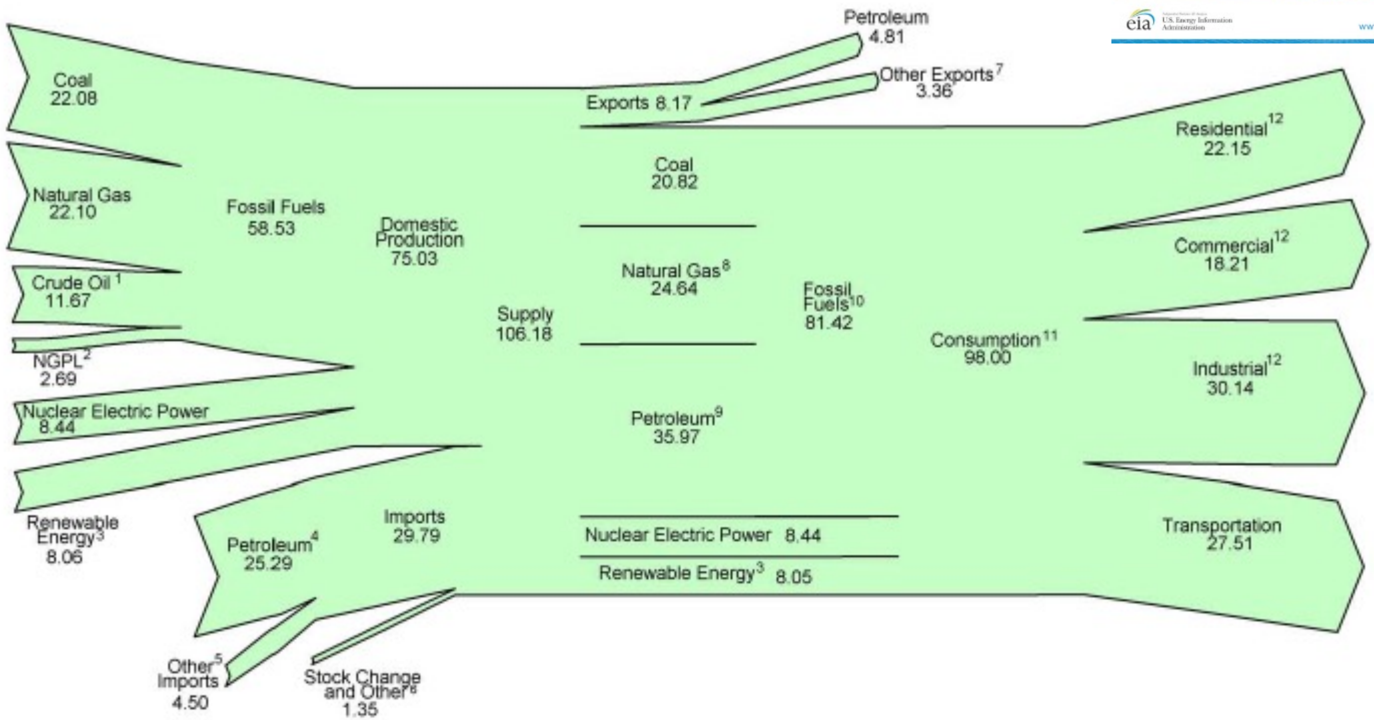


Figure 1.0 Energy Flow, 2010
(Quadrillion Btu)



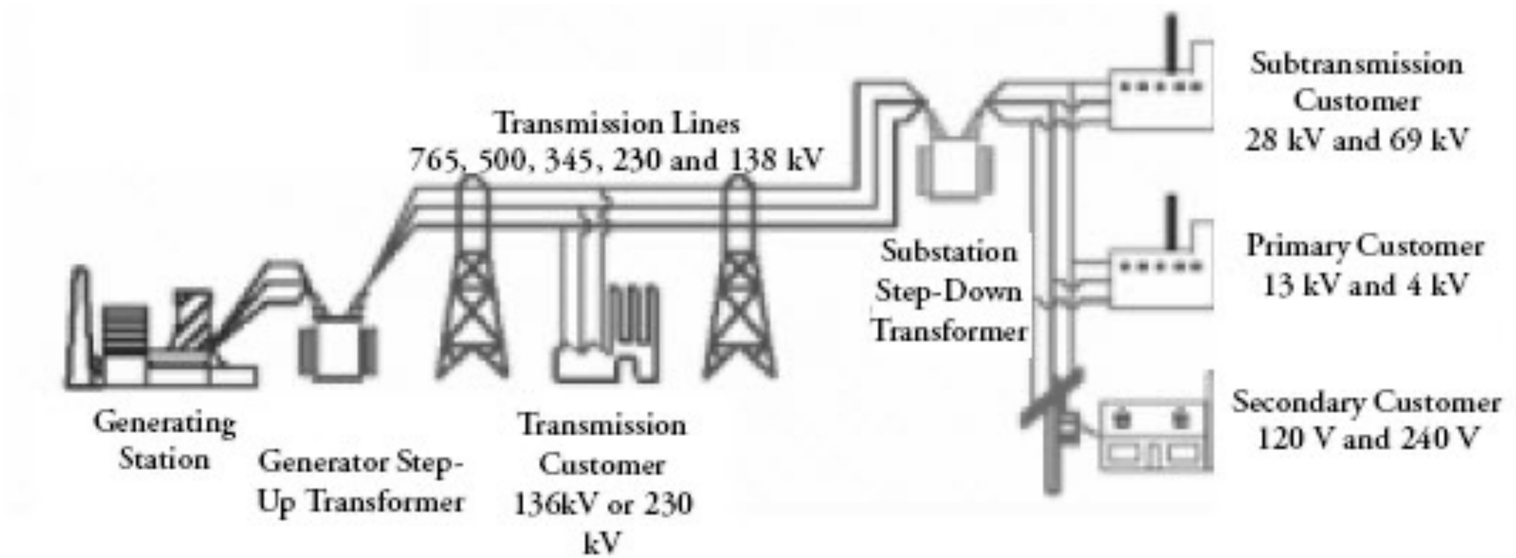
[1] Includes lease condensate.
[2] Natural gas plant liquids.
[3] Conventional hydroelectric power, biomass, geothermal, solar/photovoltaic, and wind.
[4] Crude oil and petroleum products. Includes imports into the Strategic Petroleum Reserve.
[5] Natural gas, coal, coal coke, biofuels, and electricity.
[6] Adjustments, losses, and unaccounted for.
[7] Coal, natural gas, coal coke, electricity, and biofuels.
[8] Natural gas only; excludes supplemental gaseous fuels.
[9] Petroleum products, including natural gas plant liquids, and crude oil burned as fuel.
[10] Includes 0.01 quadrillion Btu of coal coke net exports.
[11] Includes 0.09 quadrillion Btu of electricity net imports.
[12] Total energy consumption, which is the sum of primary energy consumption, electricity retail sales, and electrical system energy losses. Losses are allocated to the end-use sectors in proportion to each sector's share of total electricity retail sales. See Note, "Electrical Systems Energy Losses," at end of Section 2.

Notes: • Data are preliminary. • Values are derived from source data prior to rounding for publication. • Totals may not equal sum of components due to independent rounding.

Sources: Tables 1.1, 1.2, 1.3, 1.4, and 2.1a.

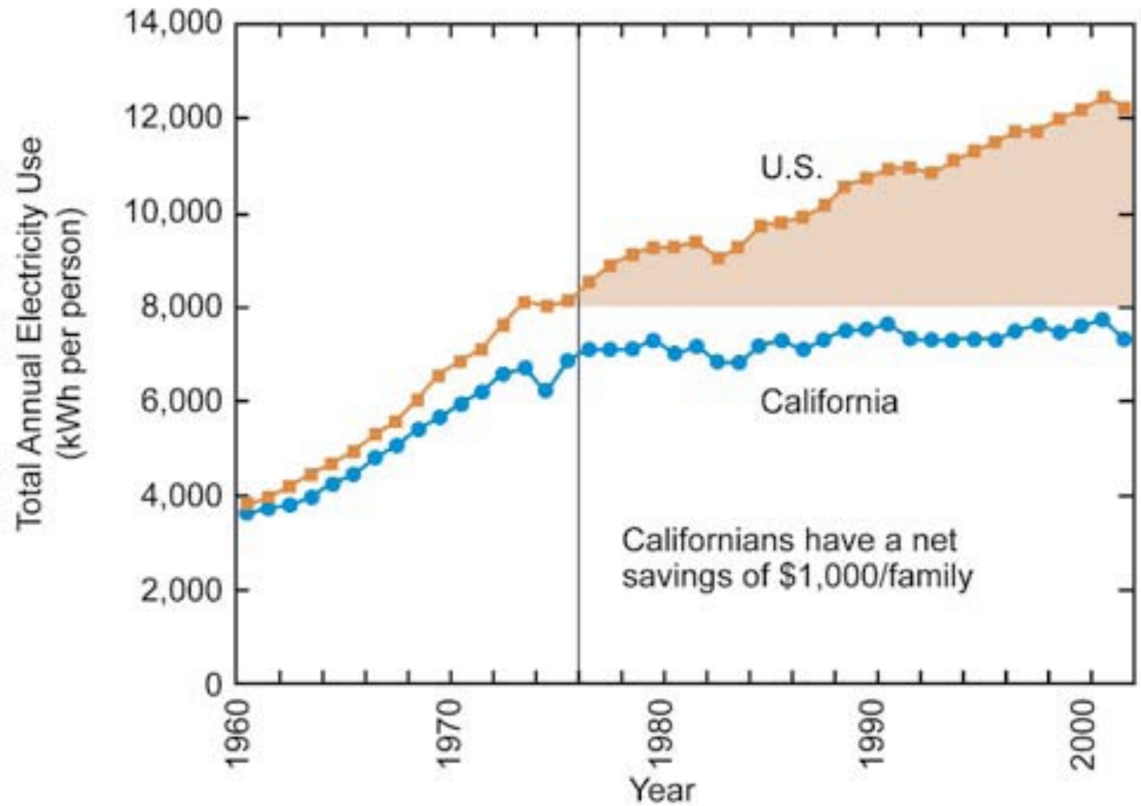
Utility interest

- Generation, Transmission, Distribution, End-Use
- Supply side management
- Demand side management



Source: U.S.-Canada Power System Outage Task Force, *Final Report on the August 14, 2003, Blackout in the United States and Canada: Causes and Recommendations*, April 2004.

Since the mid-1970s, California has pursued an aggressive set of efficiency regulations and utility programs. As a result, *per capita electricity consumption* has stabilized in that state, while it continues to grow in the United States as a whole.



Source: California Energy Commission— Available at http://www.energy.ca.gov/2005publications/CEC-999-2005-007/CEC-999-2005-007.PDF, Slide 5

For job seekers in the field of energy efficiency (EE)

- ASES forecast: 73 million jobs in renewable energy and energy efficiency by Y2030. In 2007 alone, this sector provided 9 million jobs and over $1.045T of revenues in the US.

- American Solar Energy Society Report

- Energy efficiency investments in the US were $300B in 2004 and are expected to exceed $700B annually by Y2030.

-The size of the US Energy Efficiency Market, American Council for Energy Efficient Economy, 2008

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Energy use

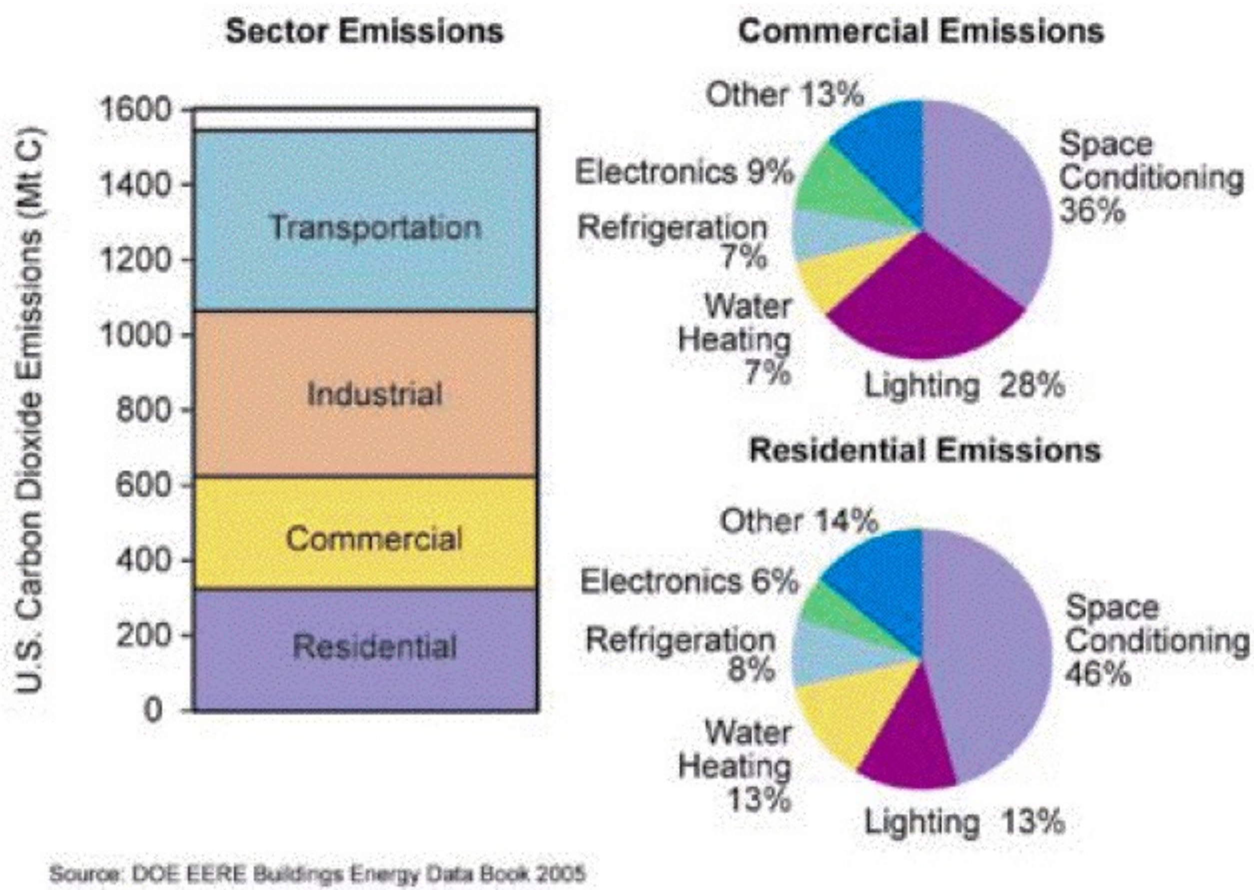
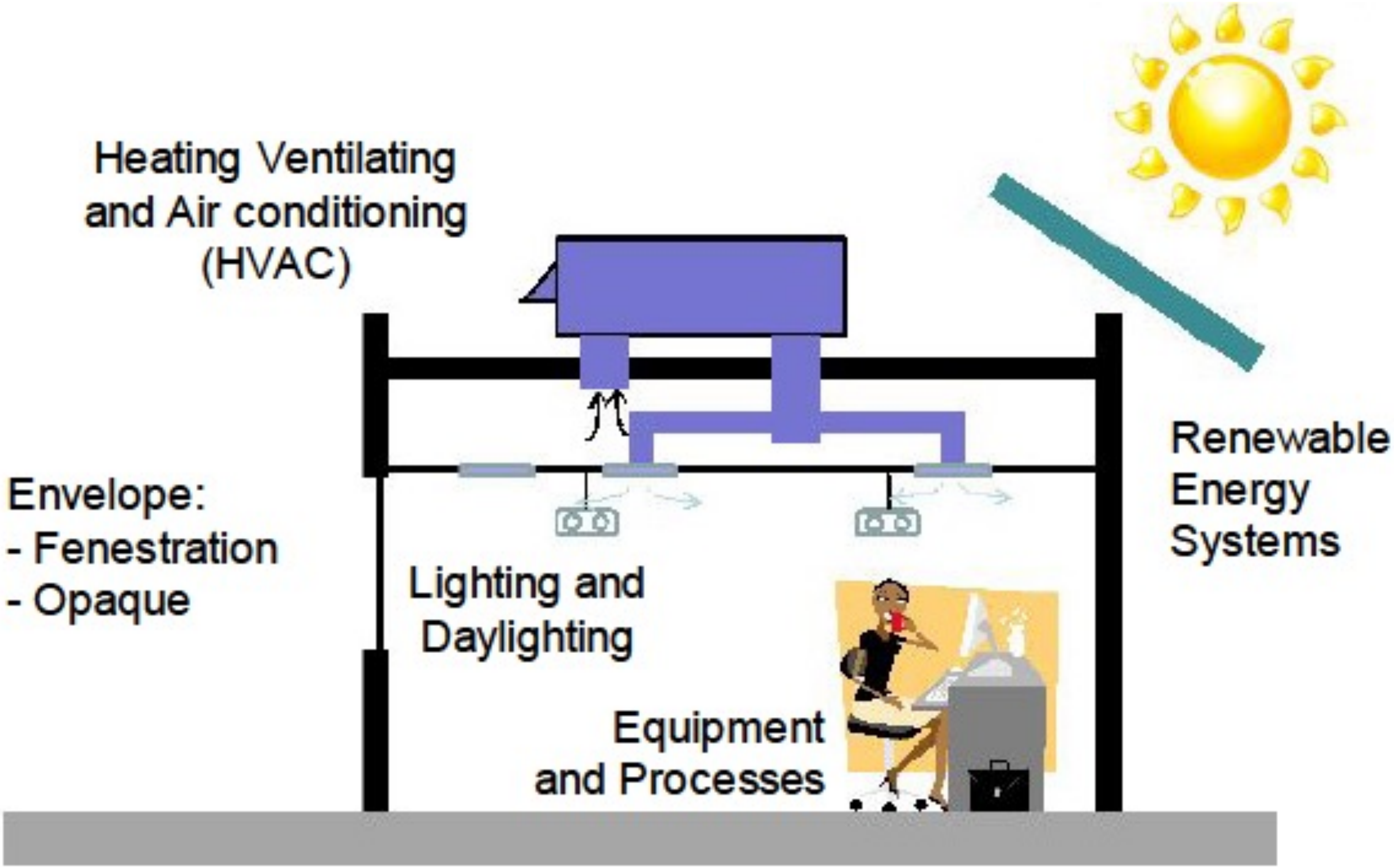


Figure 9.1 United States' carbon emissions by sector and (for commercial and residential buildings) by end use.

http://www.climatescience.gov/Library/sap/sap2-2/final-report/sap2-2-final-chapter9.pdf

Building systems



Energy Unit

Energy = Power X Time

- Energy (work)
  - watt-hour (Wh)
  - kilowatt-hour (kWh)
  - megawatt-hour (MWh)

- Power (rate of energy use)
  - watts (W)
  - kilowatts (kW)
  - megawatts (MW)

1 kWh = 1000 W X 1 hour
1 kWh = 100 W X 10 hours
1 kWh = 10 W X 100 hours

More energy and power units

Energy (work):

- British thermal unit (Btu)

 - Inch-pound (IP) unit system

 - 1 Wh = 3.413 Btu

- Therm

 - 100,000 Btu

 - Typical unit for natural gas utility bill

- Quad

 - 1015 Btu

Power:

- Btu/h

 - Heat transfer rate

 - 1 W = 3.413 Btu/h

- Ton (refrigeration)

 - 12,000 Btu/h

 - Cooling equipment capacity

 - Equals heat flow to melt one ton of ice in 24 hours

- Horsepower (hp)

 - Motors, fans, pumps

 - 1 hp = 0.746 kW

What's a Btu?

•Btu = British Thermal Unit

•1 Btu = energy required to raise the temperature of 1 pound of water (about 1 pint) by 1 degree Fahrenheit.

•The heat generated by the burning of one match (approximately)

Energy content equivalencies

1 gallon oil = 138 kBtu **1 lb coal = 12.6 kBtu** **1 ft^3 natural gas = 1.0 kBtu**

1 kWh electricity = 0.07 gal oil

= 0.5 lb coal

= 7.7 ft^3 natural gas

= 1 hour of sunlight on 52 ft^2 surface

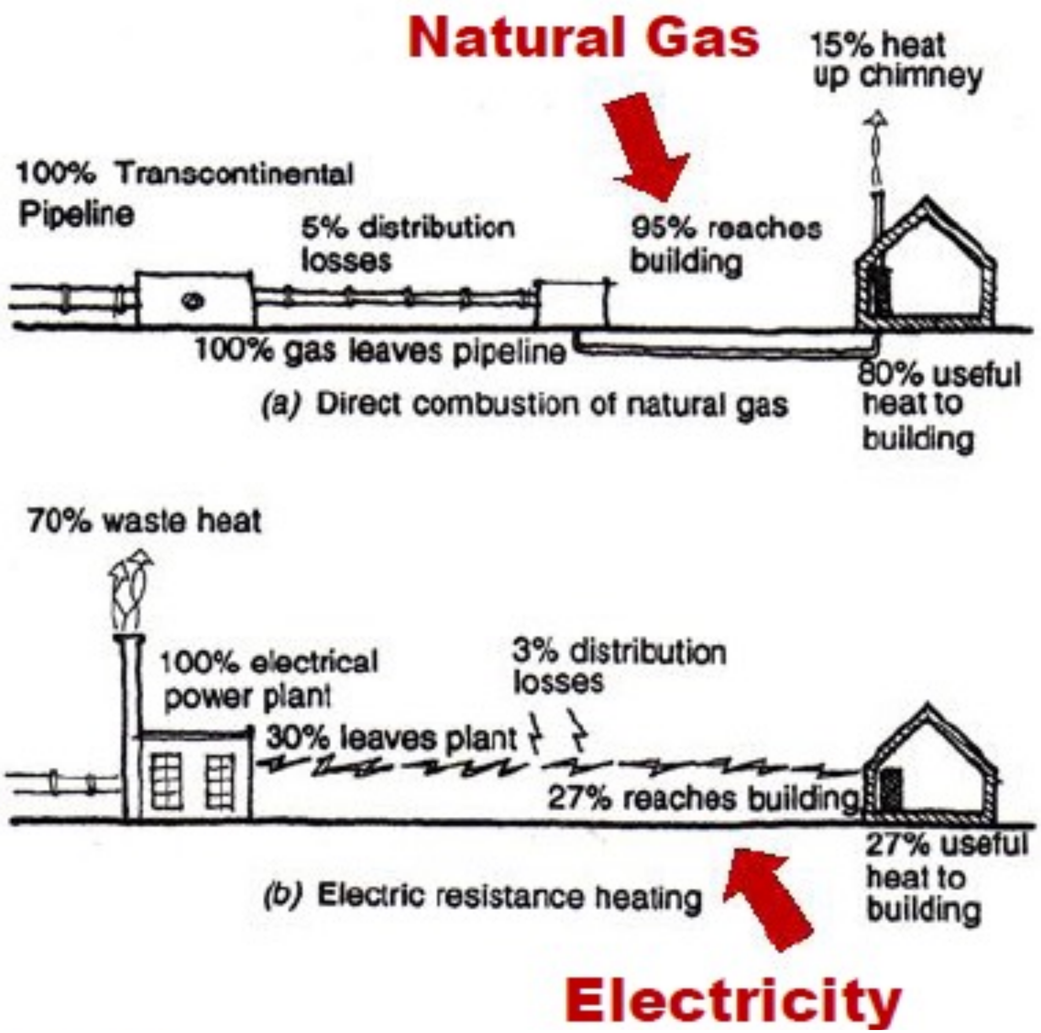
(~300Btu/hr-ft^2 and 12% PV efficiency)

Site energy vs. source energy

- Site energy: measured at the building meter
  - 1 kWh electricity = 3,412 Btu
  - 1 Btu gas = 1 Btu
- Source energy: primary energy input
  - electricity depending on source (gas, coal, etc)
    - losses in generation and transmission
    - Approx. 3 Btu source energy per 1 Btu site energy
    - 1 kWh 10,200 source Btu
  - Natural gas
    - roughly 1.04 Btu source per 1 Btu site

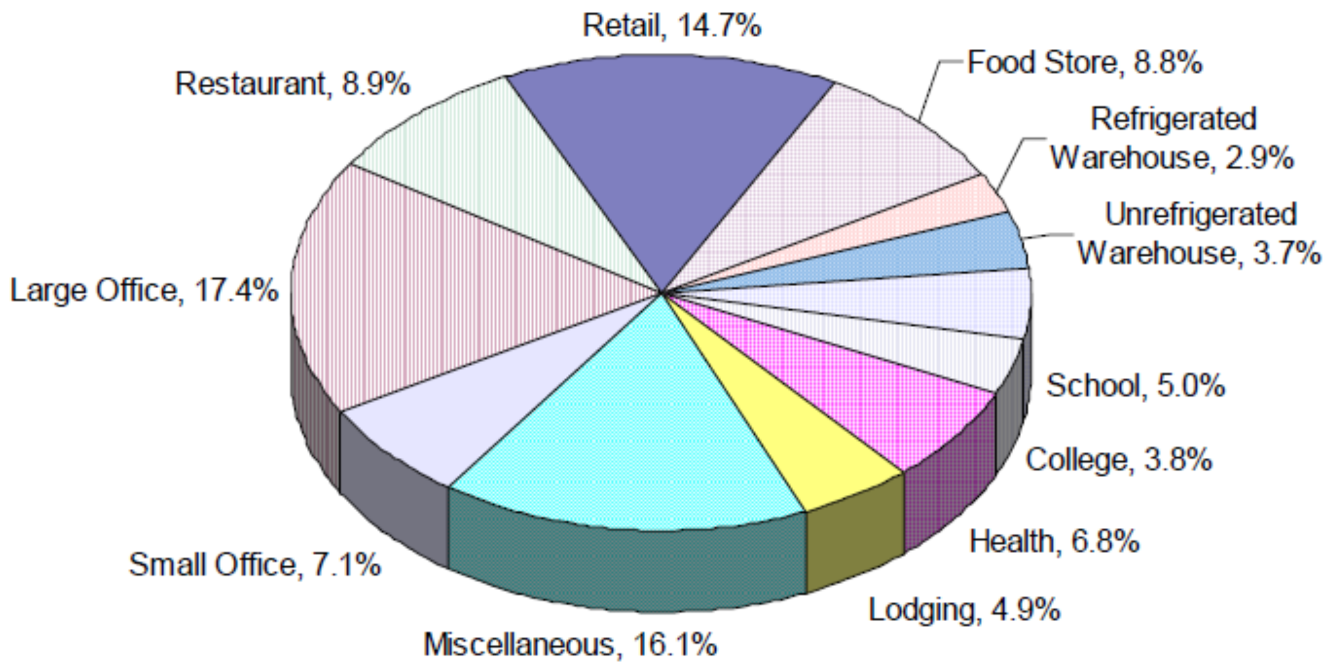
Reading material:
http://www.energystar.gov/ia/business/evaluate_performance/site_source.pdf

Site energy vs. source energy



Commercial electricity use by building type

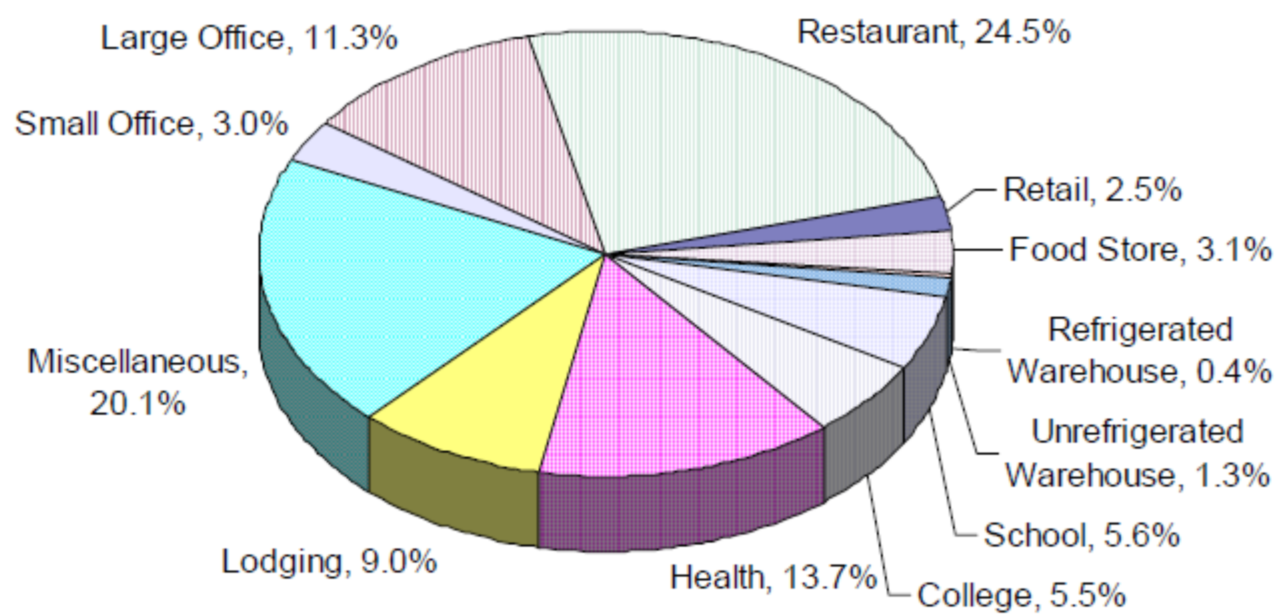
California Commercial End-use Survey



http://www.energy.ca.gov/2006publications/CEC-400-2006-005/CEC-400-2006-005.PDF

Commercial gas usage by building type

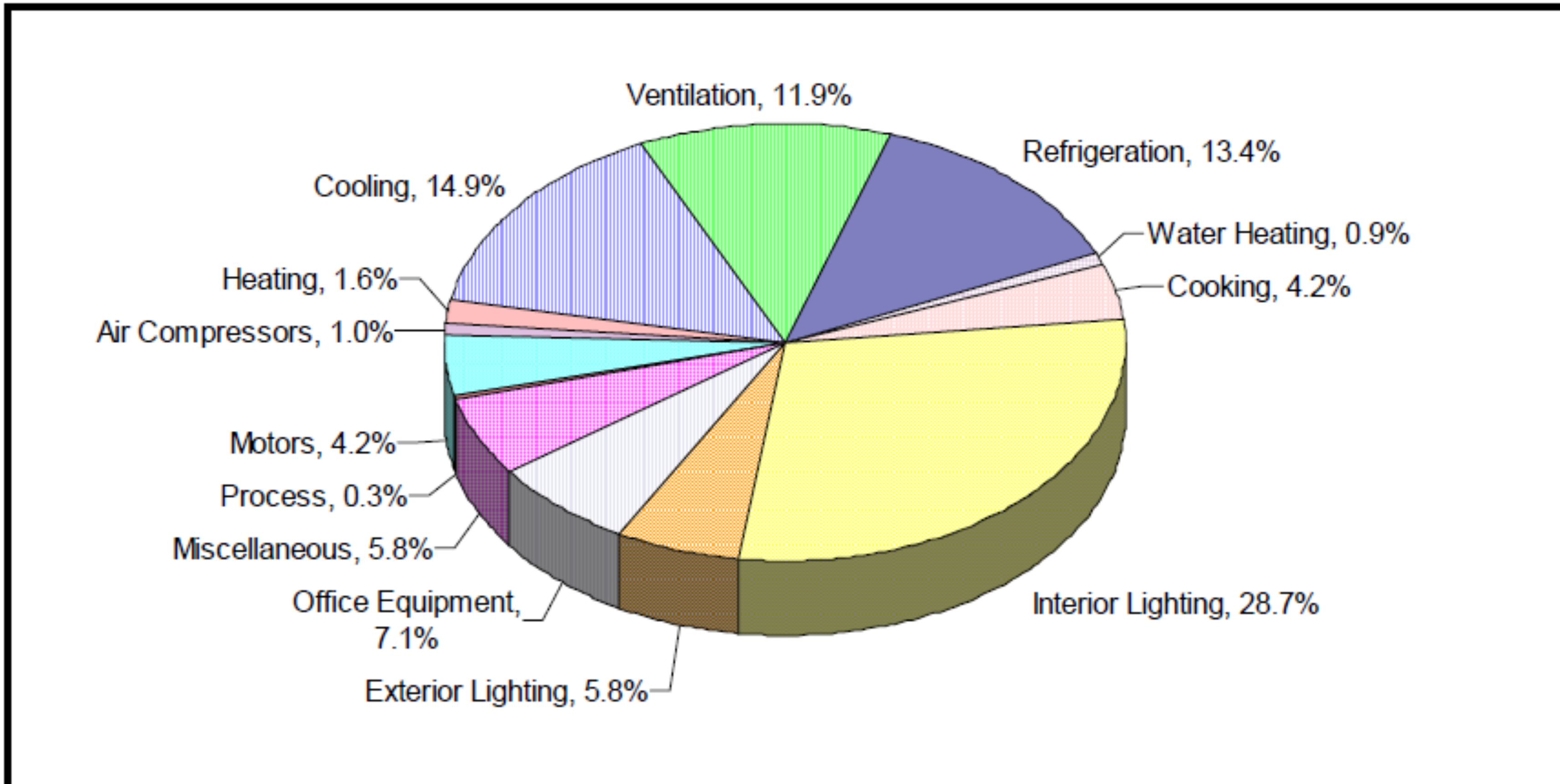
California Commercial End-use Survey



http://www.energy.ca.gov/2006publications/CEC-400-2006-005/CEC-400-2006-005.PDF

Electric usage by end use

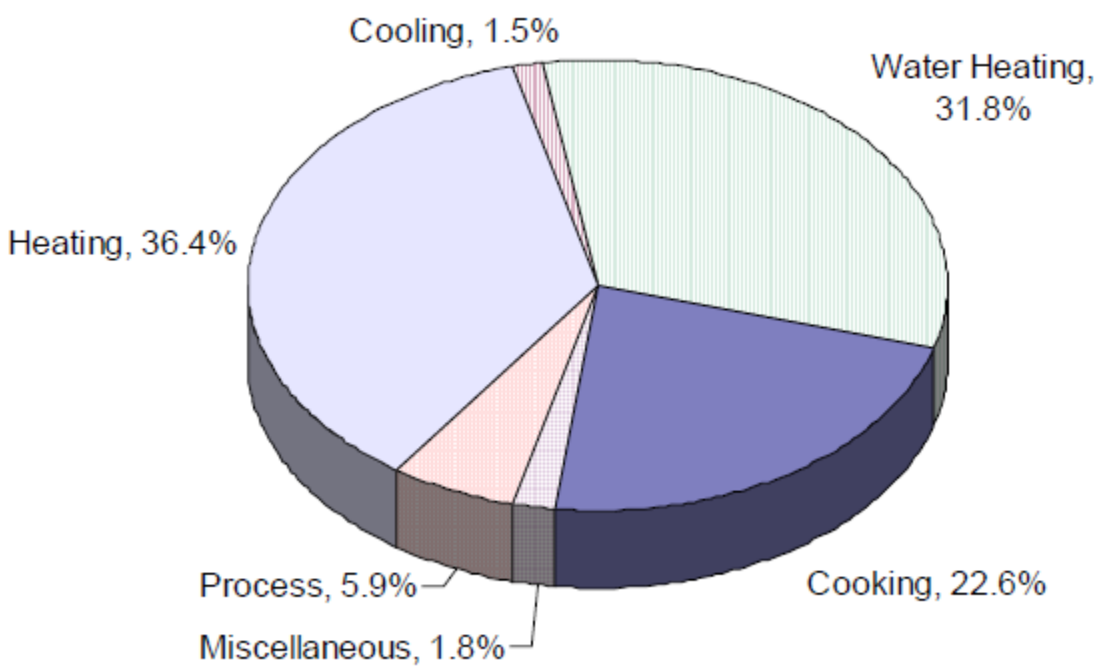
California Commercial End-use Survey



http://www.energy.ca.gov/2006publications/CEC-400-2006-005/CEC-400-2006-005.PDF

Natural gas usage by end use

California Commercial End-use Survey



http://www.energy.ca.gov/2006publications/CEC-400-2006-005/CEC-400-2006-005.PDF

Electric usage (GWh) by building type and end use

California Commercial End-use Survey

Building Type	Heat	Cool	Vent.	Refrig.	WH	Cook	Int. Ltg.	Ext. Ltg.	Office Equip.	Misc.	Air Comp.	Motors	Proc.	Total
All Commercial	1,087	10,017	8,000	9,014	611	2,805	19,265	3,916	4782	3924	204	2811	642	67,077
Small Office	72	943	467	208	90	38	1,386	343	793	283	1	79	36	4,739
Large Office	322	2358	2,019	268	80	77	2,945	324	2365	383	18	474	60	11,691
Restaurant	7	858	482	1,469	56	1,546	961	300	94	168	1	41	3	5,986
Retail	55	1553	1,267	726	96	157	4,246	644	343	483	37	201	64	9,871
Food Store	12	415	372	3,233	20	266	1,233	137	54	138	1	26	6	5,911
Refrigerated Warehouse	2	31	23	1284	3	3	262	33	17	55	4	174	22	1,913
Unrefrigerated Warehouse	20	183	156	154	26	12	1,223	145	131	215	9	162	32	2,467
School	56	520	429	225	43	78	1,281	330	206	110	1	37	7	3,322
College	159	393	423	95	25	55	790	188	148	100	2	119	28	2,524
Health	166	901	940	166	18	101	1,119	132	200	586	1	181	50	4,561
Lodging	114	650	483	244	9	185	945	165	46	301	0	128	6	3,275
Miscellaneous	104	1,212	941	942	145	287	2,874	1,175	386	1103	129	1190	330	10,817
All Offices	393	3,301	2,485	476	171	115	4,331	666	3157	666	19	553	95	16,430
All Warehouses	22	214	179	1,438	28	15	1,485	178	148	270	13	336	54	4,380

http://www.energy.ca.gov/2006publications/CEC-400-2006-005/CEC-400-2006-005.PDF

Natural gas usage (Mtherms) by building type and end use

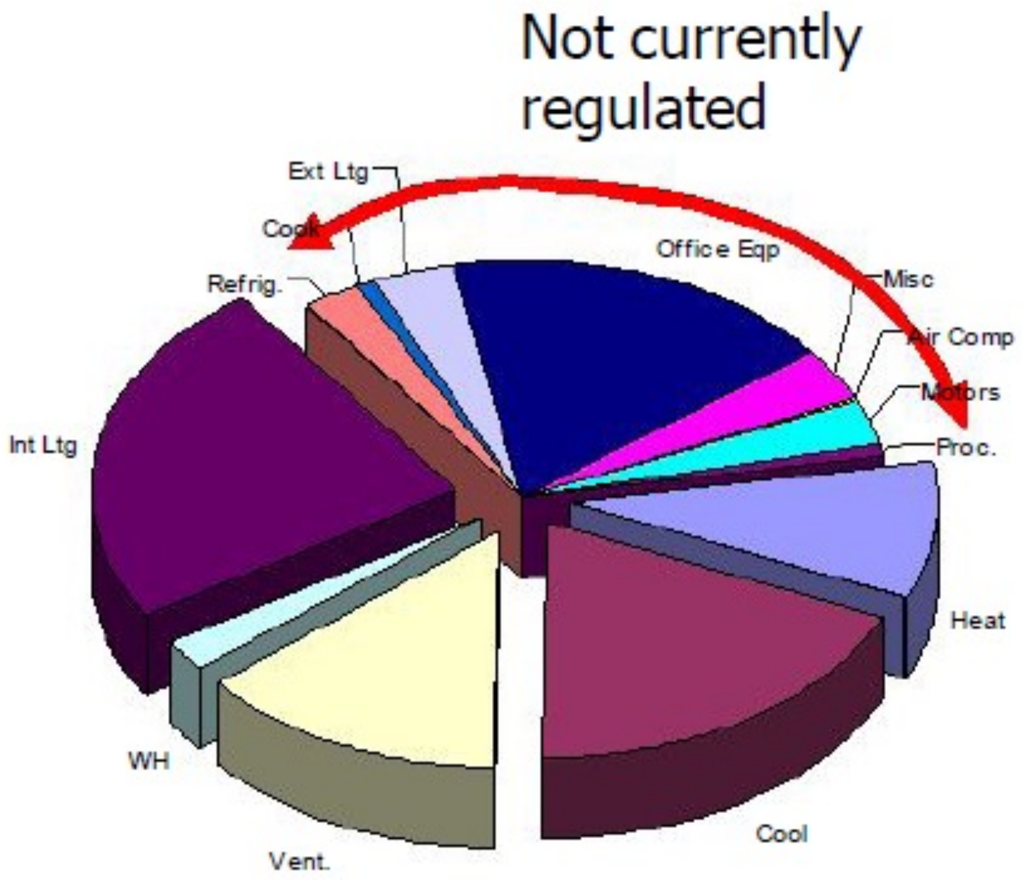
California Commercial End-use Survey

Building Type	Heat	Cool	WH	Cook	Misc.	Proc.	Total
All Commercial	465.50	19.10	406.70	289.10	23.00	75.20	1278.60
Small Office	31.20	0.00	6.00	0.50	0.10	0.40	38.10
Large Office	113.70	3.60	17.20	1.50	0.70	8.10	144.80
Restaurant	11.50	0.00	72.40	228.20	0.00	0.50	312.60
Retail	21.20	0.00	5.50	3.60	1.90	0.30	32.50
Food Store	13.70	0.00	11.00	14.90	0.00	0.10	39.80
Refrigerated Warehouse	0.80	0.00	0.80	1.20	0.00	2.70	5.30
Unrefrigerated Warehouse	14.80	0.00	1.80	0.10	0.20	0.10	17.00
School	44.60	0.60	20.90	4.70	0.10	0.30	71.10
College	40.80	7.10	17.30	3.40	1.80	0.00	70.50
Health	76.10	3.60	73.00	7.80	3.40	11.80	175.70
Lodging	19.70	0.20	78.20	11.90	3.90	0.70	114.50
Miscellaneous	77.40	4.00	102.70	11.20	10.90	50.30	256.60
All Offices	144.90	3.60	23.20	2.00	0.80	8.40	182.90
All Warehouses	15.60	0.00	2.60	1.20	0.20	2.80	22.40

http://www.energy.ca.gov/2006publications/CEC-400-2006-005/CEC-400-2006-005.PDF

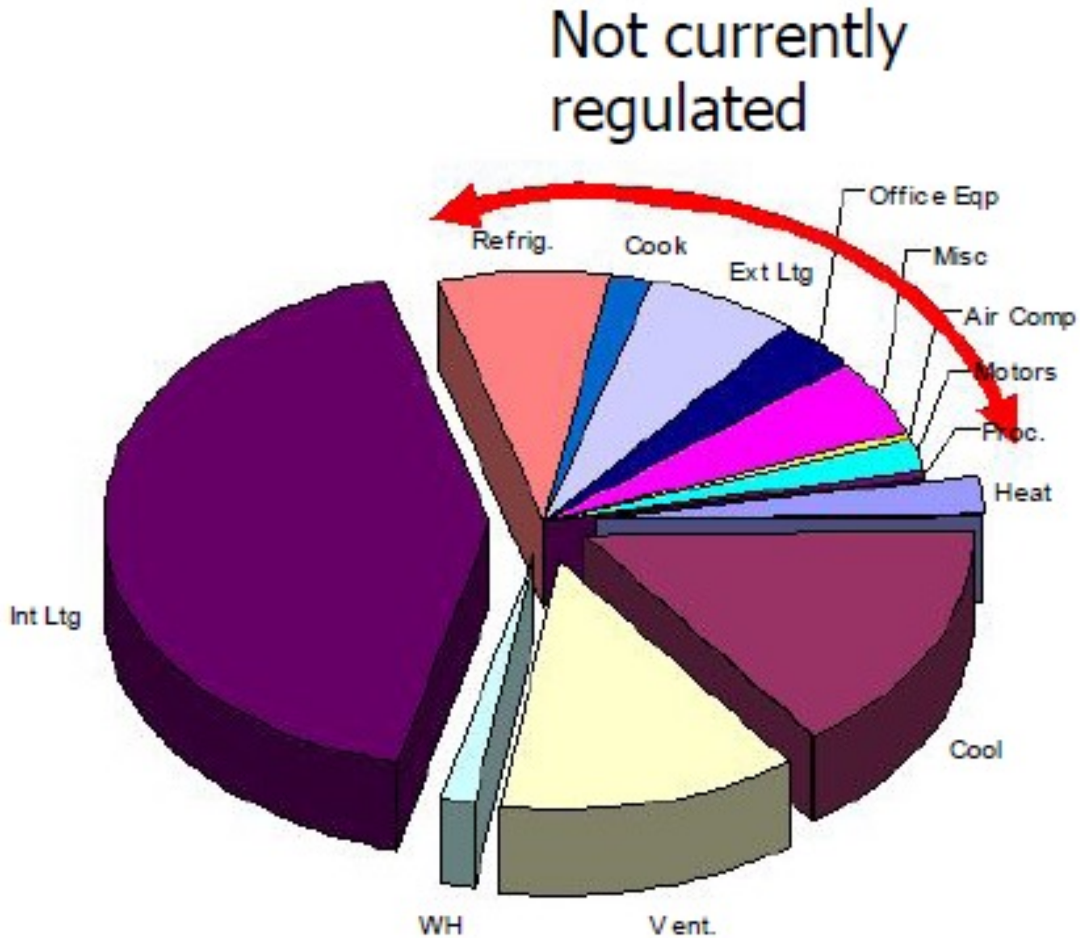
California Commercial End-use Survey

- Office



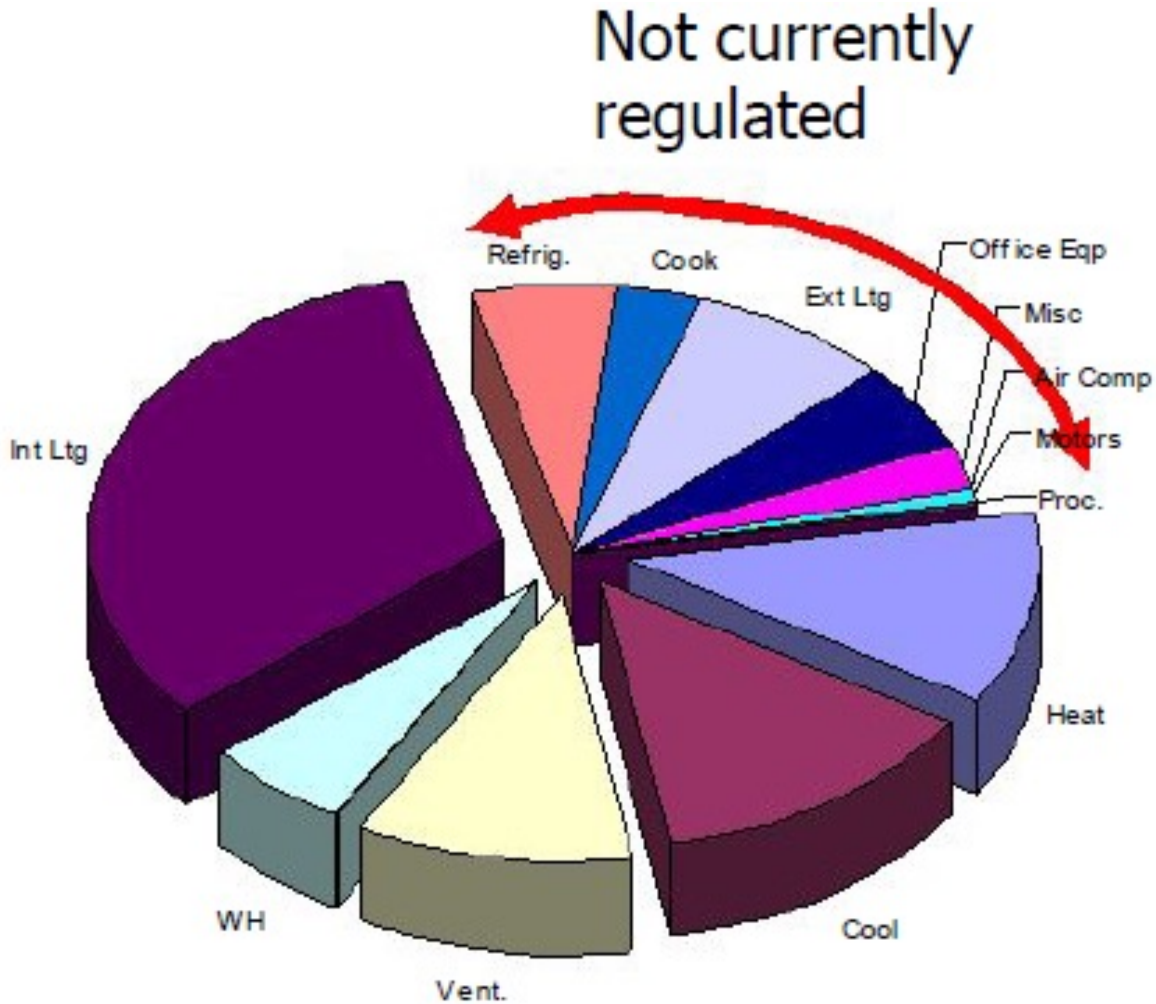
California Commercial End-use Survey

- Retail



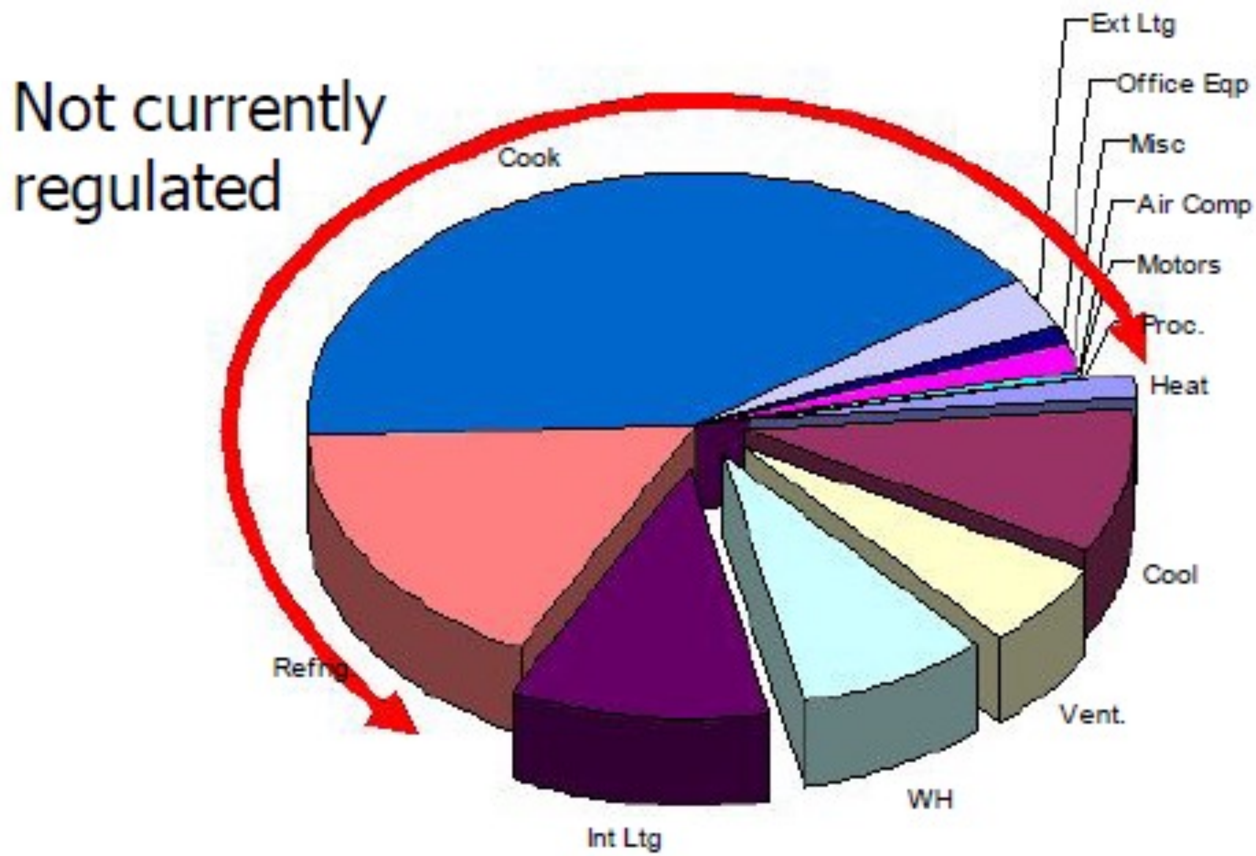
California Commercial End-use Survey

- School



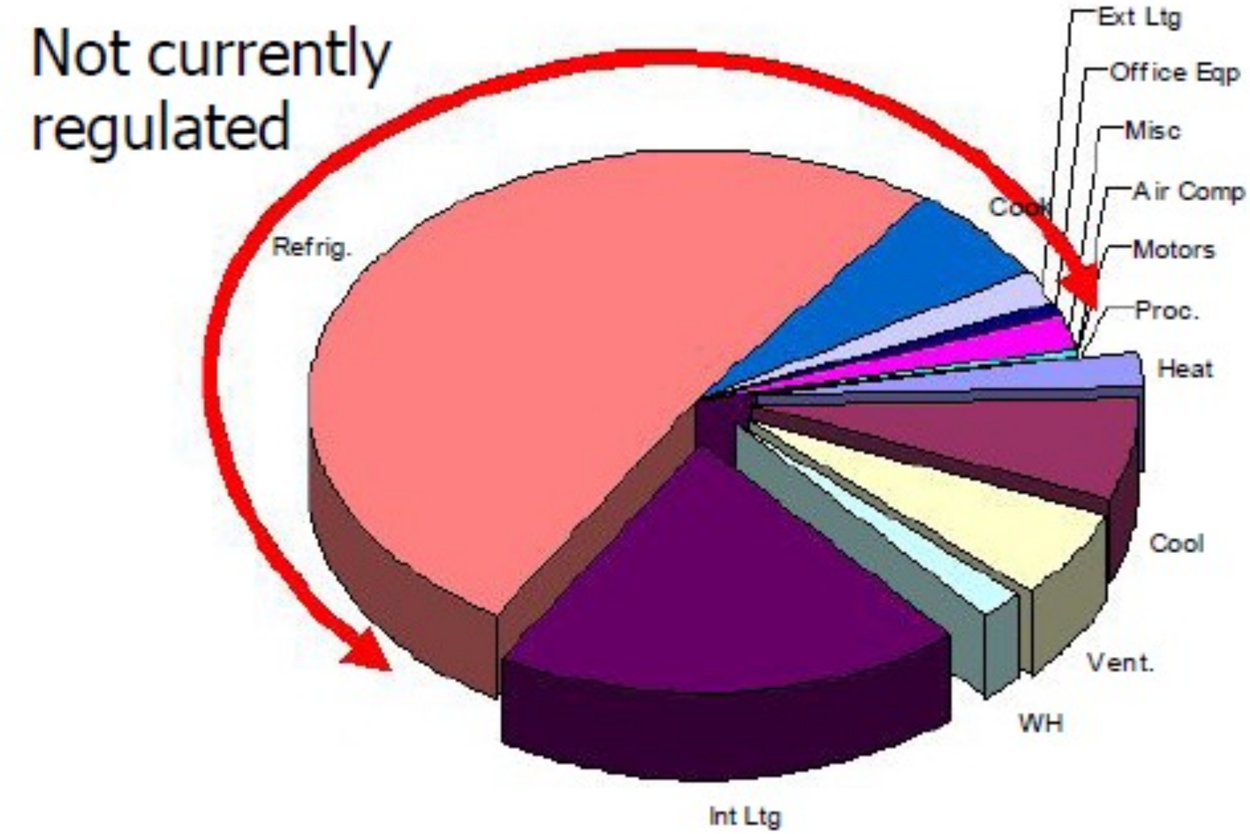
California Commercial End-use Survey

- Restaurant



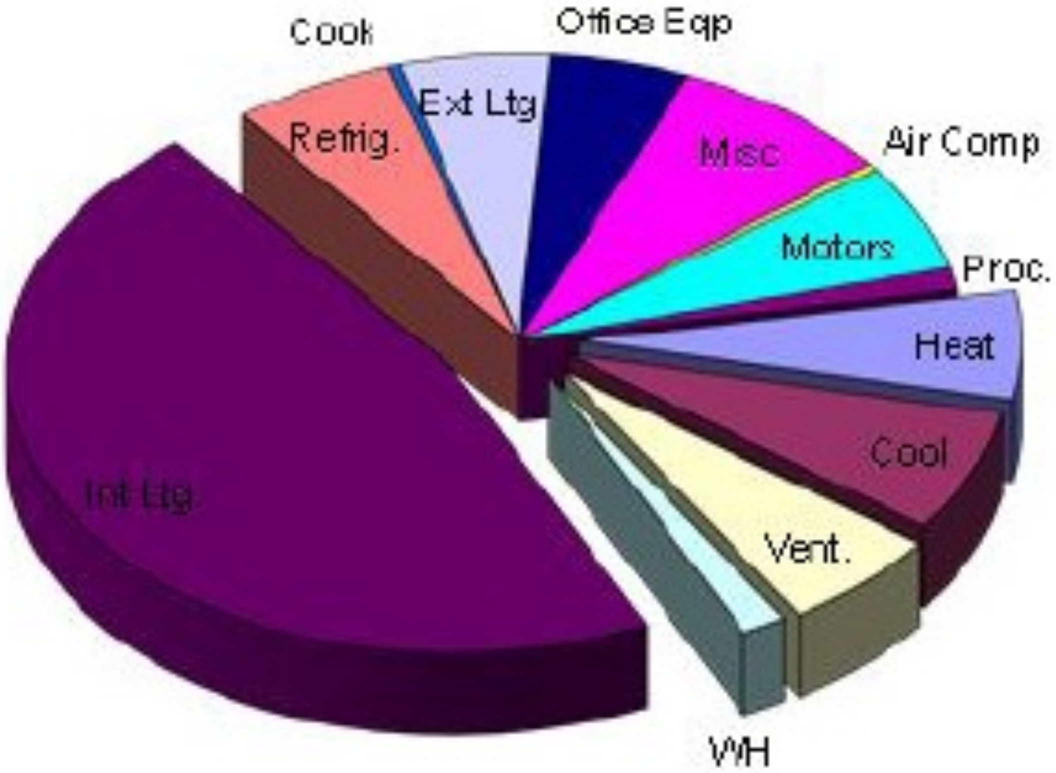
California Commercial End-use Survey

- Food stores



California Commercial End-use Survey

- Non-refrigeration warehouse



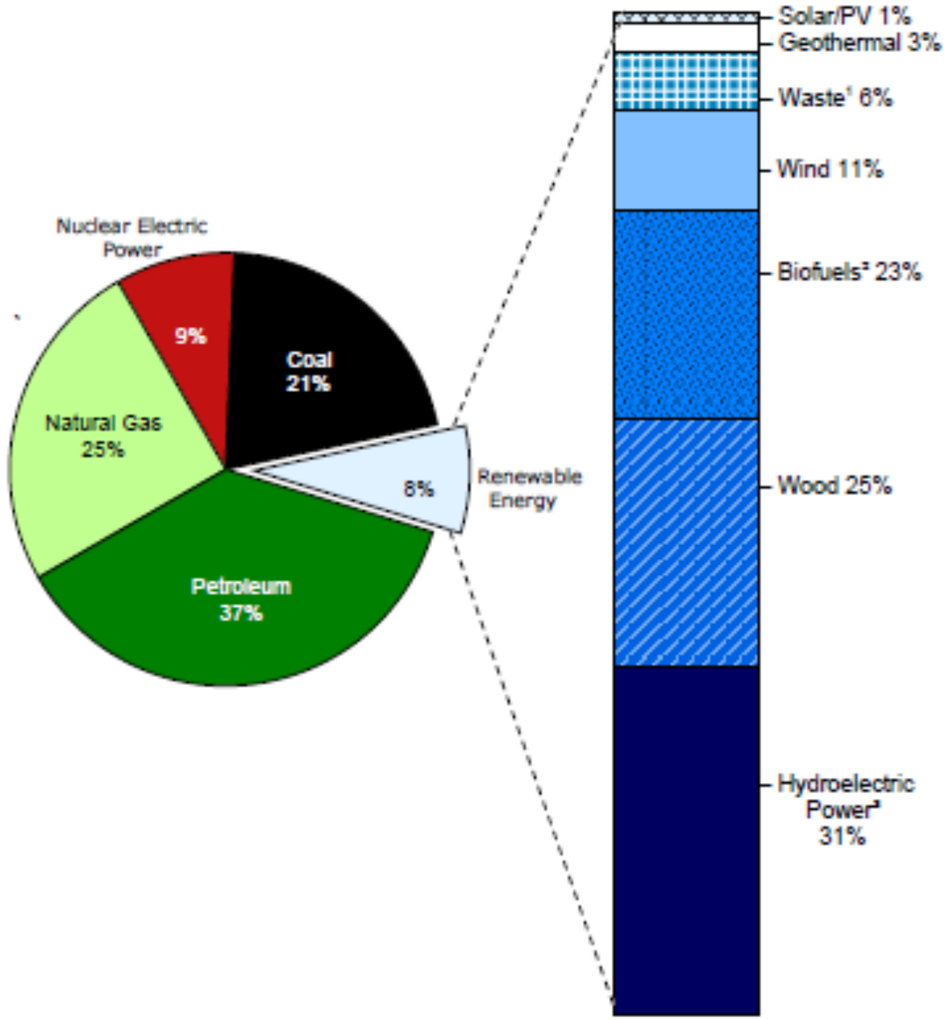
A. Introduction to concept of commercial building energy auditing

1. Why energy efficiency (EE) is important
2. Energy use and waste in commercial building operations
3. Prioritizing energy efficiency over renewable energy generation

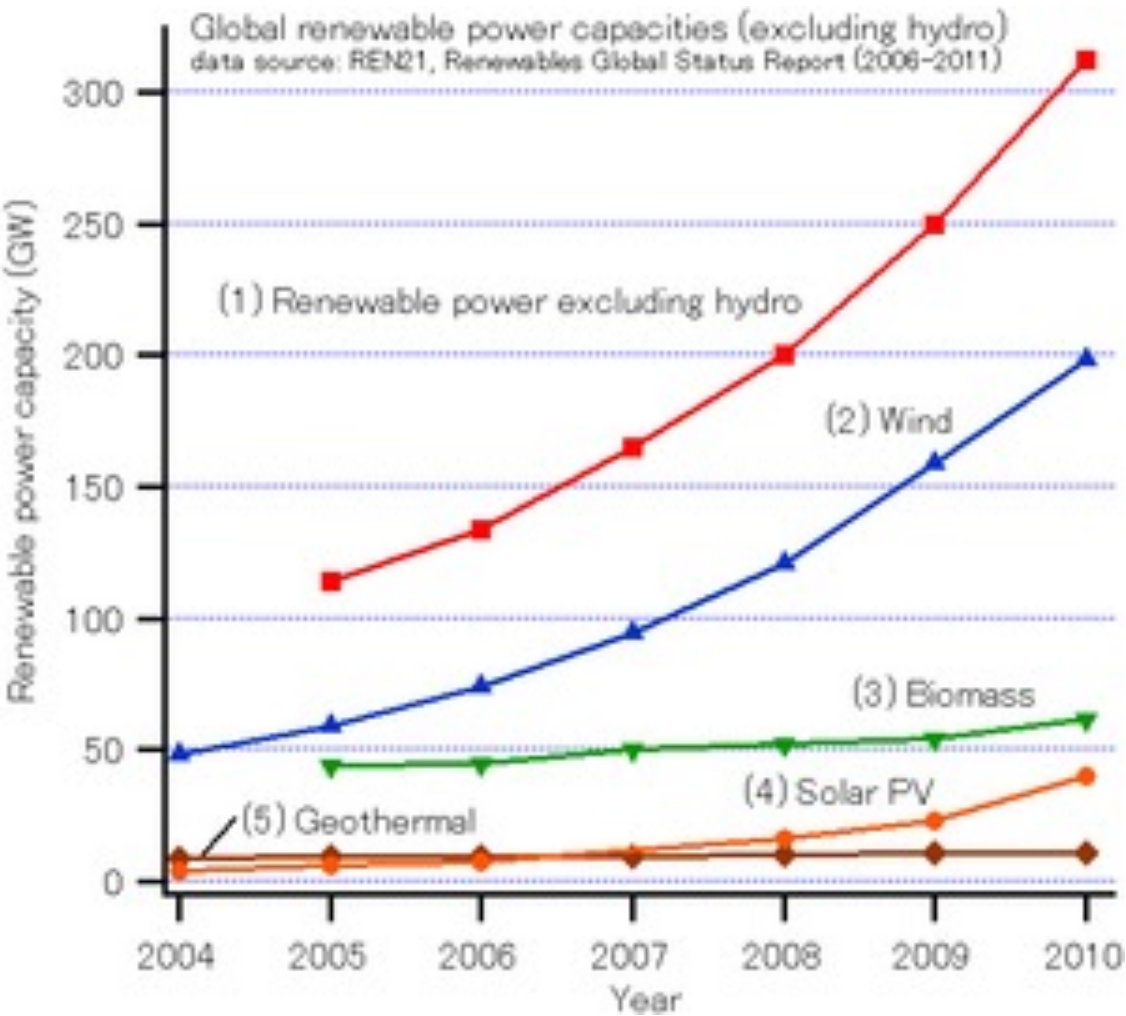
Renewable energy

- energy coming from natural resources which are renewable:

- Solar PV
- Geothermal
- Wind
- Biofuel
- Solar thermal
- Hydro



Renewable energy



RENEWABLES 2012
GLOBAL STATUS REPORT

3. Prioritizing EE over renewable energy generation

Renewable energy

RENEWABLES 2012
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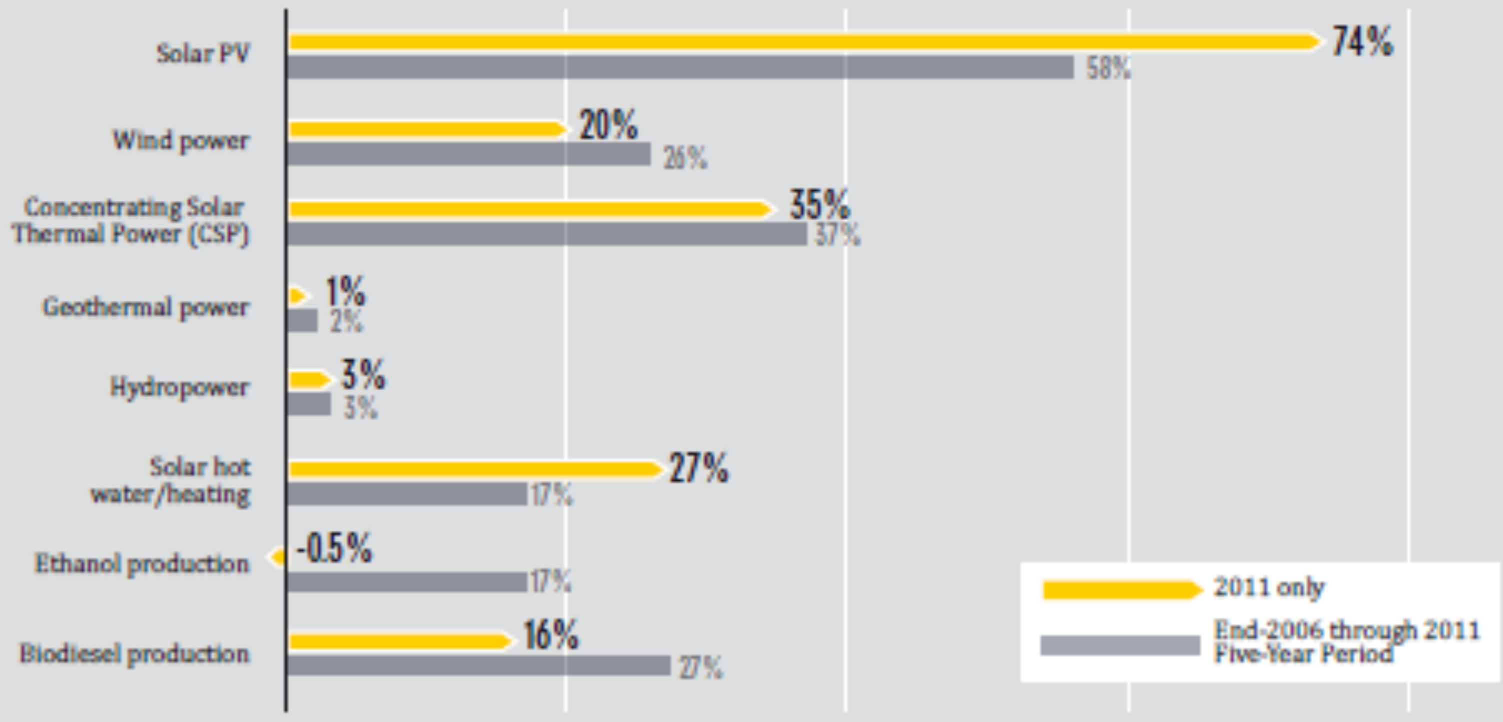
FIGURE 2. AVERAGE ANNUAL GROWTH RATES OF RENEWABLE ENERGY CAPACITY AND BIOFUELS PRODUCTION, 2006–2011



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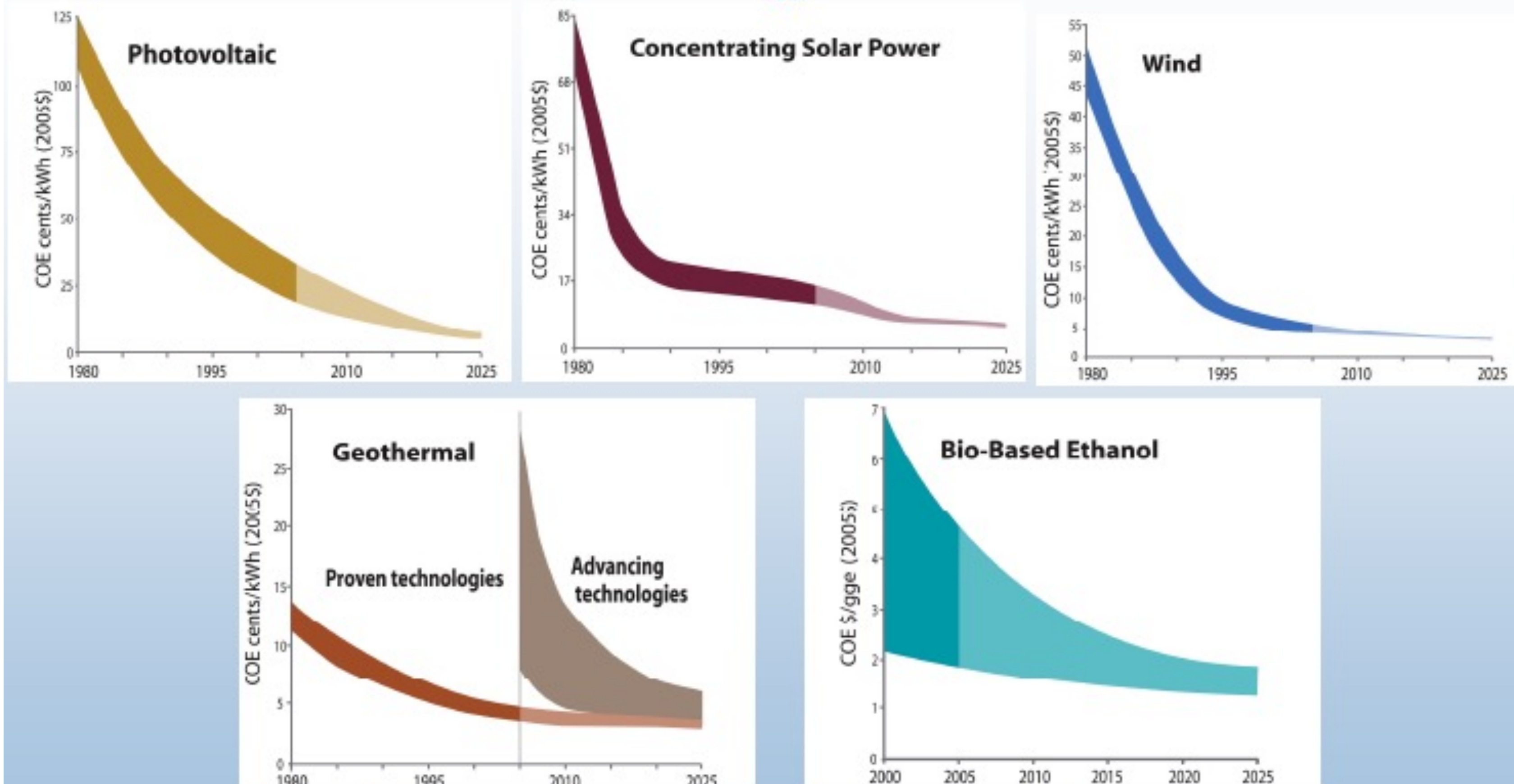
Price comparison

Renewable Energy Cost Trends

Levelized cost of energy in constant 2005$[1]



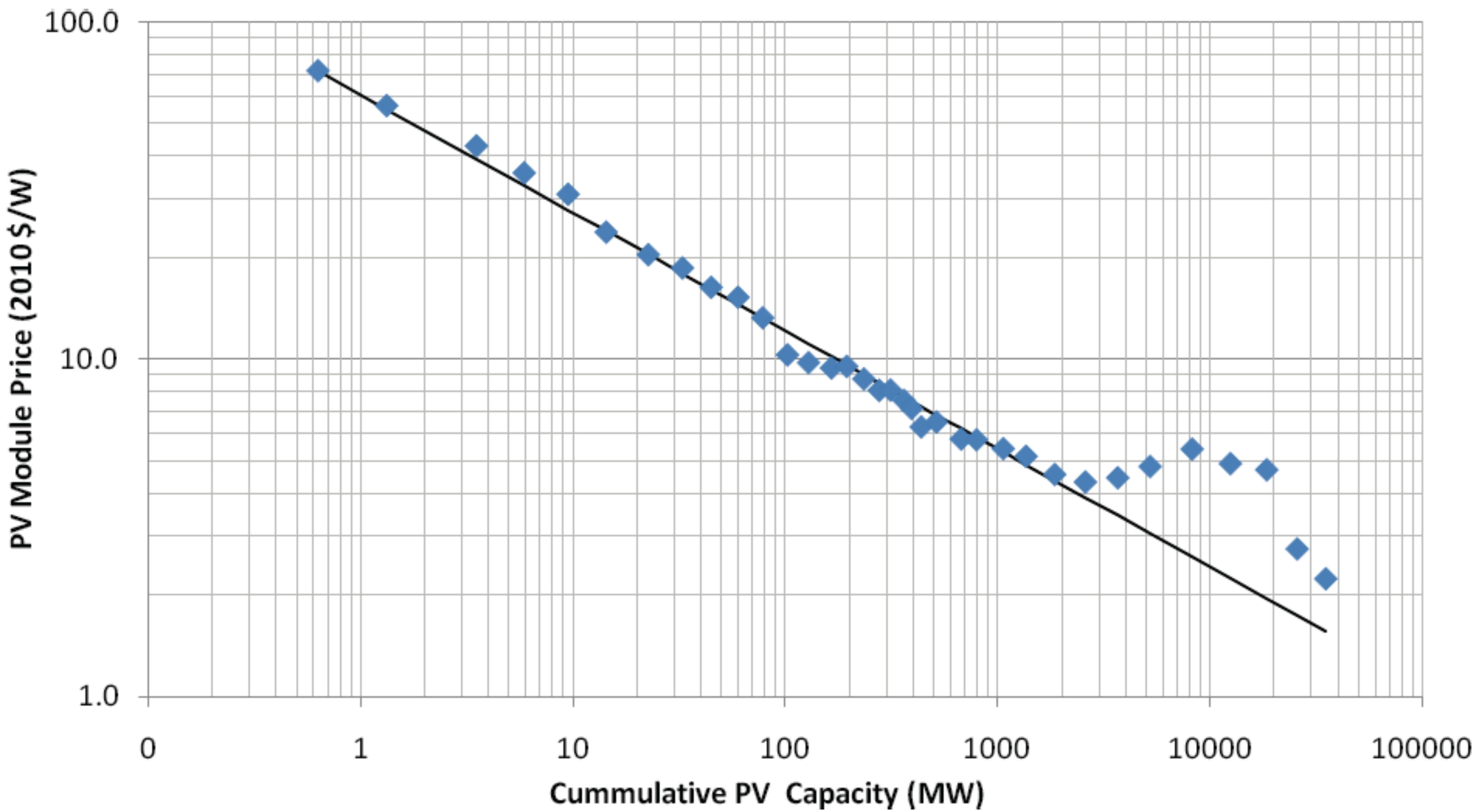
Source: NREL Energy Analysis Office (www.nrel.gov/analysis/docs/cost_curves_2005.ppt)

[1]These graphs are reflections of historical cost trends NOT precise annual historical data. DRAFT November 2005

EAO Energy Analysis Office Understanding Energy Issues

NREL National Renewable Energy Laboratory

Renewable energy price has reduced dramatically, but……



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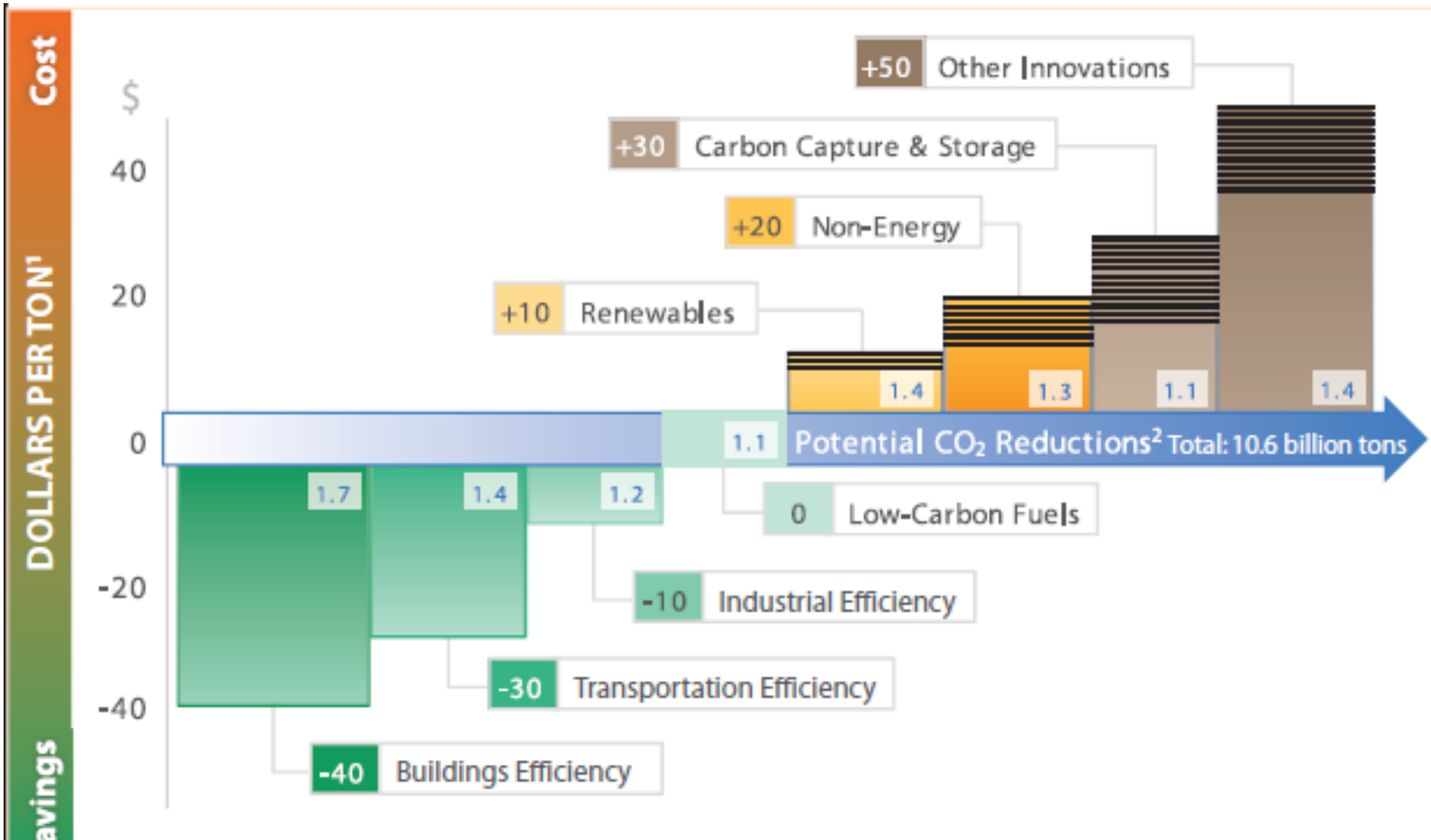
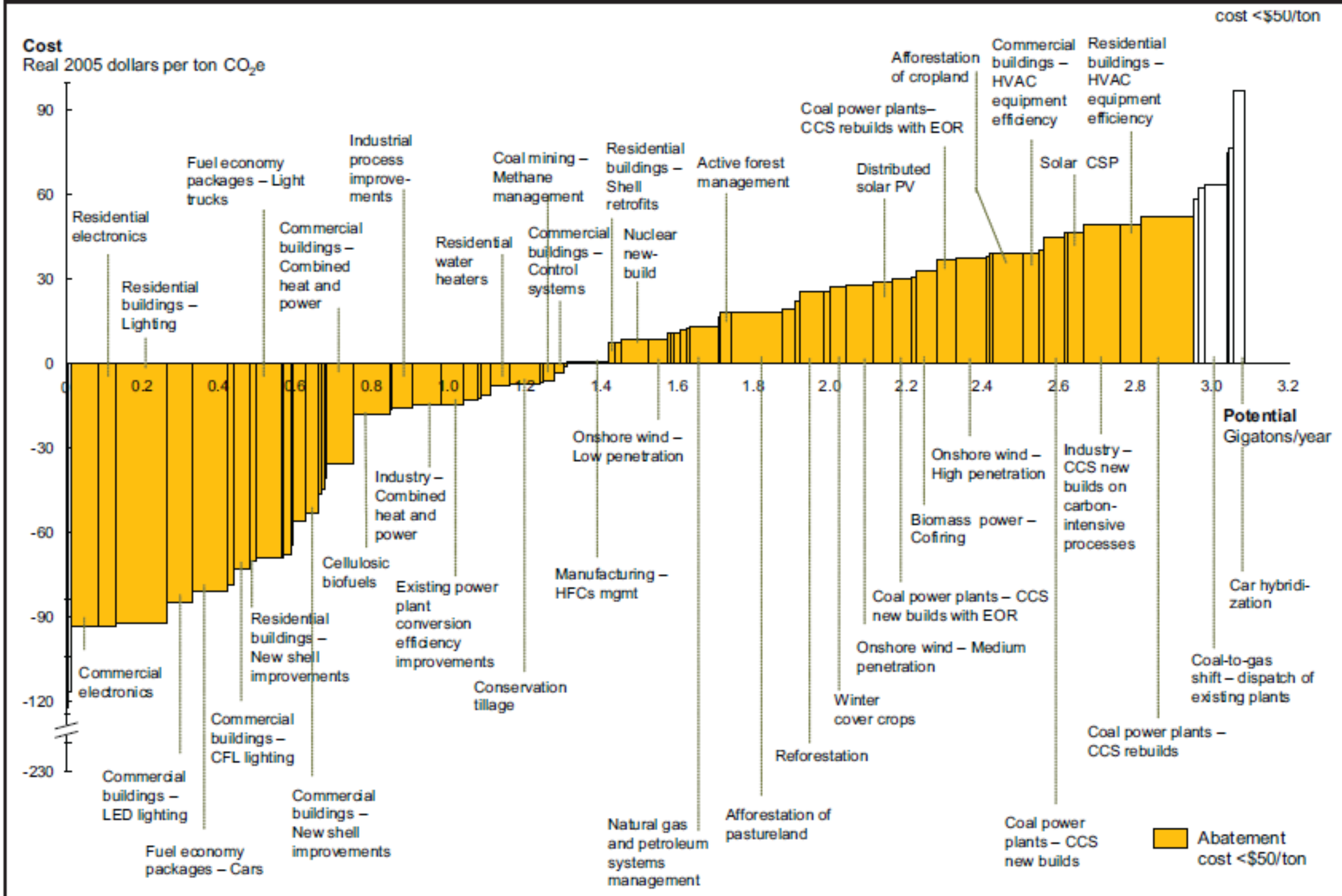
Renewables cost more to achieve the same CO2 reduction



http://www.nrdc.org/globalwarming/energy/eeconomy.pdf

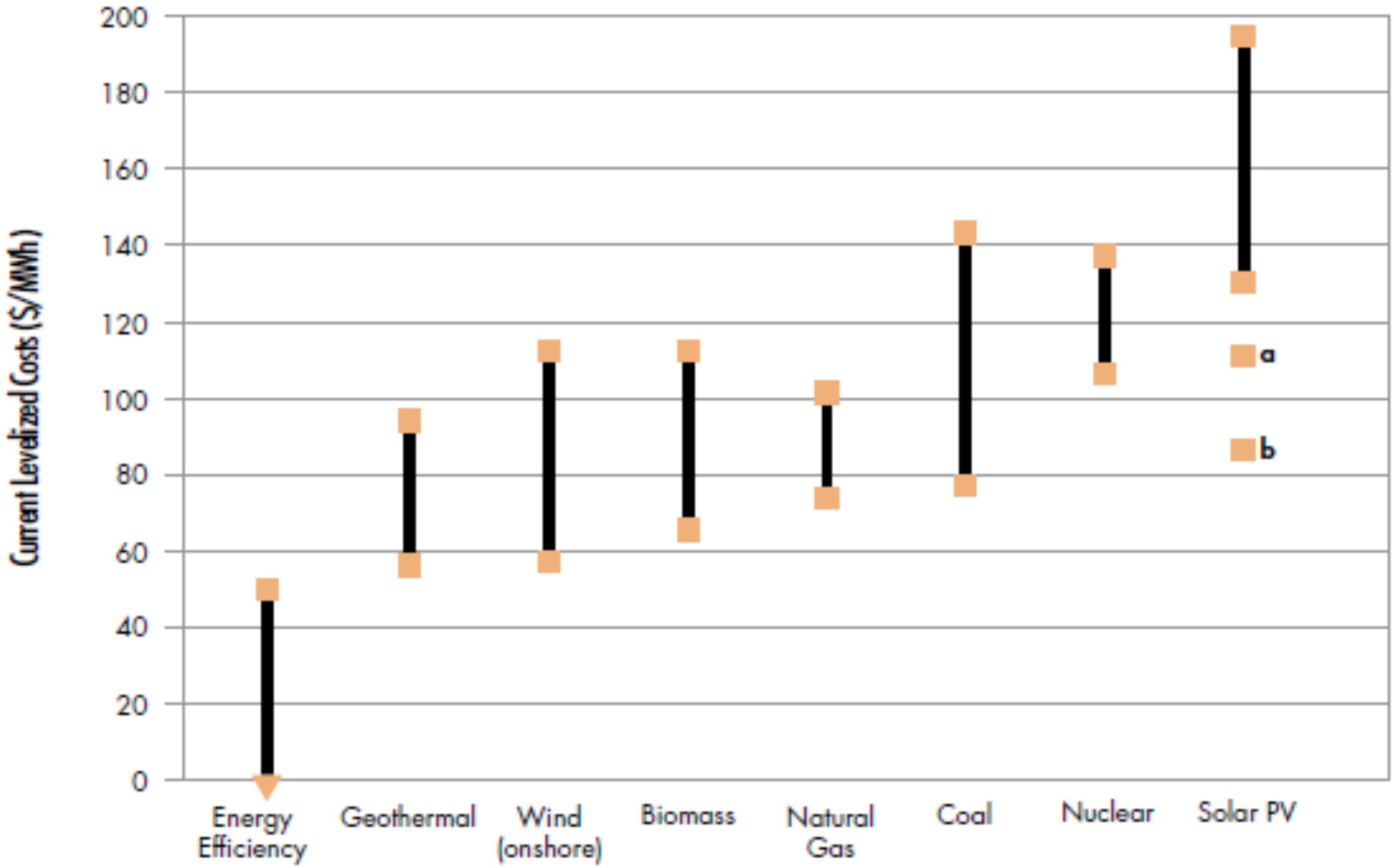
Figure 9: McKinsey's "Mid-Range Case" U.S. Supply Curve



Source: McKinsey analysis

http://www.nrdc.org/globalwarming/energy/eeconomy.pdf

Figure 2. Levelized cost of new power generation technologies in 2008



http://www.epa.gov/greenpower/documents/purchasing_guide_for_web.pdf

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Shorter payback period for energy efficiency projects

Project Description	Cost ($)	Rebate ($)	Annual savings($)	Pay-back	ROI
Installed dimmers in alcoves and stairwells	83,034	21,108	46,853	1.4 yrs	73%
Retrofitted variable-freq. drives on main supply fan	73,000	29,400	12,000	3.6 yrs	28%
Installed automated drip irrigation system	3,610	0	9,001	0.4 yrs	249%
Reduced run-time on parking garage fans to 10 mins in am/pm rush hours without sacrificing air quality	200	0	98,000	instant	48,204 %
Installed waterless urinals	35,374	5,396	6,338	4.7 yrs	21%

Source: "Building Optimization: The Value Proposition, " George Denise, National Conference on Building Commissioning, Newport Beech, Calif., 21 April 2008.

Before Adding, Try Reducing

•Reading links:

Energy Efficiency and Systems Thinking
http://www.americanprogress.org/wp-content/uploads/issues/2009/08/pdf/systems_thinking.pdf

The New Energy Economy
http://www.nrdc.org/globalwarming/energy/eeconomy.pdf

Reducing US GHG Emissions: How much at what cost?
http://www.c2es.org/docUploads/US_ghg_final_report.pdf

Solar Photovoltaics
http://www.irena.org/DocumentDownloads/Publications/RE_Technologies_Cost_Analysis-SOLAR_PV.pdf

BEST Center Curricula, Resources & Recordings

Academic Programs
Georgia Piedmont Technical College - Building Automation Systems
Milwaukee Area Technical College - Sustainable Facilities Operations
Laney College - Commercial HVAC Systems
City College San Francisco - Commercial Building Energy Analysis & Audits

Professional Development Materials, Presentations & Videos
National Institutes
Building Automation Systems Instructor Workshops
Webinars (e.g., BEST Talks)

Faculty Profile Videos
Reports & Case Studies
Marketing Resources