Estimating the Carbon Footprint of Schools

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You can't control it if you can't measure it.

- Before we can focus the CHPS program on greenhouse gas reductions, we need a better understanding of how schools contribute.
- Some things we can estimate reasonably accurately, but other things are more squirrelly.

The Feds track information that can help us understand the “big picture”.

Since 1975, Lawrence Livermore National Laboratory (LLNL) has been publishing the U.S. Energy Flow Chart

Energy Flow Chart:

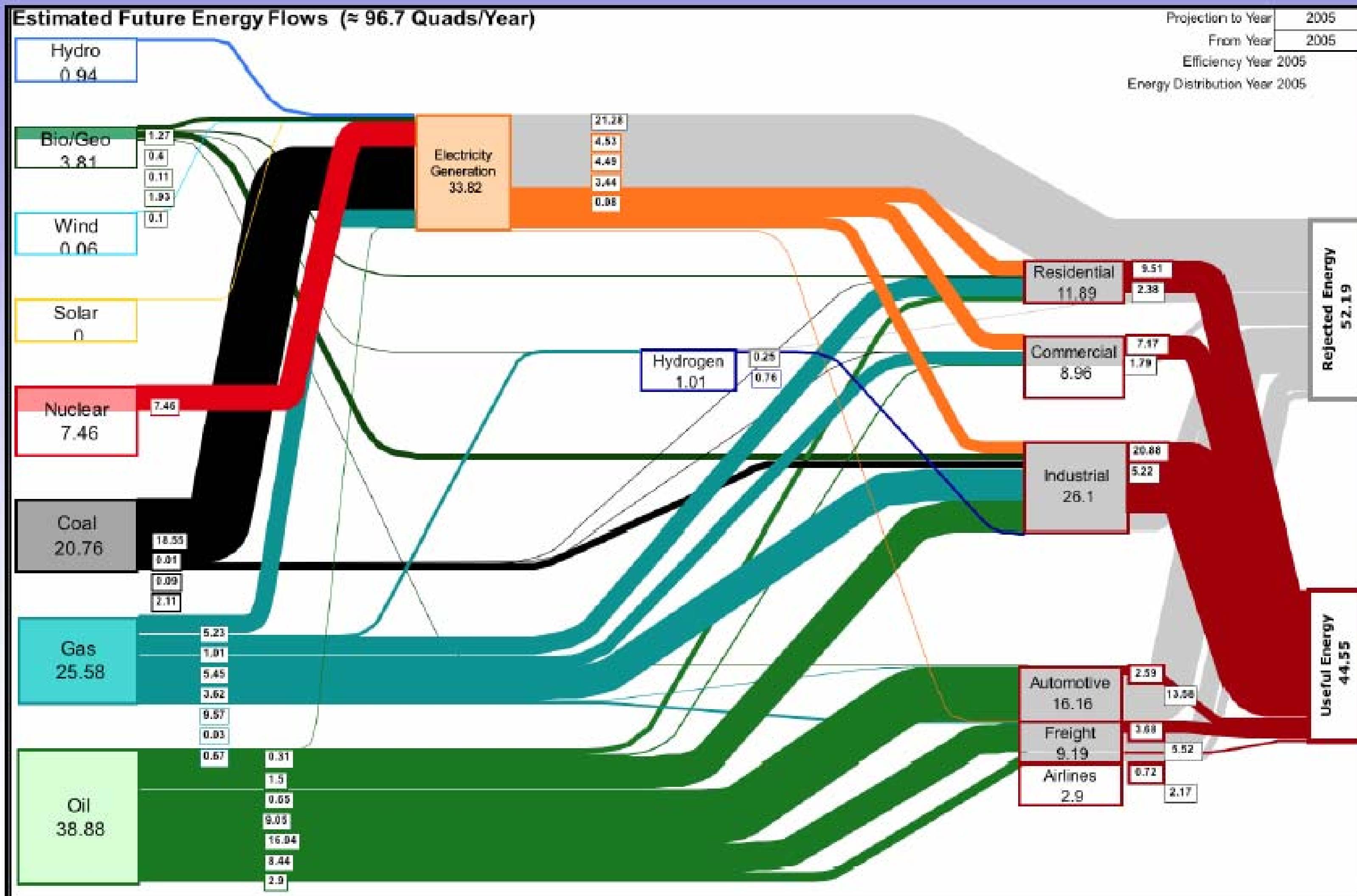
- Based on published Energy Information Agency (EIA) and other data sources
- Balances energy supplies (natural gas, coal, oil, renewables, hydro and nuclear) and demands (electrical generation, residential/commercial, industrial and transportation) with energy efficiency estimates
- Over the years associated carbon flows charts, California and hydrogen automobiles have been added
- Starting in 2003, the Energy Flow Chart was automated:
  - » Energy and carbon flow charts are drawn automatically from a database
  - » Allows for trend analysis and future projections
  - » Allows for real-time what-ifs regarding assumptions, e.g., gas mileage, electricity plant efficiency
  - » Automatically calculates carbon flows for each chart

The value of the Energy Flow Chart is to integrate and understand system response to scenario drivers and focus attention on challenges and chokepoints

Energy graphs have been common since 1975.

LLNL Energy Flow Chart is demand driven:

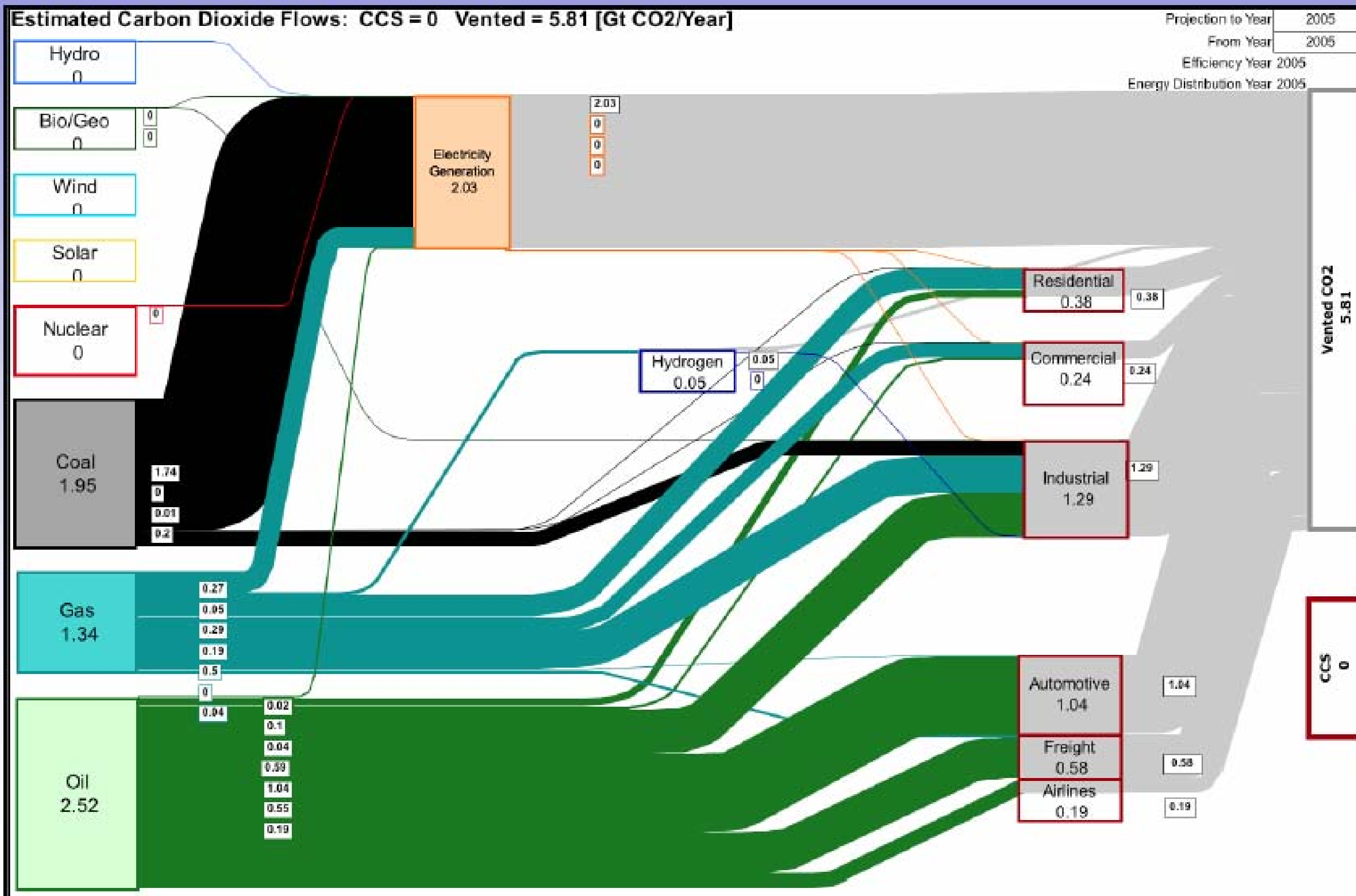
- includes major sources, electricity & H_2 generation, estimated efficiencies
- EIA 2005 forecast is shown



Introduction

Recently, a carbon version has been added.

New LLNL 2005 Carbon Flow Chart is derived from energy flow, estimates energy related CO_2 sources (5.8 $GtCO_2$/yr) and allows for an integrated CCS scenario construction



Introduction

Can schools invest in CO_2 sinks? (the carbon offset issue)

- Definition (from Wikipedia)
  - A carbon dioxide (CO_2) sink is a carbon dioxide reservoir that is increasing in size, and is the opposite of a carbon dioxide "source".
  - The main natural sinks are (1) the oceans and (2) plants and other organisms that use photosynthesis to remove carbon from the atmosphere by incorporating it into biomass and release oxygen into the atmosphere.
  - The concept of CO_2 sinks has become more widely known because the Kyoto Protocol allows the use of carbon dioxide sinks as a form of carbon offset.
- For the US to achieve the 7% reduction called for by the Kyoto Protocol through carbon offsets alone, an area the size of Texas would need to be planted and nurtured as forest every 30 years.
- Carbon offsets are highly controversial. See for instance http://www.carbontradewatch.org/pubs/carbon_neutral_myth.pdf

Making sense of the graphs

- The graphs give us some “big picture” information but how do we break this down to help us understand the impact our schools are having?
- Schools use electric, gas and other **direct energy** for heating, cooling, lighting, etc. If we can estimate the energy use, we can estimate the carbon impact. More on this later.
- Schools use **water** and there is a carbon impact associated with pumping, purification and treatment.
- Schools have **transportation** needs and the cars, buses, and light rail vehicles used to get students and teachers to and from schools have a large carbon impact.
- The **construction** of new schools and modernizations have a big impact. The industrial portion of the previous graphs illustrates this. This is the part that is probably the least understood.

USEPA Target Finder

Data from EPA Target Finder

Zip Code	95814	
Facility	K-12	
Size	150000	ft^2
Number of Students	800	
Number of PCs	50	
Operating Hours	40	h/W
Cooking Facility	Yes	
Air Conditioned	100	%
Heated	100	%
Months	10	m
Ventilated	Yes	

Results	50%	60%	70%	80%	90%	100%	
Source Energy	102.9	93.5	84.9	75.9	61.9	38.6	kBtu/ft^2-
Site Energy	38.2	34.7	31.5	28.2	23	14.3	kBtu/ft^2-
Carbon Dioxide	625.6	568.3	516.1	461.6	376.4	234.6	tons/y

The Median School **90^{th} Percentile School**

Direct Energy Use

The CEC has an easy way to determine carbon dioxide emissions.

- As part of the project to develop time dependent valued (TDV) energy, hourly emission rates were determined for each California climate zone.
- These may be applied to hourly estimates of electricity use that result from energy analysis tools to accurately estimate carbon emissions.
- Average of about 0.28 tons of CO_2 per megawatt-hour of electricity (about 0.56 lb/kWh), but it varies for northern and southern California and by time-of-use.
- Impact of direct combustion of fossil fuels may be estimated from combustion efficiency and fuel type.

What can we do about direct energy use?

- Build energy efficiency school buildings that use minimal energy for heating, cooling, lighting, etc.
- Install renewable energy sources such as PVs, and wind turbines
- Purchase energy efficiency equipment and appliances (EnergySTAR)
- Operate schools efficiently and keep them tuned up.
- Encourage energy efficiency behavior, e.g. the Flex-Your-Power campaign.

School Design and Construction

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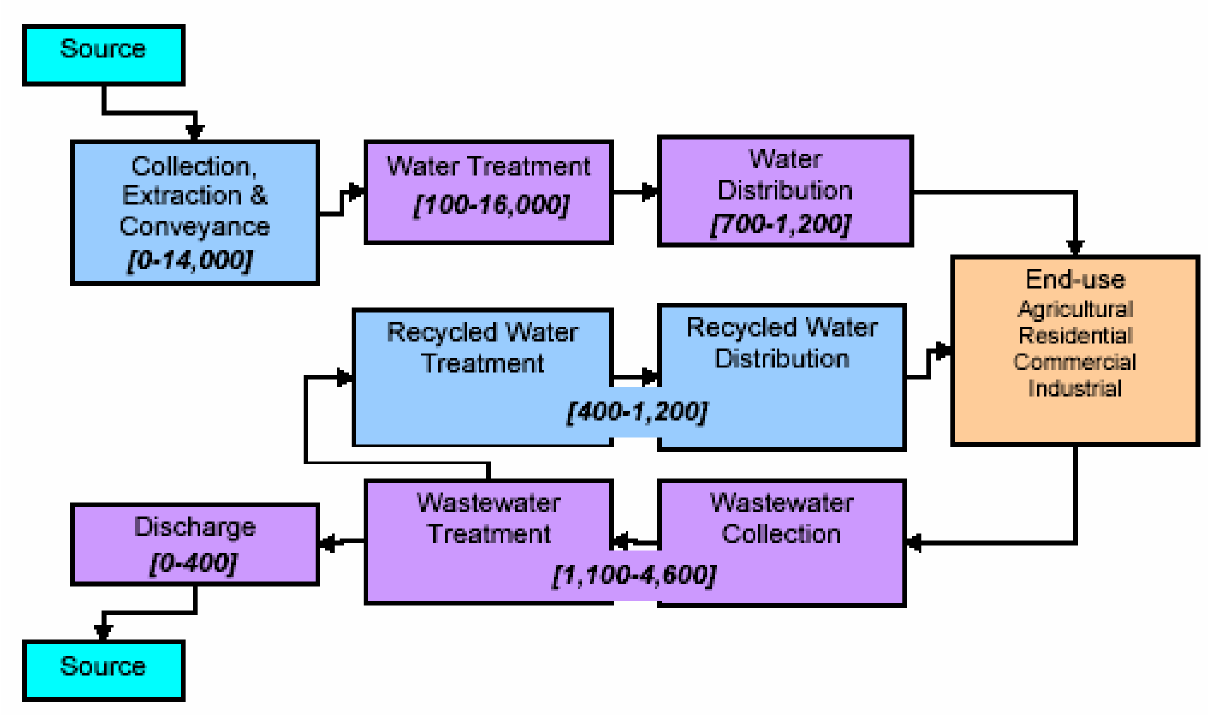
School Operation and Maintenance

Saving energy saves water and saving water saves energy.

- On average, it takes about 2 liters of water to produce a kWh of electricity in the U. S., but regional variations are significant.

- The energy associated with water use ranges from about 4,000 kWh/million gallons in northern California to about three times this energy intensity in southern California.

Energy needed for water use (kWh/million gallons)



	Northern California	Southern California
Conveyance	150	8,900
Treatment	100	100
Distribution	1,200	1,200
Wastewater Treatment	2,500	2,500
Regional Total	3,950	12,700

Source: White and Klein, The Water-Energy Connection in California, ACEEE 2006

Water

Did you know?

- Santa Rosa traffic engineers estimate that the number of cars on the road between 7:15 a.m. and 8:15 a.m. jumps 30 percent when school is in session.
- In 2001, less than 15 percent of students between the ages of five and 15 walked to or from school, and 1 percent biked.
- In 1969, 48 percent of students walked or biked to school.
- The average US travel distance from home to school is 4.8 miles and takes about 12 minutes.
- Automobiles near schools have health impacts as well as carbon.
  - During the 1996 Atlanta Olympic Games, when driving was reduced and ambient ozone levels fell by 27.9 percent, emergency room visits for asthma dropped by 41.6 percent.

Source: "Travel and Environmental Implications of School Siting", USEPA, EPA231-R-03-004, October 2003

What is the carbon impact of a typical school?

Number of Students	800	
Staff	40	
Percent Car Trips	85%	
Percent that Park at School	40%	
Average Least-Path Distance	4.8	mi
Car Miles per School Day	10,967	mi
Number of School Days	175	
Car Miles Per Year	1,919,232	mi
Average Fuel Efficiency	19.8	mi/gal
Gallons per year	96,931	gal/y
Carbon Dioxide per Gallon	22.2	lb/gal
Annual CO_2 Emissions	2,151,866	lb/y
	1,076	tons/y

Transportation

What can we do about it?

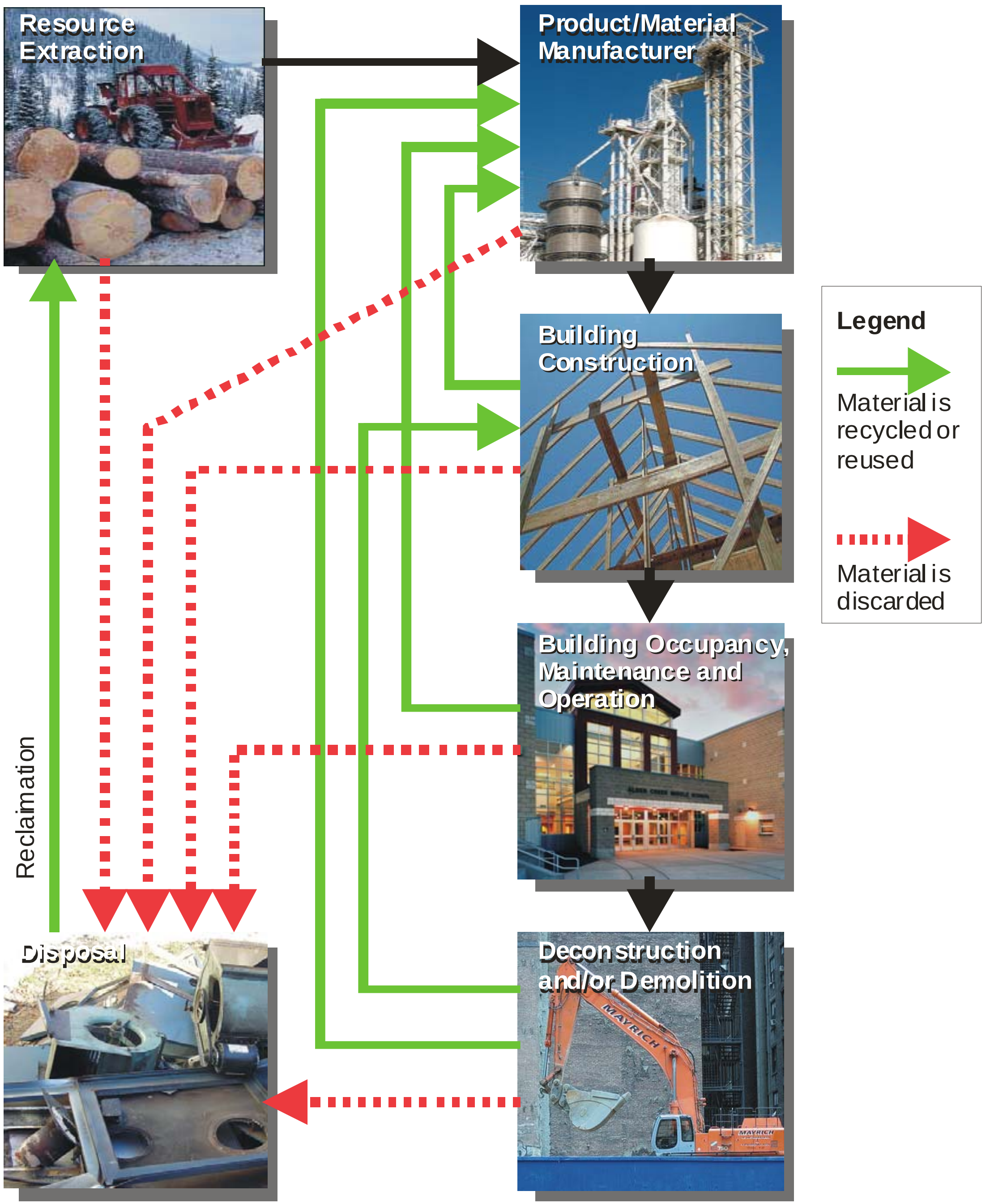
- Choose school sites that are closer to transit
- Provide safe paths for bikes and walking
- Encourage ride sharing through preferential parking and other incentives
- Operate school bus programs that use low-emission vehicles
- Charge for parking or limit parking

School Design and Construction

School Operation and Maintenance

Transportation

The process of extracting materials from the earth, processing them into building materials, delivering them to the site and assembling the building has a huge carbon impact.



Construction

Information on "embodied energy" is quite limited.

- American Institute of Architects, Environmental Resource Guide (last updated in 1997)
- ATHENA Institute (Canadian based)
- "Ballpark estimates" would indicate that the carbon impact of constructing a building is **equal to five to seven years of direct energy** consumption.
- U. S. Life-Cycle Inventory

U.S. Life Cycle Inventory

www.nrel.gov\lci

- The database provides primary data on the energy and material flows to and from the environment for several materials, energy types, transportation types, and transformation processes.

- The database is not specific to buildings and it currently does not cover all the materials used in buildings.

- It is difficult to get good LCI data and we have to take what we can get. However, we are always adding new data to expand the database. LCI data by itself does not give you the full environmental impact of a material.

- To get this information, you have to complete a life cycle assessment, which can be an arduous task. Luckily there are some tools for buildings to make this work a little easier.
  - BEES from NIST provides some LCAs for building materials.
  - The Athena institute has the Environmental Impact Estimator for building envelope, and the EcoCalculator for building assemblies.

- All of these tools use LCI data from the NREL database.

- The world of LCA is still very young and we have a long way to go to get the data and analysis tools that give us all the answers we are looking for. The field is growing very rapidly and new data and tools are being developed. We are working with several different groups to make sure that the US LCI database is supports this growing science.

What can we do about embodied energy?

- Until we have better data, we have to base our decisions mostly on anecdotal information.
- Most studies show that the energy/carbon impact of manufacturing products with a large recycled materials is less than using virgin materials (maximize the “green” lines in previous diagram).
- Materials delivered by rail or that are manufactured nearby should require less transportation energy.
- Many studies have focused on a comparison of wood, steel or concrete construction (ATHENA). Most show that it is a toss up between wood and steel, depending on how you weight the criteria, but that concrete has a much larger energy/carbon impact than the other two.