Availability of Models to Estimate Greenhouse Gas Emissions & Carbon Footprint of Water Reuse Facilities

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James R. Mihelcic, PhD, BCEEM

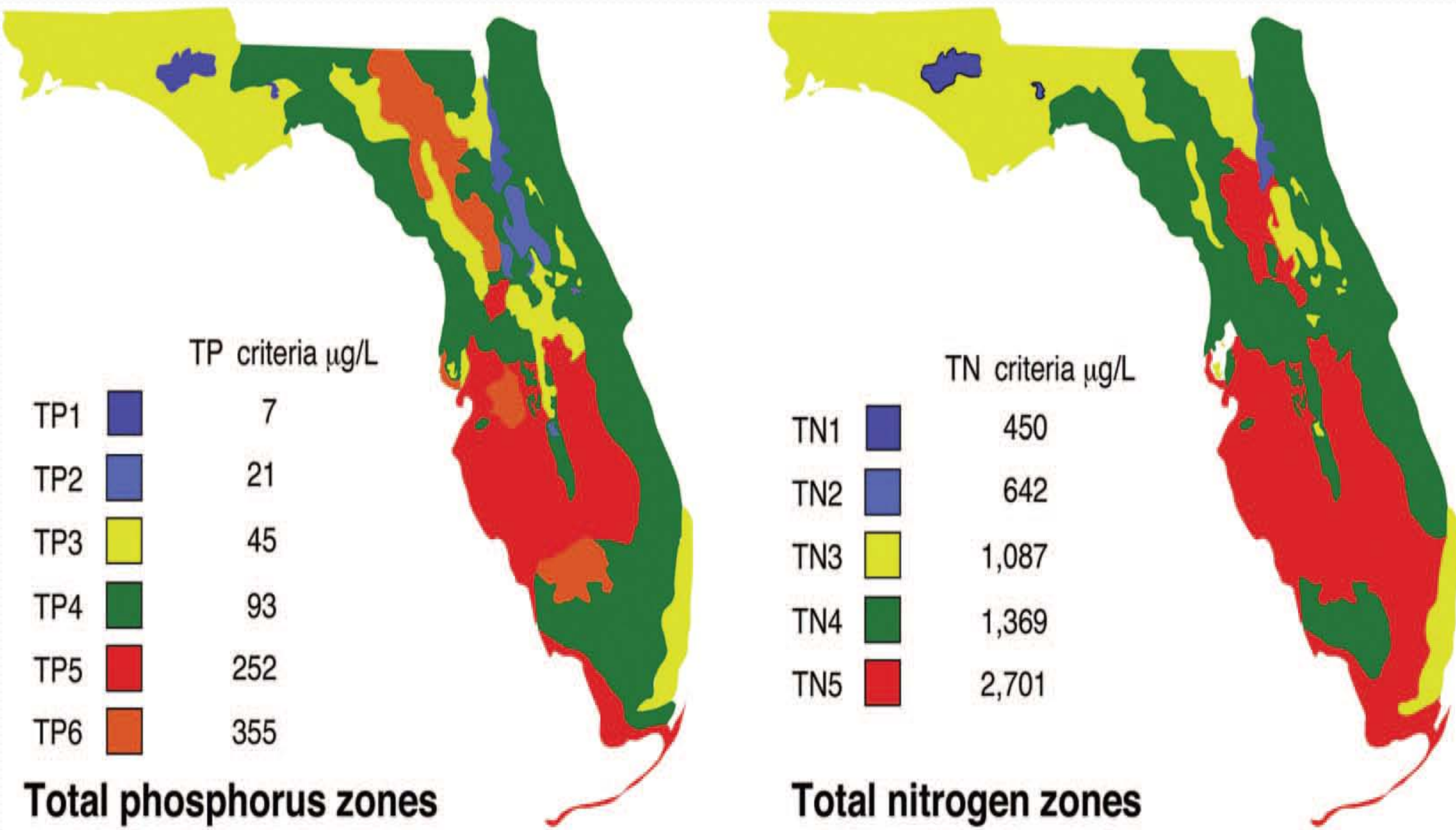
University of South Florida, Tampa

jm41@usf.edu

&

Qiong Zhang, PhD; Mark V. Santana; Pablo K. Cornejo;
Andrea Rocha, PhD; Sarah Ness
(Department of Civil and Environmental Engrg, University of South Florida, Tampa)
&
David R. Hokanson, PhD, PE, BCEE (Trussell Technologies, Inc., Pasadena, CA)

What also drives Water Reuse?



Learning Objectives

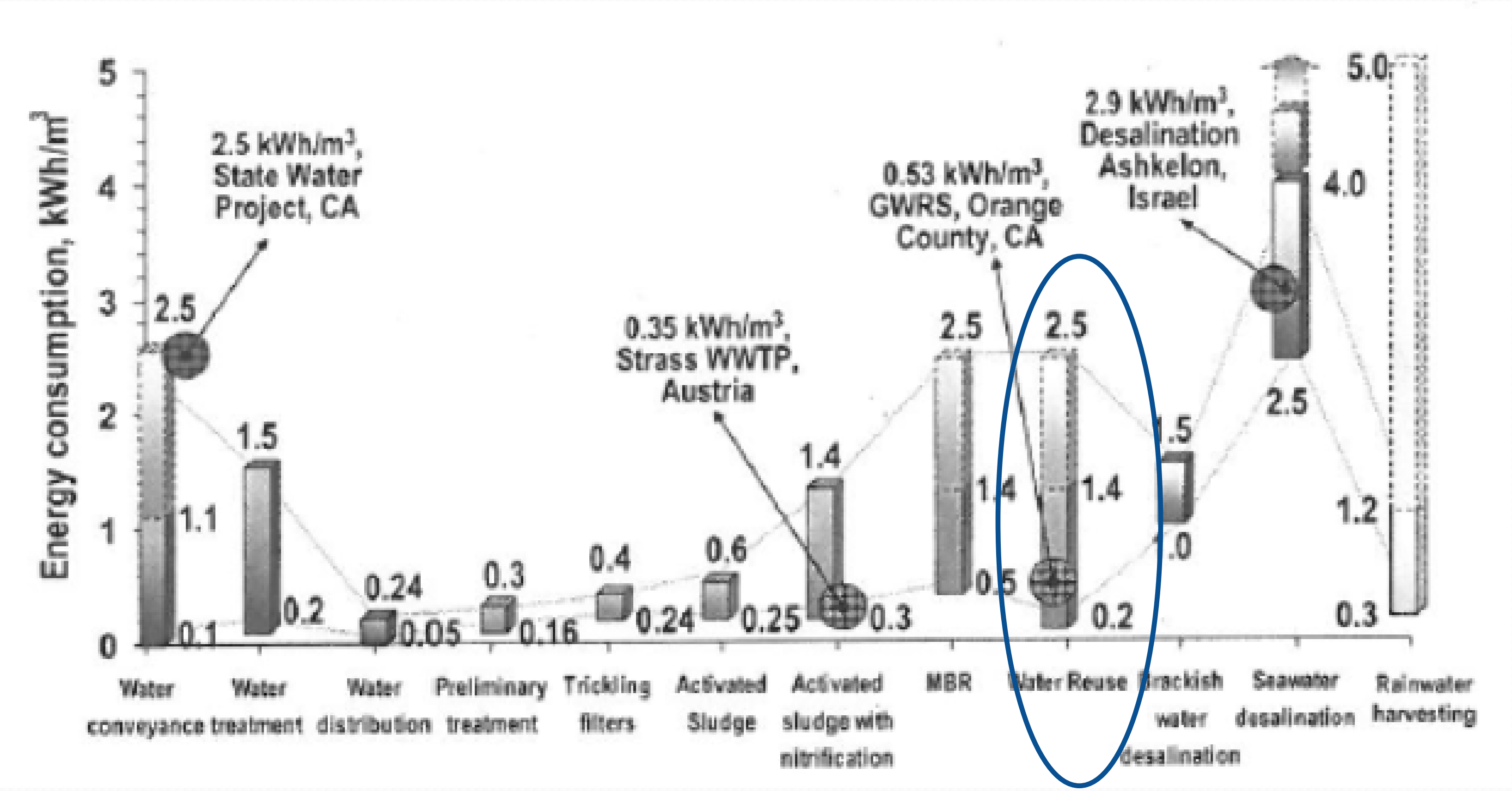
- Understand goal of our recent study for the WateReuse Foundation
- Explain difference between Embodied Energy, GHG Emissions, Carbon Footprint, and direct and indirect energy/emissions
- Understand what influences magnitude of CO_2 emissions and carbon footprints associated with water reuse
- Apply eGRID to calculate GHG emissions and carbon footprint for energy use from purchased electricity
- Be aware of available models to estimate GHG emissions and carbon footprint
- Differentiate between carbon footprint estimated using two models

Goal of Study we just completed for the WateReuse Foundation

- provide assistance to those who employ water reuse and desalination in estimating GHG emissions and carbon footprint
- recommend accessible models to utilities to provide estimations of GHG emissions and carbon footprint

Mihelcic, J.R., Zhang, Q., Hokanson, D.R., Cornejo, P.K., Santana, M.V., Rocha, A.M., Ness, S. J. (2013). "Feasibility Study on Model Development to Estimate and Minimize Greenhouse Gas Concentrations and Carbon Footprint of Water Reuse and Desalination Facilities," Project Report 10-12, 148 pages, WateReuse Research Foundation, Alexandria, VA.

Energy Consumption (e.g., direct energy) of Water Reuse and Desalination



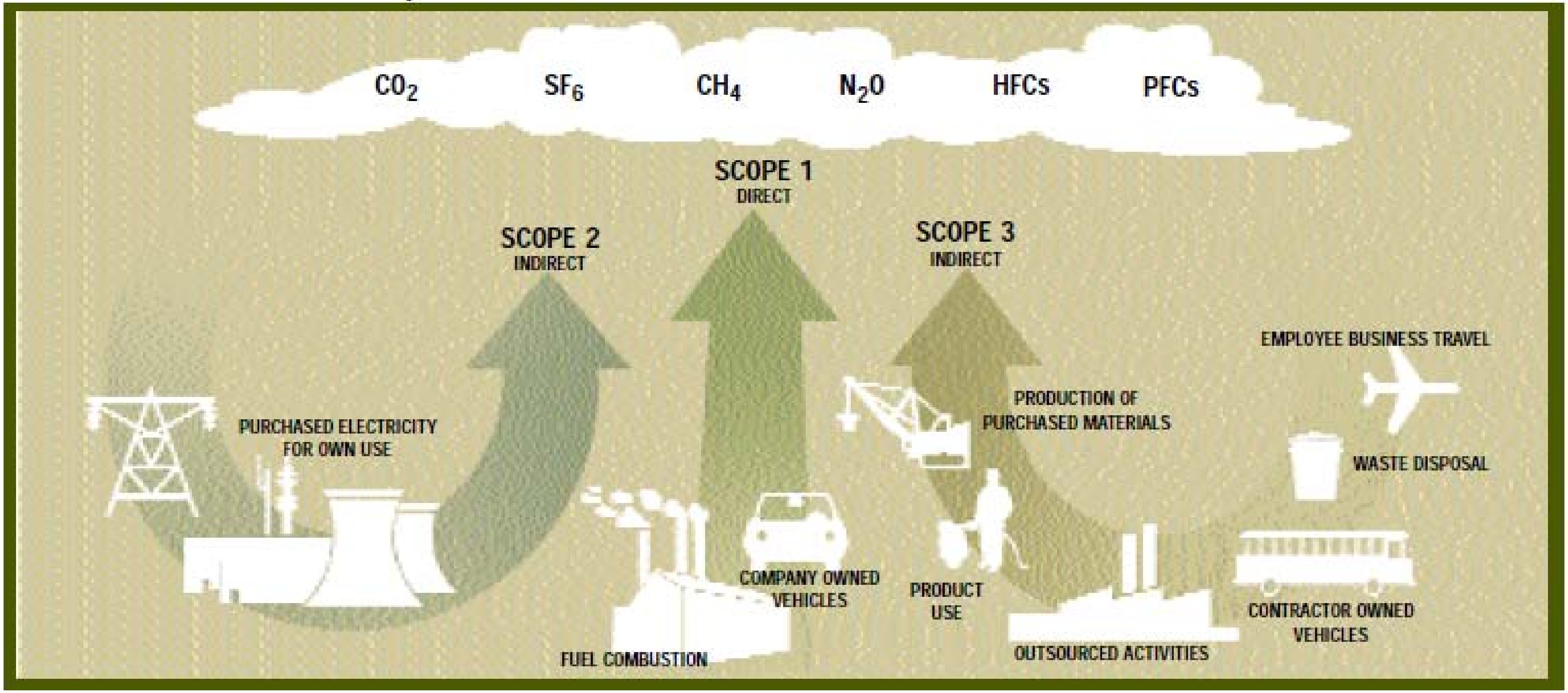
Source: Lazarova, Choo, and Cornel 2012

Lets Define Carbon Footprint, Direct and Indirect GHG Emissions and Embodied Energy

- A *carbon footprint* is defined as the total greenhouse gas emissions (reported in carbon equivalents) that are associated with a product, service, company, or other entity such as a household or water treatment plant. It consists of direct and indirect greenhouse gas emissions.
- *Direct emissions* are from sources owned or controlled by the reporting entity. *Indirect emissions* are a consequence of activities of the reporting entity, but they occur at other sources that are owned or controlled by another entity (Greenhouse Gas Protocol, 2012).

from Mihelcic, J.R., J.B. Zimmerman, *Environmental Engineering: Fundamentals, Sustainability, Design*, 2nd Edition, John Wiley & Sons, New York, 2013.

Direct & Indirect Energy when Reporting Greenhouse Gas Emissions and Carbon Footprint



GHG Protocol Corporate Accounting and Reporting Standard

Life Cycle Assessment - Energy Impact

- LCA is a quantitative tool, which estimates the environmental impact of a system over its lifetime (EPA, 2006, Life Cycle Assessment: Principles and Practice)
- Embodied Energy – lifecycle energy consumption
- Carbon Footprint – lifecycle greenhouse gas emissions (GHGs)

Impact Category	Contributors		
Embodied Energy	N/A	Direct Energy (electricity)	Indirect energy: a) produce and transport materials to the facility, b) waste disposal, c) employee business travel.

CO_2 Emissions and Carbon Footprint of Water Reuse

Change in Emissions and Footprint with Capacity (per m3 of water treated)

Capacity (MGD)	CO_2 Emissions (kg CO_2/m^3)
0.8	0.2–1.1
13	0.4–0.8

Capacity (MGD)	Carbon Footprint (kg CO_2 eq/m^3)
0.07, 0.62	0.1–0.9
1.3, 4.5, 5.6	0.5–1.2
10.6, 11.7, 26	0.1–2.4

Carbon footprint ranges from 0.1 to 2.4 kg CO_2eq/m^3

Carbon footprint per m^3 water produced appears to increase with increasing plant capacity (0.07 – 26 MGD)

Source: Mihelcic, J.R., Zhang, Q., Hokanson, D.R., Cornejo, P.K., Santana, M.V., Rocha, A.M., Ness, S. J. (2013). “Feasibility Study on Model Development to Estimate and Minimize Greenhouse Gas Concentrations and Carbon Footprint of Water Reuse and Desalination Facilities,” Project Report 10-12, 148 pages, WateReuse Research Foundation, Alexandria, VA.

Change with Energy Mix - Facilities using renewable energy or energy mix with high portion of renewable energy have relatively low carbon footprint.

Energy Mix	CO_2 Emissions (kg CO_2/m^3)
Europe	0.8–1.0
France	0.23–0.27
New South Wales	0.4–0.8
Norway	0.14–0.16
Portugal	0.7–1.1

Energy Mix	Carbon Footprint (kg CO_2 eq/m^3)
Europe	1.3–1.9[1]
Israel	2.1
California	0.5–1.0
South Africa	0.1–0.7
Spain	-2.1–0.8
United States	1.7
Photovoltaic	0.2
Solar Thermal	0.1
Low Emissions[2]	0.9

[1]Based on Europe 2020 mix, which is composed of 35% renewable electricity production

[2]Low emissions refers to "a mix of renewable energy and current California sources" (Stokes and Horvath, 2009).

Source: Mihelcic, J.R., Zhang, Q., Hokanson, D.R., Cornejo, P.K., Santana, M.V., Rocha, A.M., Ness, S. J. (2013). "Feasibility Study on Model Development to Estimate and Minimize Greenhouse Gas Concentrations and Carbon Footprint of Water Reuse and Desalination Facilities," Project Report 10-12, 148 pages, WateReuse Research Foundation, Alexandria, VA.

Energy Mix: Emissions and Generation Resource Integrated Database (eGRID)

- eGRID provides conversion factors that allow a user to convert electricity usage (reported as MWh or GWh) to lbs of CO_2, CH_4, N_2O, and CO_2e.

- What is unique about eGRID is it makes this conversion using the energy mix that is unique to a particular region of the U.S. This is because the greenhouse gas emissions associated with electricity generation from consuming a particular amount of electricity differs around the country. This is based on a region's energy mix used to produce electricity that can consist of coal, natural gas, nuclear, hydro, biomass, wind, and solar.

Comparison of Greenhouse Gas Emission Rates in U.S. and several regions (data from eGRID2007 version 1.1, year 2005 data).

See http://www.epa.gov/egrid for data for all 26 U.S. subregions.

eGRID subregion name	CO_2 (lb/MWh)	CH_4 (lb/GWh)	N_2O (lb/GWh)	CO_2e (lb/MWh)
WECC California	724.12	30.24	8.08	727.26
SERC Virginia /Carolina	1,134.88	23.77	19.79	1,141.51
SERC Midwest	1830.51	21.15	30.50	1,840.41
FRCC all (Florida)	1,318.57	45.92	16.94	1,324.79
U.S.	1,329.35	27.27	20.60	1,336.31

Relating Individual Greenhouse Gas Emissions to Carbon Footprint

Greenhouse Gases (GHG)	GHG Emissions (kg)	Global Warming Potential*	Carbon Footprint (kg CO_2 equivalent)
CO_2	100	1	100
CH_4	10	25	250
N_2O	1	298	298

*IPCC Fourth Assessment Report 100-year time horizon

Total Carbon Footprint = 100 + 250 + 298 = 648 kg CO_2 equivalent

eGRID does not account for line losses

- eGRID is based on generation of electricity and does not account for line losses from the point of generation to the point of consumption.
- Line losses range from 2.795% in Alaska, 3.691% in Hawaii, 5.333 in the Western U.S., 6.177% in Texas, and 6.409% in the Eastern U.S. (with a U.S. average of 6.179%).
- If a user wants to account for line losses in the estimation of greenhouse gas emissions, they would have to divide the eGRID generated greenhouse gas emissions by [1 – (percent line losses/100)] to determine the total greenhouse gas emissions that result from consumption of electricity

from Mihelcic, J.R., J.B. Zimmerman, Environmental Engineering: Fundamentals, Sustainability, Design, 2nd Edition, John Wiley & Sons, New York, 2013.

Example: Determine Carbon Footprint from Electricity Consumption Data

- Assume you own a building in Virginia or the Carolinas and you consume 11,000 kWh of electricity per year for heating, cooling, lighting, and operation of electronics and appliances. What is the amount of direct greenhouse gas emissions associated with CO2, CH4, and N2O (and the overall carbon footprint) for operating the building? Ignore line losses in your calculations.

from Mihelcic, J.R., J.B. Zimmerman, Environmental Engineering: Fundamentals, Sustainability, Design, 2nd Edition, John Wiley & Sons, New York, 2013.

Problem: 11,000 kWh of electricity per year. What is the amount of direct greenhouse gas emissions associated with CO2, CH4, and N2O (and the overall carbon footprint) for consuming this energy? Ignore line losses in your calculations.

eGRID subregion name	**CO_2 (lb/MWh)**	**CH_4 (lb/GWh)**	**N_2O (lb/GWh)**	**CO_2e (lb/MWh)**
WECC California	**724.12**	**30.24**	**8.08**	**727.26**
SERC Virginia/ Carolina	**1,134.88**	**23.77**	**19.79**	**1,141.51**
SERC Midwest	**1830.51**	**21.15**	**30.50**	**1,840.41**
FRCC all (Florida)	**1,318.57**	**45.92**	**16.94**	**1,324.79**
U.S.	**1,329.35**	**27.27**	**20.60**	**1,336.31**

Solution – Estimate GHG Emissions

- Using the conversion factors provided by eGRID (and listed in previous table for the sub-region of Virginia and the Carolinas), you can determine that the emissions of specific greenhouse gas emissions associated with operating this building as: 12,484 lb CO_2, 261 lb CH_4, and 218 lb N_2O. There are 1,000 kW in 1 MW and 1,000,000 kW in 1 GW. These emissions do not account for line losses which are 6.409% in the Eastern U.S. To account for line losses, divide these eGRID generated emission values by (1-6.409/100).

from Mihelcic, J.R., J.B. Zimmerman, Environmental Engineering: Fundamentals, Sustainability, Design, 2nd Edition, John Wiley & Sons, New York, 2013.

- You can determine the carbon footprint by one of two methods. The easiest is to multiply the electricity consumption of 11,000 kWh by the CO_2e conversion factor of 1,141.51 lb CO_2e/MWh provided by eGRID (and listed in previous Table).

$$11{,}000 \text{ kW} \times 1{,}141.51 \text{ lb } CO_2e/\text{MWh} \times \text{MW}/1{,}000 \text{ kW} =$$

$$= 12{,}556 \text{ lb } CO_2e$$

This results in a value of 12,556 lb CO_2e.

Problem: 11,000 kWh of electricity per year. What is the amount of direct greenhouse gas emissions associated with CO2, CH4, and N2O (and the overall carbon footprint) for consuming this energy? Ignore line losses in your calculations.

eGRID subregion name	CO_2 (lb/MWh)	CH_4 (lb/GWh)	N_2O (lb/GWh)	CO_2e (lb/MWh)
WECC California	724.12	30.24	8.08	727.26
SERC Virginia/ Carolina	1,134.88	23.77	19.79	1,141.51
SERC Midwest	1830.51	21.15	30.50	1,840.41
FRCC all (Florida)	1,318.57	45.92	16.94	1,324.79
U.S.	1,329.35	27.27	20.60	1,336.31

Solution – Estimate Carbon Footprint – Method 2

- You can find the solution in a longer manner, summing the contribution from each of the three greenhouse gases accounted for by eGRID, using the GWPs listed in Table.

- 11,000 kW x 1,134.88 lb CO2/MWh x MW/1,000 kW = 12,484 lb CO2 = 12,484 lb CO2e
- 11,000 kW x 23.77 lb CH4/GWh x GW/106 kW = 0.26 lb CH4 x 25 lb CO2e/lb CH4 = 6.5 lb CO2e
- 11,000 kW x 19.79 lb N2O/GWh x GW/106 kW = 0.22 lb CH4 x 298 lb CO2e/lb N2O = 65.5 lb CO2e

- The total GHG emissions in CO2e are the sum of these three values and equals 12,556 lb CO2e.

- Note the large amount of CO2 emissions from electricity generation here compared to the contribution of CH4 and N2O (even with their higher GWPs). This value is the carbon footprint of the building for one year when only considering direct emissions.
- Remember, these emissions do not account for line losses which are 6.409% in the Eastern U.S. To account for line losses, divide these eGRID generated emission values by [1 - (6.409/100)]. So footprint is now 13,416 lb CO2e

Previous example problem adapted from Rothschild et al., 2009, from Mihelcic, J.R., J.B. Zimmerman, *Environmental Engineering: Fundamentals, Sustainability, Desig*n, 2nd Edition, John Wiley & Sons, New York, 2013.

- You can now use e-GRID data and your specific electricity bills to determine GHG emissions and carbon footprint associated with your on site energy use.
- How about if you wish to consider emissions that consider the whole life cycle?

Available Models to Estimate GHG Emissions and Carbon Footprint

Practical Implications For Industry

- Limiting factor: data currently collected by industry
- Recommendation on data collection (at minimum)
  - information on electricity providers
  - the amount of water pumped and produced
  - facility-wide electricity usage
- Model development is needed
  - a user-friendly and robust model
  - applicable to different geographical regions
  - have an option that would require different levels of sophistication related to required input parameters

Method Used in Available Estimation Models

GHG Emission Estimation Method	Description of Methodology	Examples of Models that Fit this Methodology
Traditional LCA	Use process-based inventory	SimaPro, GaBi
Hybrid LCA-based models	Use both process-based and input-output-based inventory	Water Energy Sustainability Tool (WEST), WWEST, and WESTWeb
Specific models for estimating GHG emissions	Uses input parameters specific to user	Johnston Model, Tampa Bay Water Model
Other related models	NOT specifically used to estimate emissions from water reuse facilities, but contain aspects that are applicable	UKWIR Model, UK Environmental Agency Model, CHEApet, Systems Dynamics, GPS-X Model, mCO2, Bridle and BSM2G

Hybrid Models use combination of EIO-LCA and Process-Based LCA

- **EIO-LCA** relies on national economic input-output (EIO) tables (showing relationship between different sectors of the economy) coupled with environmental impact tables to quantify metrics such as GHG emissions based on a set level of economic activity (i.e., the cost of equipment, pipes, chemicals)
- **Process-based LCA** is more detailed in that the environmental impacts are based on a specific analysis of the components in the system or product you choose to analyze. Emissions due to production of materials are calculated by EIO-LCA, emissions associated with energy production, transportation, and equipment usage are calculated using Process-Based LCA

Summary of Model Availability

Model Type	Emission Models	Tool Type	Available	Website or Contact Information
LCA-based models	SimaPro	Software	Commercially	www.pre.nl
	Gabi	Software	Commercially	www.gabi-software.com
	SiSOSTAQUA	Software	Commercially	www.simpple.com
Hybrid LCA-based	WEST	MS-Excel	Upon request	Dr. Jennifer Stokes at ucbwaterlca@gmail.com
	WWEST	MS-Excel	Upon request	Dr. Jennifer Stokes at ucbwaterlca@gmail.com
	WESTWeb	Web-based	Publically	west.berkeley.edu
Specific models	Tampa Bay Water	MS-Excel	Upon request	www.tampabaywater.org
	Johnston Model	MS-Excel	Upon request	Dr. Tanju Karanfil at tkaranf@clemson.edu
Other related models	CHEApet	Web-based	Publically	cheapet.werf.org
	UK Environment Agency Model	MS-Excel	Upon request	enquiries@environment-agency.gov.uk
	Bridle and BSM2G Models	Software	Publically	Author Lluis Corominas at lcorominas@icra.cat
	System Dynamics	Software	Commercially	www.iseesystems.com
	GPS-X	Software	Commercially	www.hydromantis.com/GPS-X.html
	Carbon Accounting Workbook, 5th version	MS-Excel	Commercially	www.ukwir.org
	mCO2	Software	Commercially	www.mwhglobal.com

Emission Sources Considered in Hybrid LCA and Specific Models

Emission Sources Considered	Hybrid LCA Models			Specific Models	
	WEST	WWEST	WESTWeb	Johnston Model	Tampa Bay Water Model
Material production	X	X	X		
Material delivery	X	X	X		
Electricity consumption	X	X	X	X	X
Electricity mix	X	X	X	X	X
Fuel use (on-site and fleet vehicles)	X	X	X	X	
Sludge disposal	X	X	X	X[1]	
Chemical production	X	X	X	X	
Direct process emissions		X[2]	X[2]	X[1]	
Process equipment			X[3]	X[4]	
Disinfection processes			X[3]	X[4]	

Applicability of Hybrid LCA and Specific Models

Applicability & Availability	Hybrid LCA Models			Specific Models	
	WEST	WWEST	WESTWeb	Johnston Model	Tampa Bay Water Model
Previously applied to water reuse	X				
Previously applied to desalination	X				X
Designed for wastewater facilities		X			
Designed for water facilities				X	
Designed for regional water supply					X
Currently regionally transferable	X	X	X	X	
Custom, state, and national electricity mix	X	X	X	X	
Available upon request	X	X	X	X	X

Comparison of WEST and Tampa Bay Models

Output Comparison of Carbon Footprint Using Tampa Bay Water and WEST Models

Facility	**Tampa Bay Water Model**	**WEST Model**[1]	**% Tampa Bay Water Model of WEST Model Estimate**
	CO_2eq (kg)/m^3 Produced	CO_2eq (kg)/m^3 Produced	
Desalinated seawater, membrane pretreatment	1.26	2.40	52%
Desalinated brackish groundwater	1.20	1.63	74%
Recycled water	0.53	1.02	52%

- Tampa Bay Water model: includes only electricity consumption
- WEST model: electricity consumption, fuel use by equipment and vehicles, chemical and material production

Example from: Mihelcic, J.R., Zhang, Q., Hokanson, D.R., Cornejo, P.K., Santana, M.V., Rocha, A.M., Ness, S. J. (2013). "Feasibility Study on Model Development to Estimate and Minimize Greenhouse Gas Concentrations and Carbon Footprint of Water Reuse and Desalination Facilities," Project Report 10-12, 148 pages, WateReuse Research Foundation, Alexandria, VA.

Tampa Bay Water Model

- Developed By Tampa Bay Water
  - Responsible for the extraction, treatment, and sale of water to member jurisdictions in the Tampa Bay metropolitan area
  - Model determines GHG emissions associated with water treatment of its facilities

Tampa Bay Water Model

Model Inputs	Units	Data Source
Water pumped	(MG/yr)	In-house
Water produced	(MG/yr)	In-house
Electricity Use from Pumping	kWh/yr	In-house
Gross load	MWh used/yr	U.S. EPA eGRID or CAM
CO_2 emission factors based on energy mix	Tons/yr	U.S. EPA eGRID or CAM
CH_4 emission factors based on energy mix	Tons/yr	U.S. EPA eGRID or CAM
N_2O emission factors based on energy mix	Tons/yr	U.S. EPA eGRID 2005
Electricity mix	% per source	U.S. EPA data and utility contacts

Model Outputs
CO_2 eq, CO_2, N_2O, & CH_4 emissions (lbs/kWh)
CO_2 eq, CO_2, N_2O, & CH_4 emissions (lbs/yr)
CO_2 eq, CO_2, N_2O, & CH_4 emissions (lbs/MG)

Tampa Bay Water Model

From internal operations data

1. Calculate Energy consumption per water produced

$$\frac{EnergyConsumed\ (kWh)}{WaterProduced\ (MG)} = \frac{EnergyConsumed\ (kWh)}{WaterPumped\ (MG)} * \frac{AnnualWaterPumped\ (MGY)}{AnnualWaterProduced\ (MGY)}$$

2. Calculate annual energy consumption

$$EnergyConsumption\left(\frac{kWh}{yr}\right) = \frac{EnergyConsumed(kWh)}{WaterProduced(MG)} * WaterProduced(MGD) * \frac{365d}{yr}$$

3. Convert annual energy use to emissions

From eGRID

$$Emission\left(\frac{lbs}{yr}\right) = EmissionFactor\left(\frac{lbs}{kWh}\right) * EnergyConsumption\left(\frac{kWh}{yr}\right)$$

Where

$$Emission\ Factor\left(\frac{lbs}{kWh}\right) = \frac{EmissionfromPowerProvider\left(\frac{tons}{yr}\right)}{EnergyUsedbyPowerProvider\left(\frac{MWh}{yr}\right)} * \left(\frac{2000lbs}{ton}\right) * \left(\frac{MWh}{1000kWh}\right)$$

4. Convert amount of energy consumed/MG water to emissions/MG of water

$$Emission\left(\frac{lbs}{MG}\right) = EmissionFactor\left(\frac{lbs}{kWh}\right) * \frac{EnergyConsumed(kWh)}{WaterProduced(MG)}$$

Tampa Bay Water Model

Water Produced

Energy Use

	m3/yr	kWh/yr	MGD (Produced)	kWh/day	kwh/MG (Produced)	CO_2e lbs/day	CO_2e (lbs)/MG (Produced)	CO_2e kg/m3(Produced)
Water Supply								
Desal Seawater	*36000000*	*183,600,000*	26.0553	503013.6986	19305.6039	272681.7140	10465.4907	**1.256677932**
Desal Brackish	*36000000*	*103,680,000*	26.0553	284054.7945	10901.9881	153984.9679	5909.9241	**0.709653421**
Reused	*36000000*	*77,040,000*	26.0553	211068.4932	8100.7828	114419.3859	4391.4020	**0.527311917**

Adapted from Model provided by Tampa Bay Water

Inputs

Outputs

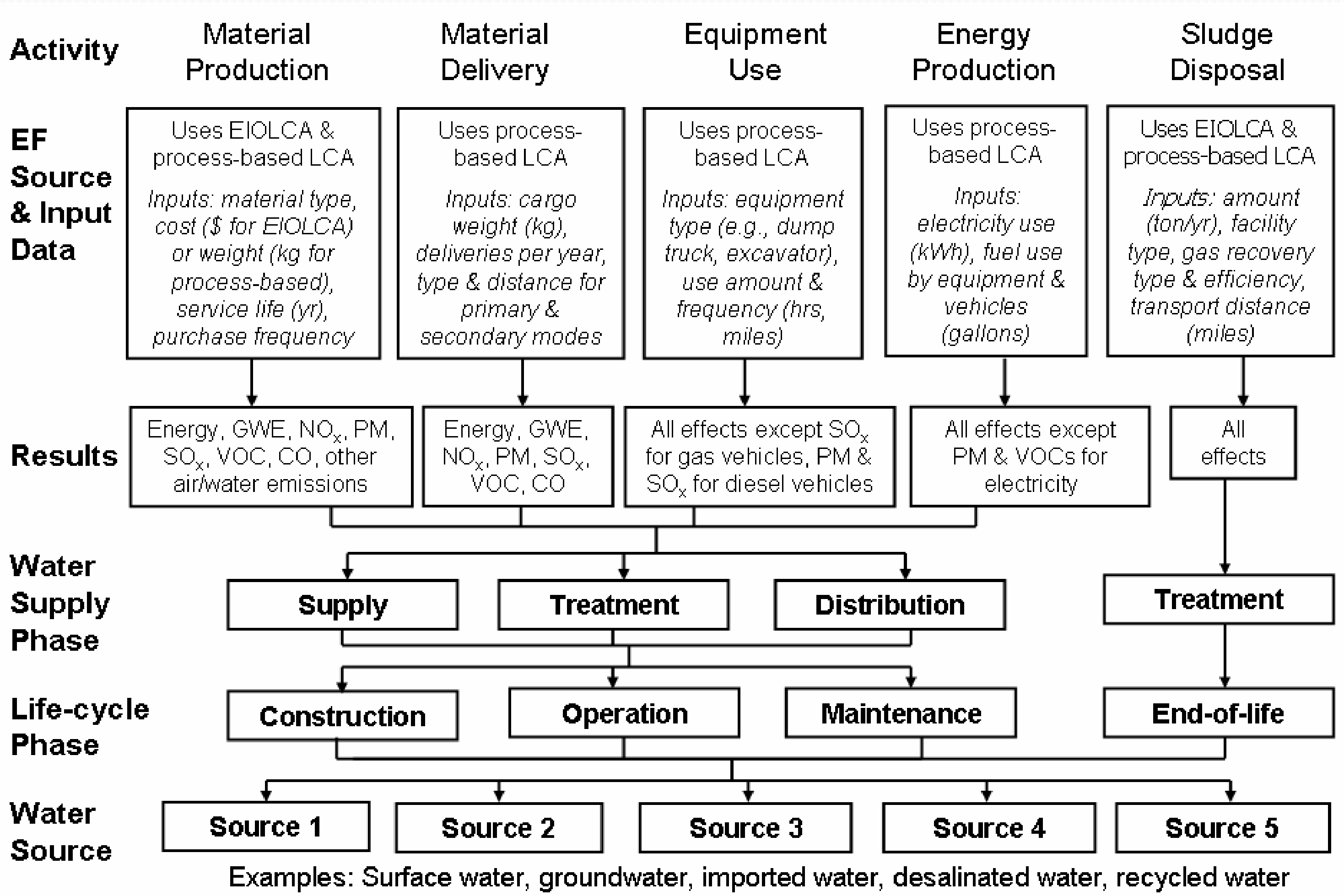
Water Energy Sustainability Tool (WEST)

- Excel-based
  - Obtainable by contacting developers
  - http://west.berkeley.edu/model.php
- WESTWeb – Online interface
  - http://west.berkeley.edu/tool.php
- Water and Wastewater Treatment
- Hybrid-Life Cycle Assessment Based
- Calculates: CO_2-eq, NO_x, SO_x, PM_{10}, VOC, CO

WEST

- Composed of Environmental Assessment Methods
  - Economic Input Output (EIO)-LCA
    - Emissions from Materials Production
  - Process-Based LCA
    - Energy Generation
    - Transportation of Resources
    - Equipment Use

Framework of WEST Model



WEST

- The next few slides are to orient you with the WESTweb interface, as it is relatively easy to use.
- The website to access this program will be provided at end of talk. However, the Excel-based version, WEST, can be obtained by contacting the developers.

WESTWeb Interface

WEST Web BETA

Modeling Parameters

Select system type: Water

Units selection: SI (metric)

Enter number of scenarios: 3

Functional Unit: 1000 (liters)

- Water or wastewater
- Units
- Number of Scenarios
- Scenario Capacities

Annual Water or Wastewater Production

Enter scenario production volume (in liters):

Scenario #	Scenario Name	Annual Scenario Production
1	Desalinated Seaw	36000000000
2	Desalinated Brack	36000000000
3	Recycled Water	36000000000

http://west.berkeley.edu/tool.php#results

WESTWeb Interface

Can include:

- Transport infrastructure information
- Material information (optional
- Processes (optional)

Infrastructure

Pipe Length and Material

Would you like to enter detailed data about pipe materials? No

Enter total length (in meters):

	Scenario #1 (meters)	Scenario #2 (meters)	Scenario #3 (meters)
Supply	3200	4800	1000
Treatment			
Distribution	1003000	1000000	35000

Reinforced Concrete Materials

Would you like to enter detailed data about buildings and pre-cast structures? No

Enter total volume of reinforced concrete (in cubic meters):

	Life (years)	Scenario #1 (cubic meters)	Scenario #2 (cubic meters)	Scenario #3 (cubic meters)
Supply				
Treatment	75			
Distribution				

Process Equipment

Would you like to enter detailed data about process equipment? No

WESTWeb Interface

Process Equipment

Would you like to enter detailed data about process equipment? Yes

Enter the dollars spent (in 2002$) on process equipment. Only include the purchase price; do not include labor or delivery costs.

Legend: ⬅ denotes supply, ⇄ denotes treatment, ➡ denotes distribution.

Component	Life (years)	Scenario 1 (2002$) ⬅	⇄	➡	Scenario 2 (2002$) ⬅	⇄	➡
Filtration							
Filter Media (Sand or Gravel)	15						
Filter Media (Anthracite or Other Coal Product)	15						
Membranes	7						
General							
Pumps	15						
Fans / Blowers	10						
Motors and Generators	15						
Turbines	30						
Metal Tanks	30						
UV Lamps / Lights	3						
Other Industrial Equipment	15						
Electrical	15						
Controls	10						

WESTWeb Interface

Operation

Electricity Mix

Electricity Mix Location: US

Enter percentages for each scenario's electricity primary fuel/energy source:

	US Mix
Coal	49.61%
Oil	3.73%
Natural Gas	18.77%
Nuclear	19.28%
Hydro	6.5%
Biomass	1.3%
Wind	0.44%
Solar	0.01%
Geothermal	0.36%
Total	100%

State energy mix can be specified

http://west.berkeley.edu/tool.php#results

WESTWeb Interface

*Use annual values

http://west.berkeley.edu/tool.php#results

Energy Use

Enter quantities of energy consumed for each scenario:

Annual Consumption of:	Scenario 1			Scenario 2			Scenario 3		
Electricity (MWh)		13680	144000		9360	86400		16200	6840
Natural Gas (MMBTU)									
Gasoline (liters)									
Diesel (liters)									

Treatment Chemical Consumption

Enter quantities of chemicals used in each scenario:

	Units	Scenario #1	Scenario #2	Scenario #3
pH Adjustment				
Hydrochloric Acid	kg/yr	2916000	2340000	
Sulphuric Acid	kg/yr			
Lime	kg/yr			
Coagulants & Flocculants				
Aluminum Sulfate	kg/yr			1908000
Aluminum Hydroxide	kg/yr			
Caustic Soda	kg/yr		612000	
Ferric Chloride	kg/yr	14400		
Polymers	kg/yr			
Disinfectants				
Chlorine	kg/yr			684000
Calcium Hypochlorite	kg/yr	234000	396000	
Ozone	kg/yr			
Aqueous Ammonia	kg/yr	302400	468000	
Others				
Fluorosilicic Acid	kg/yr			
Other Chemicals	$/yr			

WESTWeb Interface - Results

Scenario 3 Results
↳ **Recycled Water**

				GHG g CO2e/FU	EN MJ/FU
INFRASTRUCTURE	Piping	Pipe	←	0	0
			⇄	-	-
			→	1	0
	Concrete and Buildings	Concrete and Buildings	←	-	-
			⇄	-	-
			→	-	-
OPERATION	Energy Use	Electricity	←	-	-
			⇄	296	4
			→	125	1
		Natural Gas	←	-	-
			⇄	-	-
			→	-	-
		Equipment Fuels	←	-	-
			⇄	-	-
			→	-	-
	Chemicals	pH Adjustment	⇄	-	-
		Flocculants / Coagulants	⇄	15	0
		Disinfectants	⇄	25	0
		Other	⇄	-	-
Σ	Infrastructure		←	0	0
			⇄	-	-
			→	1	0
	Operation		←	-	-
			⇄	337	5
			→	125	1
	End-of-Life		→	-	-
	Scenario 3 Grand Total			464	7

http://west.berkeley.edu/tool.php#results