The Energy and Carbon Footprint of Water Reclamation and Water Management in Greater Chicago

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MWRDGC

Illinois Water Conference
Champaign, Illinois
October 9, 2008
Overview

- Overview of the District
- District Energy Demand and Generation
  - Energy Footprint
- Greenhouse Gases
- Carbon Footprint
  - Definition
    - Methodology, Boundaries and Scopes, and Calculation
  - Methane and Nitrous Oxide Emissions
  - Carbon Offsets
District Overview

- Founded in 1889 to protect water quality of Lake Michigan
- Services Cook County Illinois including city of Chicago and 125 suburban communities
- Service area covers 875 square miles and includes 5.5 million people and an industry equivalent of 5.7 million people
- Operates seven water reclamation plants (WRPs) handling daily flow of 1.5 billion gallons
- Produces ~180,000 dry tons biosolids annually
District Energy Demand

- Seven WRPs discharge to the Chicago Waterway System (CAWS) which feeds the Illinois River and finally the Mississippi
  - Stickney, Calumet, North Side, Kirie, Egan, Hanover Park, Lemont
- Tunnel and Reservoir Project (TARP) is used to accept overburden wet weather flow
- Pumping Stations pump water to WRPs
- Side stream Elevated Aeration Stations (SEPAs) are used to increase dissolved oxygen in the CAWS
- Biosolids transported to Cook and Fulton Counties for Land Application
District Energy Generation

- Lockport Powerhouse is a hydroelectric plant on the Sanitary and Ship Canal
- Anaerobic digester biogas use in boilers for heating purposes
- Excess biogas use in turbine at Stickney for electrical power
WRP Energy Distributions

Calumet WRP
- Blowers: 44%
- Pumps: 24%
- Digester: 12%
- Tarp: 14%
- Other: 6%

Egan WRP
- Blowers: 38%
- Pumps: 36%
- Solids: 11%
- Other: 15%
Energy Footprint

- Average picture of energy use and loss across an entity
- Inventory of energy supply and demand
  - **Supply**
    - Energy purchased from utilities
    - Energy that is generated on site
    - Excess electricity that is transported to the local grid
  - **Demand**
    - Allocation of supplied energy, e.g. pumps and blowers
  - **Energy losses should be considered**
    - Inefficiencies in equipment and distribution systems
      - For example, occur in energy conversion systems such as pumps, heat exchangers, and motors due to limitations by construction materials or equipment design
## 2005 District Energy Allocation

<table>
<thead>
<tr>
<th></th>
<th>Electricity kWh</th>
<th>Natural Gas Therms</th>
<th>Diesel Fuel Gallons</th>
<th>Unleaded Fuel Gallons</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stickney WRP</strong></td>
<td>261,043,378</td>
<td>105,644</td>
<td>62,858</td>
<td>113,837.40</td>
</tr>
<tr>
<td><strong>Calumet WRP</strong></td>
<td>76,946,825</td>
<td>942,888</td>
<td></td>
<td>39,024.70</td>
</tr>
<tr>
<td><strong>North Side WRP</strong></td>
<td>65,452,466</td>
<td>408,319</td>
<td>1,946</td>
<td></td>
</tr>
<tr>
<td><strong>Egan WRP</strong></td>
<td>25,532,305</td>
<td>351,627</td>
<td>1,946</td>
<td>3,180.70</td>
</tr>
<tr>
<td><strong>Kirie WRP</strong></td>
<td>21,942,017</td>
<td>168,876</td>
<td>2,810</td>
<td></td>
</tr>
<tr>
<td><strong>Hanover Park WRP</strong></td>
<td>6,008,290</td>
<td>124,889</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Lemont WRP</strong></td>
<td>2,554,476</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Pumping Stations</strong></td>
<td>72,573,444</td>
<td>95,892</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Aeration Stations</strong></td>
<td>2,488,597</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Solids Drying</strong></td>
<td>1,035,918</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Fulton County</strong></td>
<td>55,656</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Other</strong></td>
<td>11,791,781</td>
<td>1174886.7</td>
<td>0.10</td>
<td>33,364.70</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>547,425,153</td>
<td>3,373,022</td>
<td>69,559</td>
<td>189,408</td>
</tr>
</tbody>
</table>
## 2005 District Energy Allocation

### Energy (MWh)

<table>
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<tr>
<th>Energy</th>
<th>MWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity</td>
<td>547,425</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>98,830</td>
</tr>
<tr>
<td>Automobile Fuel</td>
<td>9,478</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>655,733</strong></td>
</tr>
</tbody>
</table>

**MWRDGC**  

- **Electricity**: 84%  
- **Natural Gas**: 15%  
- **Fuel**: 1%  

![Pie chart showing energy allocation](image)
2005 District Energy Generators

- Biogas Production and Use
  - 259,498 MWh
- Lockport Hydroelectric Power
  - 38,017 MWh
- Stickney Turbine
  - 15 MWh
  - Out of Service most of year
## 2005 Energy Footprint

<table>
<thead>
<tr>
<th>Energy (MWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy Purchased</td>
</tr>
<tr>
<td>Energy Generated</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

- **31.2% of District Energy Use is Generated by the District**
Why is the District’s Energy Footprint Important?

- The combustion of fossil fuels such as coal, natural gas, and gasoline increase carbon dioxide (CO$_2$) emissions which is a known greenhouse gas.
Greenhouse Gases

- When sunlight strikes the Earth’s surface, some of it is re-radiated back towards space as infrared radiation (heat).
  - Greenhouse gases absorb this infrared radiation and trap the heat in the atmosphere, i.e. the “greenhouse” effect
- Most significant anthropogenic greenhouse gases in wastewater
  - CO$_2$, CH$_4$, N$_2$O
- Taking an inventory of greenhouse emissions develops a carbon footprint
Carbon Footprint

- Define a methodology
  - GHG Protocol, International Organization for Standardization (ISO) 14064

- Specify boundary and scope of coverage
  - CO$_2$ only or all greenhouse gases?
  - Direct emissions from fuel use onsite and from transport?
  - Direct emissions from manufacturing processes onsite?
  - Emissions from the electricity the organization purchased?
  - Emissions from the organization’s supply chain and other activities for which the operation is indirectly responsible, such as outsourced activities or manufacture and transport of raw materials, by another company, which your organization then uses?

- Collect emissions data and calculate the footprint
2005 District Carbon Footprint

Definition

- Methodology
  - **Greenhouse Gas Protocol** is the most widely used international accounting tool for government and business leaders to understand, quantify, and manage greenhouse gas emissions
    - Provides guidelines for setting organizational and operational boundaries, tracking emissions, calculating emissions, and accounting for GHG reductions (offsets)
District Organizational Boundaries

- A control approach is used
  - The District accounts for 100 percent of the GHG emissions from operations over which it has control

- No concern for double counting as no other entity holds an interest in the District
District Operational Boundaries

- Identify emissions associated with our operations and categorizing them as direct or indirect emissions
  - Direct: Emissions from sources that are owned or controlled by the District
  - Indirect: Emissions that are a consequence of activities of the District but occur at sources controlled by another entity

- Choosing scope of accounting for emissions
  - Scope 1: Direct GHG emissions
  - Scope 2: Electricity indirect GHG emissions
  - Scope 3: Other indirect GHG emissions

- GHG Protocol suggests that Scopes 1 and 2 are accounted for
Overview of Scopes and Emissions

- **Scope 1**: Fuel combustion, District vehicles, etc.
- **Scope 2**: Purchased Electricity
- **Scope 3**: Production of Purchased Materials, Product Use, Outsourced Activities, Employee Business Travel, Waste Disposal, etc.
District Scopes

- **Scope 1**
  - Generation of electricity, heat, or steam
    - Boilers, turbines, etc.
  - Physical or chemical processing
    - CO$_2$ from open aeration basins
  - Transportation of materials products, waste, and employees
  - Fugitive emissions
    - CH$_4$ from digesters floating cover edges

- **Scope 2**
  - Purchased electricity
GHG Emissions

- Calculation
  - Identify sources
  - Select calculation approach
  - Collect data and choose emission factors
  - Apply calculation tools

- But the above only accounts for CO$_2$ emissions...
Methane Emissions

- Wastewater Treatment is the 6th highest contributor of CH$_4$ emissions (EPA)
  - 21 times the global warming potential of CO$_2$
  - Source: Anaerobic digestion of organic matter
    - Anaerobic digesters, low oxygen zones in aeration batteries and clarifiers, collection systems, lagoons
  - Control
    - Cogeneration of digester gas, flaring of unused gas, efficient operation of aeration batteries, using methanogen inhibitors in batteries, stripping dissolved methane from dewater sludge
Nitrous Oxide Emissions

- Human Sewage is the 4\textsuperscript{th} highest contributor of N\textsubscript{2}O emissions (EPA)
  - 310 times the global warming potential of CO\textsubscript{2}
  - Source: Incomplete nitrification and denitrification
    - Low oxygen zones in aeration batteries, collection systems, untreated nitrogen discharged to effluent receiving waters, thermal drying of biosolids
- Control:
  - Efficient operation of aeration batteries, use of different nitrifying genera, oxidation controls to clean gas coming form thermal drying treatment
**CH₄ Emissions (IPCC)**

\[
CH_4 = \left[ \sum_{i,j} (EF_j) \right] (TOW - S) - R
\]

- \( CH_4 \) = Total methane emissions from domestic wastewater (kg/year)
- \( i \) = Income group (rural, urban high income, urban low income)
- \( j \) = Each treatment/discharge pathway or system, i.e. AEROBIC AND ANAEROBIC TREATMENT
- \( EF_j \) = Emission factor (kg CH₄/kg BOD)
- \( TOW \) = Total organics in wastewater in inventory year (kg BOD/year)
- \( S \) = Organic component removed as sludge in inventory year (kg BOD/yr)
- \( R \) = Amount of CH₄ recovered in inventory year (kg CH₄/yr)
**CH₄ Emissions (cont.)**

\[ EF_j = B_0 \cdot MCF_j \]

- **B₀** = Maximum CH₄ producing capacity (kg CH₄ /kg BOD)
  - = 0.6 kg CH₄ /kg BOD (IPCC)
  - = 0.4 kg CH₄ /kg BOD (NACWA: National Organization of Clean Water Agencies)

- **MCF_j** = Methane correction factor
  - = 0-0.1 (Aerobic Treatment of Wastewater)
  - = 0.8-1.0 (Anaerobic Treatment of Sludge)

**DISTRICT EMISSIONS (2000)**

- **CH₄** = 30.95x10⁶ kg CH₄ (IPCC)
  - = 650x10⁶ kg CO₂ equivalents (IPCC)

- **CH₄** = 11.41x10⁶ kg CH₄ (NACWA)
  - = 239.5x10⁶ kg CO₂ equivalents (NACWA)
### N$_2$O Emissions (IPCC)

\[
N_2O_{\text{Plants}} = P \cdot T_{\text{Plant}} \cdot F_{\text{IND-COM}} \cdot EF_{\text{Plant}}
\]

- $N_2O_{\text{Plants}}$ = Total N$_2$O emissions from plants, kg N$_2$O/year
- $P$ = Population, persons
- $T_{\text{Plant}}$ = Degree of use of wastewater treatment plants per capita, unitless
- $F_{\text{IND-COM}}$ = Fraction of industrial and commercial co-discharged protein, unitless
- $EF_{\text{Plant}}$ = Emission factor, kg N$_2$O/person/year

\[
N_2O_{\text{Effluent}} = N_{\text{Effluent}} \cdot EF_{\text{Effluent}} \cdot 44 / 28
\]

- $N_2O_{\text{Effluent}}$ = Total N$_2$O emissions from effluents, kg N$_2$O/yr
- $N_{\text{Effluent}}$ = Nitrogen in the effluent discharged to aquatic environments, kg N/yr
- $EF_{\text{Effluent}}$ = Emission factor, kg N$_2$O-N/kg N
- $44/28$ = Conversion of kg N$_2$O-N to kg N$_2$O
$F_{IND-COM} = 1.25 \ (IPCC)$

\[= 1.0 \ (NACWA)\]

**DISTRICT EMISSIONS (2000)**

$N_2O = 49,353 \ \text{kg N}_2\text{O} \ (IPCC)$

\[= 15.3 \times 10^6 \ \text{kg CO}_2 \ \text{equivalents} \ (IPCC)\]

$N_2O = 45,120 \ \text{kg N}_2\text{O} \ (NACWA)$

\[= 13.99 \times 10^6 \ \text{kg CO}_2 \ \text{equivalents} \ (NACWA)\]
Accounting for GHG Reductions

- Reductions in indirect emissions
  - House keeping
  - Using energy efficient pumps and motors
  - Using dissolved oxygen controlled blowers in aeration batteries
  - Efficient heating, cooling, and lighting systems

- Project based reductions and offsets/credits
  - Renewable energy use
  - Methane use and capture
  - Land use, land use change, and forestry
Land Use and Carbon Sequestration

- District owns 5,715 acres of forested property in Cook County and Fulton County.
- District has applied 892,747 metric tons of biosolids to 2,287 acres of barren or strip mined land to encourage vegetative growth.
## 2005 Maximum District Carbon Footprint

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<td>547,425,153</td>
<td>0.7058 kg CO₂/kWh¹</td>
<td>386,373</td>
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<tr>
<td><em><em>Natural Gas</em> (TJ)</em>*</td>
<td>355.79</td>
<td>53,295 kg CO₂/TJ²</td>
<td>67,827</td>
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<td><strong>Unleaded Gas (gall)</strong></td>
<td>189,407</td>
<td>9.02 kg CO₂/gall²</td>
<td>1,708</td>
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<td><strong>Diesel Gas (gall)</strong></td>
<td>69,559</td>
<td>10.39 kg CO₂/gall²</td>
<td>723</td>
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<tr>
<td><em><em>Biogas</em> (TJ)</em>*</td>
<td>934.25</td>
<td>51,870 kg CO₂/TJ²</td>
<td>48,753</td>
</tr>
<tr>
<td><strong>CH₄ † (IPCC)</strong></td>
<td></td>
<td></td>
<td>649,981</td>
</tr>
<tr>
<td><strong>N₂O † (IPCC)</strong></td>
<td></td>
<td></td>
<td>15,300</td>
</tr>
<tr>
<td><strong>Forested land (ac)</strong></td>
<td>5,715</td>
<td>9,035 kg CO₂/acre³</td>
<td>51,635</td>
</tr>
<tr>
<td><strong>Biosolid applied land (ac)</strong></td>
<td>2,287</td>
<td>2,449 kg CO₂/acre⁴</td>
<td>5,510</td>
</tr>
</tbody>
</table>

*CH₄ and N₂O Emissions are included but minimal  
†Emission data from 2000  
¹North American Electricity Research Council  
²International Panel of Climate Change  
³EPA 2006 Greenhouse Gas Inventory  
⁴Tian et al. (2008)
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<td>48,753</td>
</tr>
<tr>
<td><strong>CH₄ † (NACWA, min MCF)</strong></td>
<td></td>
<td></td>
<td>15,675</td>
</tr>
<tr>
<td><strong>N₂O † (NACWA)</strong></td>
<td></td>
<td></td>
<td>13,987</td>
</tr>
<tr>
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</tr>
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**Total**: 477,900
Incomplete Carbon Footprint

- Are the CH₄ and N₂O calculations correct?
  - Currently performing monitoring project at largest District plant for both GHGs from all unit processes and borders

- CO₂ from aeration batteries

- Unused Flared Biogas

- Other Offsets?
  - Microturbines for unused biogas
  - Alternative Energies