BEAM -- Accounting for Greenhouse Gas Emissions from Biosolids Management

ANZBP Lunch & Learn Webinar
February 2024

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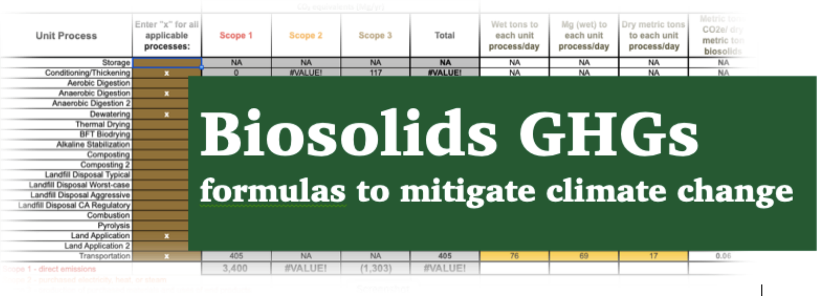
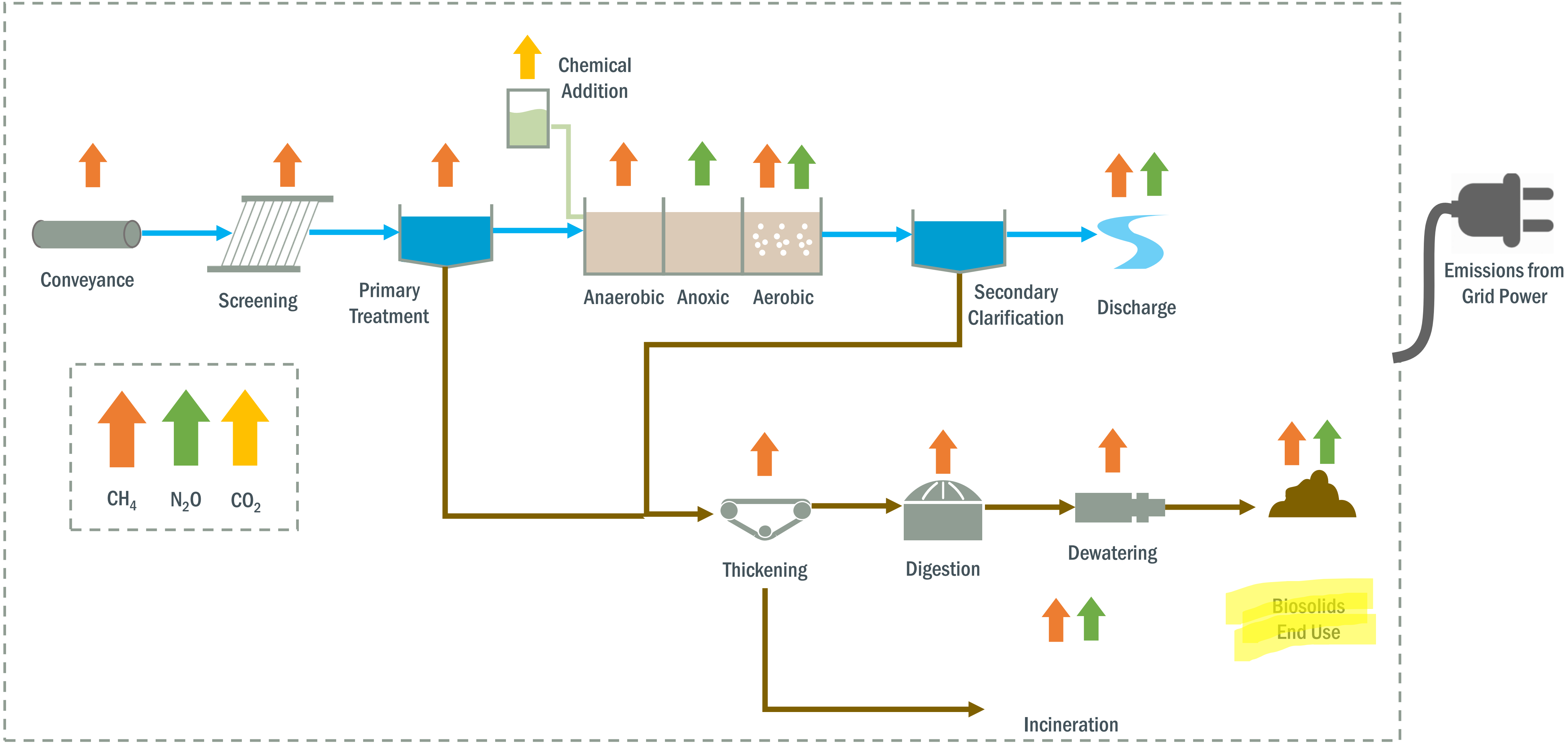
North East Biosolids & Residuals Association



What We Will Cover Today

- History of the Biosolids Emissions Assessment Model (BEAM)
- BEAM Basics
- Current version and planned updates
- How BEAM can be used
  - Examples from water resource recovery facilities (WRRFs)
- BEAM findings, lessons learned, future uses

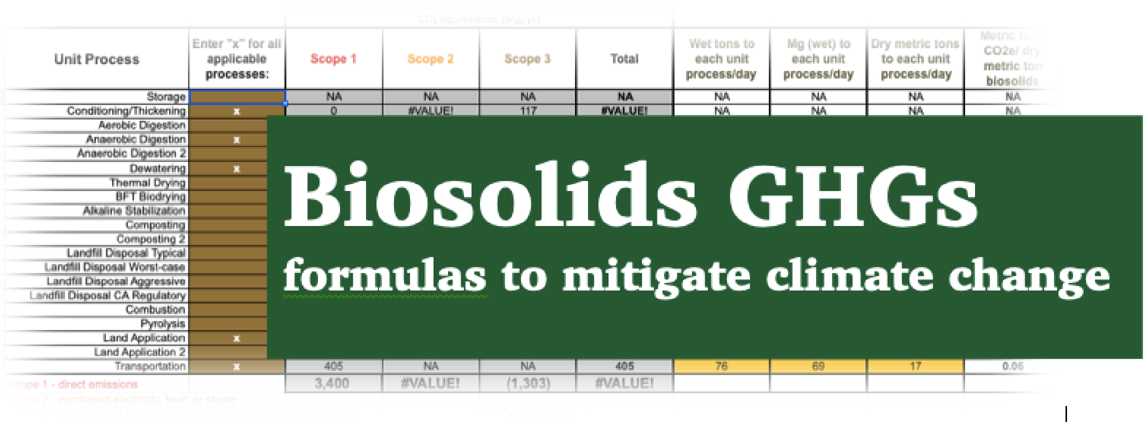
GHG Emission Sources from Wastewater Treatment Processes



Water Environment Federation
the water quality people®

Disclaimer: Wastewater treatment greenhouse gas emissions are highly variable and process-specific. This figure is generalized and does not account for variables that could introduce or eliminate emissions from certain processes

Biosolids Emissions Assessment Model (BEAM)



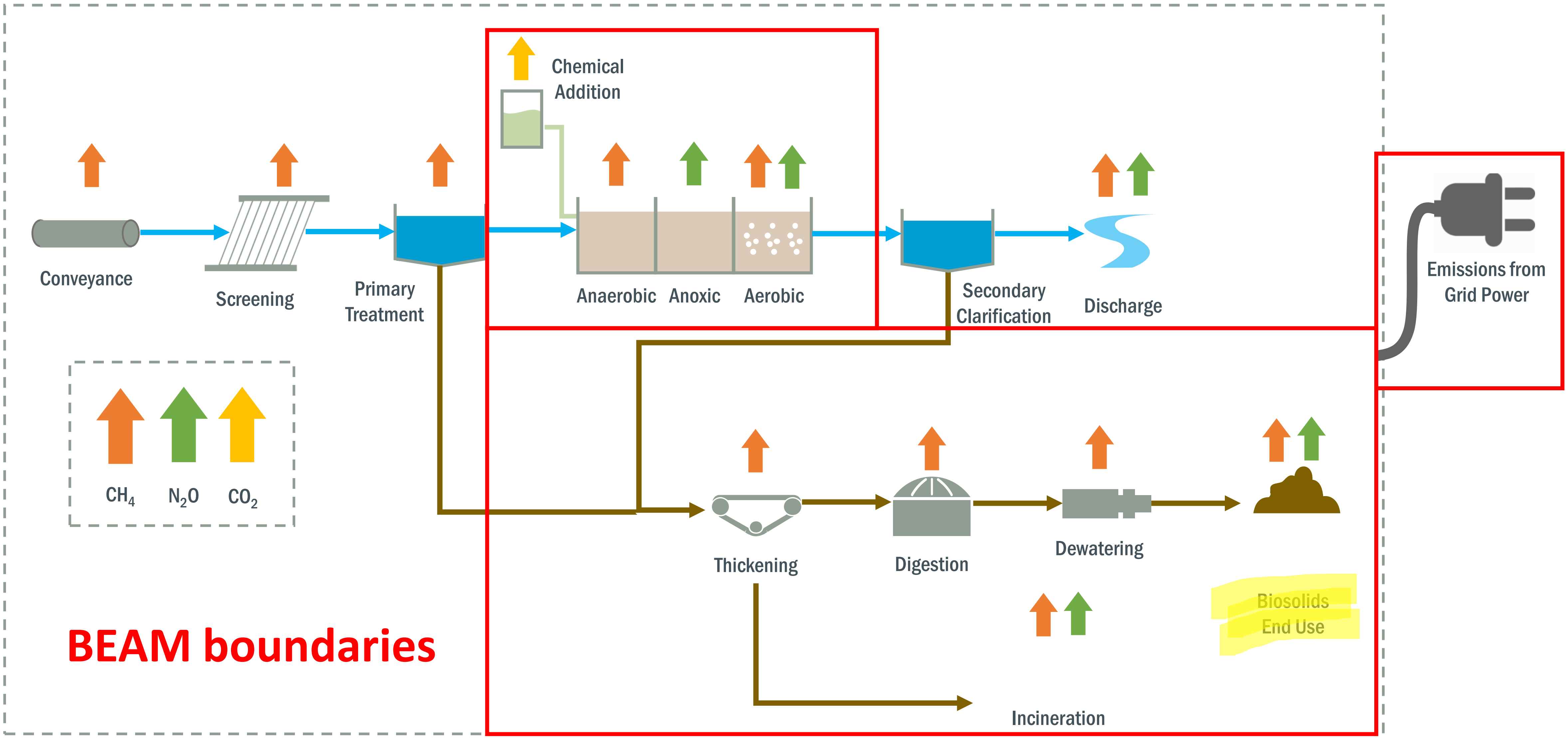
What is it?

- Excel spreadsheet
- Just for solids, not whole WRRF
- Scopes 1, 2, 3, and biogenic emissions
- Emissions factors from published literature

Purpose (from original CCME User Guide, 2009):

- estimate a program’s GHG emissions, including establishing a baseline
- compare different biosolids management scenarios
- estimate impacts from changes in biosolids management
- understand the factors that have the greatest impact on GHG emissions

GHG Emission Sources from Wastewater Treatment Processes



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Disclaimer: Wastewater treatment greenhouse gas emissions are highly variable and process-specific. This figure is generalized and does not account for variables that could introduce or eliminate emissions from certain processes

BEAM – Background and History

2008 - 2009 BEAM created under contract from Canadian Council of Ministers of the Environment (CCME) by Sylvis (Mike van Ham, Mark Teshima, John Lavery); with assistance from Sally Brown (Univ. of WA), Andrew Carpenter (Northern Tilth), and Ned Beecher (NEBRA)

2009 BEAM 1.0 & User Guide published by CCME

Oct. 2010 BEAM 1.1, paper, and supplemental material by Brown et al. in Env. Sci. & Tech.

2011 CCME publishes BEAM 1.1

2021 CCME allows updates but is no longer formally involved

2021 Effort to update BEAM merged with Northwest Biosolids online GHG calculator project

Nov. 2021 North East Biosolids & Residuals Association (NEBRA) takes on BEAM*2022 development and publishes it & new website, Sept. 2022.

2023-24 next update by Science Review Team (SRT)

2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023

BEAM*2022 and the new www.BiosolidsGHGs.org launched on September 20, 2022!

Updates Included:

Up to 10 scenarios can be compared side by side
More options for unit processes (e.g., pyrolysis)
Key factors and calculations reviewed and updated
Updated user guide
Default values and suggested ranges
Regular reviews & updates by the Science Review Team

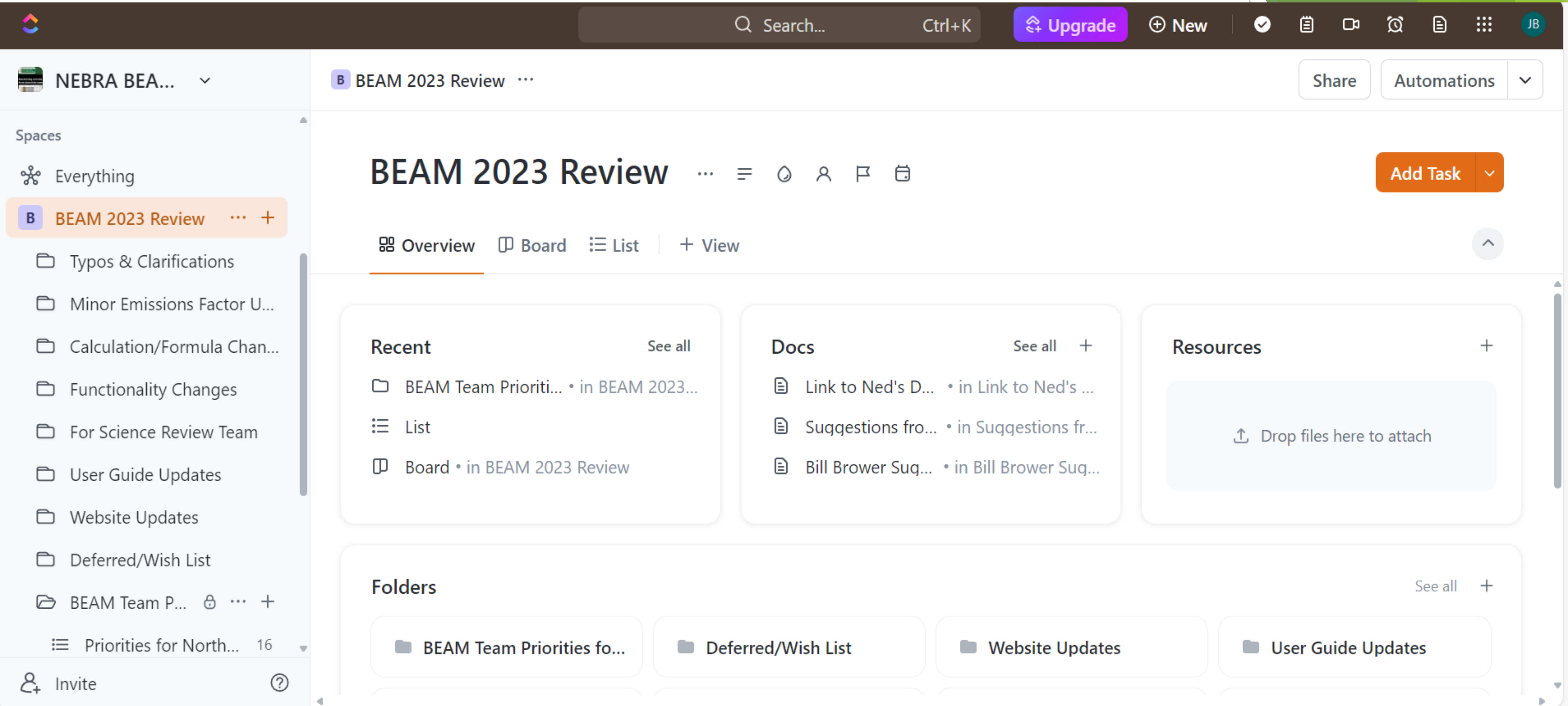
Thanks to the Science Review Teams (SRT)!

- **2022** Science Review Team (all PhDs)
  - Sally Brown (University of Washington), Washington state, USA
  - John Willis (Brown & Caldwell), Georgia, USA
  - Emma Shen (Jacobs), Toronto, Canada
  - Céline Vaneeckhaute (Université Laval), Quebec City, Canada
  - Mike Badzmierowski (Virginia Tech/ Oregon Department of Agriculture), OR, USA

- **2023-24** Science Review Team (all PhDs)
  - Sally Brown (University of Washington), Washington state, USA
  - Emma Shen (Jacobs), Toronto, Canada
  - Céline Vaneeckhaute (Université Laval), Quebec City, Canada
  - Tarek Abichou (Florida State University), Florida, USA
  - Ruth Richardson (Cornell University), New York state, USA

Identifying & tracking updates

ClickUp



BEAM is a Transparent Model!

References, Calculations, Assumptions and Default Values

Cell Color Key for References Worksheet	
[illegible]umber used in original BEAM calculations (CCME, 2011)	
Input Cell	
Calculated Result	
Constant	

Fuel & Transport

	CO_2 (kg/gal)	CH_4 (g/mi)	N_2O (g/mi)	Total CO2e (kg/gal)	
diesel emissions	10.21	0.0051	0.0048	10.21	https://www.geotab.com/truck-mpg-benchmark/)
	CO_2 (kg/ton-mile)	CH_4 (g/ton-mile)	N_2O (g/ton-mile)	[illegible]otal CO_2 eq (kg/ton-mile)	
rail emissions	0.023	0.0018	0.0006	0.023	from EPA emission factors for GHG Inventories - last mod. March 2018 - Table 9

CO_2 eq diesel (kg/gallon)	10.21	The Climate Registry's 2019 Default Emissions Factors
CO_2 eq diesel (g/L)	2,697	calculated from numbers above
Average truck miles/gal (diesel)	5.82	(for New York) From GeoTab data gathered from 31,170 trucks 2016-2017
Average truck km/l (diesel)	2.5	calculated from numbers above
Train hauling emissions (kg CO_2 eq/Mg-km)	0.016	calculated from numbers above

Natural Gas

CO_2 eq from combustion of natural gas(g/m^3)	1,901	Canadian default CO_2 emissions factors for combustion of natural gas - Climate Registry General Reporting Protocol V. 1.1
Heat content (Btu/m^3)	36,263	Canadian default CO_2 emissions factors for combustion of natural gas - Climate Registry General Reporting Protocol V. 1.1

Methane

density of methane gas (kg /m^3) - at standard temp. and pressure	0.71	EPA 2006, Solid Waste Management and GHG Emissions
Heat content of methane (Btu/m^3)	35,830	EPA 2004, Unit Conversions, Emissons Factors, and Other Reference Data

Propane

Mg CO_2 eq/cylinder	0.02	https://www.epa.gov/energy/greenhouse-gases-equivalencies-calculator-calculations-and-references
pounds propane/cylinder	18	https://www.epa.gov/energy/greenhouse-gases-equivalencies-calculator-calculations-and-references
CO_2 eq propane (Mg CO_2 eq/kg)	0.0029	

Wastewater Treatment Factors

Typical TSS in sludge after primary sedimentation (kg/1000 m^3)	150	Metcalf & Eddy, 2003, p. 1456
Expected solids concentration of combination primary/WAS unthickened sludge (%)	1.0%	Metcalf & Eddy, 2003, p. 1492
Expected solids concentration in sludge from gravity thickener, primary and WAS (%)	4%	Metcalf & Eddy, 2003, p. 1457

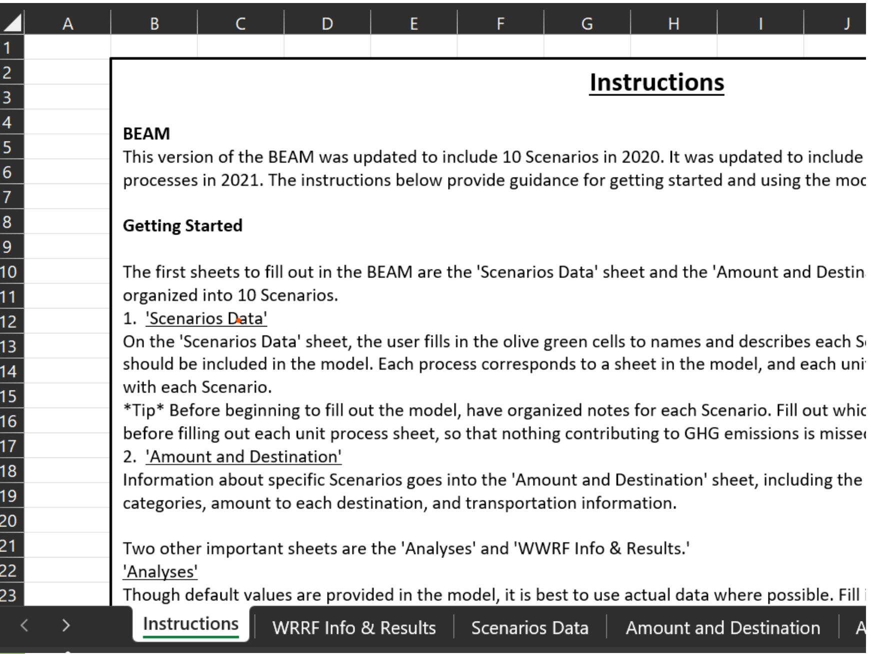
Typical Biosolids Characteristics (De-watered cake)

	unprocessed	*digested*	*limed*	
Total nitrogen (%-dry weight)	4.0%	5.0%	3.2%	Northern Til[illegible] sugg[illegible] [illegible] if data not available
Total phosphorus (%-dry weight)	1.5%	1.9%	1.2%	
TVS(%-dry weight)	78.0%	65.0%	52[illegible]%	

... | Landfill Disposal CA Regulatory | Combustion | Land Application (2) | Misc Emissions | References Assum[illegible] | Project Specific

All process assumptions and emission factors are listed in the Reference Assumptions tab.

THE NEW BEAM*2022
Screenshots



Instructions

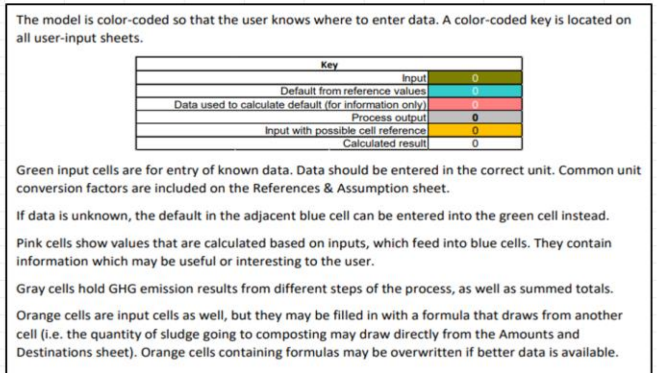
BEAM
This version of the BEAM was updated to include 10 Scenarios in 2020. It was updated to include processes in 2021. The instructions below provide guidance for getting started and using the moc

Getting Started

The first sheets to fill out in the BEAM are the 'Scenarios Data' sheet and the 'Amount and Destin organized into 10 Scenarios.
1. 'Scenarios Data'
On the 'Scenarios Data' sheet, the user fills in the olive green cells to names and describes each S should be included in the model. Each process corresponds to a sheet in the model, and each uni with each Scenario.
Tip Before beginning to fill out the model, have organized notes for each Scenario. Fill out whic before filling out each unit process sheet, so that nothing contributing to GHG emissions is missed
2. 'Amount and Destination'
Information about specific Scenarios goes into the 'Amount and Destination' sheet, including the categories, amount to each destination, and transportation information.

Two other important sheets are the 'Analyses' and 'WWRF Info & Results.'
'Analyses'
Though default values are provided in the model, it is best to use actual data where possible. Fill

Instructions | WRRF Info & Results | Scenarios Data | Amount and Destination



The model is color-coded so that the user knows where to enter data. A color-coded key is located on all user-input sheets.

Key	
Input	0
Default from reference values	0
Data used to calculate default (for information only)	0
Process output	0
Input with possible cell reference	0
Calculated result	0

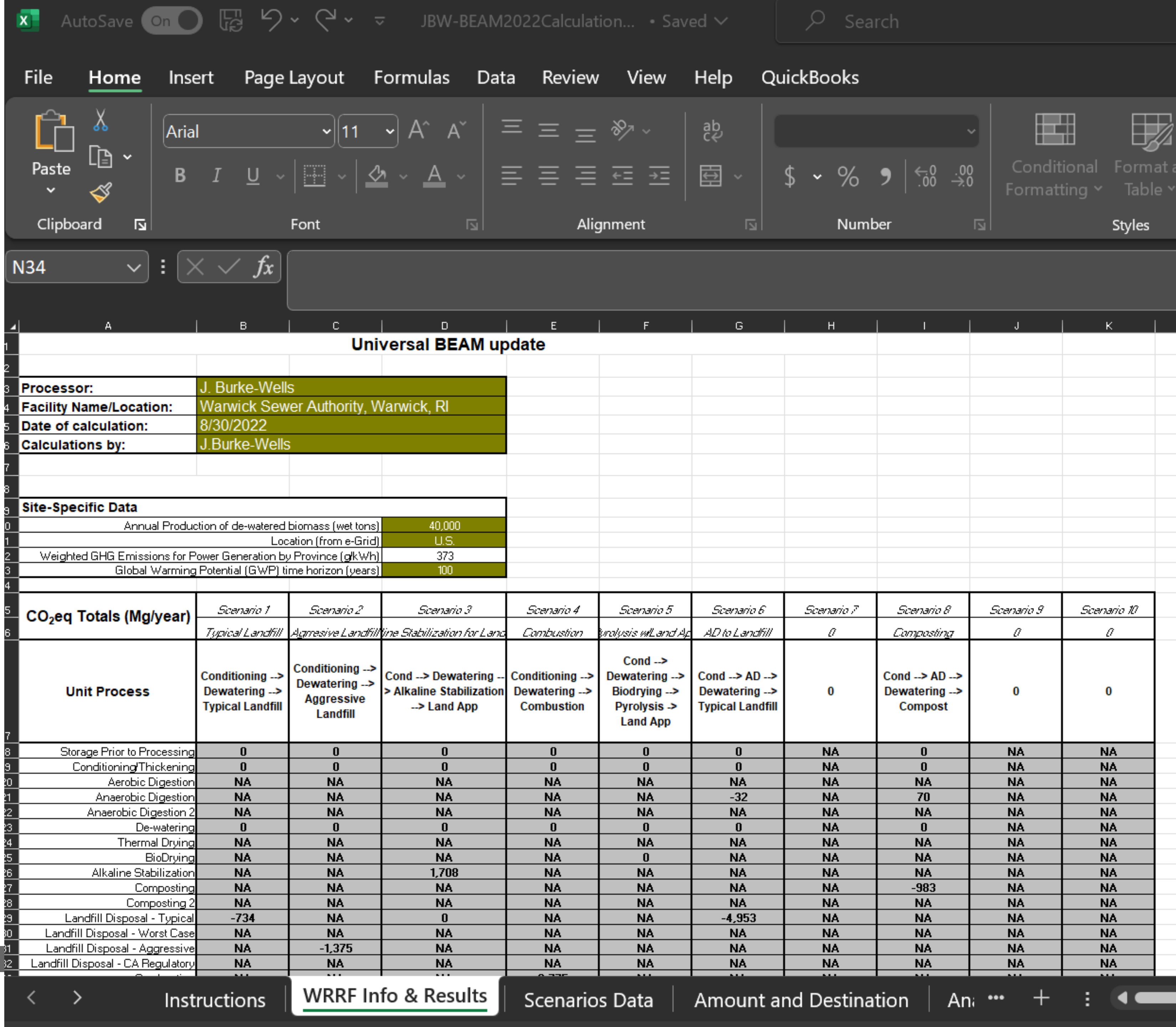
Green input cells are for entry of known data. Data should be entered in the correct unit. Common unit conversion factors are included on the References & Assumption sheet.

If data is unknown, the default in the adjacent blue cell can be entered into the green cell instead.

Pink cells show values that are calculated based on inputs, which feed into blue cells. They contain information which may be useful or interesting to the user.

Gray cells hold GHG emission results from different steps of the process, as well as summed totals.

Orange cells are input cells as well, but they may be filled in with a formula that draws from another cell (i.e. the quantity of sludge going to composting may draw directly from the Amounts and Destinations sheet). Orange cells containing formulas may be overwritten if better data is available.



JBW-BEAM2022Calculation... • Saved

Universal BEAM update

Processor:	J. Burke-Wells
Facility Name/Location:	Warwick Sewer Authority, Warwick, RI
Date of calculation:	8/30/2022
Calculations by:	J.Burke-Wells

Site-Specific Data	
Annual Production of de-watered biomass (wet tons)	40,000
Location (from e-Grid)	U.S.
Weighted GHG Emissions for Power Generation by Province (g/kWh)	373
Global Warming Potential (GWP) time horizon (years)	100

CO_2eq Totals (Mg/year)	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9	Scenario 10
	Typical Landfill	Agresive Landfill	ine Stabilization for Land	Combustion	rolysis w/Land Ap	AD to Landfill	0	Composting	0	0
Unit Process	Conditioning --> Dewatering --> Typical Landfill	Conditioning --> Dewatering --> Aggressive Landfill	Cond --> Dewatering --> Alkaline Stabilization --> Land App	Conditioning --> Dewatering --> Combustion	Cond --> Dewatering --> Biodrying --> Pyrolysis -> Land App	Cond --> AD --> Dewatering --> Typical Landfill	0	Cond --> AD --> Dewatering --> Compost	0	0
Storage Prior to Processing	0	0	0	0	0	0	NA	0	NA	NA
Conditioning/Thickening	0	0	0	0	0	0	NA	0	NA	NA
Aerobic Digestion	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Anaerobic Digestion	NA	NA	NA	NA	NA	-32	NA	70	NA	NA
Anaerobic Digestion 2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
De-watering	0	0	0	0	0	0	NA	0	NA	NA
Thermal Drying	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
BioDrying	NA	NA	NA	NA	0	NA	NA	NA	NA	NA
Alkaline Stabilization	NA	NA	1,708	NA	NA	NA	NA	NA	NA	NA
Composting	NA	NA	NA	NA	NA	NA	NA	-983	NA	NA
Composting 2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Landfill Disposal - Typical	-734	NA	0	NA	NA	-4,953	NA	NA	NA	NA
Landfill Disposal - Worst Case	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Landfill Disposal - Aggressive	NA	-1,375	NA	NA	NA	NA	NA	NA	NA	NA
Landfill Disposal - CA Regulatory	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Instructions | WRRF Info & Results | Scenarios Data | Amount and Destination | An

THE NEW BEAM*2022 Instructions

- Instructions
- Step 2: WRRF Info and Results
- Step 3: Scenarios Data
- Step 4: Amount and Destination
- Step 5: Analyses
- Step 6: Digestion Process
- Step 7: Unit Processes
- Step 8: Transportation
- Step 9: Inspect Results

Appendix A: Sheet-by-Sheet Instructions for E

Best practice is to save a copy of the original, unaltered s
all future projects. When beginning a new project, open
with a project-specific name. It may also be prudent to s
changes are made to a project's BEAM*2022 spreadshee
password protected to prevent accidentally changing formulas.
The following instructions are organized by worksheet, **listed in the order in which data should be added.**

Step 1: Instructions

Review the instructions prior to beginning work on the model.

Step 2: WRRF Info & Results

Fill in the olive green input cells with the project's basic information. Once all other worksheets are filled out, this worksheet displays emissions for each of 10 possible Scenarios in the gray output cells. The "Processor" refers to the entity managing the material that is being modeled. Emissions generated by each unit process are displayed in CO_2 equivalents per dry metric ton of material. Total emissions per scenario are also shown, broken down into CO_2, CH_4, N_20, and biogenic CO_2.

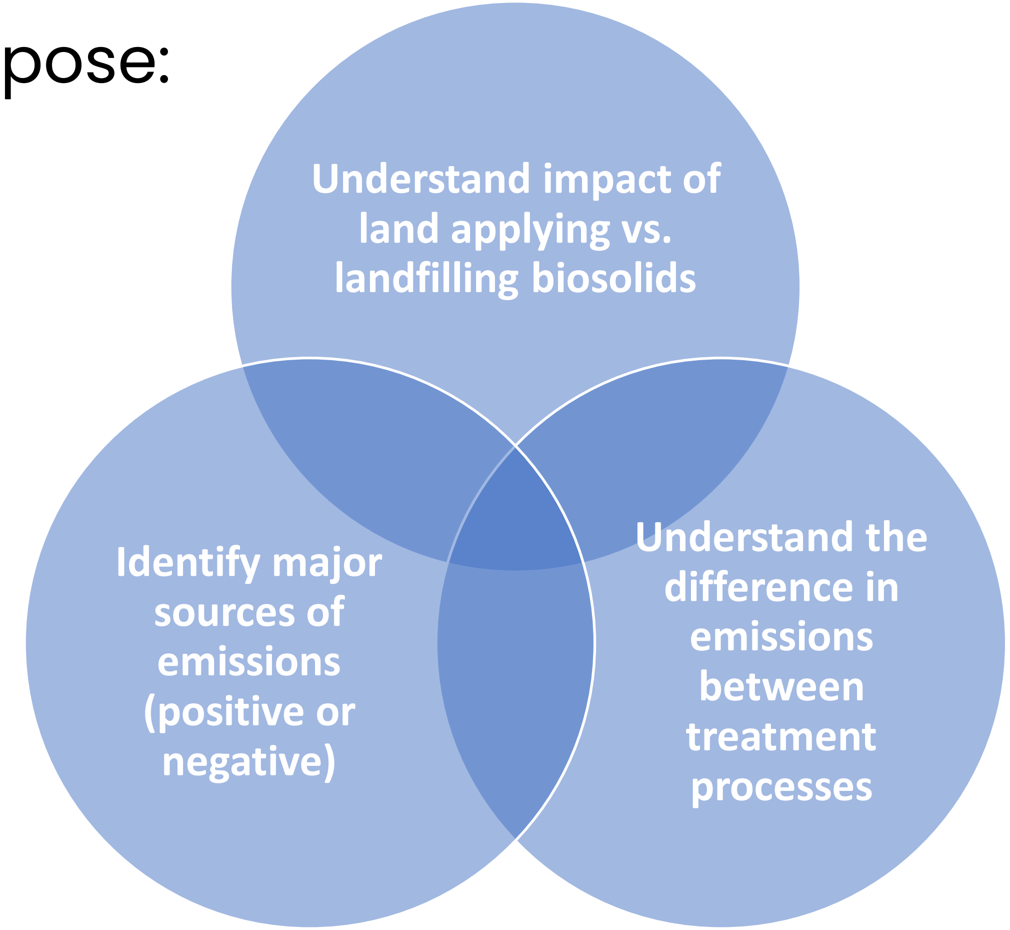
Input data for WRRF Info & Results sheet:

Site-Specific Data	Data Entry Notes
Annual Production of de-watered biosolids (wet tons)	*Entered for information purposes only; not used in model calculations*
Location (from e-Grid)	*Choose from drop-down list of e-Grid regions*
GWP time horizon (years)	*Choose from drop-down list: 20-year or 100-year time horizon for Global Warming Potentials. BEAM*2022 default CO_2-eq for CH_4 & N_2O follow the IPCC's 4th Assessment Report. Users have option to overwrite the CO_2-eq values in the References & Assumptions worksheet if needed; see notes under Section 7: References & Assumptions of this User Guide.*

THE NEW BEAM*2022

Example of Use

Purpose:



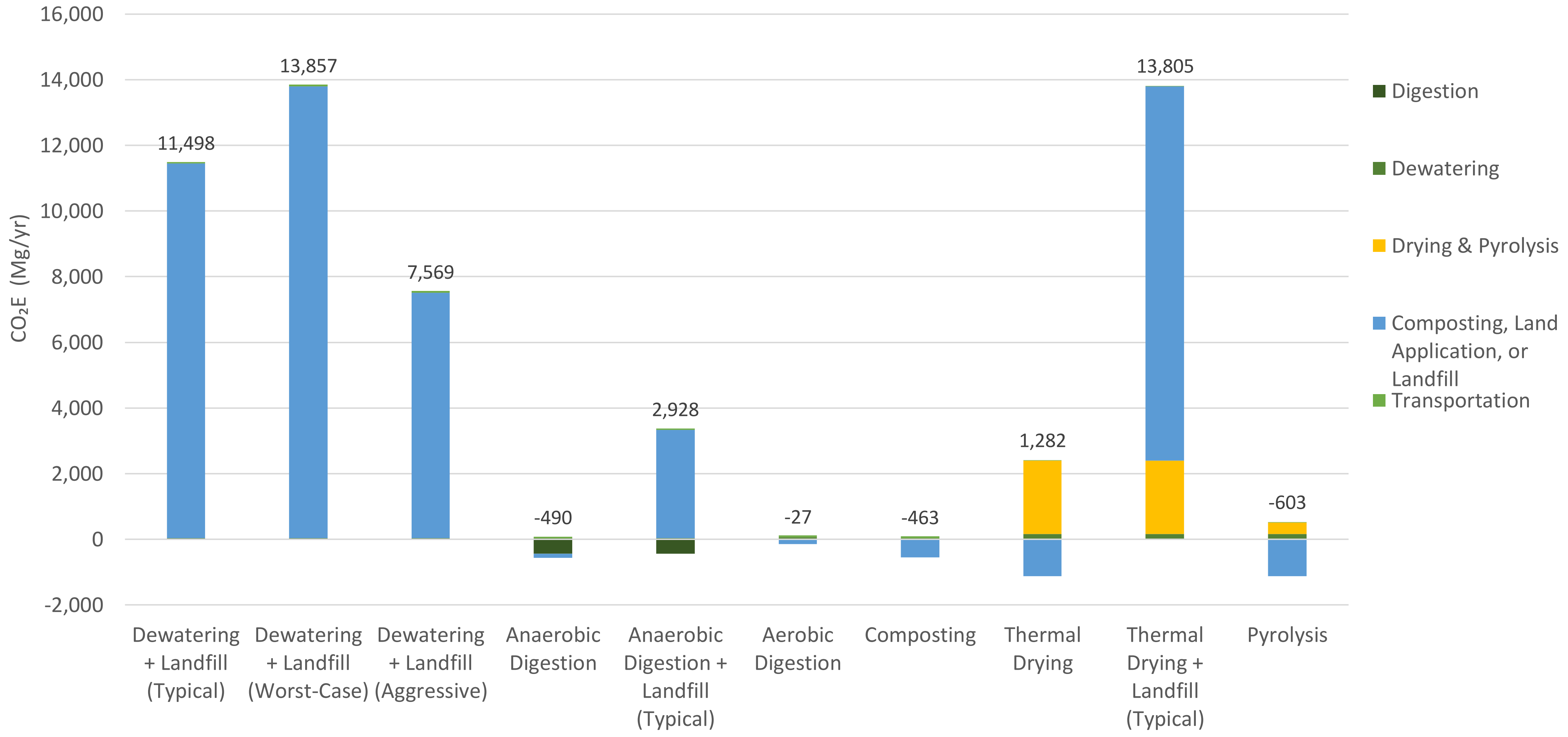
Estimating GHG Emissions for a 10-mgd WWTP

Treatment and End-Use Alternatives:

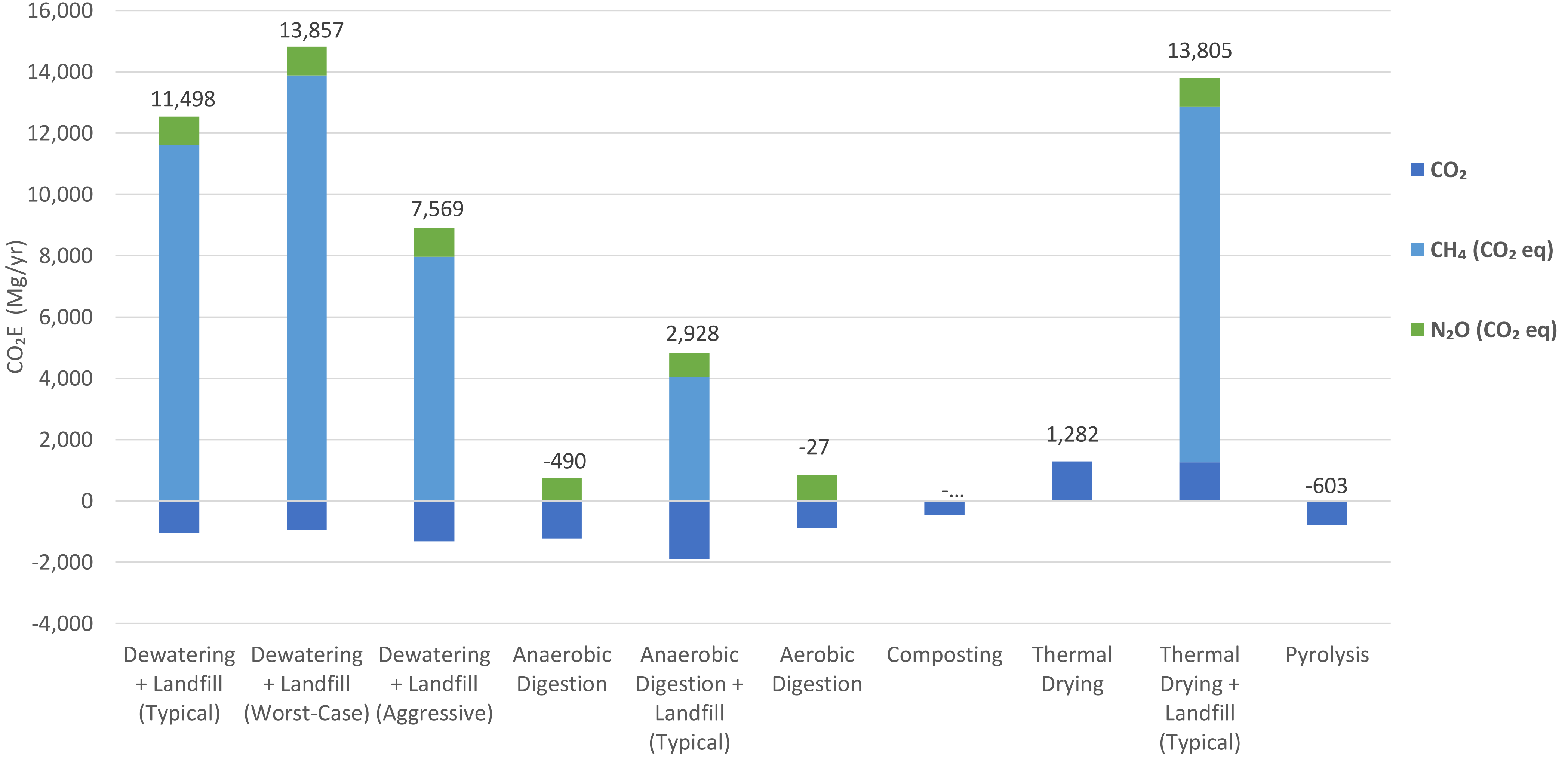
1. Dewatering + Landfill (Typical)
2. Dewatering + Landfill (Worst-case)
3. Dewatering + Landfill (Aggressive)
4. Anaerobic Digestion + Land Application
5. Anaerobic Digestion + Landfill (Typical)
6. Aerobic Digestion + Land Application
7. Composting + Land Application
8. Thermal Drying + Land Application
9. Thermal Drying + Landfill (Typical)
10. BioDrying + Pyrolysis + Land Application

Slide courtesy of Christine Polo (Carollo Engineers)

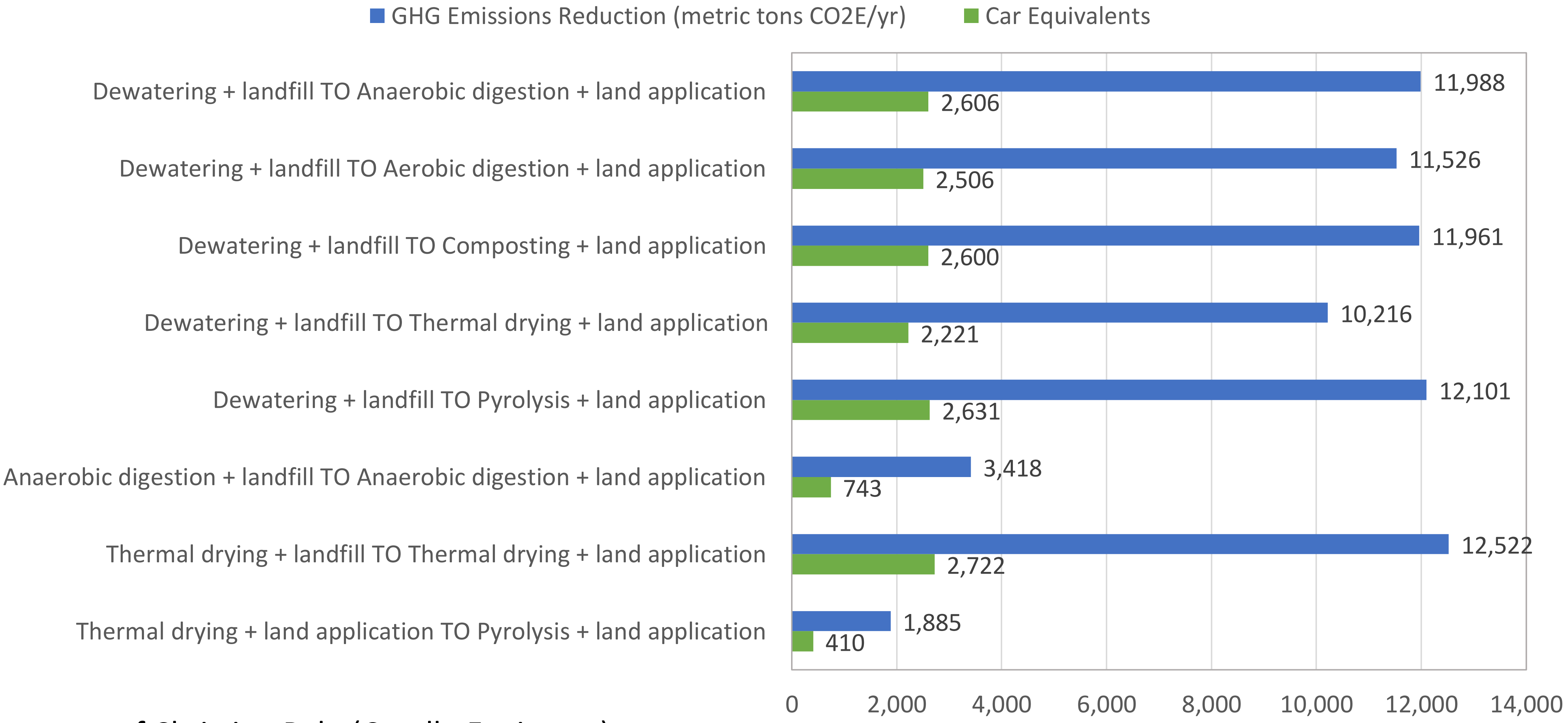
Emissions by Process



Emissions by Greenhouse Gas



GHG Emission Reduction Opportunities

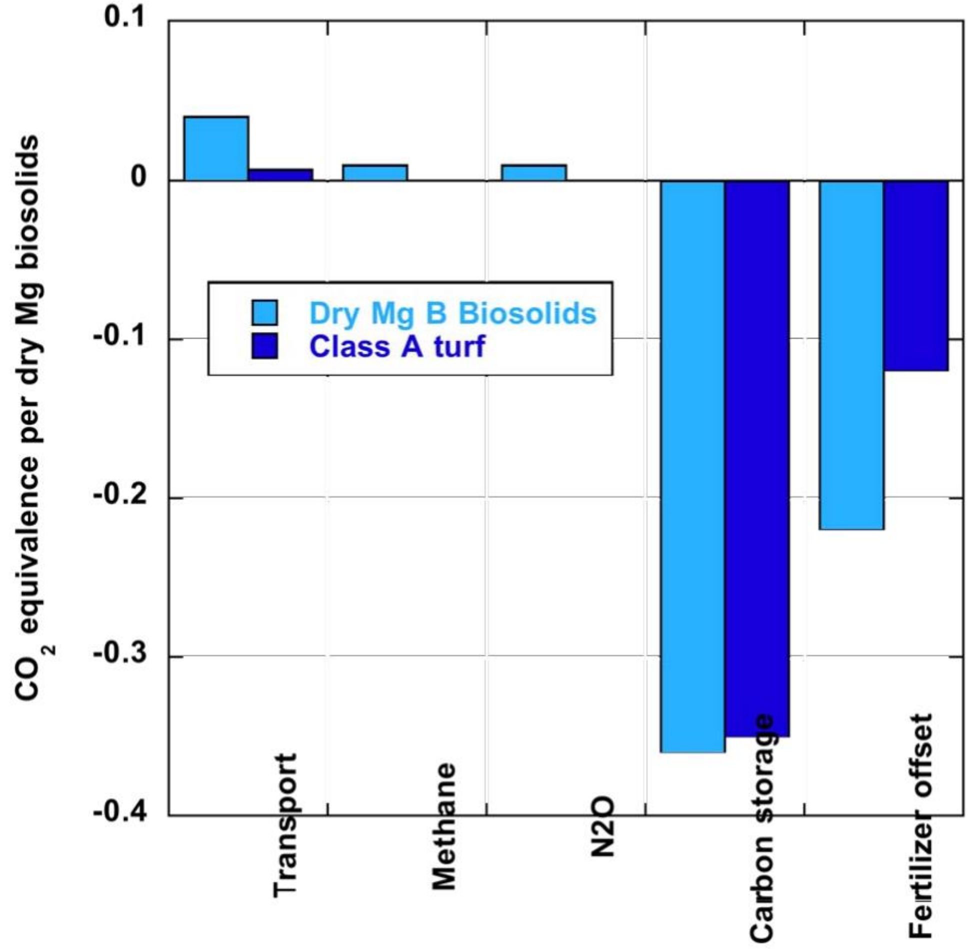


Slide courtesy of Christine Polo (Carollo Engineers)

Examples of Using BEAM Over the Past Decade

more examples at:
https://www.biosolidsghgs.org/sharing

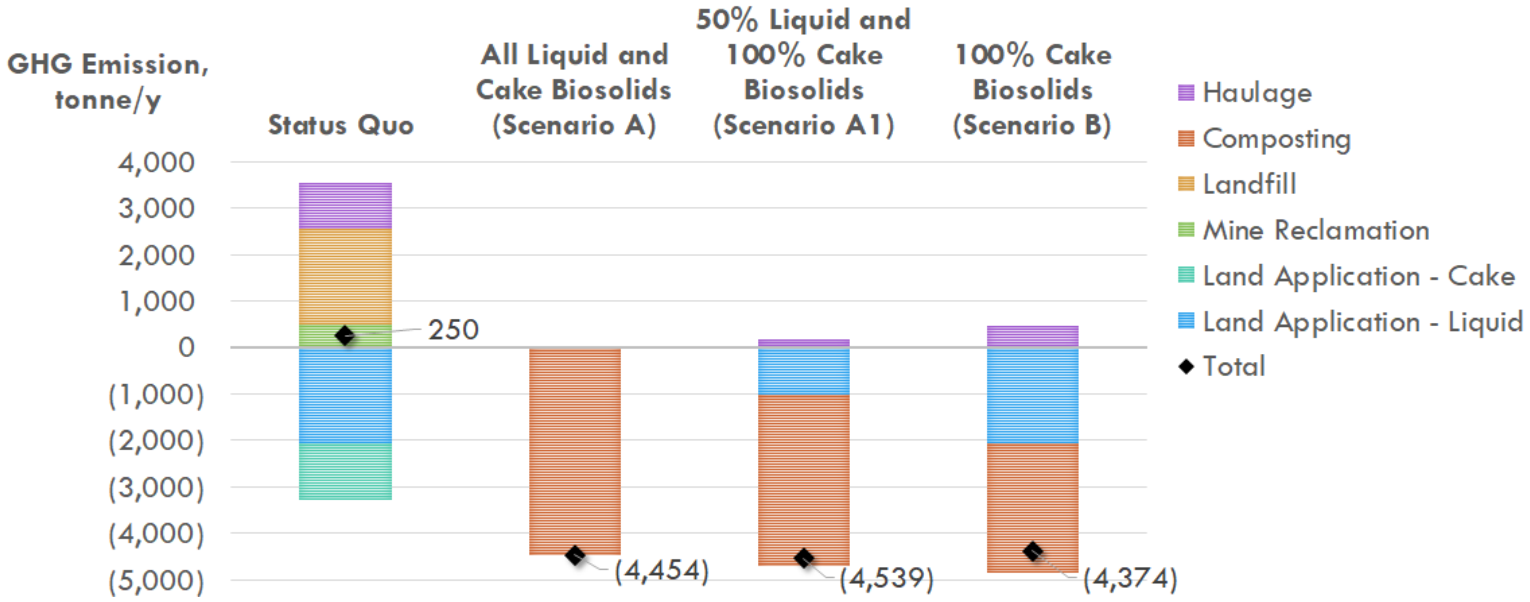
Chicago MWRD: Comparing Management Options



Brown & Tian; 2010. https://mwrd.org/sites/default/files/documents/M&RSeminar_07-30-2010-Seminar-Brown_Tian_MWRD_CO2.pdf

Halton Region, Ontario: Biosolids Composting Feasibility Study

- Demonstrating GHG benefits of composting over status quo to assist decision making



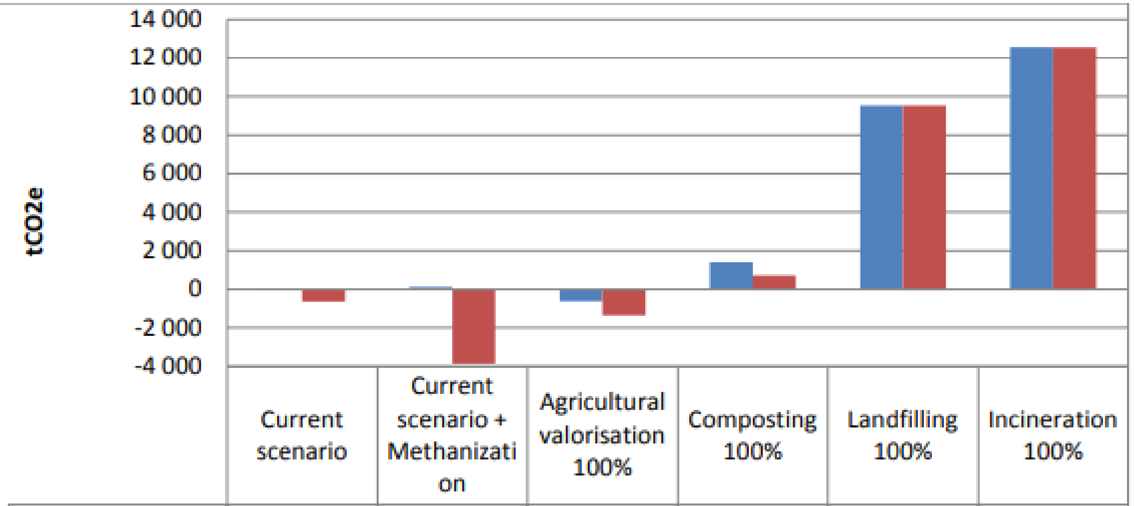
Reference: Proceedings from WEFTEC 2019, paper presentation by T.O. Williams. E. Shen, D. Ross, P. Morden, D. Iamarino – see https://www.accesswater.org/?id=-328435&fromsearch=true#iosfirsthighlight

Québec: Baseline & Comparing Alternatives

Table 1. Summary of emissions for the current scenario

Agricultural valorisation (65%)	tCO_2e	Composting (35%)	tCO_2e
1-Process direct emissions			
Transportation	80	Transportation	41
Machinery	31	Machinery	88
CH_4 emissions	67	CH_4 emissions	221
N_2O emissions	47	N_2O emissions	360
Sequestration	-599	Sequestration	-287
2- Indirect emissions linked to energy use			
Electricity consumption	0	Electricity concumption	5
3- Other indirect emissions			
N replacement	-393	N replacement	-193
P replacement	-81	P replacement	-42
Total (1 + 2)	**54**		
Total (1 + 2 + 3)	**-655**		

Figure 2. Comparison of annual emissions for five different scenarios of biosolids management for the city of Saguenay.

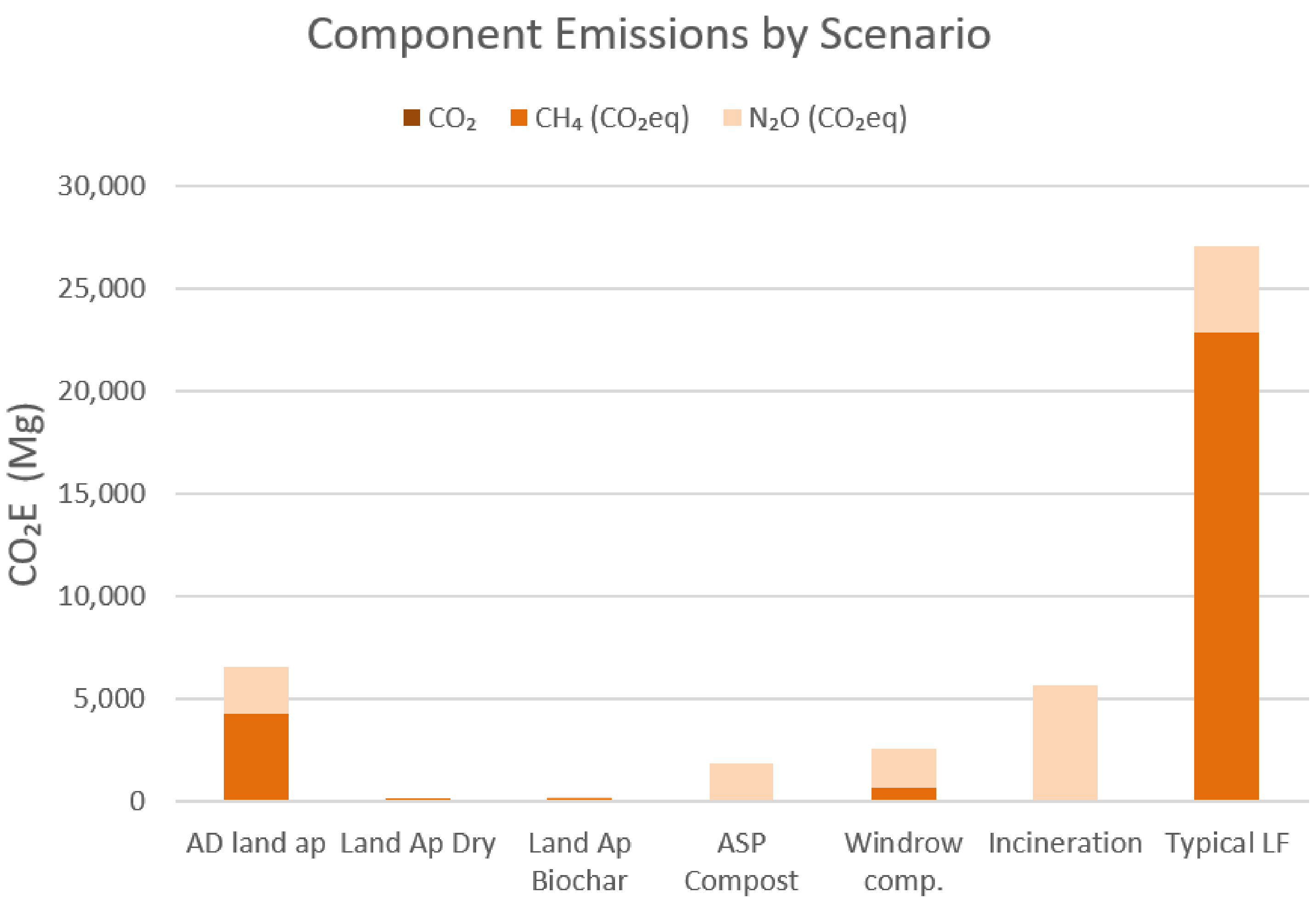


	Current scenario	Current scenario + Methanization	Agricultural valorisation 100%	Composting 100%	Landfilling 100%	Incineration 100%
Inventory	54	127	-635	1 409	9 532	12 562
Carbon footprint	-655	-3863	-1 364	719	9 532	12 559

Saguenay, Villaneuve & Dessurealt; 2011: https://www.environnement.gouv.qc.ca/matieres/articles/Municipal-biosolids.pdf

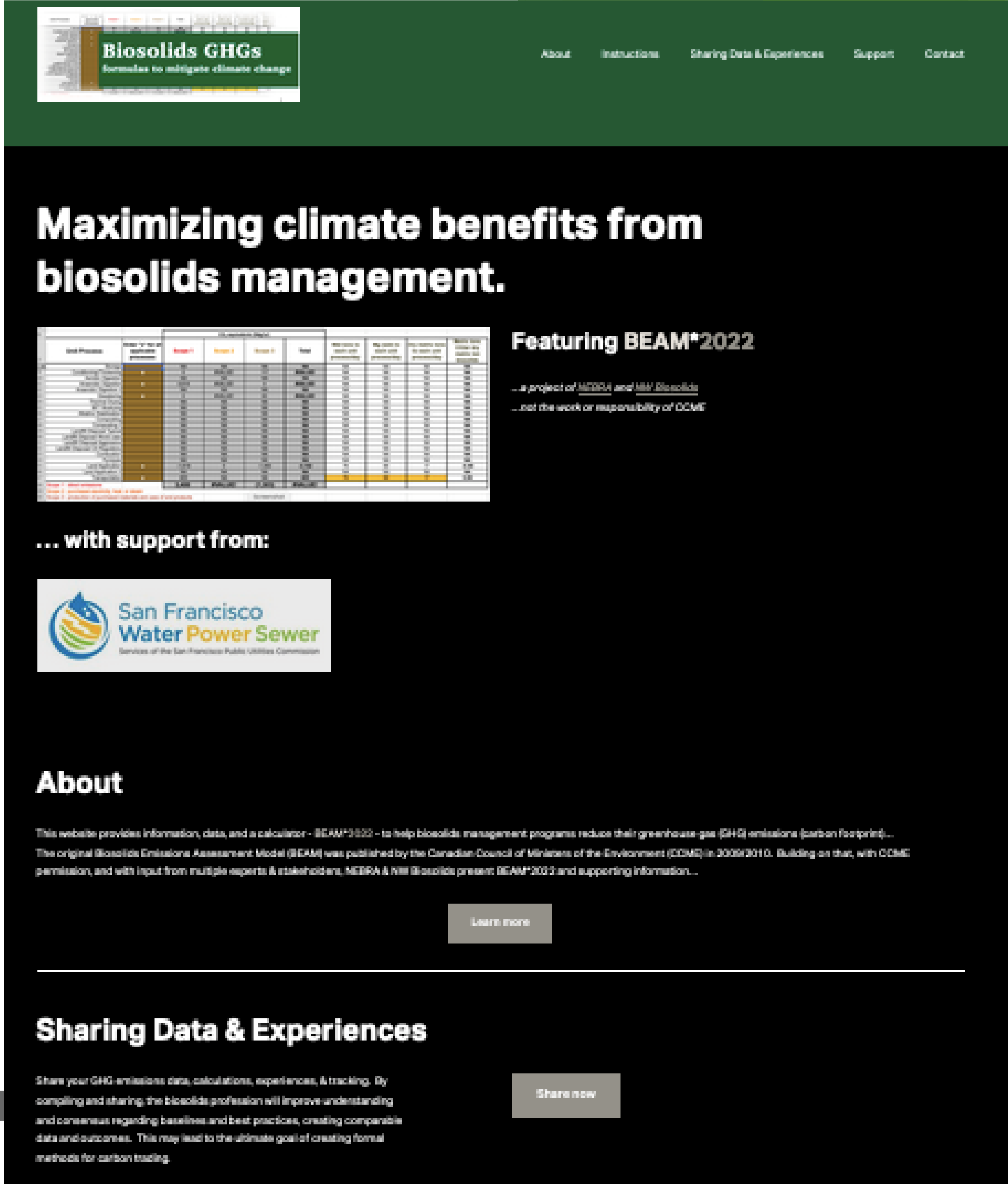
BEAM*2022 Screenshot: Generic findings

actual results are dependent on local details & what options are possible



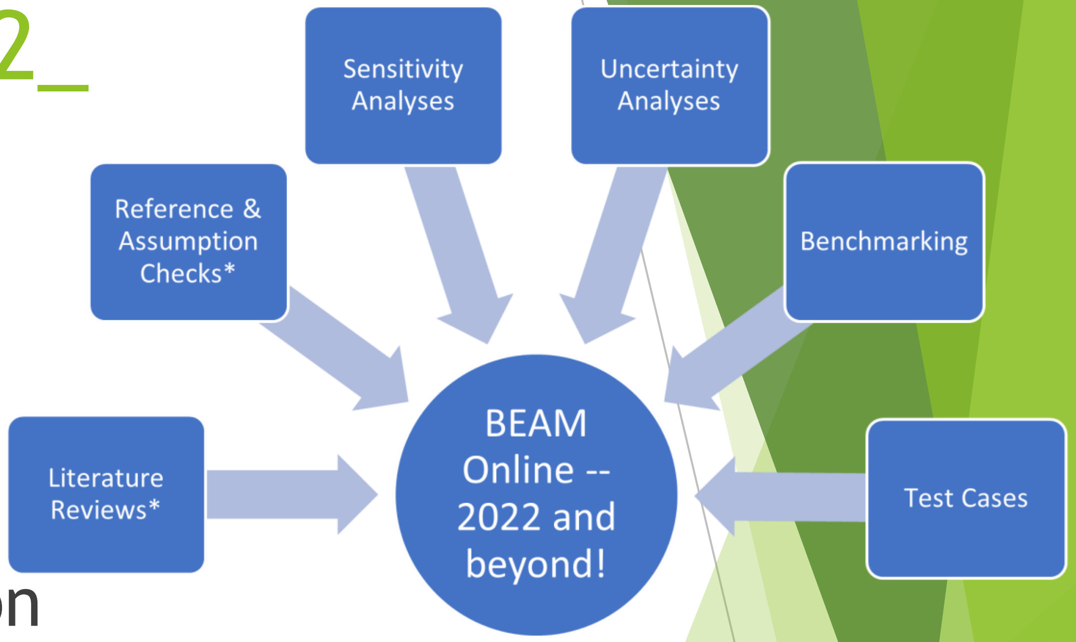
BiosolidsGHGs.org

- Spreadsheet available for download
  - Recommended $$$ donation by sliding scale - to support ongoing annual reviews & website hosting
- Supporting documents & links
  - Resources for utilities on GHG emissions & calculations
  - Standard protocols
- Space for sharing
  (send us your examples of BEAM use)
  - results
  - tips
  - uses of data



High Priority Topics for current SRT Review BEAM*202_

- Fertilizer offsets (GHG emissions from commercial fertilizer production)
- N_2O from combustion
- N_2O and methane from land application
- Fugitive CH_4 emissions from Anaerobic Digestion
- Carbon sequestration values



Future?

- BEAM*202_ further builds consensus as *THE* method for calculating GHG emissions from biosolids management
- A resource hub with crowd-sourced supporting information & examples
- Respected source for biosolids-specific emissions/reductions/sequestration factors (as found in references)
- Eventually helping develop protocols and working with registrars to allow for marketable carbon offsets
- **Your input welcome & needed.**

Thanks to the Supporters…

BAY AREA BIOSOLIDS COALITION

San Francisco Water Power Sewer
Services of the San Francisco Public Utilities Commission

Denali WATER SOLUTIONS

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CASELLA ORGANICS

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Northern Tilth

BOISE CITY OF TREES

NYC Environmental Protection

BIOFORCETECH Corporation

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Particularly:
Janine Burke-Wells, Ned Beecher, and Andrew Carpenter

North East Biosolids & Residuals Association

… and Northwest Biosolids!

Particularly:
Maile Lono-Batura

(now Director of Sustainable Biosolids Programs at WEF)