METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

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

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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

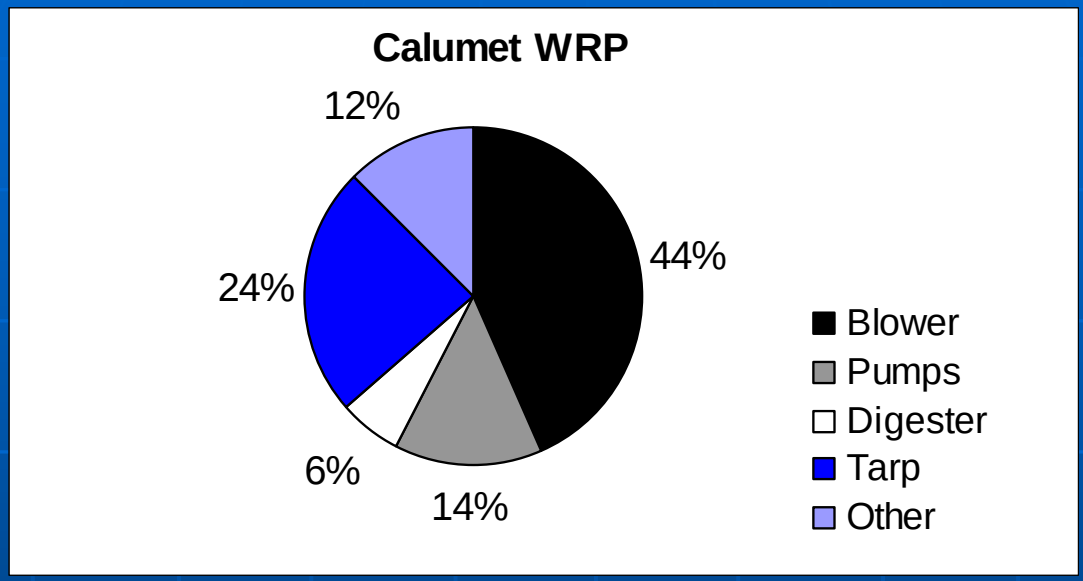
District Energy Demand

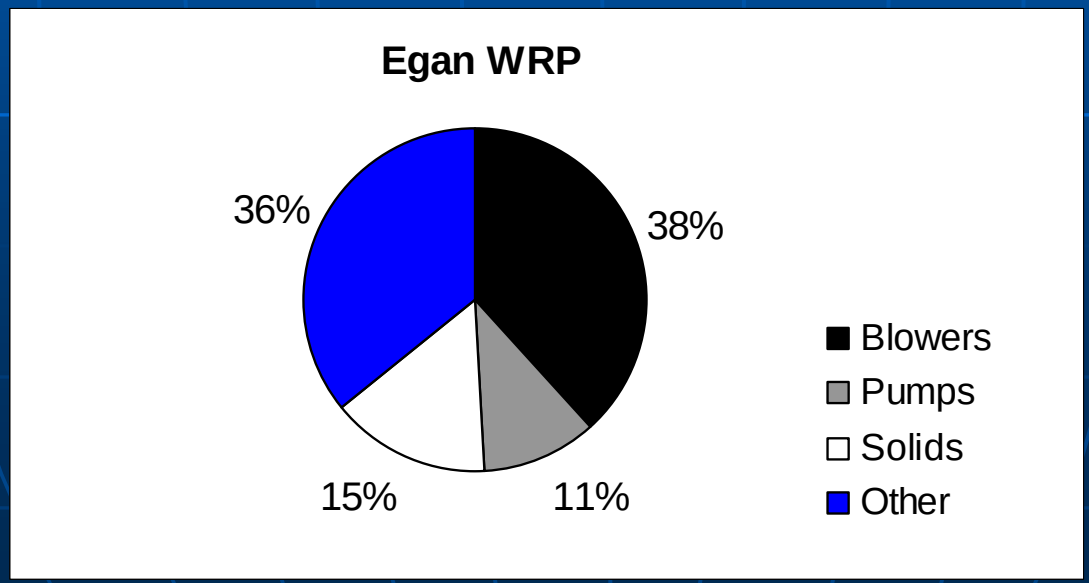
- Seven WRPs discharge to the Chicago Waterway System (CAWS) which feeds the Illinois River and finally the Mississippi
  - Stickney, Calumet, North Side, Kirie, Egan, Hanover Park, Lemont
- Tunnel and Reservoir Project (TARP) is used to accept overburden wet weather flow
- Pumping Stations pump water 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





Energy Footprint

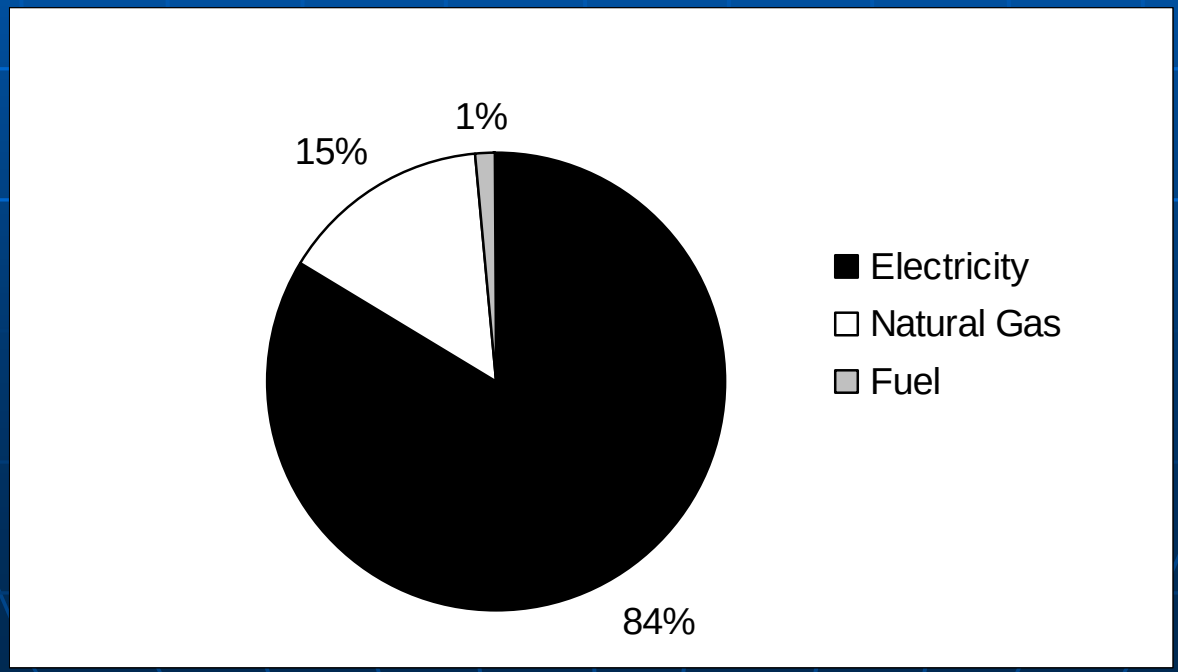
- Average picture of energy use and loss across an entity
- Inventory of energy supply and demand
  - Supply
    - Energy purchased from utilities
    - Energy that is generated on site
    - Excess electricity that is transported to the local grid
  - Demand
    - Allocation of supplied energy, e.g. 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

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

2005 District Energy Allocation

	Energy (MWh)
Electricity	547,425
Natural Gas	98,830
Automobile Fuel	9,478
	655,733



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

	Energy (MWh)
Energy Purchased	655,733
Energy Generated	297,530
	953,263

- **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_2O
- 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)

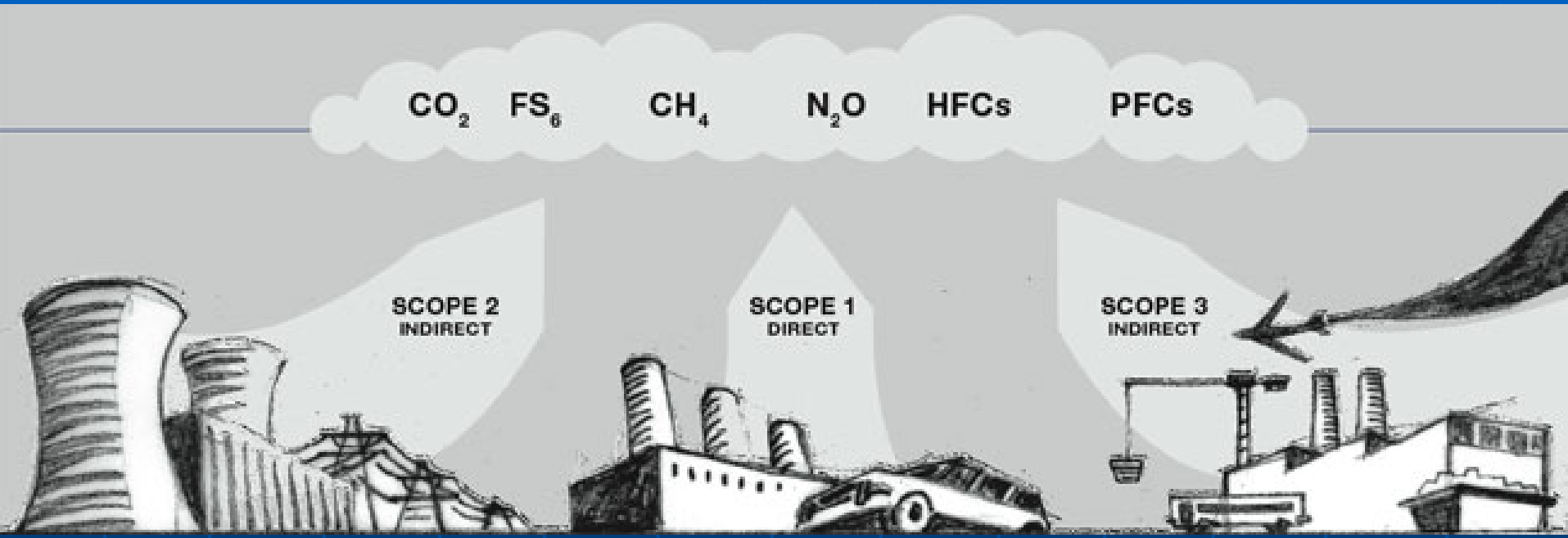
District Organizational Boundaries

- 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 4th highest contributor of N_2O emissions (EPA)
  - 310 times the global warming potential of CO_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

CH_4 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 CH_4/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 CH_4 recovered in inventory year (kg CH_4/yr)

CH_4 Emissions (cont.)

$$EF_j = B_0 \cdot MCF_j$$

B_0 = Maximum CH4 producing capacity (kg CH4 /kg BOD)
= 0.6 kg CH_4 /kg BOD (IPCC)
= 0.4 kg CH_4 /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)

CH_4 = 30.95×10^6 kg CH_4 (IPCC)
= 650×10^6 kg CO_2 equivalents (IPCC)

CH_4 = 11.41×10^6 kg CH_4 (NACWA)
= 239.5×10^6 kg CO_2 equivalents (NACWA)

N_2O Emissions (IPCC)

$$N_2O_{Plants} = P \cdot T_{Plant} \cdot F_{IND-COM} \cdot EF_{Plant}$$

N_2O_{Plants}	=	Total N_2O emissions from plants, kg N_2O/year
P	=	Population, persons
T_{Plant}	=	Degree of use of wastewater treatment plants per capita, unitless
$F_{IND-COM}$	=	Fraction of industrial and commercial co-discharged protein, unitless
EF_{Plant}	=	Emission factor, kg N_2O/person/year

$$N_2O_{Effluent} = N_{Effluent} \cdot EF_{Effluent} \cdot 44/28$$

$N_2O_{Effluent}$	=	Total N_2O emissions from effluents, kg N_2O/yr
$N_{Effluent}$	=	Nitrogen in the effluent discharged to aquatic environments, kg N/yr
$EF_{Efflu-ent}$	=	Emission factor, kg N_2O-N/kg N
44/28	=	Conversion of kg N_2O-N to kg N_2O

N_2O Emissions (cont.)

$F_{IND\text{-}COM}$ = 1.25 (IPCC)

= 1.0 (NACWA)

DISTRICT EMISSIONS (2000)

N_2O = 49,353 kg N_2O (IPCC)

= 15.3×10^6 kg CO_2 equivalents (IPCC)

N_2O = 45,120 kg N_2O(NACWA)

= 13.99×10^6 kg CO_2 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

	Total	Conversion	Metric Tons CO_2 Equiv
Electricity (kWh)	547,425,153	0.7058 kg CO_2/kWh[1]	386,373
Natural Gas* (TJ)	355.79	53,295 kg CO_2/TJ[2]	67,827
Unleaded Gas (gall)	189,407	9.02 kg CO_2/gall[2]	1,708
Diesel Gas (gall)	69,559	10.39 kg CO_2/gall[2]	723
Biogas* (TJ)	934.25	51,870 kg CO_2/TJ[2]	48,753
CH_4† (IPCC)			649,981
N_20† (IPCC)			15,300
Forested land (ac)	5,715	9,035 kg CO_2/acre[3]	51,635
Biosolid applied land (ac)	2,287	2,449 kg CO_2/acre[4]	5,510
			1,113,518

*CH_4 and N_2O Emissions are included but minimal
†Emission data from 2000
[1]North American Electricity Research Council
[2]International Panel of Climate Change
3 EPA 2006 Greenhouse Gas Inventory
4 Tian et al.(2008)

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	Total	Conversion	Metric Tons CO_2 Equiv
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Biogas* (TJ)	934.25	51,870 kg CO_2/TJ[2]	48,753
CH_4† (NACWA, min MCF)			15,675
N_20† (NACWA)			13,987
Forested land (ac)	5,715	9,035 kg CO_2/acre[3]	51,635
Biosolid applied land (ac)	2,287	2,449 kg CO_2/acre[4]	5,510
			477,900

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Incomplete Carbon Footprint

- Are the CH_4 and N_2O calculations correct?
  - Currently performing monitoring project at largest District plant for both GHGs from all unit processes and borders
- CO_2 from aeration batteries
- Unused Flared Biogas
- Other Offsets?
  - Microturbines for unused biogas
  - Alternative Energies