

CARBON FOOTPRINTS AND TURF MANAGEMENT: CARBON EMISSIONS AND SEQUESTRATION FOR GOLF COURSES

by

Stuart Z. Cohen, Ph.D., CGWP

Aaron J. Harding

N. LaJan Barnes, M.S., PG

Kenneth B. Ingram, M.S., CGCS, MG

ENVIRONMENTAL & TURF SERVICES, INC.

Wheaton, MD

before the

Division of Agrochemicals

American Chemical Society

at the

239th National Meeting

San Francisco

March 21, 2010

PRESENTATION OUTLINE

I. The Science of Climate Change

- A. What is the greenhouse effect and what are the sources of greenhouse gases?
- B. The evidence for global warming and climate change
- C. What is a carbon footprint?

II. Carbon Emissions

- A. National and global context
- B. Electricity in the clubhouse and the maintenance facility
- C. Turf chemicals and fuel

III. Golf Course Carbon Sequestration

- A. Playing surfaces
- B. Trees, shrubs, and native grasses

IV. Opportunities

I. The Science of Climate Change

What is the Greenhouse Effect?

Normally, the sun irradiates the earth with high energy radiation (e.g., ultraviolet light), and lower energy light and other radiation (e.g., infrared) is irradiated back into outer space.

“Greenhouse gases” - - carbon dioxide (CO₂), methane (CH₄), and nitrous oxide (N₂O) - - absorb some of that outgoing radiation, converting it to heat (thermal energy).

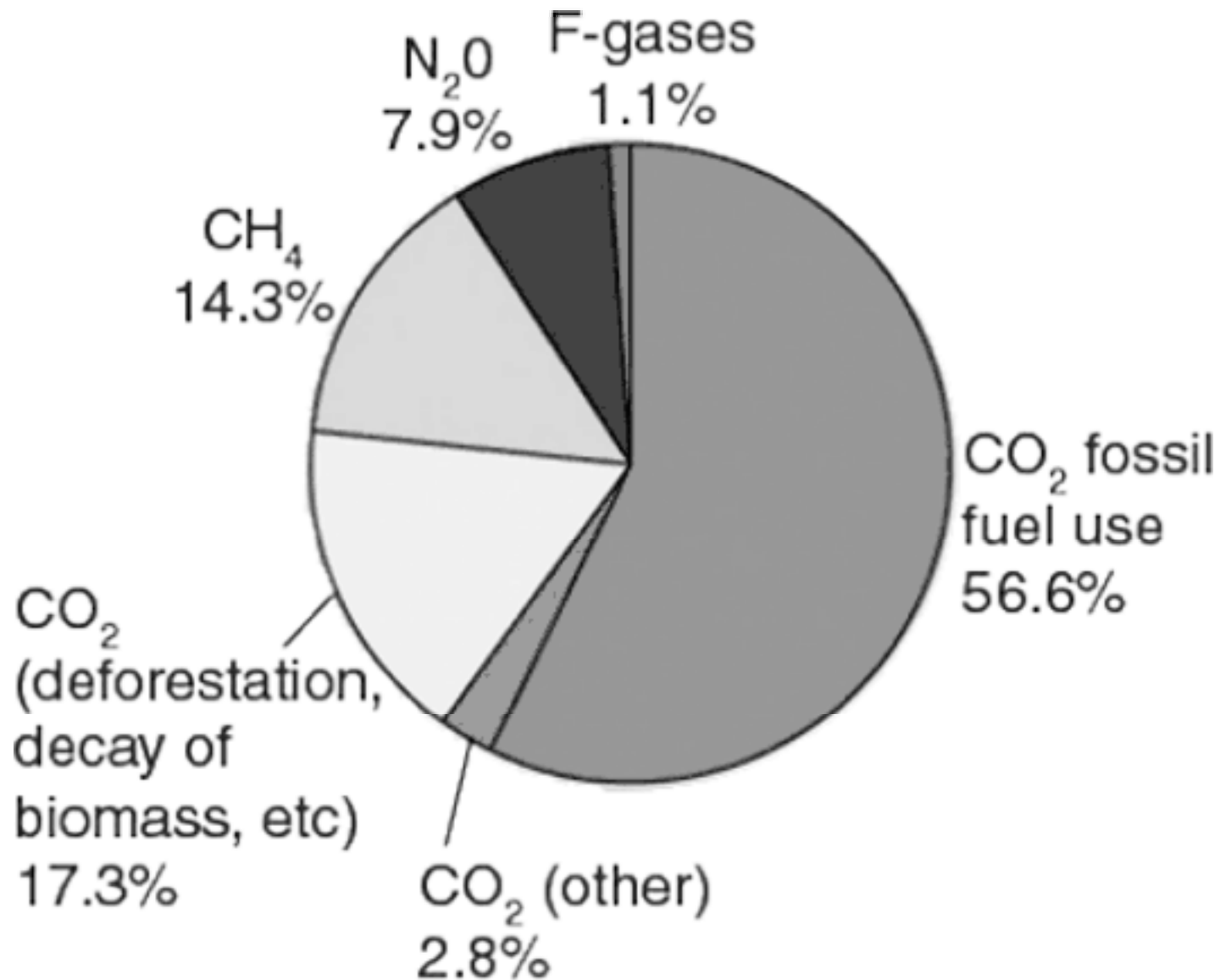
The natural/background greenhouse effect is a good thing, and earth would be approximately 60°F cooler without it (EPA, 2009).

Not all Greenhouse Gases are Created Equal

GAS	MOLECULAR FORMULA	RELATIVE GREENHOUSE GAS POTENCY
carbon dioxide	CO ₂	1
methane	CH ₄	21
nitrous oxide	N ₂ O	310

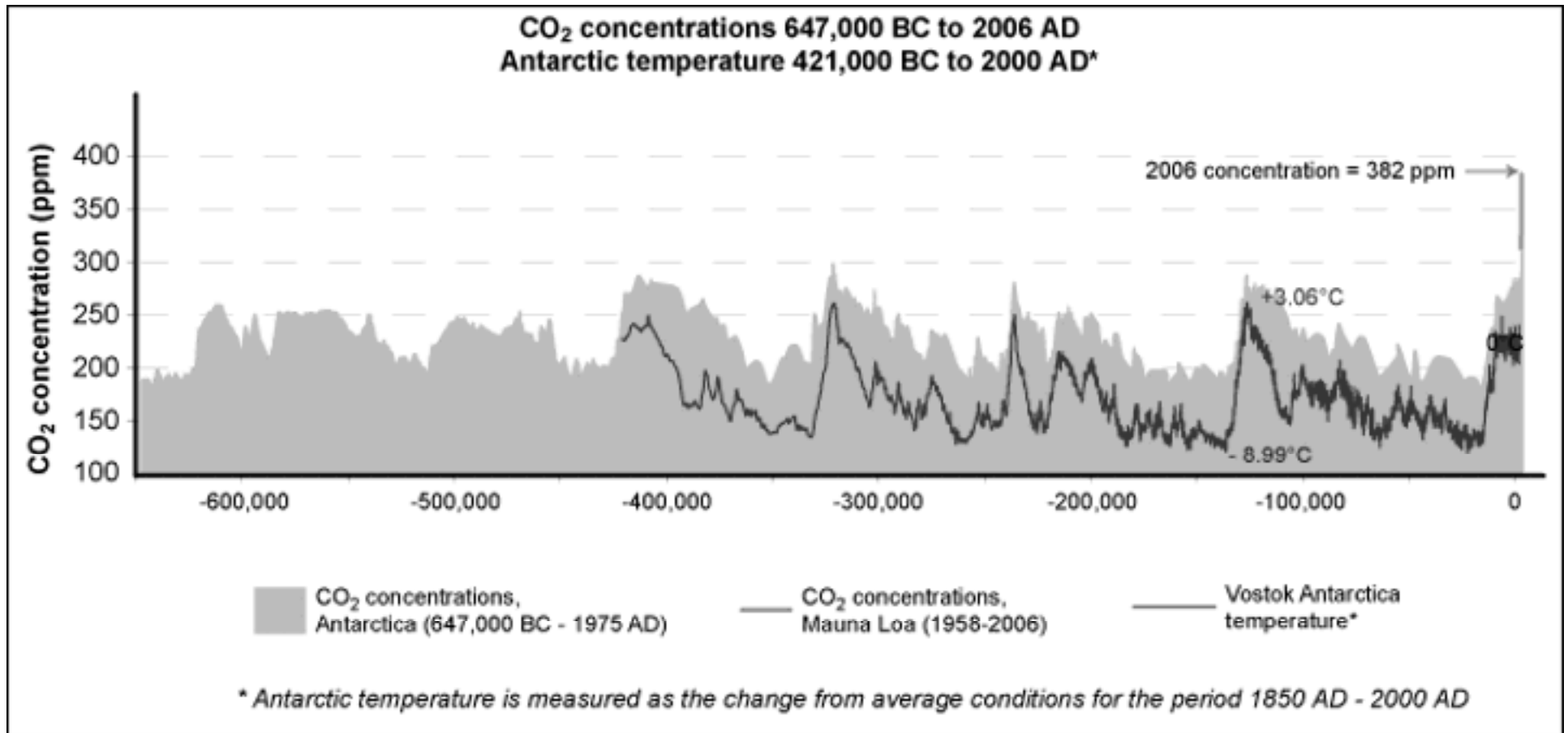
Adapted from Global Anthropogenic Emissions of Non-CO2 Greenhouse Gases 1990-2020 (EPA Report 430-R-06-003). June 2006 revised. www.epa.gov/climatechange/economics/international.html

Global Anthropogenic Greenhouse Gas Emissions in 2004 (measured in watts/meter²)



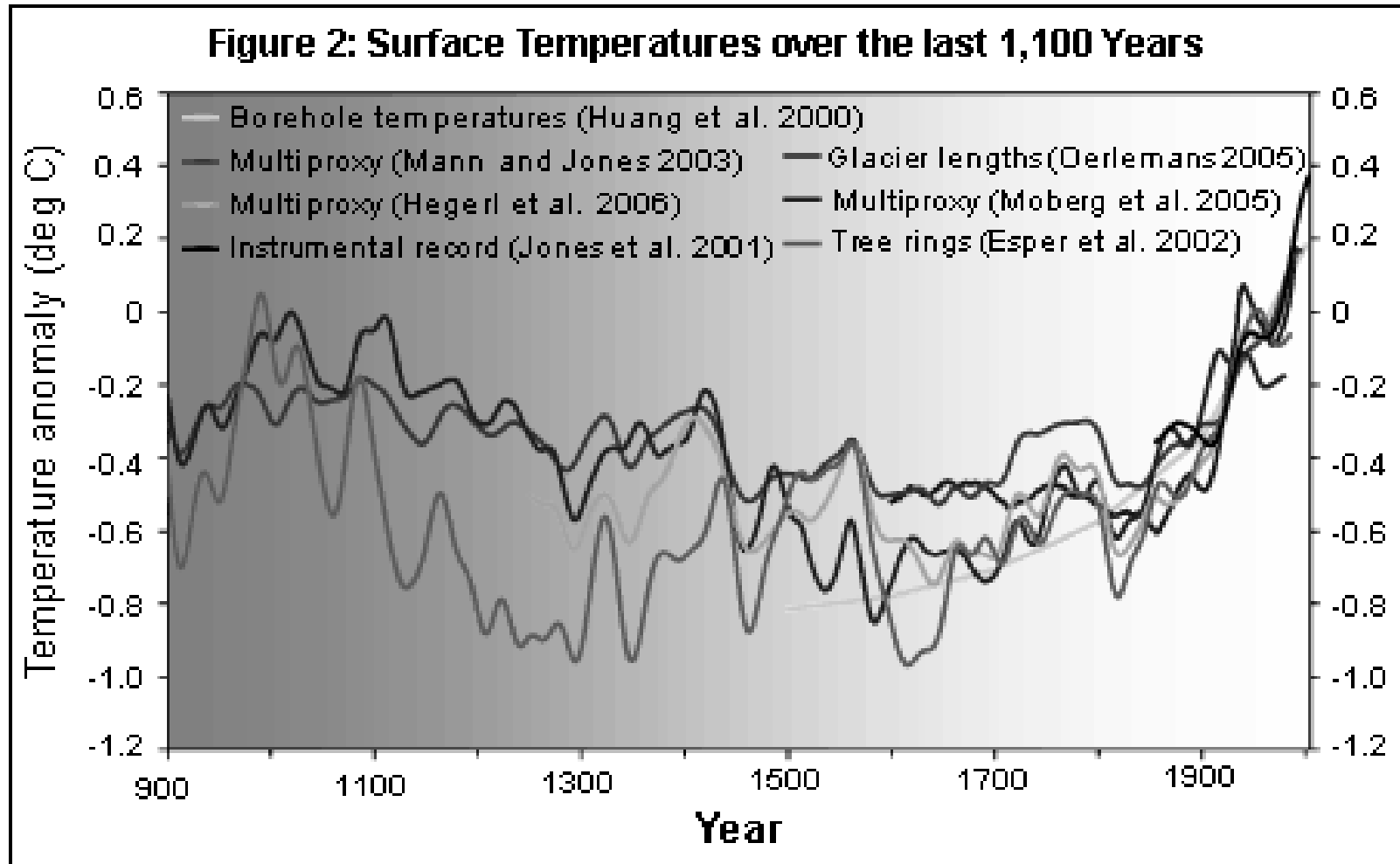
Reference: *IPCC 4th Assessment Report: Climate Change 2007: Synthesis Report*

Changes in Carbon Dioxide and Temperature



http://www.epa.gov/climatechange/science/pastcc_fig1.html

Evidence



http://www.epa.gov/climatechange/science/images/surface_temps.gif

This “Little Ice Age” (ca. 1400-1700) may have been due to weaker solar intensity.

Questions about the evidence?

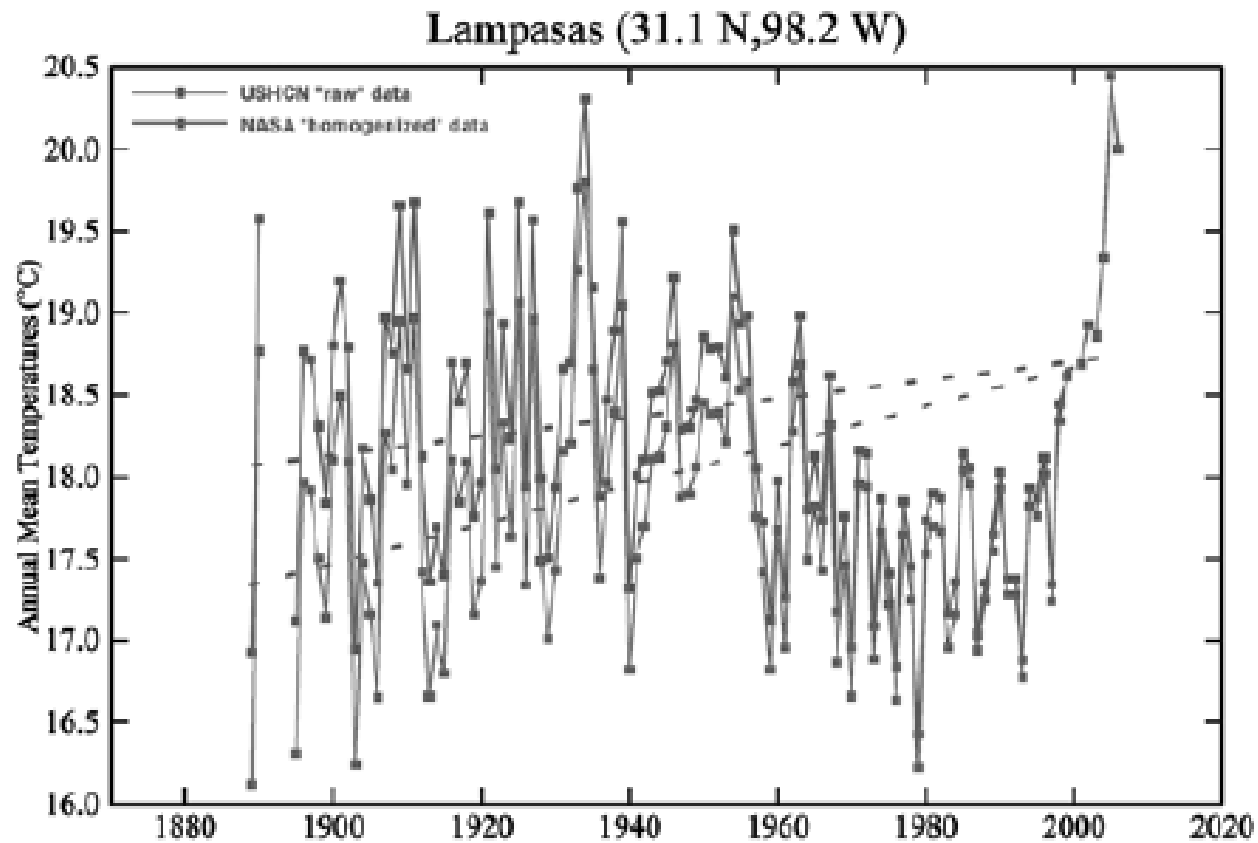


Figure 22. USHCN "raw" data and NASA GISS "homogenized" data for Lampasas, Texas. NASA's adjustments made the recent temperature increase look even steeper. Source: http://data.giss.nasa.gov/gistemp/station_data/.

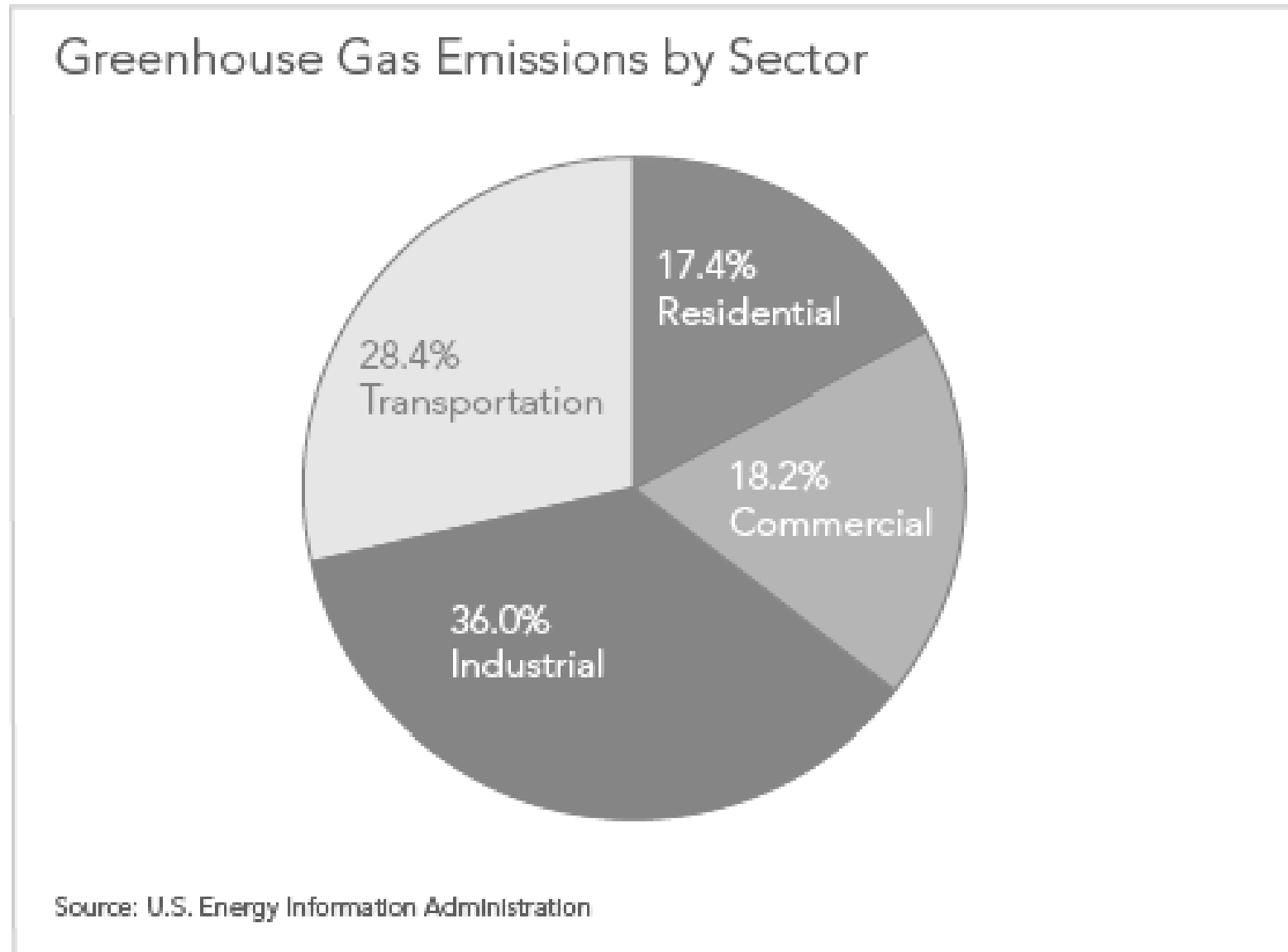
Figure: Watts, 2009

Conclusions of the Intergovernmental Panel on Climate Change:

- Global atmospheric concentrations of carbon dioxide, methane and nitrous oxide have increased markedly as a result of human activities since 1750 and now far exceed pre-industrial values determined from ice cores spanning many thousands of years.
- The global increases in carbon dioxide concentration are due primarily to fossil fuel use and land use change, while those of methane and nitrous oxide are primarily due to agriculture.
- Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level.
- For the next two decades, a warming of about 0.2°C per decade is projected for a range of SRES emission scenarios.

IPCC, 2007: Summary for Policymakers. In: Climate Change 2007: The Physical Science Basis. Cambridge University Press, Cambridge, UK)

II. Carbon Emissions



Makower, J., M. Wheeland, T. Herrera, and J. Bardelline (Eds). 2008. State of Green Business 2008. GreenBiz.com, greenerworldmedia.com; www.stateofgreenbusiness.com.

Carbon Emissions (cont'd)

Per Capita GHG Footprint of Nations in 2001*

Country	Footprint [tCO ₂ e/p]	Domestic Share	Population (million)
1. Luxembourg	33.8	56%	0.4
2. Hong Kong	29.0	17%	7.2
3. United States	28.6	82%	277.5
4. Australia	20.6	82%	19.4
5. Canada	19.6	75%	31.2
6. United Kingdom	15.4	62%	59.3
7. Germany	15.1	63%	82.0
8. Japan	13.8	68%	126.8
9. South Africa	6.0	90%	43.4
10. China	3.1	94%	1269.9
11. Brazil	4.1	88%	172.3
12. India	1.8	95%	1032.1
13. Bangladesh	1.1	86%	132.1

*Table adapted from Hertwich (2009)

Golf Course Emissions: Electricity as a Principal Source

The largest single source of carbon (C) emissions at golf courses is electricity use, followed by gas heat in cooler areas and turf chemicals.

The biggest users of electricity are the clubhouse, followed by the maintenance facility and the irrigation system.

Electricity-source carbon emissions vary significantly depending on the region: 0.72 lb CO₂/kWh in upstate NY to 2.0 lb CO₂/kWh in an area that includes Kansas.

Median annual electricity use at 18-hole facilities is 243,000 kWh (Throssel, 2010).

The ranges of regional averages varied from 137,323 kWh (NE) to 580,435 kWh (SW).

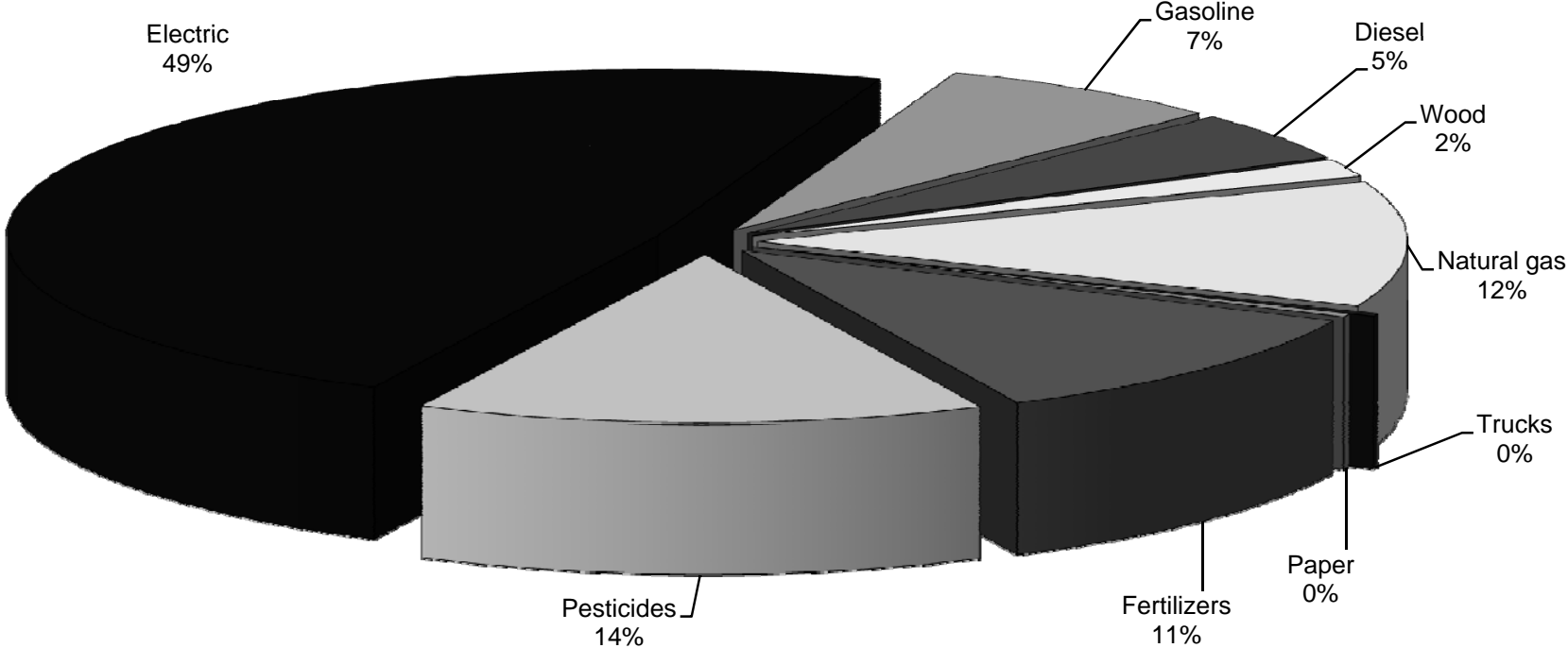
Golf Course Emissions: Pesticides, Fertilizers, Fuel

Herbicides	6.3 kg CE/kg Product	Lal, 2004
Insecticides	5.1 kg CE/kg Product	Lal, 2004
Fungicides	3.9 kg CE/kg Product	Lal, 2004
Synthetic N fert.	1.3 kg CE/kg Product	Lal, 2004
'Organic' N fert.	0.48 kg C/kg Product	Derived from West & Marland 2002; Lal, 2004
Phosphorus	0.2 kg CE/kg Product	Lal, 2004
Potassium	0.15 kg CE/kg Product	Lal, 2004
Lime	0.16 kg CE/kg Product	Lal, 2004
Gasoline/diesel	2.42 kg C/gal gas; 2.78 kg C/gal diesel	US EPA 2003
Wood	half of the weight of its mass	Skog and Nicholson, 2000
Wood sent to landfill*	3% of the weight of its mass	Skog and Nicholson, 2000
Propane	3.24 pounds carbon/gal	US EPA, 2009
Natural gas	1.08 lbs of carbon/ft ³	ORNL, 2010

*Does not include transport to landfill.

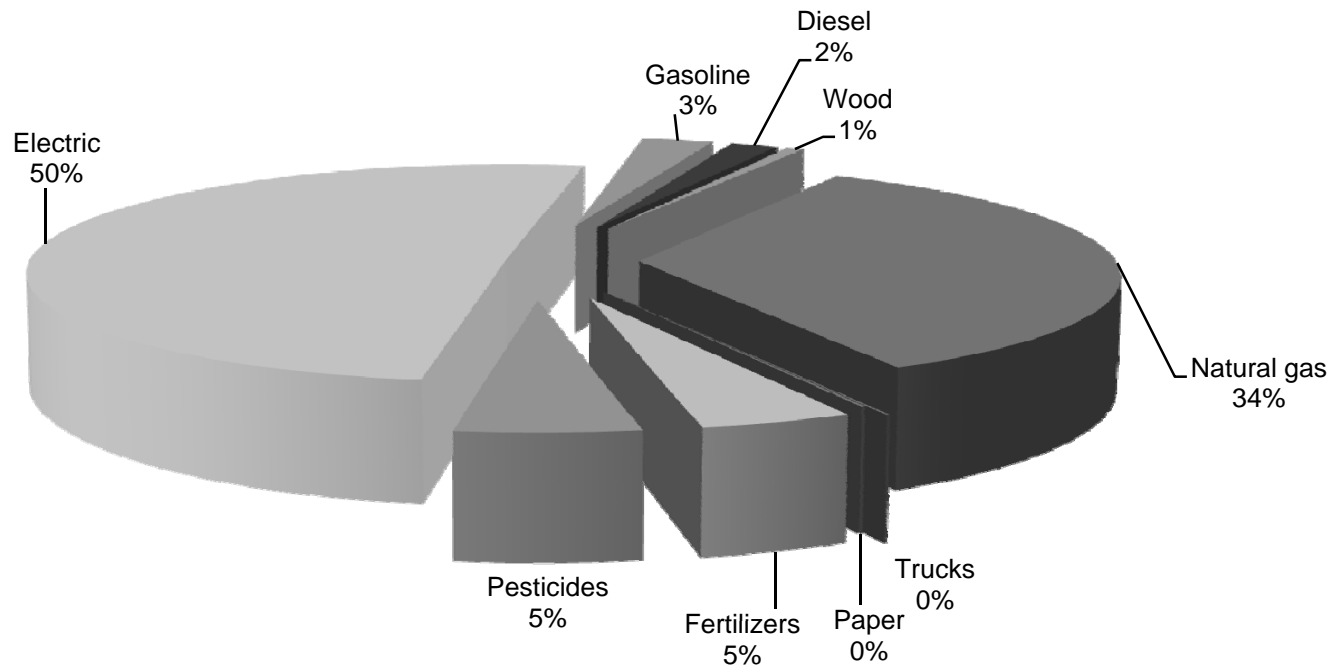
The literature reports a mix of English and metric units.

Golf Course Complex Only % Carbon Emissions for the Golf Course



Total Carbon Golf Course Emissions = 77 tons/year for the golf course - 66 tons/yr C Seq = 11 tons/yr net emissions

Total Golf Facility % Carbon Emissions for the Facility



Total Carbon Facility Emissions = 203 tons/year for the golf course - 66 tons/yr C Seq = 137 tons/yr net emission

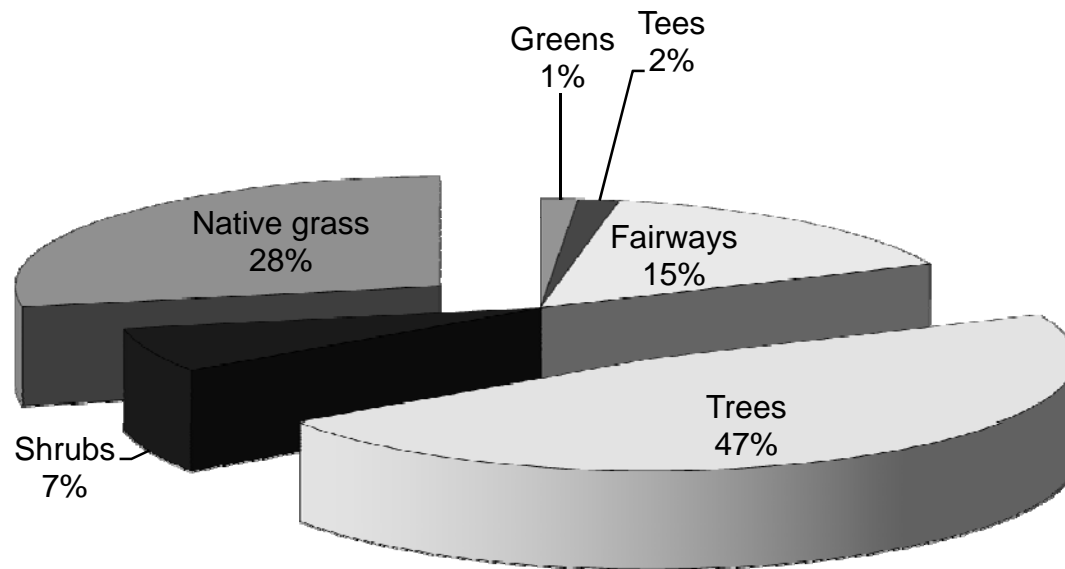
III. Golf Course Carbon Sequestration

Opportunities to sequester C (this is a good thing!):

Trees > shrubs > greens/tees/fairways > native grasslands

Greens	1 ton/ha/yr (Qian and Follett, 2002)
Tees	1 ton/ha/yr (Qian and Follett, 2002)
Fairways	0.9 ton/ha/yr (Qian and Follett, 2002)
Trees	1.87 ton/ha/yr (Jo and McPherson, 1995)
Shrubs	0.56 ton/ha/yr (Jo and McPherson, 1995)
Native grass	0.365 ton/ha/yr (Post and Kwon, 1999)

Example of Golf Course Carbon Sequestration



Carbon Sequestered: 69 tons/year

IV. Carbon Footprint Reduction Opportunities

1. Clubhouse electricity use.
2. Maintenance facility electricity use.
3. Improve the efficiency of the irrigation system.
4. Shift some synthetic fertilizer use to compost/'organic'/'natural' products.
5. Plant more natural areas, with a focus on trees and shrubs.
6. Club owners (and golfers?) can buy C offsets.

Uncertainties

Carbon Sequestration

Does net C sequestration in turfgrass go to zero after a few decades (Qian & Follett, 2002) or does it continue to increase?

- Data points from hundreds of U.S. golf courses indicate carbon sequestration increases indefinitely (Gaussoin, 2010), whereas Qian & Follett (2002) indicate net zero increases beginning at ca. 30 yr.

GHG Emissions

Nitrous oxide contributions from post nitrogen fertilization

- Relative green house potency 310X ($\text{CO}_2=1$) (slide 4)

Pesticide C emissions

Conclusions

- There are many uncertainties in climate change science, but the multiple forecasts do not look good.
- Anything we do to reduce our carbon footprint will tend to reduce our overall ecological footprint and it will help make us more independent of foreign energy sources.
- Golf course facilities (golf course, clubhouse, etc.) have many opportunities to reduce their C footprint and save money.
- There are many uncertainties in these C footprint calculations.

References

- Gaussoin, R. 2009. Organic Matter, Why it Matters Now. Golf Course Superintendents Association of America. GCSAA webinar October 21, 2009.
- Hertwich, E.G. and G.P. Peters. 2009. Carbon Footprint of Nations: A Global, Trade-Linked Analysis, *Environ. Sci. & Tech.* 43(16):6414-6420.
- Huai, T., S.D. Shah, J.W. Miller, T. Younglove, D.J. Chernich, A. Ayala. 2006. Analysis of Heavy-Duty Diesel Truck Activity and Emissions Data. *Atmospheric Environment* 40:2333-2344.
- Jo, H.K. and E.G. McPherson. 1995. Carbon Storage and Flux in Urban Residential Greenspace. *J Env Mgmt*,45:109–133.
- Lal, R. 2004. Carbon Emission from Farm Operations. *Environmental International* 30:981-990.
- ORNL. 2010. Quick-reference list of conversion factors used by the Bioenergy Feedstock Development Programs. Oak Ridge National Laboratory, Oak Ridge, TN. http://bioenergy.ornl.gov/papers/misc/energy_conv.html
- Post, W.M. and K.C. Kwon. 2000. Soil Carbon Sequestration and Land-Use Change: Processes and Potential. *Global Change Biology*, 6:317-328.
- Qian, Y. and R.F. Follett. 2002. Assessing Soil Carbon Sequestration in Turfgrass Systems Using Long-Term Soil Testing Data. *Agron J*, 94:930-935.
- Skog, K.E. and G.A. Nicholson. 2000. Carbon Sequestration in Wood and Paper Products. USDA Forest Service Gen. Tech. Rep. RMRS-GTR-59. Chapter 5, pp. 79-88.
- Throssel, C. February 8, 2010. Energy Use at Golf Facilities, a presentation of the interim results of a national survey at the Golf Industry Show, San Diego, CA.
- U.S. EPA. 2009. Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2007. Washington DC, 410 pp. http://www.epa.gov/climatechange/emissions/downloads09/GHG2007entire_report-508.pdf
- U.S. EPA. 2003. 40 CFR 600.113-78 Fuel Economy Calculations. http://edocket.access.gpo.gov/cfr_2003/julqtr/40cfr600.113-78.htm
- U.S. EPA. 2002. Light Truck Average Fuel Economy Standards Model Years 2005-07. Federal Register: December 16, 2002, Volume 67, Number 241, pp 77015-77029. <http://www.epa.gov/EPA-IMPACT/2002/December/Day-16/i31522.htm>
- West, T.O. and G. Marland. 2002. A Synthesis of Carbon Sequestration, Carbon Emissions, and Net Carbon Flux in Agriculture: Comparing Tillage Practices in the United States. *Agric. Eco. Environ.* 91:217-232.
- Watts, A. 2009. Is the U.S. Temperature Record Reliable? The Heartland Institute, Chicago IL. SurfaceStations.org.