Greenbacks from Greenhouse Gases: Carbon Sequestration and Nutrient Management

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Metropolitan Water Reclamation District of Greater Chicago, Cicero, IL

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Definition of Green House Gases and Green House Effect

**GHGs:** Gaseous Components of the Atmosphere that Contribute to the Green House Effect

**GREEN HOUSE EFFECT:** The phenomenon whereby the earth's atmosphere traps solar radiation, because of the atmosphere containing gases that allow incoming sunlight to pass through but absorb heat radiated back from the earth's surface.
The Green House Effect

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

Solar radiation passes through the clear atmosphere.

Most radiation is absorbed by the earth’s surface and warms it.

Some of the infrared radiation passes through the atmosphere, and 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.

Infrared radiation is emitted from the earth’s surface.
History of Global Warming

- **1827:** Jean-Baptiste Fourier proclaimed that Earth’s atmosphere traps heat like a “glass vessel.” Later becomes known as Greenhouse Effect.
- **1896:** Svante Arrhenius was the first one to quantify the degree of warming of Earth due to CO₂. “We are evaporating our coal into the air.”
- **1985:** Hole in the Ozone Layer Discovered by American and British Scientists. Global Warming becomes prominent in politics.
- **1988:** Intergovernmental Panel on Climate Change (IPCC) formed by the UN. In the US, half of the Bill aimed at reducing global warming by Rep. Claudine Schneider passes.
- **1990:** First IPCC Report: 0.5°C rise in earth’s temp, in the last century.
History of Global Warming - Contd.

- **1992:** UN Framework Convention on Climate Change – Reverse Warming by Cutting Emissions down to 1990 Level by 2000
- **1997:** Kyoto Protocol proposed. Pres. Clinton signs the treaty but never submitted it to the Senate; first see meaningful participation of developing nations before ratifying.
- **2005:** Kyoto Protocol takes effect. USA and Australia are not signatories.
- **2006:** “Inconvenient Truth” released – a documentary on Gore’s campaign on Climate Change
- **2007:** IPCC Report – 90% certainty that global warming is man-made. Another report predicts that global temperatures and sea levels will rise

7/27/2007: Tata, a retired MWRD Employee says that Municipal Agencies can help minimizing global warming and can possibly make money through the sale of carbon credits earned through offsets, conservation of energy, careful nutrient management, and afforestation.
# Green House Gases and Origin

<table>
<thead>
<tr>
<th>Gas</th>
<th>Origin</th>
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</thead>
<tbody>
<tr>
<td>CO₂</td>
<td>Oxidation of Carbon</td>
</tr>
<tr>
<td>CH₄</td>
<td>Anaerobic Decomposition, Combustion</td>
</tr>
<tr>
<td>N₂O</td>
<td>Denitrification, Combustion</td>
</tr>
<tr>
<td>HFCs</td>
<td>Man made</td>
</tr>
<tr>
<td>PFCs</td>
<td>Man made</td>
</tr>
<tr>
<td>SF₆</td>
<td>Man made</td>
</tr>
</tbody>
</table>
## The Units

<table>
<thead>
<tr>
<th>Gas</th>
<th>Global Warming Potential</th>
</tr>
</thead>
<tbody>
<tr>
<td>$CO_2$</td>
<td>1</td>
</tr>
<tr>
<td>$CH_4$</td>
<td>21</td>
</tr>
<tr>
<td>$N_2O$</td>
<td>310</td>
</tr>
<tr>
<td>HFCs</td>
<td>1.5- 260</td>
</tr>
<tr>
<td>PFCs</td>
<td>6,500 - 9,200</td>
</tr>
<tr>
<td>SF6</td>
<td>23,900</td>
</tr>
</tbody>
</table>
Changes in GHG Emissions With Time

Changes in Greenhouse Gases from ice-Core and Modern Data

- Carbon Dioxide (ppm)
- Methane (ppb)
- Nitrous Oxide (ppb)

Radiative Forcing (W m⁻²)

Time (before 2005)
# Increases in Ambient GHG Concentration

<table>
<thead>
<tr>
<th></th>
<th>N2O</th>
<th>CO2</th>
<th>CH4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre Industrial Revolution</td>
<td>280*</td>
<td>715**</td>
<td>270**</td>
</tr>
<tr>
<td>Current Levels</td>
<td>370</td>
<td>1,774</td>
<td>319</td>
</tr>
</tbody>
</table>

*ppmv

**ppbv
Let us See What The World Is Doing About Climate Change
Article 3: “... to reducing their overall emissions of such gases by at least 5 per cent below 1990 levels in the commitment period 2008 to 2012.”
## Annexe I Parties and Emission Targets

<table>
<thead>
<tr>
<th>Annexe I Parties</th>
<th>Emission Target*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria, Belgium, Bulgaria, Czech Republic, Denmark,</td>
<td>-8 %</td>
</tr>
<tr>
<td>Estonia, European Community, Finland, France, Germany,</td>
<td></td>
</tr>
<tr>
<td>Greece, Ireland, Italy, Latvia, Liechtenstein, Lithuania, Luxembourg, Monaco,</td>
<td></td>
</tr>
<tr>
<td>Netherlands, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, UK, Northern Ireland</td>
<td></td>
</tr>
<tr>
<td>USA**</td>
<td>-7 %</td>
</tr>
<tr>
<td>Canada, Hungary, Japan, Poland</td>
<td>-6 %</td>
</tr>
<tr>
<td>Croatia</td>
<td>-5 %</td>
</tr>
<tr>
<td>New Zealand, Russian Fed., Ukraine</td>
<td>0 %</td>
</tr>
<tr>
<td>Norway</td>
<td>+1 %</td>
</tr>
<tr>
<td>Australia**</td>
<td>+8 %</td>
</tr>
<tr>
<td>Iceland</td>
<td>+10 %</td>
</tr>
</tbody>
</table>

*Compared to Base Year (usually 1990)

** Countries which haven’t ratified the KP
Mechanisms Proposed in Kyoto Protocol to Achieve Goals

- **CAP and TRADE**: International Emissions Trading of Emission Permits (EPs) Measured by Assigned Amount Units (AAUs)

- **Joint Implementation (JI)**: Crediting of Emission Offsets From Projects Among Developing Countries Measured by Emission Reduction Units (ERUs)

- **Clean Development Mechanism (CDM)**: Crediting Emission Offsets Resulting from Developing Countries Project to Developed Countries
GHG Emission Categories

- Energy
- Agriculture
- Wastes (Agricultural and Municipal)
- Industry
- Land Use
Greenhouse Gas Emission Sources

**Sources**
- Fossil Fuel Combustion (CO2, N2O, CH4)
- Natural Gas Systems (CH4)
- Agricultural Soils (N2O, CO2)
- Manure Management (CH4, N2O)
- Domesticated Animals (CH4)
- Burning of Field Wastes (CH4, N2O)
- Solid Waste Disposal (CH4, CO2, N2O, CH4)
- Wastewater Treatment (CO2, CH4, N2O)
- Industrial Processes (CO2, N2O, HFC, PFC, SF6)

**Sinks & Negative Emissions**
- Carbon Sequestration
- Forest Management
- Agriculture Land Use
- Methane Recovery & Flaring
- Landfills
- Wastewater Treatment
Now Let Us Turn Our Attention to:

Our Own Business of Wastewater Treatment & Explore How We Can Make Some Green Backs Out of the GHGs Emitted From Wastewater Treatment Processes.
GHGs of Importance and Concern in Wastewater Treatment Processes

- Carbon Dioxide
- Methane
- Nitrous Oxide
Where Do GHGs Come From In Wastewater Treatment Processes?

- From the Same Carbon and Nitrogen Cycles That Guide Aerobic, Anoxic, and Anaerobic Wastewater Treatment Processes
  - **Aerobic Process End Product:** $CO_2$
  - **Anaerobic Process End Products:** $CH_4$ and $CO_2$
  - **Anoxic Process End Products:** $N_2$, $N_2O$, and $CO_2$
How Money Can be Made from Controlling GHG Emissions
Mechanisms Available For Revenue Generation

- Emissions Trading: CAP and TRADE
- Generation of Carbon Offsets
A Regulator Establishes a CAP on Designated Polluters, e.g. Power Plants, To a Lower Level of Emissions than Their Level of Current Emissions

These New Limits Are Divided Among Polluters and Individual Permits Issued

Polluters who Emit Less Than What is Allowed Can Sell the Emissions That They Did Not Emit to Others who Cannot Reduce Their Emissions, but it is Economical for Them to Buy Credits Rather Than Reducing Emissions Themselves at a Higher Cost
Emissions Trading

- Involves Earning Validated and Verified Carbon Credits Through Implementation of Cost Effective Technologies and Practices to Offset GHG Emissions

- Removal of GHG Emissions by Cost Effective Methods is Essential for Making Money by Selling Carbon Credits
**Chicago Climate Exchange (CCX)**

- **CCX** is the only Exchange in the USA that Does Trading in Carbon Credits
- The Baseline (BL) Year is 2000 or the Average Emissions of 1998 to 2001
- The Reductions are Fixed
  - Phase I: For 2003 to 2006 - 4% compared to BL
  - Phase II: For 2007 to 2010 - 6% (additional 2%)
Emissions Trading Prices

- Carbon Emissions Trading Prices Although Started Low are now Trading Higher on CCX Than What They Were at the Beginning ($\sim 3.50 \text{ vs. } <$1.00/ton in 2003, went as high as $\sim 4.50/ton$)

- Many Companies Are Members of the CCX and Are Already Trading

- The Price of Carbon Sequestered Trades at a Considerably Higher Price in European Union Carbon Trading Market
CCX

Members Include:
- State of Illinois
- State of New Mexico
- Various Municipalities, including Chicago
- King County, Sacramento County
- American Electric Power
- Various Universities
- Various Major Industries, and
- Many Others
Breaking News!


The US is leading the rapidly growing market for voluntary carbon credits in terms of both supply and demand, according to a report from Ecosystem Marketplace and analysts New Carbon Finance.

Emission reductions equivalent to approximately 23.7 million tonnes of carbon dioxide were traded in 2006, at a volume-weighted average price of $4.10 a tonne, giving the market a value of $91 million.
Let Us See How Carbon Dioxide Can be Captured and Stored to Slow Down Climate Change

- Through Carbon Sequestration
- Through Earning Carbon Credits
What is Carbon Sequestration?

- Carbon sequestration is the process through which carbon containing emissions are lowered and permanently stored and/or removed either directly from their source or from the atmosphere.

- Can be directly or indirectly achieved by:
  - Modifying industrial and energy production operations and treating waste gas streams
  - Capturing and storing emissions in geological formations
  - Capturing and storing by biological means
Carbon Sequestration Technologies

- **Geological Sequestration**
  - Injection into Oil and Gas Reservoirs
  - Injection into Unmineable Coal Seams (Coal Bed Methane)
  - Injection into Deep Saline Reservoirs

- **Capture Technologies**
  - Absorption
  - Adsorption
  - Low Temperature Distillation
  - Gas Separation Membranes
  - Mineralization and Biomineralization

- **Terrestrial Sequestration**
  - Forest Lands
  - Agricultural Lands
  - Biomass Crop Lands
  - Degraded and Desert Lands
  - Wet Lands and Peat Lands
What is Terrestrial Carbon Sequestration?

Terrestrial carbon sequestration is the process through which carbon dioxide (CO2) from the atmosphere is absorbed by trees, plants and crops through photosynthesis, and stored as carbon in biomass (tree trunks, branches, foliage and roots) and soils.
Potential Level of Carbon Sequestration by Afforestation and Reforestation

- 1 to 3 GT C/ Year
  -US DOE, 2000

- 1 Tree will sequester CO2 from:
  - air travel of 4 hrs.
  - Car travel of 1242 miles
  - Train/coach travel of 6210 miles
  - Carbon Bank, USA
Carbon Offsets

- Wind
- Biomass
- Solar
- Alternative Fuels
- Recycling
- Afforestation and Reforestation
Wind Energy is Converted into Electrical Energy. Energy derived from Carbon Fuels can be offset by the energy derived by wind.
Biomass

**Fuels**
- Wood
- Mill Residues
- Forest Residue
- Urban Wood Waste
- Agricultural Residue
- Grasses

**Technologies**
- Co-fire with coal
- Gasification
Biomass

- CH4 Recovery
  - Livestock
  - Sewage
  - Landfill
Solar

• One Square Meter of a Conventional Solar Panel Can Produce 0.5 to 1 KWh/day depending on Length of Day and Brightness of Sun

• Installation of Solar Panels on Roof Tops of Single Family Homes Offsets GHG Emissions
Recycling

Landfill Reduction

= MTCE in Avoided Emissions
## Summary of Reduction Strategies to Reduce GHG Emissions by Offsets

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Offsets Achievable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind</td>
<td></td>
</tr>
<tr>
<td>Biomass - Vegetative</td>
<td></td>
</tr>
<tr>
<td>Biomass - Biogas</td>
<td></td>
</tr>
<tr>
<td>Solar</td>
<td></td>
</tr>
<tr>
<td>Other Alternative Fuels</td>
<td></td>
</tr>
<tr>
<td>Recycling</td>
<td></td>
</tr>
<tr>
<td>Carbon Sequestration</td>
<td></td>
</tr>
</tbody>
</table>
Potential for Carbon Sequestration through Land-use Management

- Agriculture
  - No till

- Biomass
  - Grasses
  - Woody trees

- Reforestation & Afforestation
  - Acres available

Estimate Potential million MTCO$_2$ due to Offsets or Reforestation and Afforestation
Trees conducive for Carbon Sequestration*

- Common Horse-chestnut
- Black Walnut
- American Sweetgum
- London Plane
- Douglas Fir
- Scarlet Oak, Red Oak, Virginia Live Oak
- Bald Cypress

*Nowak, D., US Forest Service (Northern Research Station, Syracuse, NY) 2002
Agricultural Practices to Increase Carbon Sequestration and Reduce GHG Emissions

- Residue Management (Direct Seed and No-Till)
- Nutrient Management
- Methane Reduction from Live Stock and Lagoons
- Afforestation and Reforestation (forest, pasture, and croplands)
- Biogas Recovery
Some Are Still Skeptical!
Whether Climate Change is Real or Not,

- Probably, our lifestyles will be altered because of increased emissions.
- If we intend to prevent shifts in climate, we need to change the status quo.
- Since we produce more emissions than most people in the world, we stand to need the most change.
- As time is passing, even our Govt. is mellowing
- Several States even have voluntarily joined the efforts
Opportunities to Earn Carbon Credits for Municipal Agencies

- **Carbon Sequestration by Afforestation and Reforestation**
  - Explore In-House Opportunities
  - Explore Synergistic Opportunities with Forest Preserves and Park Districts
  - Explore Utilizing Final Effluent for Irrigation and Biosolids Growing Grasses, Native Plants, and Woody Trees on Open Land Owned
  - Explore using constructed or natural wetlands as media for sequestering carbon

- **Carbon Credits Earned by Offsets**
  - Explore In-house and Synergistic Opportunities
Potential Benefits Resulting from Carbon Sequestration Practices

- Water Quality Improvements
- Meeting Total Maximum Daily Load Targets
- Air Quality Improvement (Odor Abatement)
- Improvement in Public Relations
Steps to Determine Potential Carbon Credits

- Acres Available (MWRDGC: ~25,200 acres; Chicago Forest Preserves: 68,303 acres, Chicago Park District: 10,000 ac.)
- Aggregate Acreage with other Interested Parties (Park Districts, Forest Preserves, Arboretum, Golf Courses, Cemeteries in Cook, Du Page and other counties)
- Determine effluent irrigation requirements to grow corn and/or trees (36” p.a. per acre)
- Determine N Requirement for Fertilization through effluent and biosolids
- Determine C offsets due to N substitution for commercial N fertilizer (16.75 cu.ft of natural gas/lb anh. NH3 used)
- Determine C fixed by crops and/or biomass planted above ground
- Determine C fixed in roots and soil
- Determine C fixed by wetlands (4.6 kg C/sq. m/yr.)
- Get C credits for overall C fixed
Other Factors to Be Considered

- Determine C offsets by changing all vehicles to Alternative Fuel Vehicles
- Determine C offsets by Energy Saving Mechanisms (e.g. Changing Light Bulbs from Incandescent Ones to others, etc.)
- Claim C offsets for every little effort made
- Employ a risk factor of 20% to cover contingencies as suggested by CCX unless justify a lower risk
- Consider transaction costs, brokerage fees, and legal fees, if any
### Potential Annual Revenue for Landowners*

<table>
<thead>
<tr>
<th>Acres</th>
<th>@ $1.00/ton C sequestered</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000 - Morton Arboretum</td>
<td>$360,000</td>
</tr>
<tr>
<td>20,000 - DuPage Co. Forest Preserve</td>
<td>$3,600,000</td>
</tr>
<tr>
<td>35,000 - DuPage Co. Parks &amp; Golf Courses</td>
<td>$6,300,000</td>
</tr>
</tbody>
</table>

**Assumption:**

Plant 300 trees per acre × 60% increased growth rate = 180 tons of C/Year/acre (1 tree = 1 ton of carbon) (after J.V. Sheaffer, Personal Communication, 2007)
Path Forward

- Every organization should voluntarily try to reduce GHG emissions to the atmosphere to promote a sustainable world.
- Recommend that the District also like several public and private organizations look into undertaking a study to reduce C emissions and perhaps make money, if it hasn’t yet done so.
- Hopefully, there is a Potential for Saving Money to the Taxpayers.