What's Your Building's CO_2 footprint?

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the University of Georgia
Environmental ENGINEERING
A conscience for the world. A foundation in technology. The blending of both…

Engineering Outreach SERVICE
The University of Georgia

Introduction and greetings from the University of Georgia

Topical Outline

- How we got to where we are now
  - IPCC reports and history
- Calculating a carbon footprint
- Speculation on future
  - Cap and trade versus carbon tax

What's Different from Past Periods of Environmental Concern?

- Compare now versus the 1960's & 70's

Environmental Pollution Concerns

We've come a long way in past 40 years

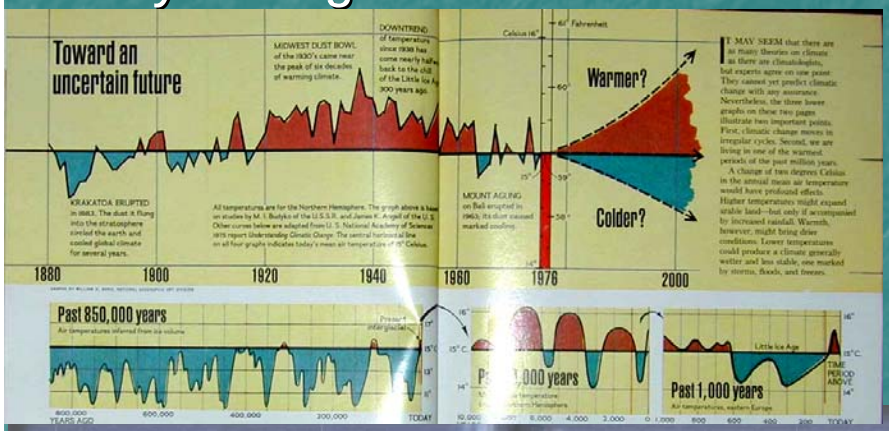
Love Canal

Cuyahoga River Fire

- Regulatory climate
- Emissions trading
- Society attitude
- Industrial attitude

Global Cooling and Next Ice Age

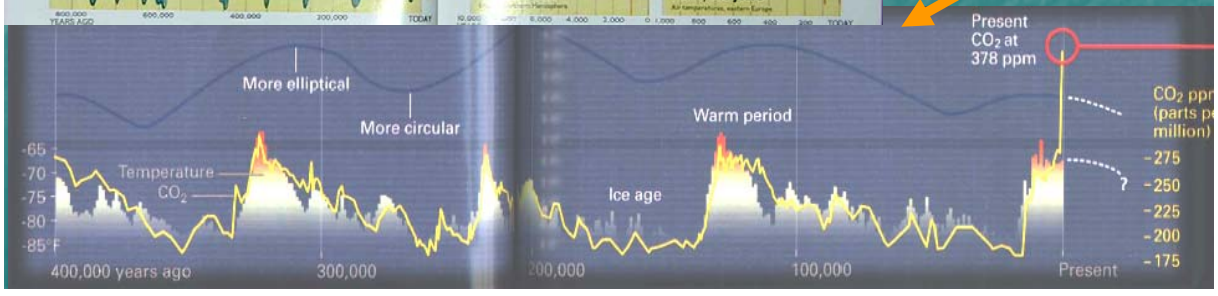
30 years ago concern was a new Ice Age...



National Geographic

1976

2004



Fourth IPCC Reports (2007)

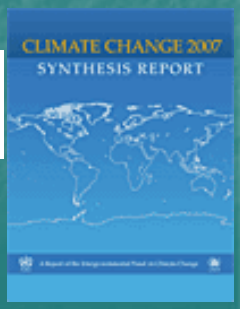
- **Led by science:** 450 lead authors, 800 contributing authors, 2500+ reviewers from 130+ countries
- Conclusive that the change is real and is "likely" man-induced
- Politics involved as usual

Climate Change 2007
The Physical Science Basis

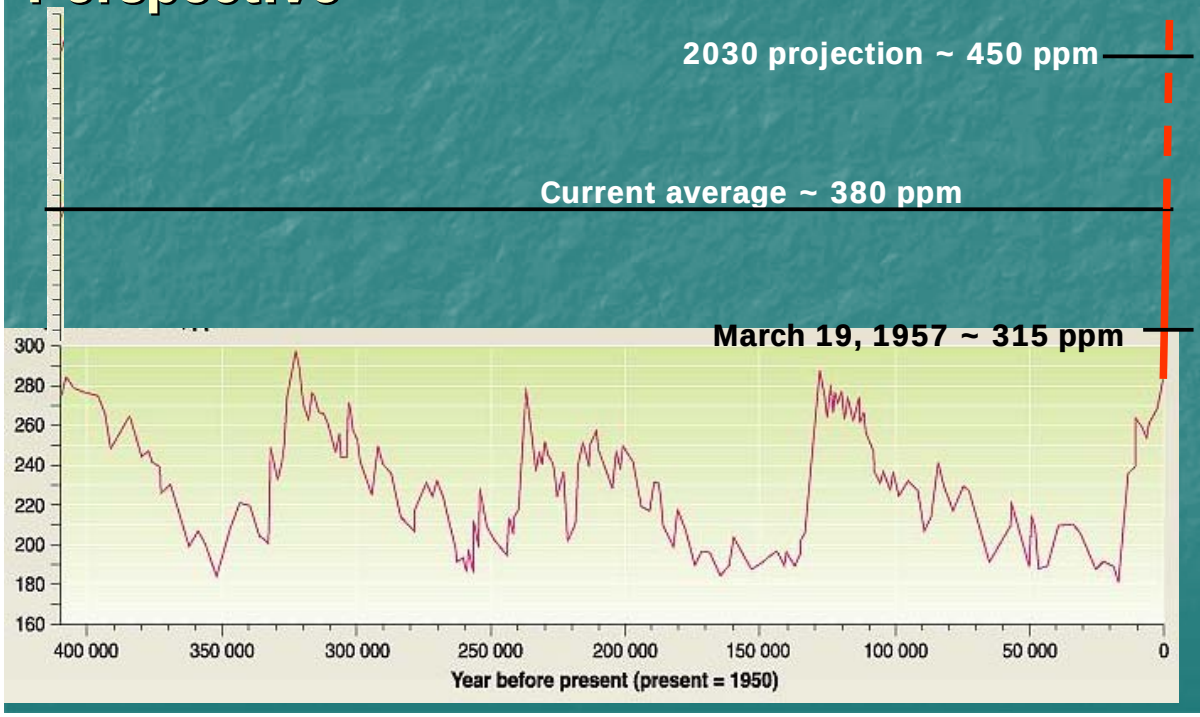
Climate Change 2007
Mitigation

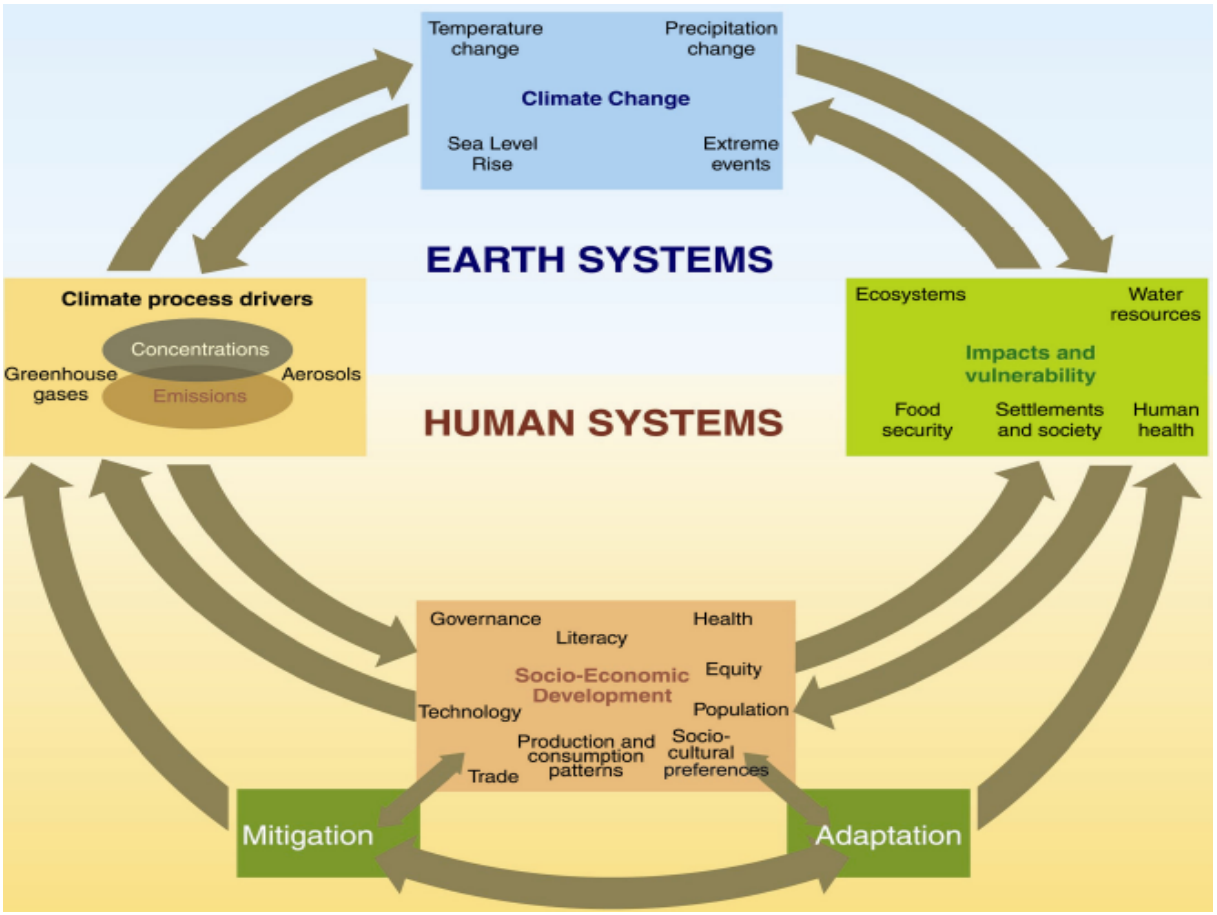
www.ipcc.ch

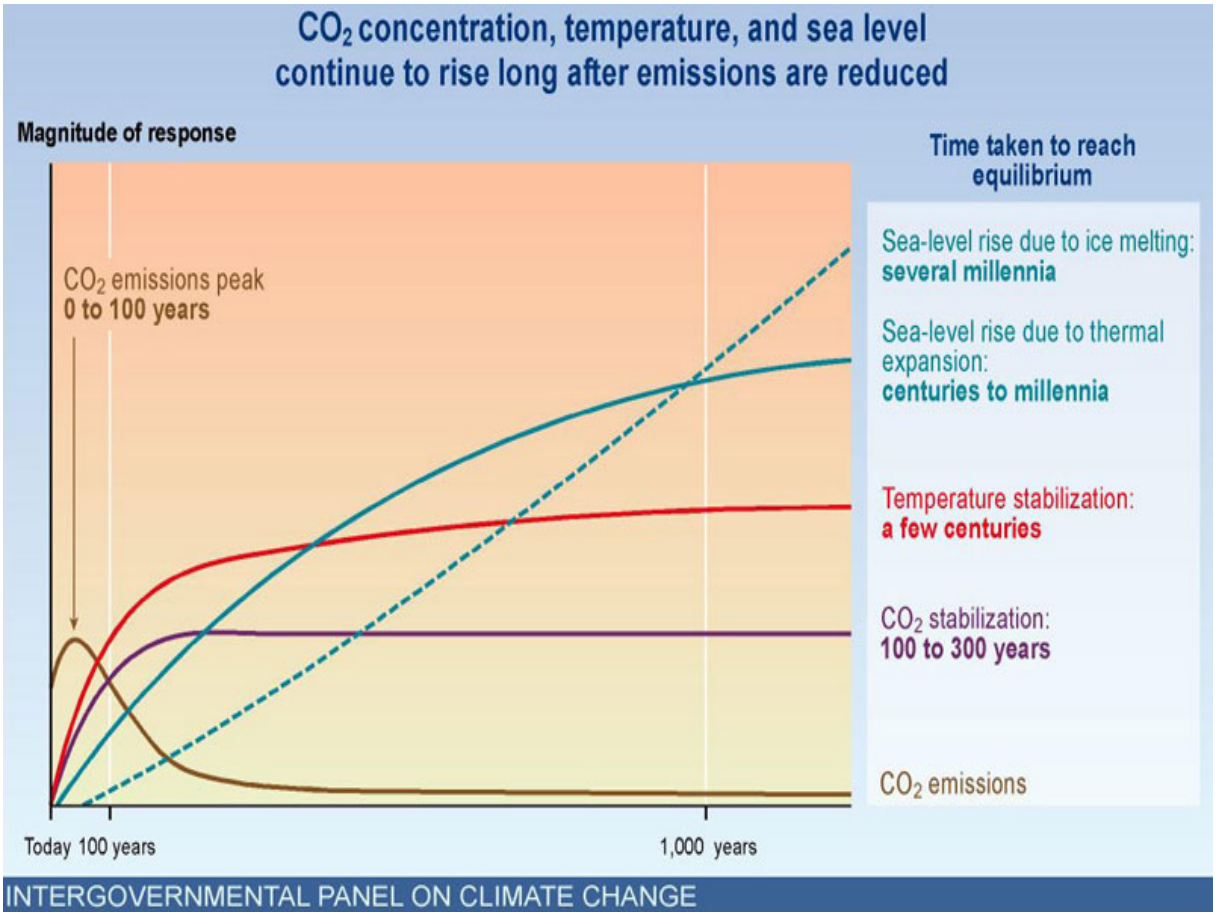
Climate Change 2007:
Impacts, Adaptation and Vulnerability



CO_2 History and Near-Term Projections Put in Perspective

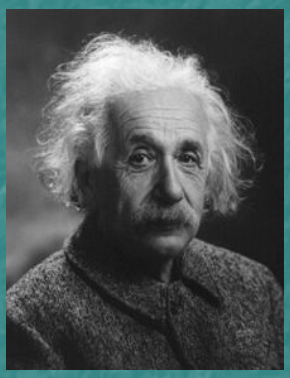



Temperature change
Precipitation change
Climate Change
Sea Level Rise
Extreme events
EARTH SYSTEMS
Climate process drivers
Concentrations
Greenhouse gases
Aerosols
Emissions
HUMAN SYSTEMS
Ecosystems
Water resources
Impacts and vulnerability
Food security
Settlements and society
Human health
Governance
Health
Literacy
Socio-Economic Development
Equity
Technology
Population
Production and consumption patterns
Socio-cultural preferences
Trade
Mitigation
Adaptation


CO_2 concentration, temperature, and sea level continue to rise long after emissions are reduced
Magnitude of response
CO_2 emissions peak 0 to 100 years
Today 100 years
1,000 years
Time taken to reach equilibrium
Sea-level rise due to ice melting: several millennia
Sea-level rise due to thermal expansion: centuries to millennia
Temperature stabilization: a few centuries
CO_2 stabilization: 100 to 300 years
CO_2 emissions
INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE

What Can We Do About It?

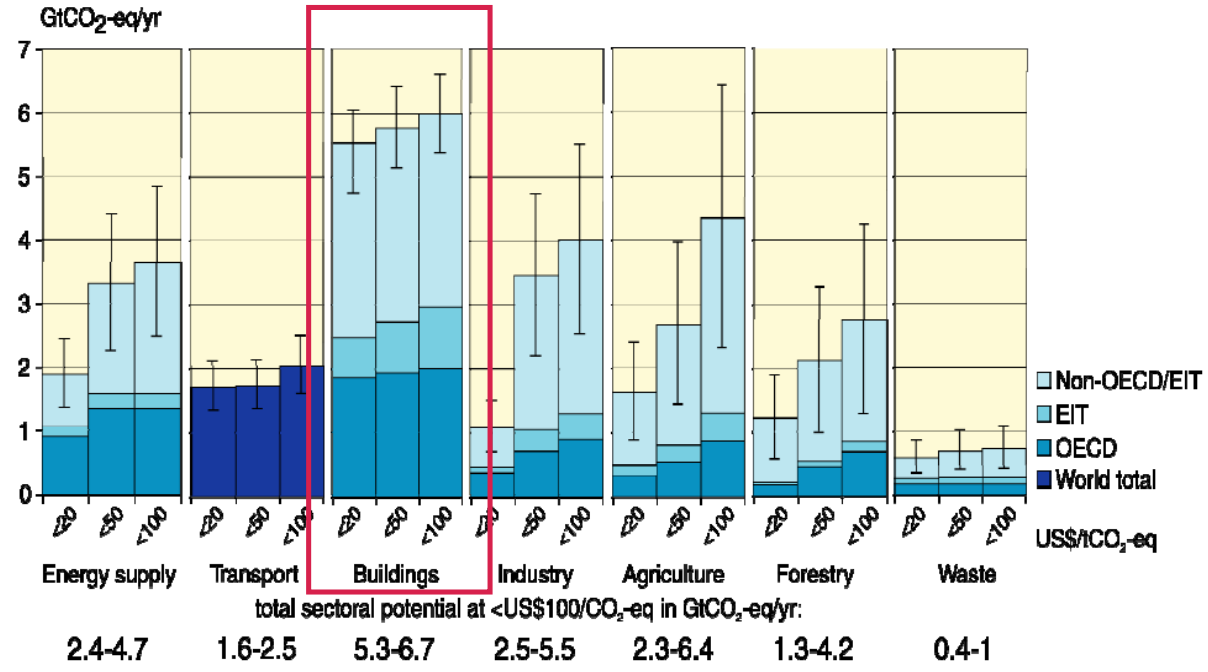
- As a society?
- As a company or organization?
- As an individual?



"No problem can be solved from the same level of consciousness that created it."

Albert Einstein

Economic mitigation potential by sector in 2030



- **"Every problem is just an opportunity in disguise"**
  - Individuals
  - Companies, organizations
  - Nations

Calculating the Carbon Footprint

- Buildings
- Organization as a Whole

Where to Draw the Boundary?

- Is it just at the property line of the building infrastructure?
  - Building energy
  - Transportation?
  - Source or site?
  - Embodied energy?
  - Water use?
  - Supplied services?
  - Etc.

What Do These Actually Mean?

Each factor contributes

- Building energy – The one real obvious one
- Transportation? – Indirectly; owner occupied?
  - Transportation Management Plan
- Source or site? – Full accounting → source
- Embodied energy? – Energy expended to build
- Water use? – Not at the site, but energy is needed *somewhere*, provided by *someone*
- Supplied services? – But these are 3rd parties?!
- Etc. – Materials purchase, cleaning,

Energy Consumption – The Obvious Big Player

Source versus Site Emissions

Site

- On-site combustion
- Electricity used on-site, but is generated elsewhere

Source

- Where to draw boundary here?

Energy Consumption – Emissions Factors

Quiz

- For every 1 kWh of electricity consumed, what is the average resulting CO_2 emissions from this?
  - ½ lb of CO_2?
  - 1.0 lb of CO_2?
  - 2.0 lb of CO_2?
  - Don't have a clue?

Building Project Energy Source	CO_2e kg/kWh (lb/kWh)
Grid delivered electricity and other fuels not specified in this table	0.758 (1.670)
LPG or propane	0.274 (0.602)
Fuel oil (residual)	0.312 (0.686)
Fuel oil (distillate)	0.279 (0.614)
Coal (except lignite)	0.373 (0.822)
Coal (lignite)	0.583 (1.287)
Gasoline	0.309 (0.681)
Natural gas	0.232 (0.510)

From: Draft ASHRAE Standard 189.1

First Step:
Compile Energy Consumption

Utility Meter(s) for Existing Buildings

Example:

Electricity Meter #3

Account ID 129 **Location** Main Library Annex **PPD** 62000
Account Number 30-872-086 **Building** 0054

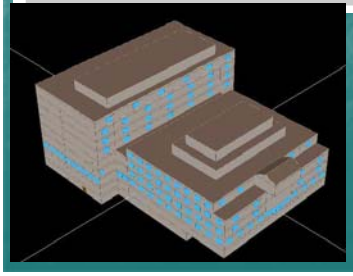
Billing Period	Days	kWh	per Day	Peak kW	Amount	Cost per Day
FY 2006						
6/30/05 - 7/27/05	27	352,000	13,037	680	$17,600	$651.85
7/27/05 - 8/30/05	34	380,000	11,176	720	$19,000	$558.82
8/30/05 - 9/28/05	29	373,200	12,869	720	$18,660	$643.45
9/28/05 - 10/28/05	30	296,000	9,867	640	$14,800	$493.33
10/28/05 - 11/29/05	32	336,000	10,500	600	$16,800	$525.00
11/29/05 - 1/3/06	35	283,600	8,103	880	$14,180	$405.14
1/3/06 - 1/30/06	27	271,600	10,059	680	$13,580	$502.96
1/30/06 - 2/28/06	29	284,000	9,793	720	$14,200	$489.66
2/28/06 - 3/30/06	30	322,800	10,760	680	$16,140	$538.00
3/30/06 - 4/27/06	28	318,000	11,357	680	$15,900	$567.86
4/27/06 - 5/30/06	33	348,400	10,558	640	$17,420	$527.88
5/30/06 - 6/13/06	14	140,800	10,057	600	$7,040	$502.86
Total		**3,706,400**	**10,651**		**$185,320**	**$532.53**

First Step:
Compile Energy Consumption

Modeling for New Buildings

Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	43.0	44.1	71.5	86.7	111.3	127.4	150.2	158.4	128.2	92.3	61.9	46.1	1,121.0
Heat Reject.	0.0	0.0	0.1	0.2	1.2	3.1	5.8	6.5	2.9	0.5	0.0	0.1	20.3
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	40.2	37.1	40.5	40.8	41.6	40.9	43.6	45.9	43.8	42.3	38.7	39.9	495.3
Pumps & Aux.	42.7	39.0	44.8	44.5	46.6	45.3	47.7	48.1	45.4	45.8	42.8	42.9	535.6
Ext. Usage	0.5	0.4	0.4	0.4	0.3	0.3	0.3	0.5	0.4	0.5	0.4	0.5	4.9
Misc. Equip.	16.3	14.9	17.0	16.5	17.1	16.5	16.5	17.7	15.3	17.1	15.7	15.8	196.5
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	303.2	271.8	301.4	295.3	230.4	196.1	202.5	249.4	286.0	307.0	287.9	271.5	3,202.4
Total	445.9	407.3	475.7	484.3	448.5	429.7	466.6	526.4	522.0	505.4	447.5	416.6	5,575.9



Next Step: Translate to CO_2 Emissions

Options

- Emissions factor, such as:

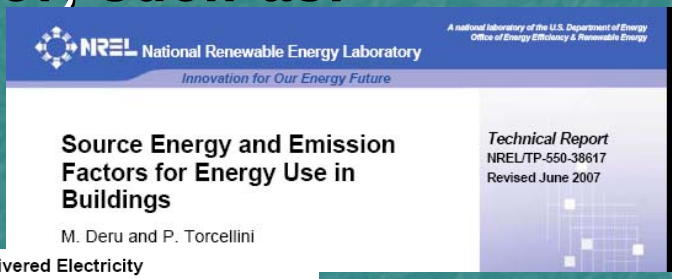


Table 3 Total Emission Factors for Delivered Electricity
(lb of pollutant per kWh of electricity)

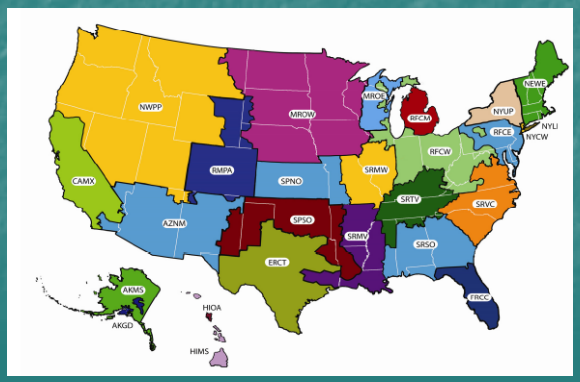
Pollutant (lb)	National	Eastern	Western	ERCOT	Alaska	Hawaii
CO_{2e}	1.67E+00	1.74E+00	1.31E+00	1.84E+00	1.71E+00	1.91E+00
CO_2	1.57E+00	1.64E+00	1.22E+00	1.71E+00	1.55E+00	1.83E+00
CH_4	3.71E-03	3.59E-03	3.51E-03	5.30E-03	6.28E-03	2.96E-03
N_2O	3.73E-05	3.87E-05	2.97E-05	4.02E-05	3.05E-05	2.00E-05
NO_X	2.76E-03	3.00E-03	1.95E-03	2.20E-03	1.95E-03	4.32E-03
SO_X	8.36E-03	8.57E-03	6.82E-03	9.70E-03	1.12E-02	8.36E-03
CO	8.05E-04	8.54E-04	5.46E-04	9.07E-04	2.05E-03	7.43E-03
TNMOC	7.13E-05	7.26E-05	6.45E-05	7.44E-05	8.40E-05	1.15E-04
Lead	1.31E-07	1.39E-07	8.95E-08	1.42E-07	6.30E-08	1.32E-07
Mercury	3.05E-08	3.36E-08	1.86E-08	2.79E-08	3.80E-08	1.72E-07
PM10	9.16E-05	9.26E-05	6.99E-05	1.30E-04	1.09E-04	1.79E-04
Solid Waste	1.90E-01	2.05E-01	1.39E-01	1.66E-01	7.89E-02	7.44E-02

Next Step: Translate to CO_2 Emissions

Options

- U.S. EPA eGrid

(Plant emissions



Year 2004 State Emissions
(Source: eGRID2006 Version 2.1, April 2007)

State	Carbon dioxide (CO_2) Emissions (tons)	Carbon dioxide (CO_2) Output emission rate (lb/MWh)	Sulfur dioxide (SO_2) Emissions (tons)	Sulfur dioxide (SO_2) Output emission rate (lb/MWh)
AK	3,610,850	1,106	3,925	1.203
AL	89,170,715	1,299	423,774	6.172
AR	33,174,715	1,280	87,555	3.379
AZ	60,271,433	1,219	60,941	1.232
CA	67,521,916	700	12,369	0.128
CO	47,532,473	1,986	64,095	2.678
CT	12,279,200	754	8,120	0.499
DC	65,937	3,614	173	9.500
DE	6,766,288	1,804	36,964	9.854
FL	145,001,520	1,348	427,255	3.972
GA	87,968,286	1,388	577,234	9.110

Range

0.007 – 2.28 lb/kWh

Example Calculation

Example

- From annual utility meters or model data:
  - electricity consumption = 5,575,900 kWh
  - natural gas (heat, DHW) = 9.0 x 10^9 Btu or 2.64 x 10^6 kWh equivalent
- Resulting emissions:
  - Electricity

$$CO_2 = 5,575,900 \times 1.67 \text{ lb } CO_2/\text{kWh}$$
$$= 9.31 \times 10^6 \text{ lb } CO_2 = 4,656 \text{ tons per year}$$

  - Gas

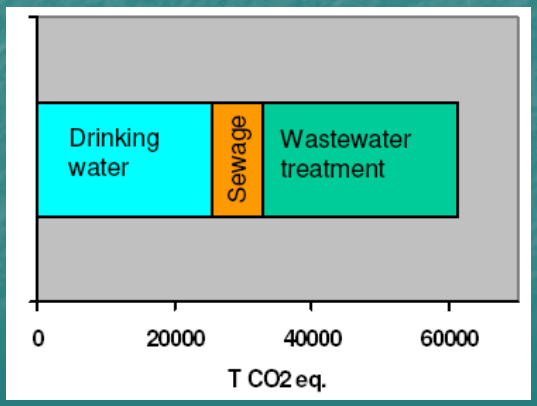
$$CO_2 = 2,637,749 \times 0.232 \text{ lb } CO_2/\text{kWh}$$
$$= 612,000 \text{ lb } CO_2 = 306 \text{ tons per year}$$

And Did you Forget About…?

- Water usage
- Transportation
- Embodied energy
- Supplied services
- Materials used in operation

CO_2 Emissions from Water Use

- Water usage
  - From one major city: 2.31 lb CO_2 per 1,000 gallons potable water provided (plus ~ same for waste treatment)
  - If not known, could assume in range of 4 to 5 lb CO_2 per 1,000 gallons



Water Use Example

Comparative Readings

Water / Sewer

Account ID 723 **Location** CCRC-New **PPD** 64000 66000 **Account Number** 2006-172531

Address 315 Riverbend Rd. **Building Number** 2419 **Meter Number** 70025983

Billing Period	Days	Cubic Feet	Cubic Ft per Day	Water Cost	Sewer Cost	Total Cost	Total Cost / Day
FY 2006							
5/25/2005 - 6/24/2005	30	124,540	4,151	$2,177.73	$1,923.52	$4,101.25	$136.71
6/24/2005 - 7/28/2005	34	189,830	5,583	$3,307.25	$2,928.98	$6,236.23	$183.42
7/28/2005 - 8/24/2005	27	152,840	5,661	$2,667.32	$2,359.34	$5,026.66	$186.17
8/24/2005 - 9/27/2005	34	159,900	4,703	$2,933.65	$2,596.26	$5,529.91	$162.64
9/27/2005 - 10/26/2005	29	110,360	3,806	$2,032.02	$1,793.71	$3,825.73	$131.92
10/26/2005 - 11/23/2005	28	76,320	2,726	$1,412.49	$1,242.26	$2,654.75	$94.81
11/23/2005 - 12/22/2005	29	60,370	2,082	$1,122.20	$983.87	$2,106.07	$72.62
12/22/2005 - 1/27/2006	36	77,440	2,151	$1,432.88	$1,260.41	$2,693.29	$74.81
1/27/2006 - 2/24/2006	28	58,920	2,104	$1,095.81	$960.38	$2,056.19	$73.44
2/24/2006 - 3/27/2006	31	83,330	2,688	$1,540.08	$1,355.83	$2,895.91	$93.42
3/27/2006 - 4/27/2006	31	104,750	3,379	$1,929.92	$1,702.83	$3,632.75	$117.19
4/27/2006 - 5/25/2006	28	104,370	3,728	$1,923.00	$1,696.67	$3,619.67	$129.27
Total FY 2006	365	1,302,970	3,570	$23,574.35	$20,804.06	$44,378.41	$121.58

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Total FY 2006	365	1,302,970	3,570	$23,574.35	$20,804.06	$44,378.41	$121.58

- 1,302,970 ft^3 x 7.48 gal/ ft^3 = 9,746,000 gal
- ~ 39,000 lb CO_2 per year
- ***But these are indirect emissions***

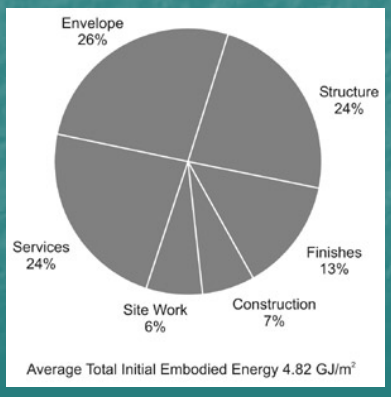
Transportation Impact

- Transportation management planning
- Location and policies
- Personal travel (commuting) versus business required travel

Other Stuff (cont'd)

- **Embodied energy**

  (still developing)



	EMBODIED ENERGY	
MATERIAL	MJ/kg	MJ/m3
Aggregate	0.10	150
Straw bale	0.24	31
Soil-cement	0.42	819
Stone (local)	0.79	2030
Concrete block	0.94	2350
Concrete (30 Mpa)	1.3	3180
Concrete precast	2.0	2780
Lumber	2.5	1380
Brick	2.5	5170
Cellulose insulation	3.3	112
Gypsum wallboard	6.1	5890
Particle board	8.0	4400
Aluminum (recycled)	8.1	21870
Steel (recycled)	8.9	37210
Shingles (asphalt)	9.0	4930
Plywood	10.4	5720
Mineral wool insulation	14.6	139
Glass	15.9	37550
Fiberglass insulation	30.3	970
Steel	32.0	251200
Zinc	51.0	371280
Brass	62.0	519560
PVC	70.0	93620
Copper	70.6	631164
Paint	93.3	117500
Linoleum	116	150930
Polystyrene Insulation	117	3770
Carpet (synthetic)	148	84900
Aluminum	227	515700

NOTE: Embodied energy values based on several international sources - local values may vary.

Recommendations for Near-Term

- Look at emissions reduction potential
- Do what is verifiable … verify it … and document it
- Direct emissions from electrical energy use, using source emissions factors
- Emissions from on-site energy, use on-site factors

Carbon Footprint Calculation Tools

- A number available for personal footprint calculation
  - www.bp.com/carboncalculator
  - http://green.yahoo.com/calculator/
- For business, more complicated, less available
  - www.carbontrust.co.uk General org
  - www.thegreenoffice.com/carbon Offices
  - buildcarbonneutral.org/ Construction

Soon to be a Universal Requirement?

- UK Environment Agency requires use of online carbon footprint calculator for new projects (Nov 2007)
- ASHRAE Standard 189.1P
- San Francisco may require green building for all commercial, residential (LEED) aimed at reducing carbon footprint (March 2008)
- Part of ***Life Cycle Assessment***

Related Development

- April 17, 2008: EPA meeting on proposed rule to ".. *require mandatory reporting of greenhouse gas emissions above appropriate thresholds in all sectors of the economy*." and to"
  "*include in its rule reporting of emissions resulting from upstream production and downstream sources*."

Speculation on the Future

What's In Store for Future?

- "Carbonomics"
  Carbon tax vs. carbon trading vs. do nothing
  - Which is the 'free market' approach?
  - Some think:
    Cap & trade = Carbon tax + Corporate Welfare
- Regulation or market approach?
- How much is enough? Can we do enough?
- What can we do about it? What do you want to do about it?
- What's in it for you (me)?

The Great Debate of 2009

Cap and Trade:

- Set overall maximum of carbon emissions allowed, reduce over time
- Permitting
- Market for buying, selling of allowances

Carbon Tax:

- Taxing of carbon emissions or production
- Ideally, money used to offset price increases severe impact
- Coal most impacted, natural gas lower impact

The Great Debate – A Paradox

Cap and Trade:

- Tends to be the favorite of politicians
- Obscures the costs
- May give political 'cover' to decision makers
- (Some think) may be only method that guarantees reductions

Carbon Tax:

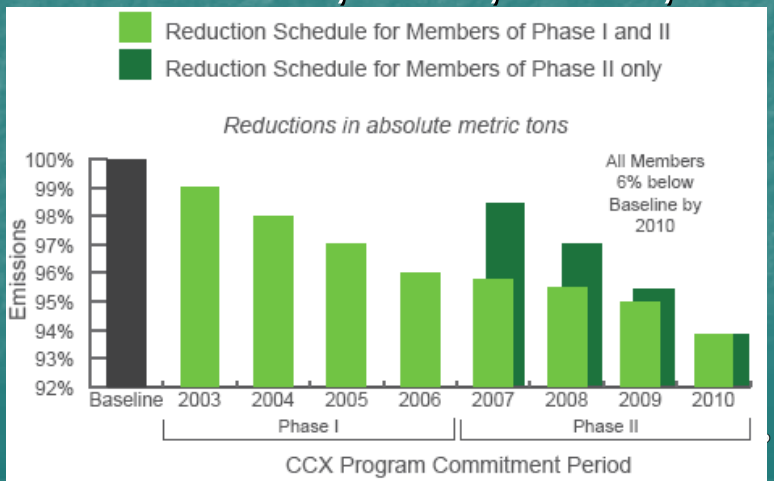
- Tends to be the favorite of economists
- One estimate*: $15 / ton of carbon
  - $80 billion revenue
  - 1.63 ¢/kWh increase electricity
  - Gasoline increase $0.14 / gallon

** American Electric Power Institute*

Chicago Climate Exchange

CCX Chicago Climate Exchange

- Founded 2003
- Voluntary membership: industries, cities, states, universities



Baseline:

Avg. of 1998-2001 emissions

Chicago Climate Exchange

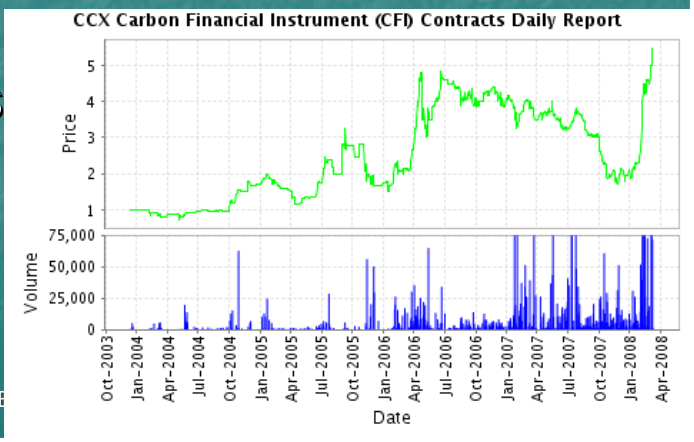
- Key element: Carbon Financial Instrument, a tradable commodity
- More than just CO_2, includes methane, nitrous oxide, HFCs, perfluorcarbons and SF_6 (converted through Global Warming Potential)
- Offset projects include methane and soil carbon management, renewable energy, forestry, energy efficiency

Chicago Climate Exchange

- Members include:
  Ford Motor, American Electric Power, Motorola, United Technologies
- Other stakeholders include associate members, offset aggregators and providers

1 CFI contract = 100 metric tons

Price in $/ton



European Trading Programs

- European Union Emissions Trading Scheme (EUTS)
- European Climate Exchange: Founded by CCX in 2006
- Current (March 2008) European price of around €20 per ton
- March 14, 2008 futures trading begins

Compare Context of Scale

	2006 Volume (Million tCO_2)	2006 Value (US$ Million)
Voluntary OTC Offset Market	13.4	54.9
CCX	10.3	36.1
Total Voluntary Market	23.7	91 $3.84 / ton
Other GHG Trading Schemes		
EU ETS Trading Scheme [2]	1,101	24,357 $22.12 / ton
Primary Clean Development Mecha-nism	450	4,813
Secondary Clean Development Mecha-nism	25	444
Joint Implementation	16	141
New South Wales	20	225

[2] The World Bank. *State and Trends of the Carbon Market*, 2007. <http://carbonfinance.org/docs/Carbon_Trends_2007-_FINAL_-_May_2.pdf>.

Source: K. Hamilton, et al., 2007. "State of the Voluntary Carbon Market 2007: Picking up Steam" www.ecosystemmarketplace.com

Carbon Tax Comments

- British Columbia recently adopted a "revenue neutral" carbon tax
  - Effective July 1, 2008 @ $10/ton
  - Rises by $5 per year up to $30 in 2012
  - How to integrate with cap and trade (Western Regional Climate Initiative)?
- What is the real price elasticity?

The Crystal Ball

- Nothing happens in U.S. until 2009
- One estimate: U.S. carbon market could reach $1 trillion by 2020
- Beyond the original Kyoto Protocol
  - Montreal 2005 – Agree to create plan for beyond Kyoto end in 2012
  - Bali, Dec. 2007 – outlines the deal "*Lead, follow or get out of the way*"
  - Who caused the problem? Who fixes it?

Montréal 2005

World vs. Country vs. Regional

- One common approach worldwide will not work
- In the U.S., most action to date by the various states in 3 groups
  - Western Regional Climate Initiative (AZ, NM, CA, OR, WA, MT + BC and Manitoba)
  - Regional Greenhouse Gas Initiative (CT, DE, ME, NH, NJ, NY and VT) with other observers
  - Midwest (IL, IA, KS, MI, MN and WI)
- But, preferred action through federal government

Barriers to Implementation and ASHRAE Member's Opportunities

- In your opinion, what are barriers?
  - Economic?
  - Technical?
  - Political?
  - Managerial?
- Can these be changed?
- Opportunities?

Thank you!

- Comments, questions, concerns, advice ...

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