

F10: Carbon Footprint: Should a Data Center Manager Care?

What is carbon footprint?

"the total set of greenhouse gas (GHG) emissions caused by an organization, event, product or person."

[1] Greenhouse gases can be emitted through transport, land clearance, and the production and consumption of food, fuels, manufactured goods, materials, wood, roads, buildings, and services.

[2] For simplicity of reporting, it is often expressed in terms of the amount of carbon dioxide, or its equivalent of other GHGs, emitted.

Source: http://en.wikipedia.org/wiki/Carbon_footprint



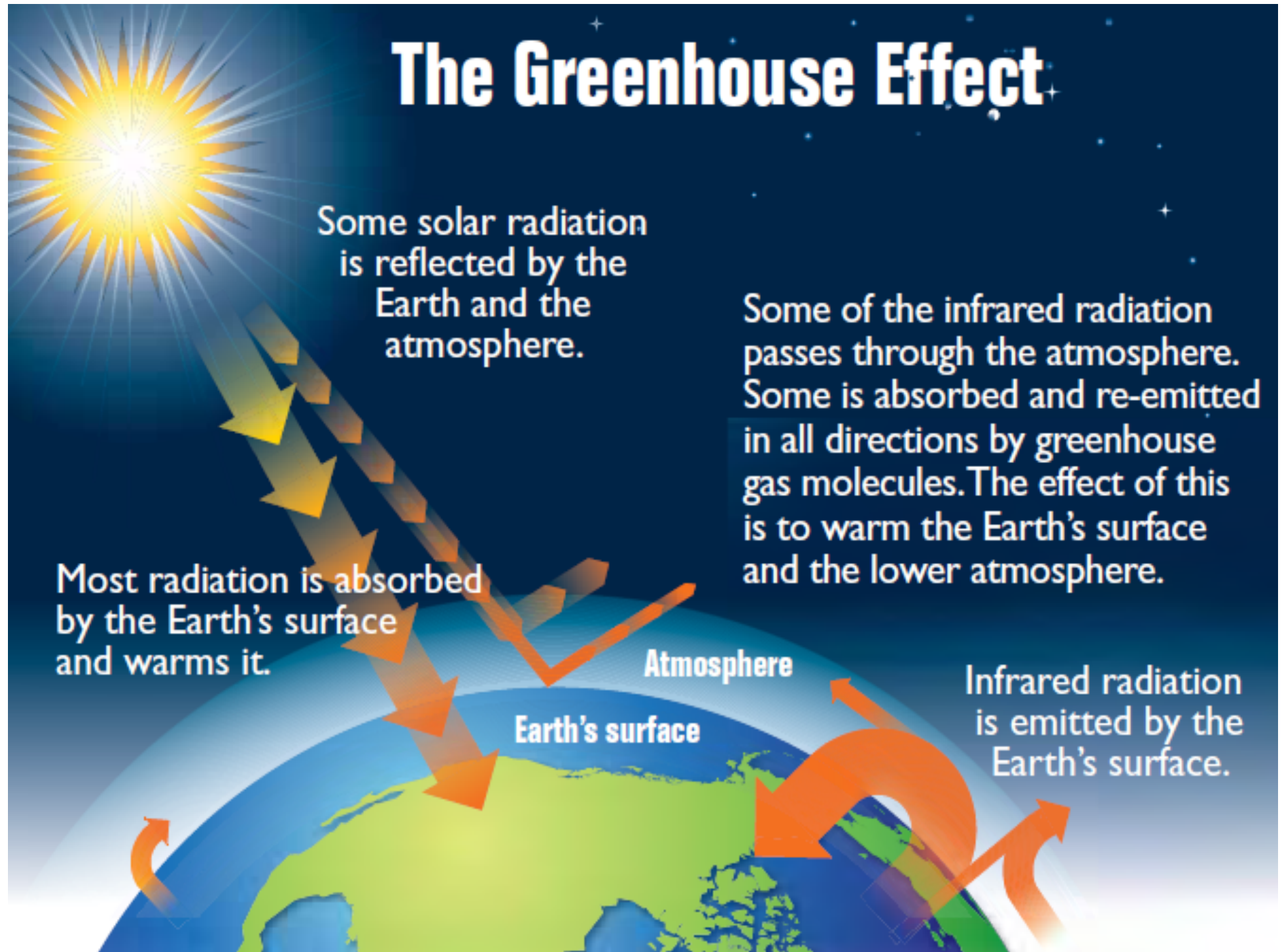
The Greenhouse Effect

Some solar radiation is reflected by the Earth and the atmosphere.

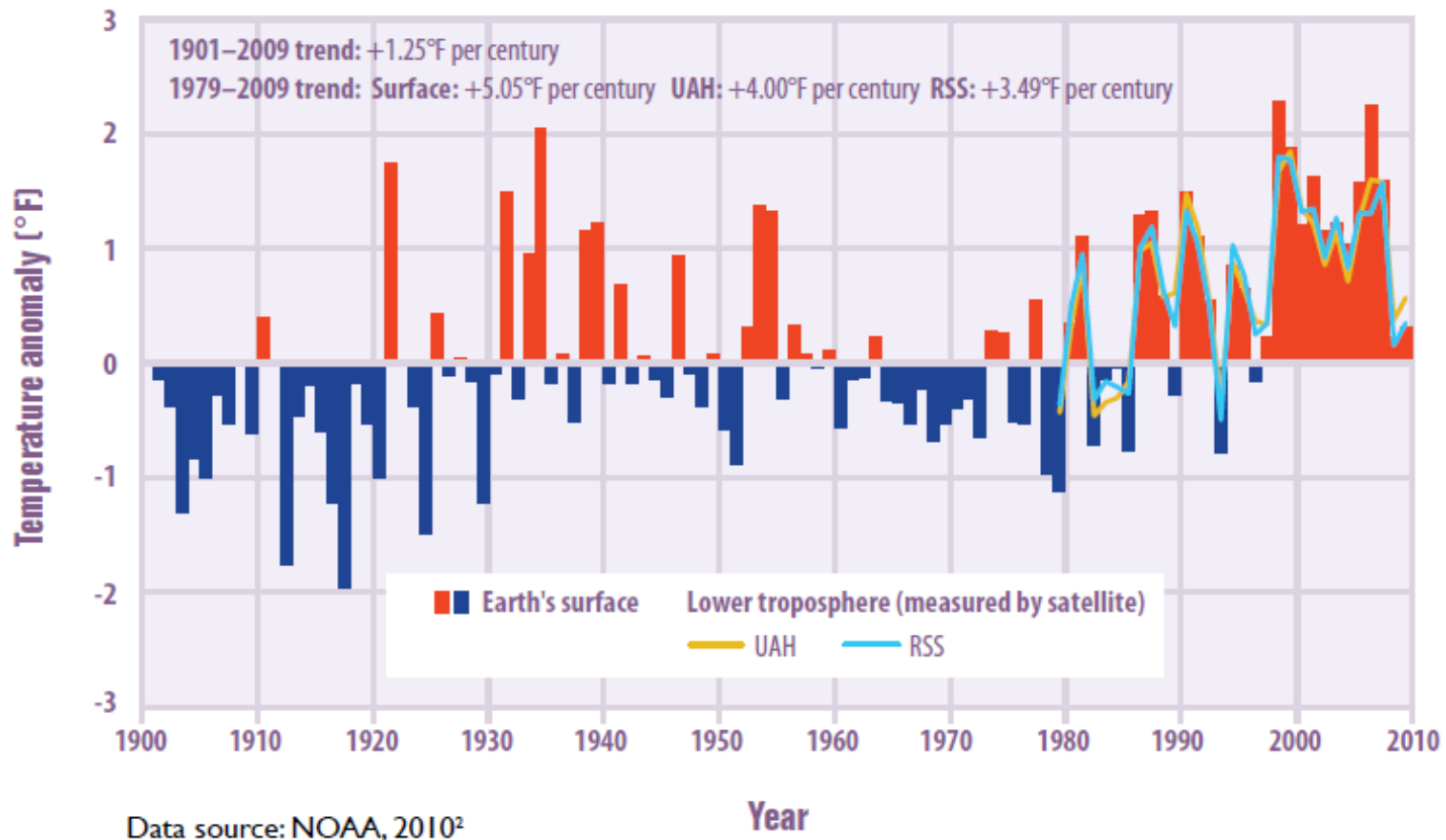
Some of the infrared radiation passes through the atmosphere. Some is absorbed and re-emitted in all directions by greenhouse gas molecules. The effect of this is to warm the Earth's surface and the lower atmosphere.

Most radiation is absorbed by the Earth's surface and warms it.

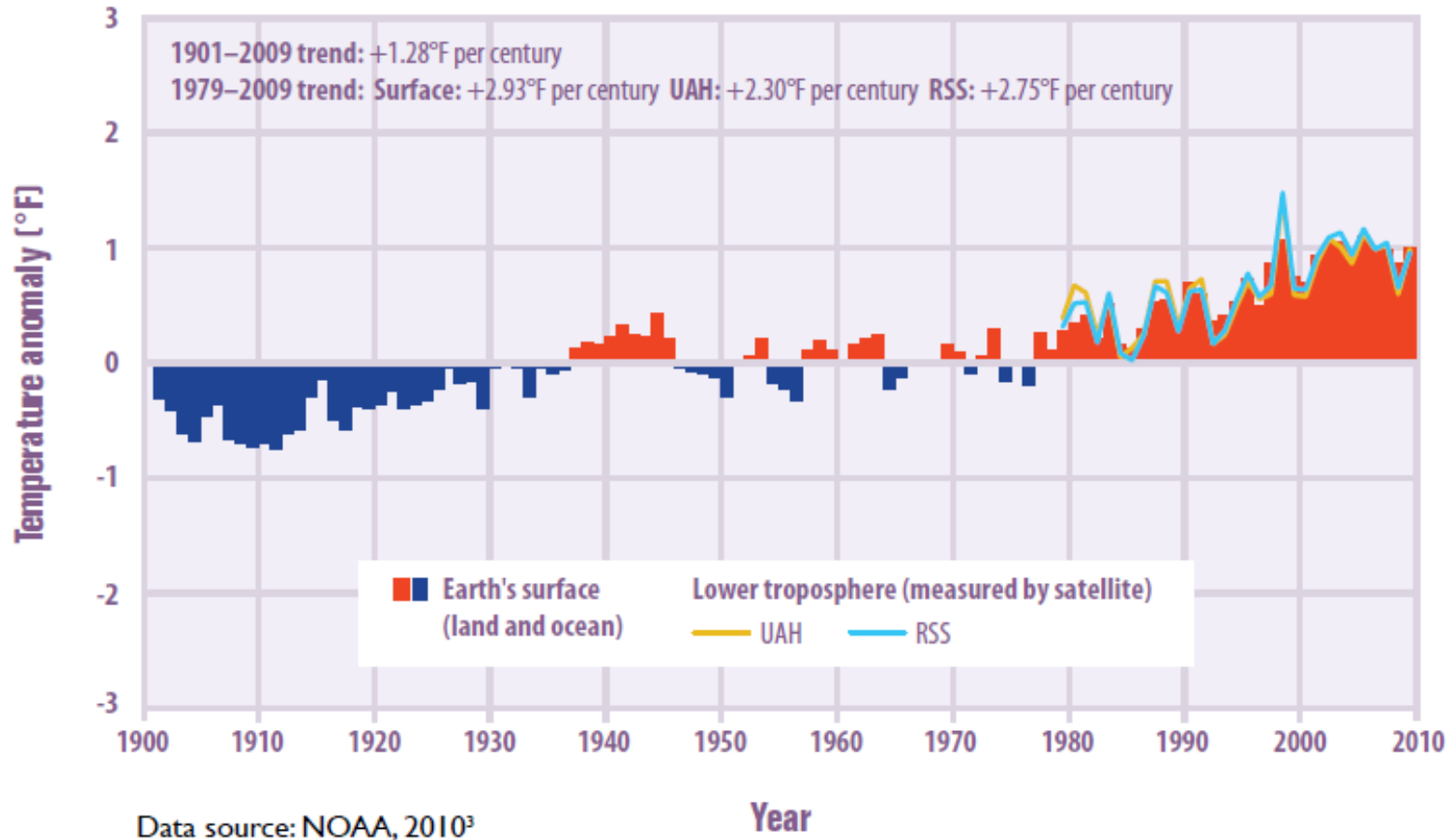
Infrared radiation is emitted by the Earth's surface.



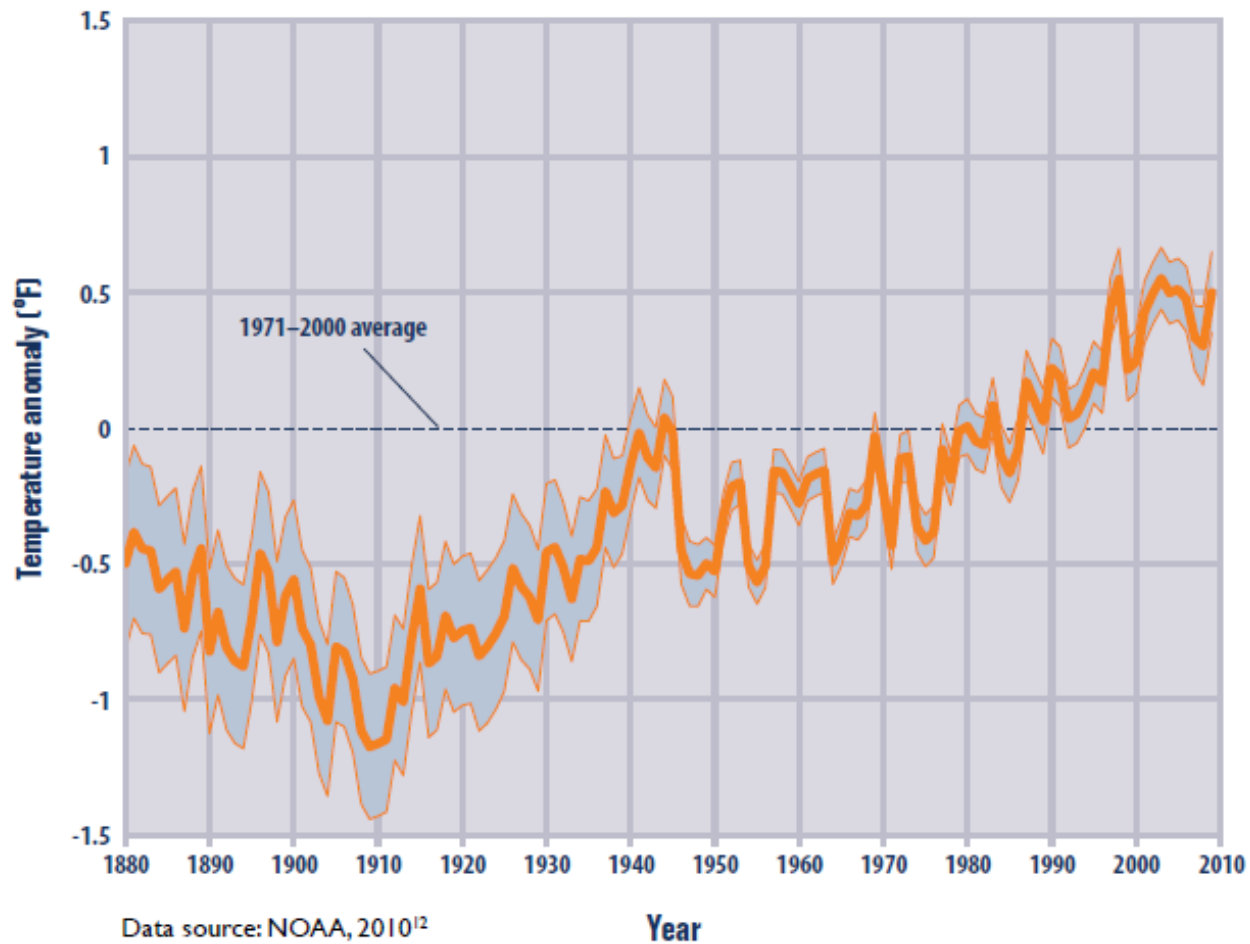
Temperature in the lower 48 states, 1901 – 2009



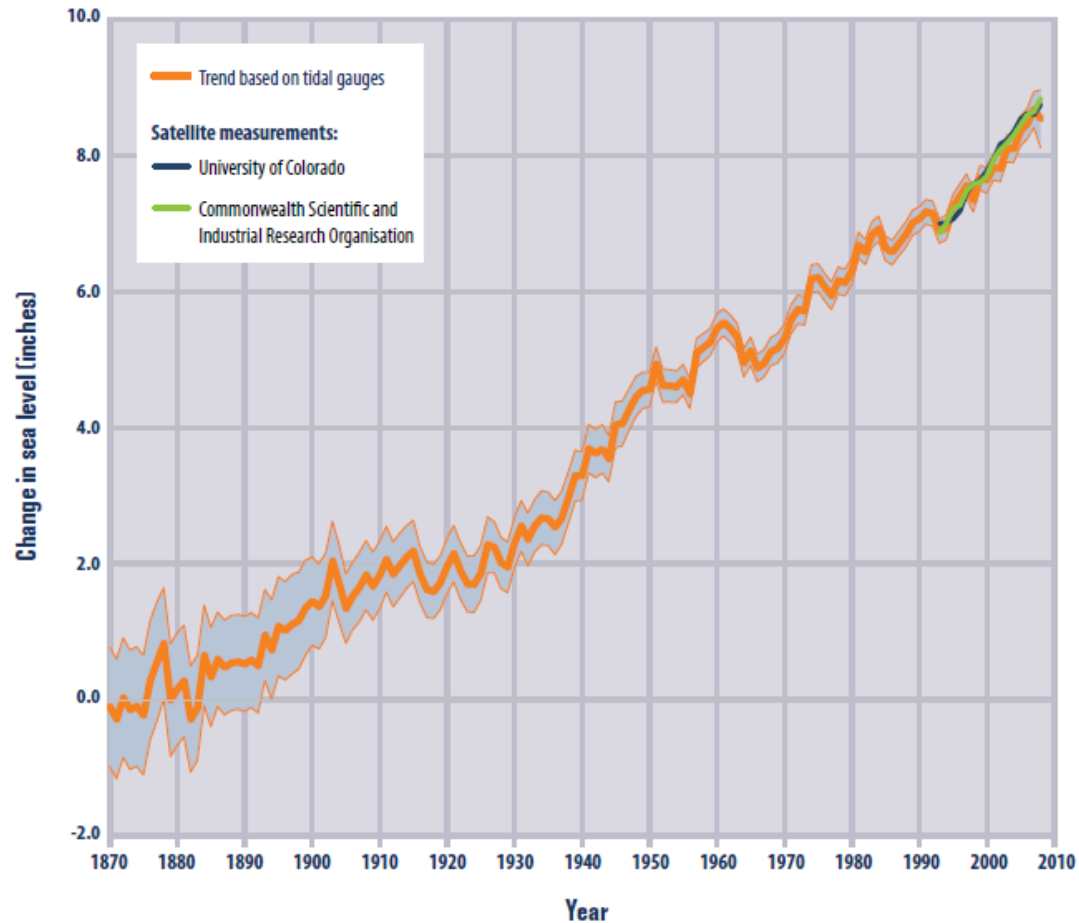
Temperatures WW, 1901–2009



Average Global Sea Surface Temperature, 1880–2009



Trends in Global Average Absolute Sea Level, 1870–2008



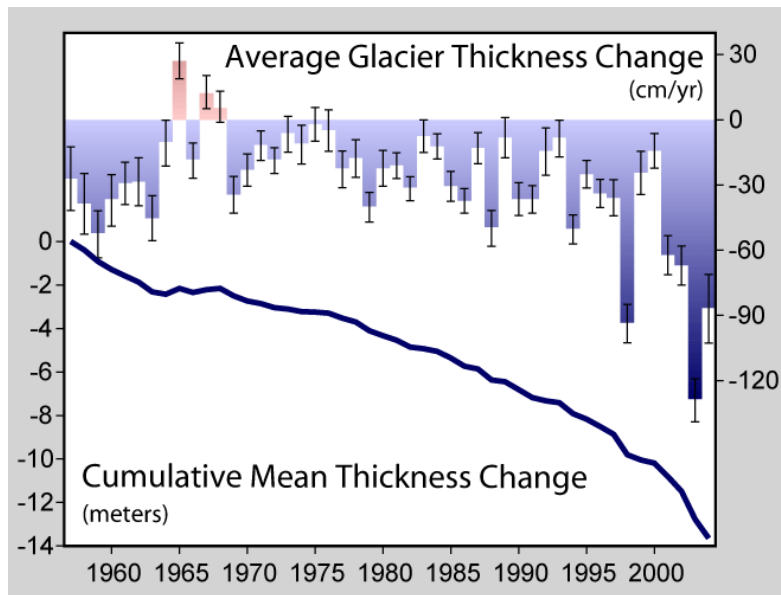
Data sources: CSIRO, 2009;¹⁴ University of Colorado at Boulder, 2009¹⁵

Dwindling arctic sea ice



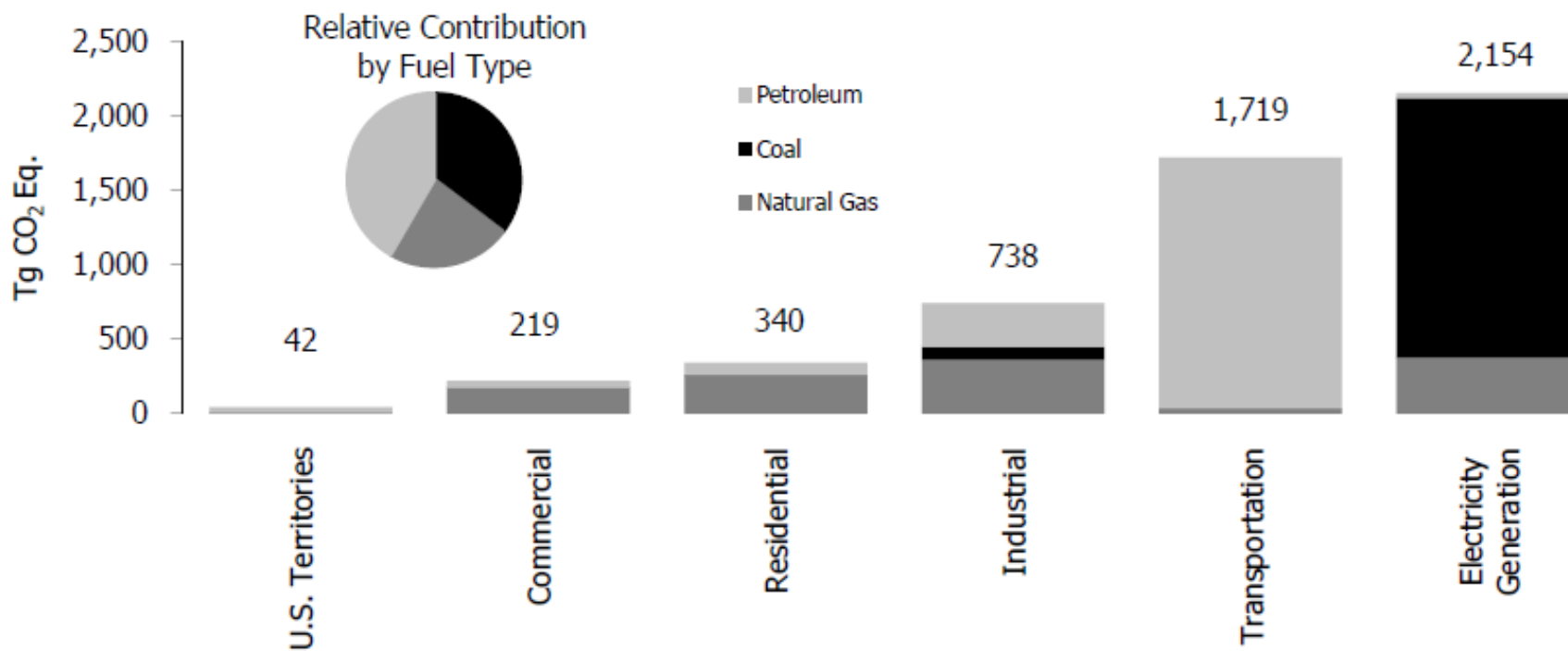
Source: NASA, 2009*

Photographs of Muir Glacier, Alaska, 1941 and 2004



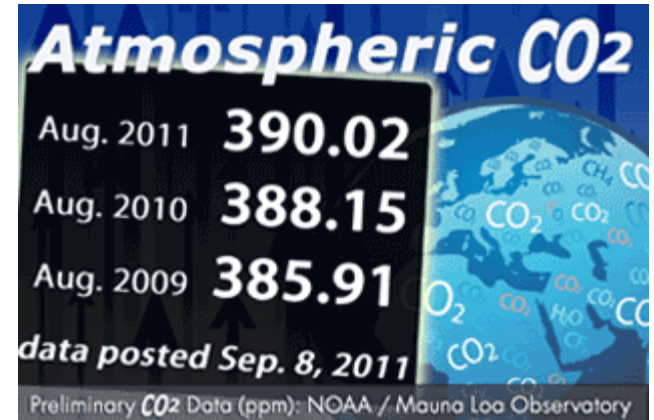
Sources: Field, 1941;² Molnia, 2004⁴

2009 CO2 Emissions from Fossil Fuel Combustion by Sector and Fuel Type

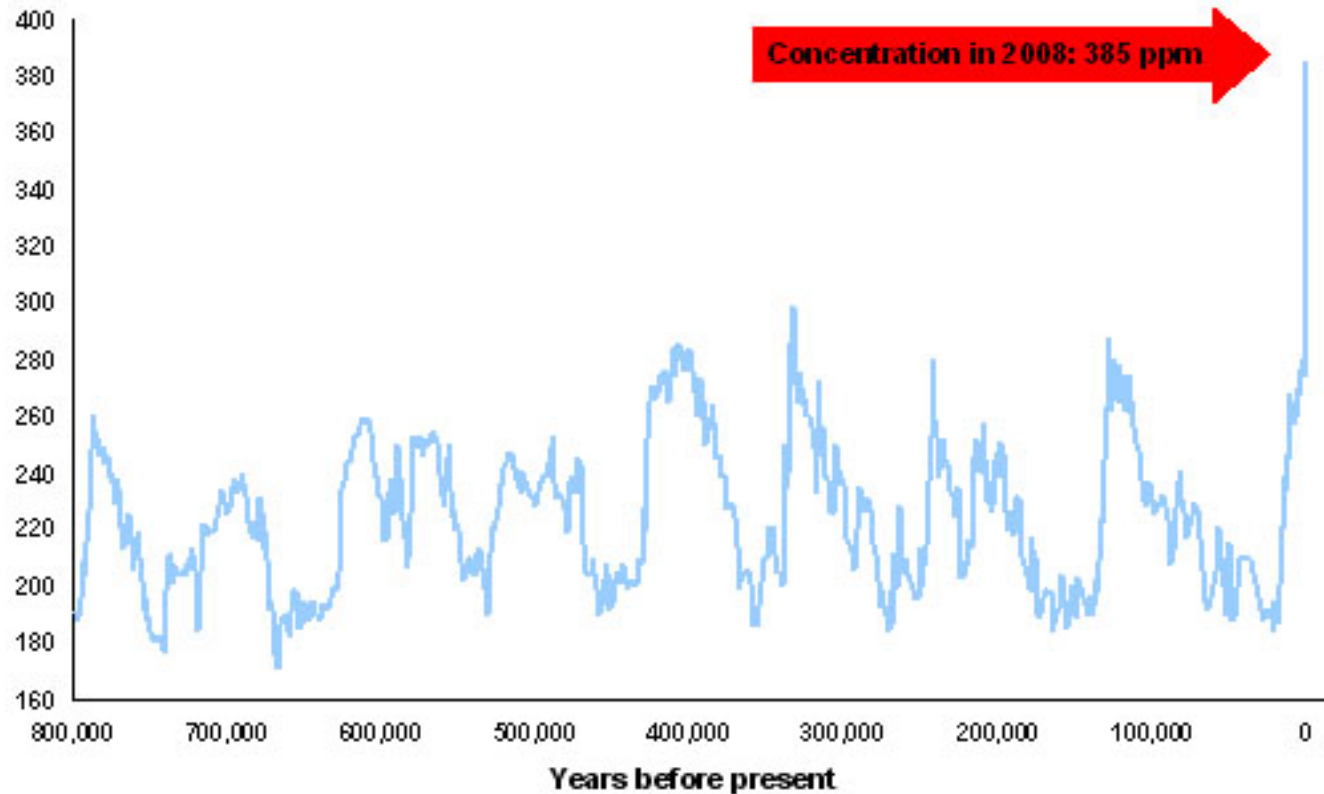


Source: DRAFT INVENTORY OF U.S. GREENHOUSE GAS EMISSIONS AND SINKS: 1990-2009 (February 2011)

800,000 years ago



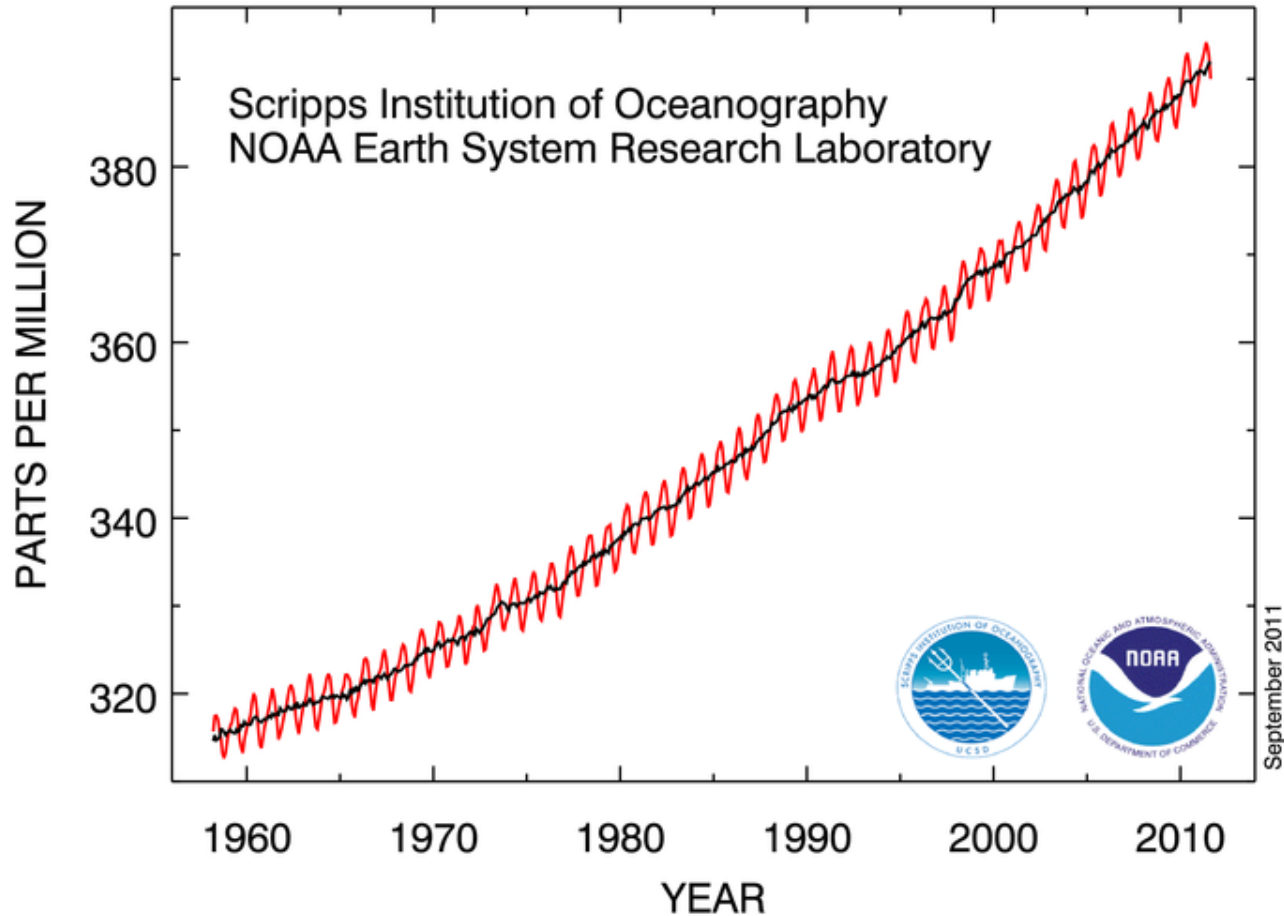
**Atmospheric CO₂
concentration (ppm)**



Source: D. Lüthi, "High-resolution carbon dioxide concentration record 650,000-800,000 years before present," *Nature*, 15 May 2008.

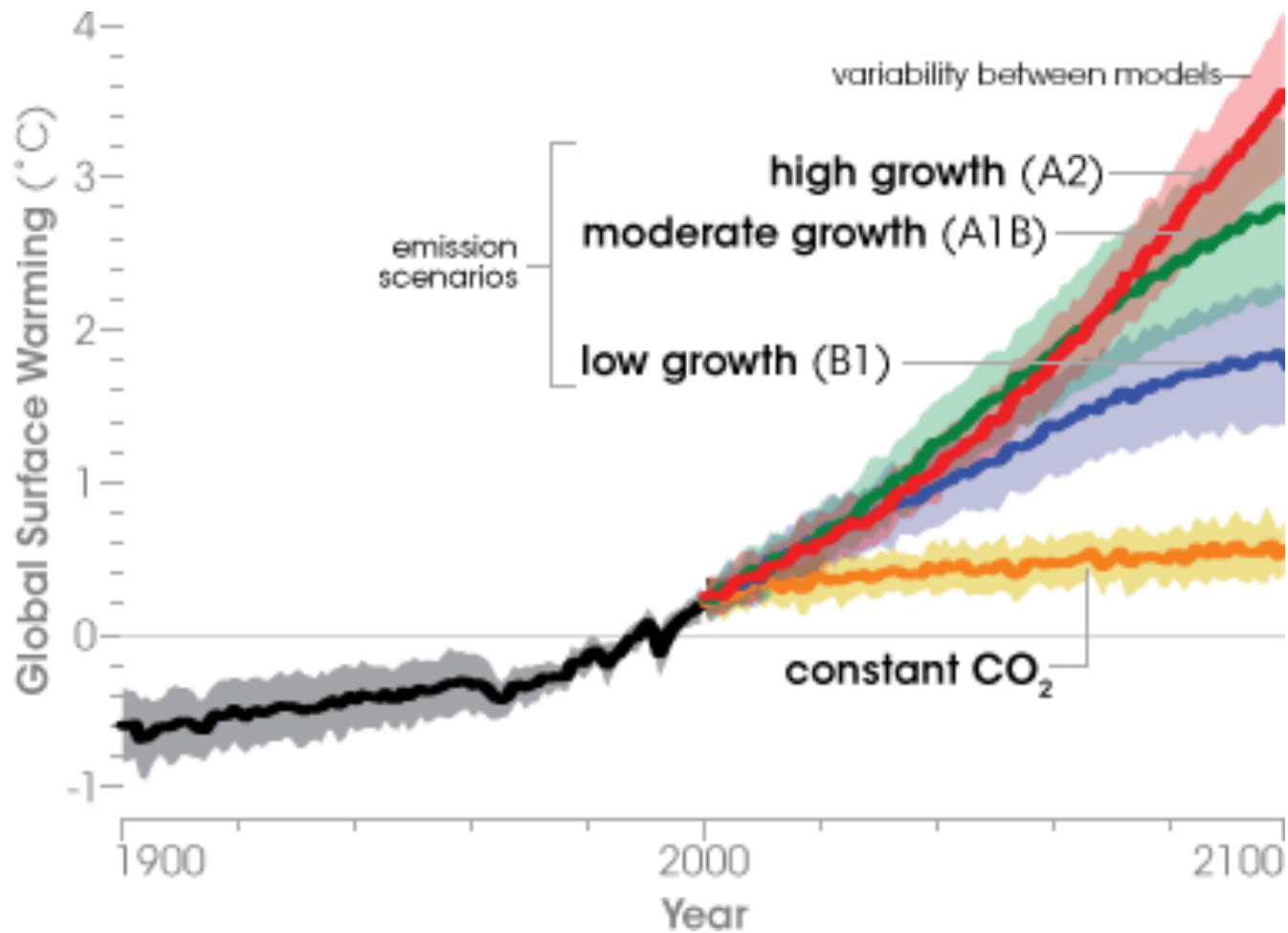
Last 50 years

Atmospheric CO₂ at Mauna Loa Observatory



Source: NOAA & Scripps Institute of Oceanography, Instrument Record for Atmospheric Carbon Dioxide (CO₂) at the Mauna Loa Observatory

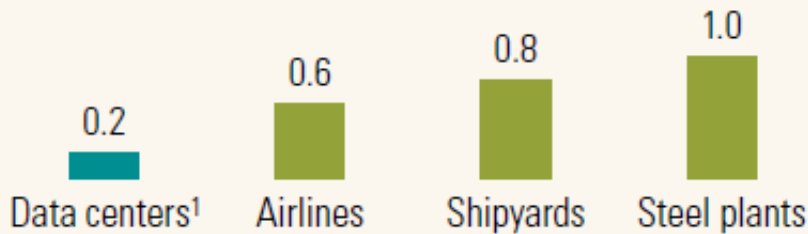
Temperature in 2100?



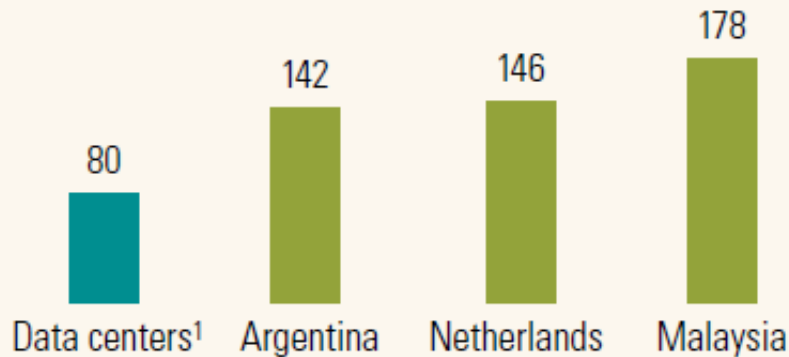
<http://www.epa.gov/climatechange/science/futuretc.html>

Data center carbon emissions

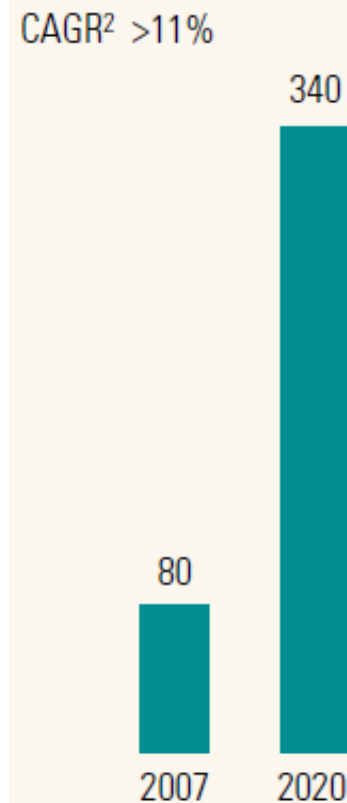
Carbon dioxide (CO₂) emissions as % of world total, by industry



CO₂ emissions by country, megatons CO₂ a year



Emissions from data centers worldwide, metric megatons CO₂



Source: McKinsey

What's the current state of regulations?

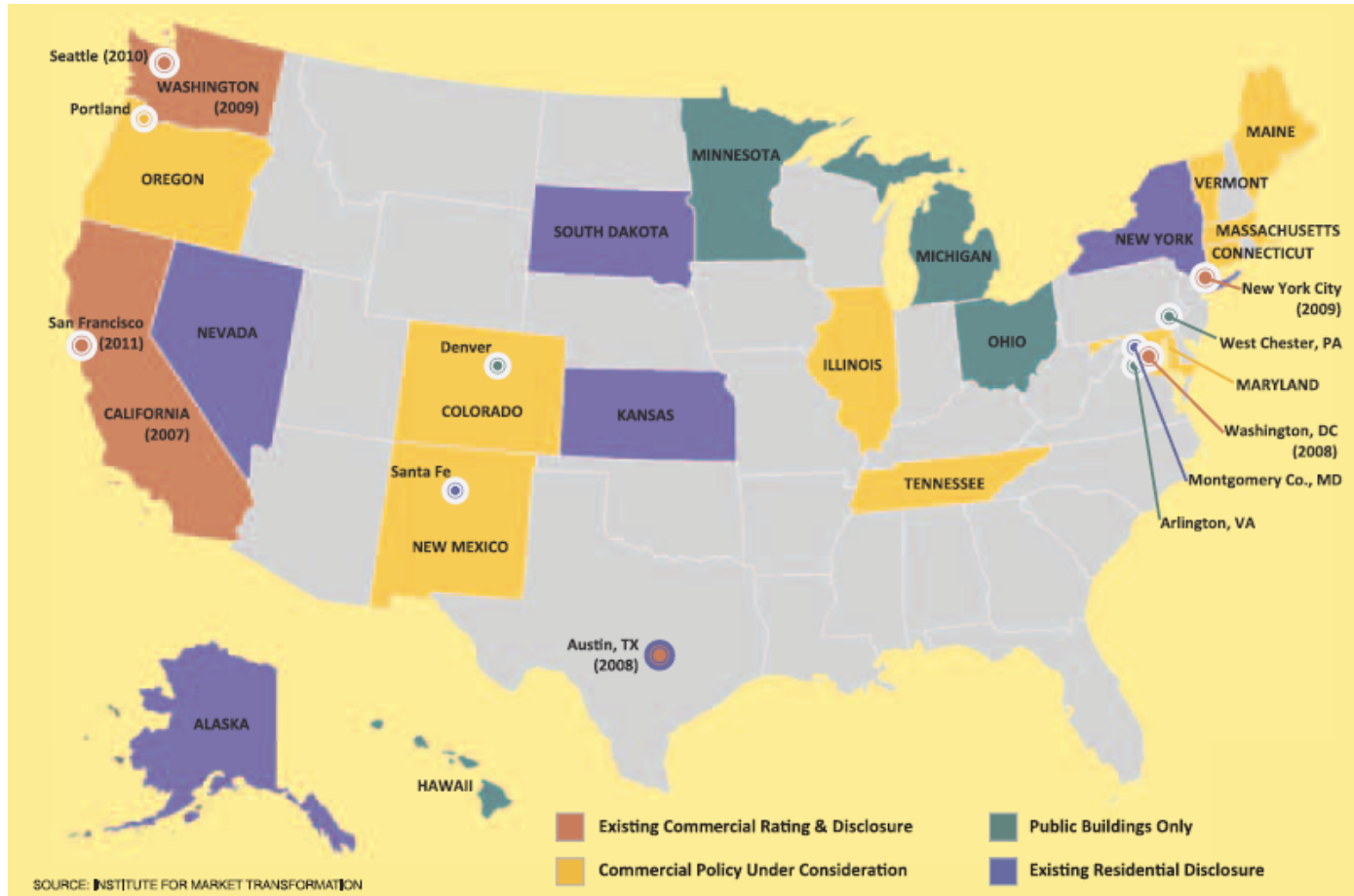
- ▶ **EPA, December 2009**
 - “Carbon dioxide, methane, and other greenhouse gasses (GHGs) pose a hazard to human health”, and the EPA has the authority to regulate them
- ▶ **U.K. Carbon Reduction Commitment Energy Efficiency Scheme (CRC)**
 - Reporting comes into force April 2010
 - First sales of carbon allowances April 2011 (£12/tonne)
 - Cover all organizations using more than 6,000MWh per year of electricity (equivalent to an annual electricity bill of about £500,000)
 - Requires companies in U.K. to forecast their energy usage, purchase carbon allowances from the government, and monitor actual usage against forecast emissions
- ▶ **The American Clean Energy and Security Act of 2009 (ACES)**
 - Also known as the Waxman–Markey Bill, or H.R. 2454
 - Would establish a cap-and-trade plan for greenhouse gases (CO₂)
 - Approved by the House of Representatives on June 26, 2009
 - Never became law – cleared from the books



What's the current state of regulations?

- ▶ The U.S. SEC new guidance for public companies on what must be disclosed regarding the "materiality" of their impact on climate. Includes four areas that might trigger requirements for companies to disclose their vulnerability to sustainability concerns:
 - 1) impact of legislation and regulation
 - 2) impact of International Accords
 - 3) indirect consequences of regulation or business trends
 - 4) physical impacts of climate change
- ▶ San Francisco requires buildings to disclose energy usage.
 - Feb 2011 San Francisco Existing Commercial Building Energy Performance Ordinance
 - By Oct. 1, non-residential facilities greater than 50,000 square feet will have to submit summary benchmarked energy use information
 - By Apr 1, 2012, 25K square feet
 - By Apr 1, 2013, 10K square feet
 - Mandatory audits every 5 years

States and local government taking the lead



Are data centers doing something?



Denver data center

- ▶ 245 days of sun per year
- ▶ ~100KW (430 – 230W PV cells)
- ▶ $\frac{3}{4}$ off the roof, 20K sq. ft.
- ▶ \$500K investment
- ▶ 3.5 year payback (with tax rebates and incentives)
- ▶ 109,000 lbs carbon offset
Dec 2010–June 2011



Put it in perspective



9.7 cars
5500 gallons gas
115 barrels foreign oil
2057 propane cylinders
10.5 acres of trees

Deutsche Bank Climate Strategy

- ▶ Global business operations CO₂-neutral from 2013 onwards
- ▶ External "Climate Change Advisory Board" (CCAB), which supports Deutsche Bank in the development and implementation of its climate protection strategy
- ▶ Increasing recognition of Deutsche Bank as a partner in the dialog with governments, clients, and regulatory interest groups
- ▶ Intensified development of products such as funds for climate change, new resources, and agriculture with a volume of about \$4 billion (as of March 2009)
- ▶ Commitment to building up a private equity franchise in "green" investments



Dr. Josef Ackermann
Chairman of the Management Board and the
Group Executive Committee
<http://annualreport.deutsche-bank.com/2011/q1/servicepages/welcome.html>

Deutsche Bank 

<http://www.dbcca.com/dbcca/EN/what-we-are-doing/our-impact.jsp>
<http://www.dbcca.com/dbcca/EN/what-we-are-doing/our-initiatives.jsp>

The survey says: PUE



Uptime Institute®

Where do you measure PUE in your organization?

PUE Category 0: IT load measured at UPS output (s). Total data center power measured at the utility meter (s). Peak utilization/demand in a single snapshot measurement. -- 29%

PUE Category 1: IT load is measured by a 12-month cumulative kW-h reading of the UPS output (s), total data center power measured at utility, 12 month cumulative readings. -- 17%

PUE Category 2: IT load measured by 12-month total kW-h reading taken at the output of the PDU's supporting IT loads. Total data center power measured at utility, 12-month cumulative readings. -- 15%

PUE Category 3: IT load measured 12-month total kW-h reading taken at the point of connection of the IT devices to the electrical system. Total data center power measured at a utility, 12-month cumulative readings. -- 5%

Don't measure PUE -- 27%

Use an alternate method of measuring PUE -- 7%

Source: Uptime Institute 2011 Data Center Survey

The survey says: CO2



Uptime Institute®

Please rate the following, important, not important, or not applicable to your organization:

Carbon reporting for your data center

Important -- 45%
Not Important -- 30%
NA -- 25%

Water usage reporting for your data center

Important -- 33%
Not Important -- **38%**
NA -- 29%

Source: Uptime Institute 2011 Data Center Survey

How do you do something about it?

1. Measure and monitor with kWh meters, whether at building, circuit, device level
2. Take actions to eliminate waste (bypass airflow, temperature set points)
3. Take actions to upgrade technology (new servers, VFD's, economizers, efficient ups)
4. Take actions to better utilize what you have (virtualize)
5. Consider adding renewable energy sources (solar, wind)



How does one calculate carbon footprint?

- ▶ Option 1: Focus on all sources, e.g. electricity, gas, gasoline. The largest list of calculators on the web <http://www.co2list.org/files/calculators.htm>
- ▶ Option 2: Simple approach, focus on electricity as a start.

Carbon Emissions (kg) = Energy (kWh) * Carbon Factor (kg/kWh)

Example Carbon Factors:

PG&E = .24 kg/kWh

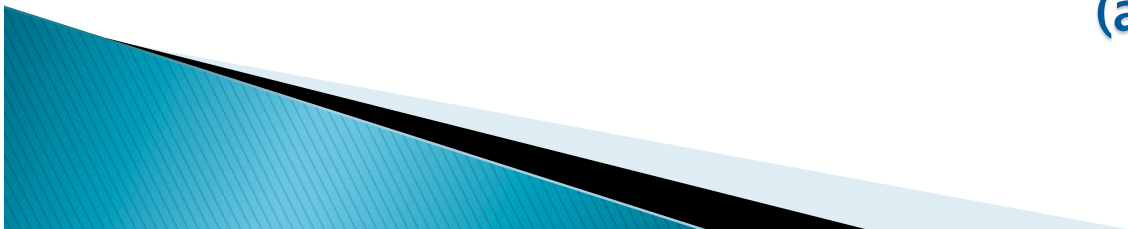
Con Ed = .35 kg/kWh

Example calculation:

10 MWx .35 kg/kWh

CO₂ = 30,660,000 kg

(about 6759* cars)



What industry metrics are available?

Carbon Usage Effectiveness (CUE)

$$\text{CUE} = \frac{\text{Total CO}_2 \text{ emissions caused by the Total Data Center Energy}}{\text{IT Equipment Energy}}$$

$$\text{CUE} = \text{Carbon Emissions Factor (CEF)} * \text{PUE}$$

$$\text{CUE} = \text{kgCO}_2\text{eq per kWh}$$

CUE provides a way to determine:

- ▶ Opportunities to improve a data center's sustainability
- ▶ How a data center compares with similar data centers
- ▶ If the data center operators are improving the designs and processes over time
- ▶ Opportunities for the consideration of renewable power sources
- ▶ Tradeoffs in energy efficiency strategies by comparing total CUE under various use scenarios, operating conditions, etc.

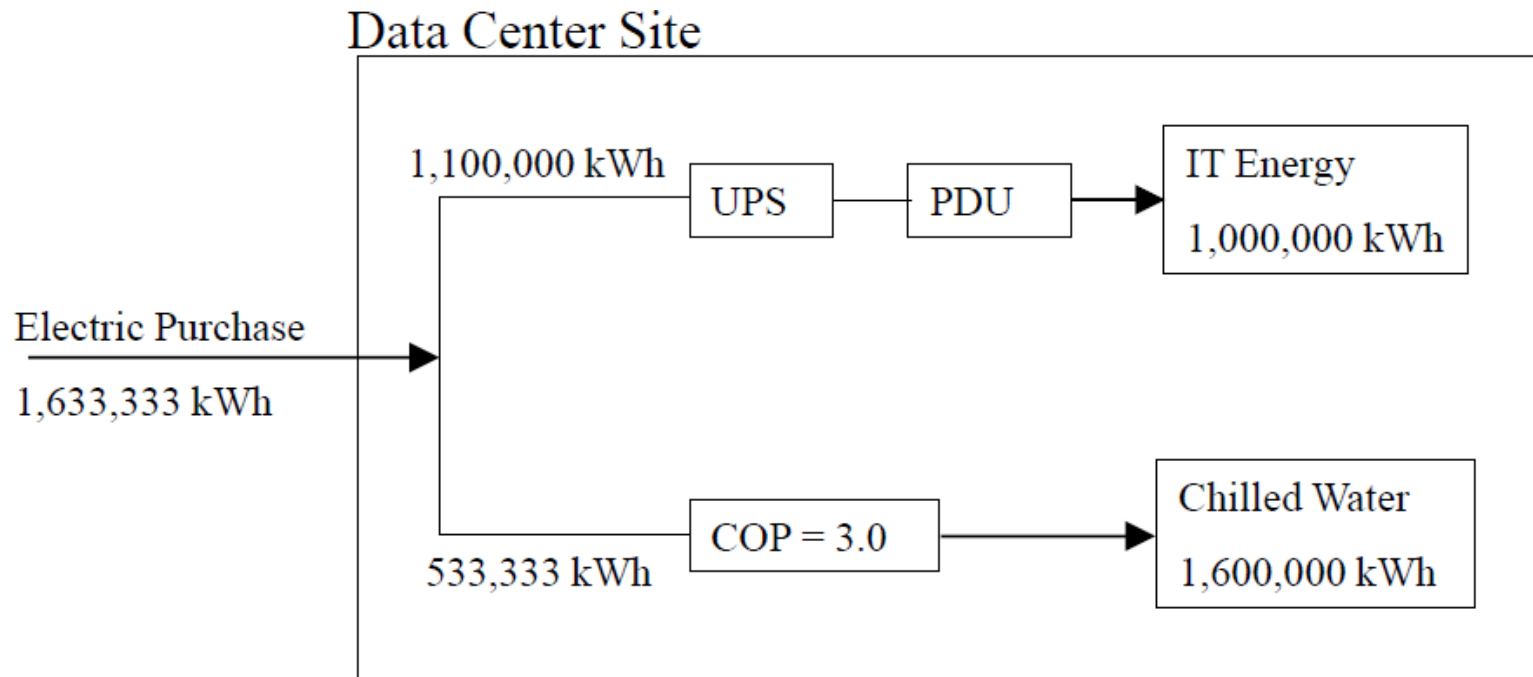
Source: White paper #32, Carbon Usage Effectiveness, A Green Grid Data Center Sustainability Metric

CUE recommendations

| CUE Level 2 Yearly Continuous | CUE _{L2YC} |
|---|--|
| Unit of measure | Kilograms of carbon dioxide (kgCO ₂ eq) per kilowatt-hour (kWh) |
| Frequency of measurement | Continuous |
| Averaging Period of Measurement | Annually |
| Data center measurement location | Utility(ies) hand-off |
| Information Technology measurement location | PDU output |

Source: White paper #32, Carbon Usage Effectiveness, A Green Grid Data Center Sustainability Metric

CUE example



PUE = Total Source Energy/IT Source Energy

$$\text{PUE} = (1,633,333 * 1) / (1,000,000 * 1)$$

$$\text{PUE} = 1.63$$

CUE = Total CO₂ emissions/IT Source Energy

$$\text{CUE} = (1,633,333 * 1) * .3298 / (1,000,000 * 1)$$

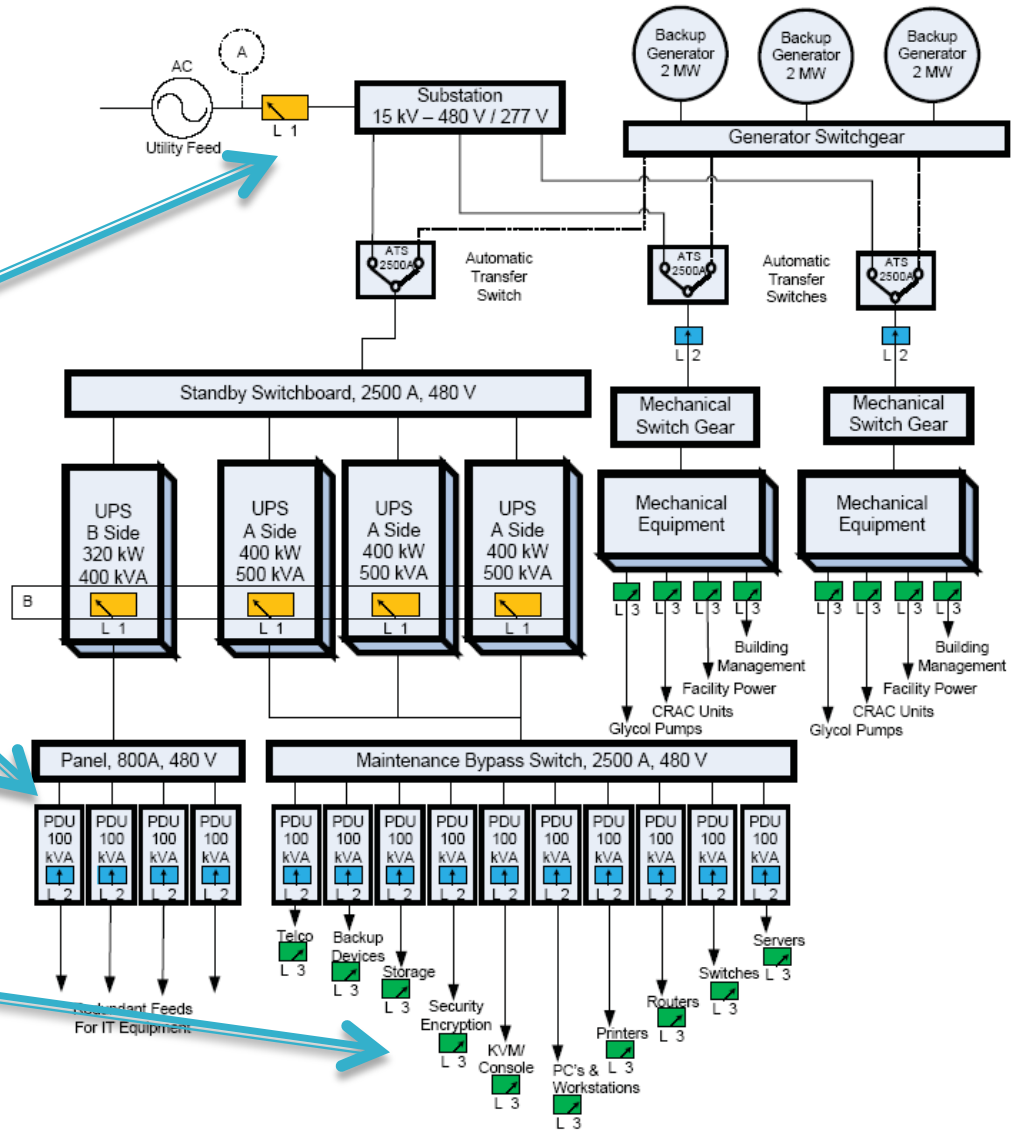
$$\text{CUE} = .5386$$

Beyond CUE

Carbon Footprint of data center

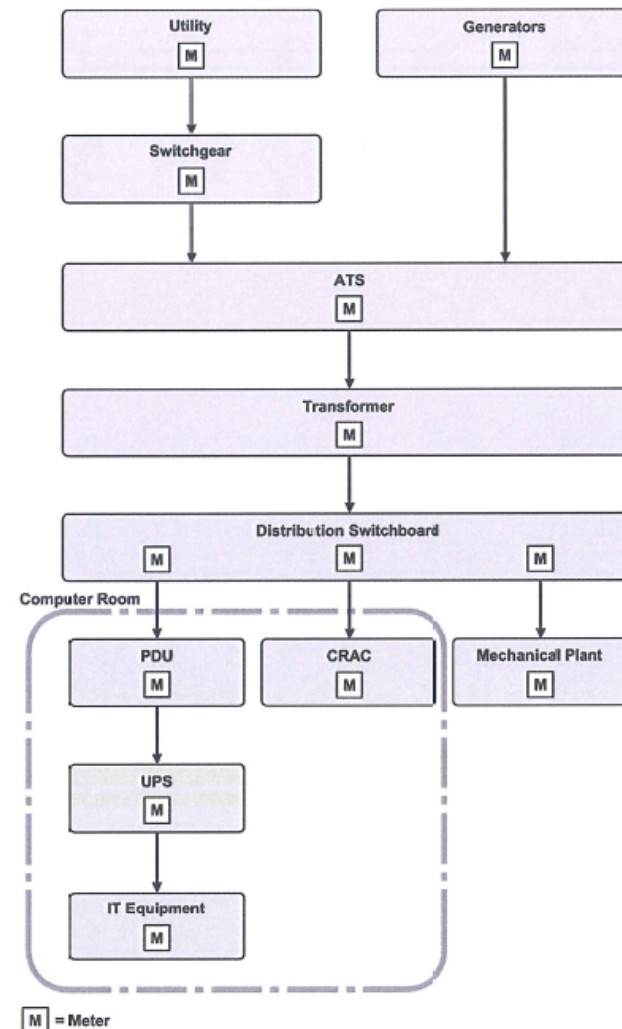
Carbon Footprint customer cages

Carbon Footprint of business units or applications



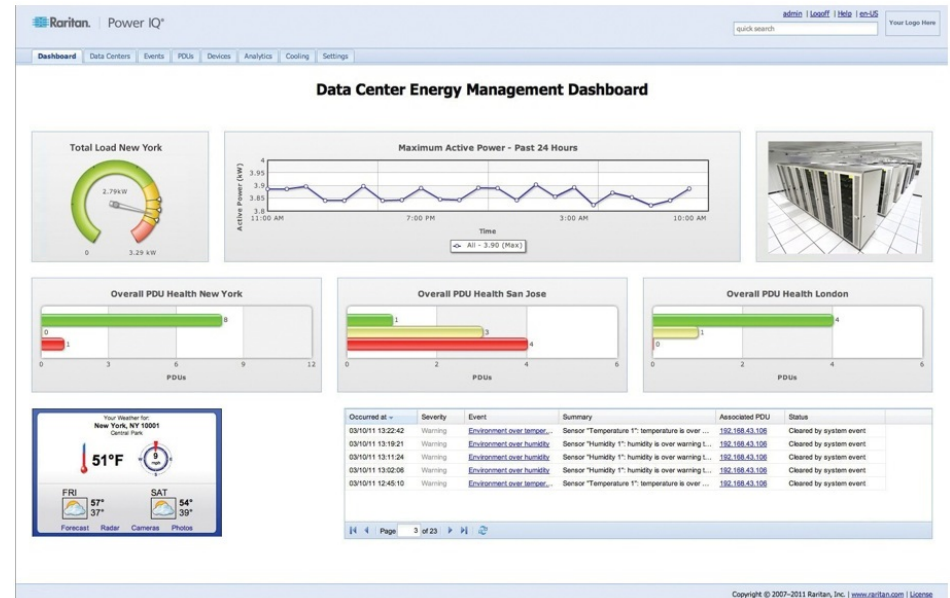
Where to measure

- ▶ Depends on what you're trying to achieve
- ▶ Manual or 50/50 or fully automated
- ▶ Challenges
 - Point solutions with own H/W and S/W
 - Different protocols
 - Central view



Real time energy monitoring considerations

- ▶ Data type
- ▶ Calculated vs. accumulated
- ▶ Data accuracy
- ▶ Polling frequency
- ▶ Buffering
- ▶ Enterprise architecture
- ▶ Open or closed
- ▶ Security



Why do something about it?

- A. Societal benefits
- B. Corporate benefits
- C. Cost benefits

Cost of data center electricity

(Assumptions: 10Mw total, 5 Mw IT, \$0.10/kwh, 7x24 operation)

$PUE = 10 \text{ mW} / 5 \text{ mW} = 2.0$, $DCiE = 50\%$
 $8760 \text{ hours} \times \$0.10/\text{kwh} \times 10 \text{ Mw} =$
 $\$8.76\text{M}$ annual cost of power

If $PUE = 1.5$ so $7.5\text{mW}/5\text{mW} = 1.5$
 $8760 \text{ hours} \times \$0.10/\text{kwh} \times 10 \text{ Mw} =$
 $\$6.57\text{M}$ annual cost of power
 $\$2.19\text{M}$ annual savings in power cost

Carbon Footprint

Example Carbon Factors:

PG&E = .24 kg/kwh, Con Ed = .35 kg/kwh

$CO_2 = 8760 \text{ hours} \times 10 \text{ mW} \times .35 \text{ kg/kWh}$
 $CO_2 = 30,660,000 \text{ kg}$ (about 6759* cars)

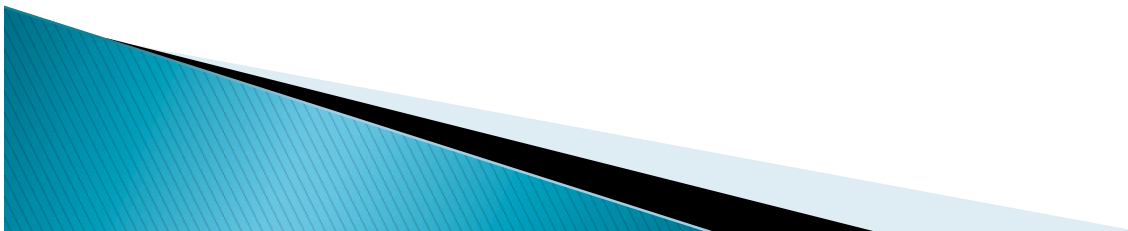
$CO_2 = 8760 \times 7.5\text{mW} \times .35 \text{ kg/kWh}$
 $CO_2 = 22,995,000 \text{ kg}$ (about 5069* cars)
25% in carbon footprint reduction
Equivalent of taking 1700 cars off the road

*based on ~12k miles and ~4536kg

Key takeaway – Yes, it's all related
and it all depends on kWh

Continuous
Real-time
Accumulated

kWh is the required measurement
for both calculations (energy cost and CO₂)



Resources

- ▶ www.greengrid.org, White paper #32, Carbon Usage Effectiveness, A Green Grid Data Center Sustainability Metric
 - ▶ <http://www.epa.gov/climatechange/index.html>, EPA Climate change website
 - ▶ <http://www.ebaygreenteam.com/posts/denver-solar-project>, eBay Denver data center solar array
 - ▶ <http://www.dbcca.com/dbcca/EN/>, Deutsche Bank Climate Strategy
 - ▶ <http://www.ashrae.org/publications/page/1900>, Real Time Energy Consumption Monitoring in Data Centers
 - ▶ <http://www.analyticspress.com/datacenters.html>, Growth in Data Center Electricity Usage
 - ▶ <http://www.raritan.com/energy-monitoring/>, Raritan Energy Management Solutions, white papers, case studies
 - ▶ www.co2now.org, most current co2 levels and what it means
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