Food waste and the Water-Energy-Food Nexus

Dr. Kelly M. Kibler

Department of Civil, Environmental & Construction Engineering
University of Central Florida
kelly.kibler@ucf.edu

International Virtual Workshop on Water, Energy, Food Nexus
G20 Meeting of Agricultural Chief Scientists
Riyadh, Kingdom of Saudi Arabia
August 31, 2020

Food Waste in the WEF nexus

Food Loss

Food Waste

Food Loss & Waste

- Food loss and waste are a considerable portion of the global food supply (FAO 2011, Thyberg et al. 2015, Buzby et al. 2014):
  - By weight, roughly one-third of food produced, or
  - By energy, one of every four kilocalories produced.
- WEF Nexus approach can be a framework for quantifying impacts of wasted food to energy and water sectors, leading to better management decisions.

Food Waste in the WEF nexus

Human decision making is at the root of the Water-Energy-Food waste nexus:

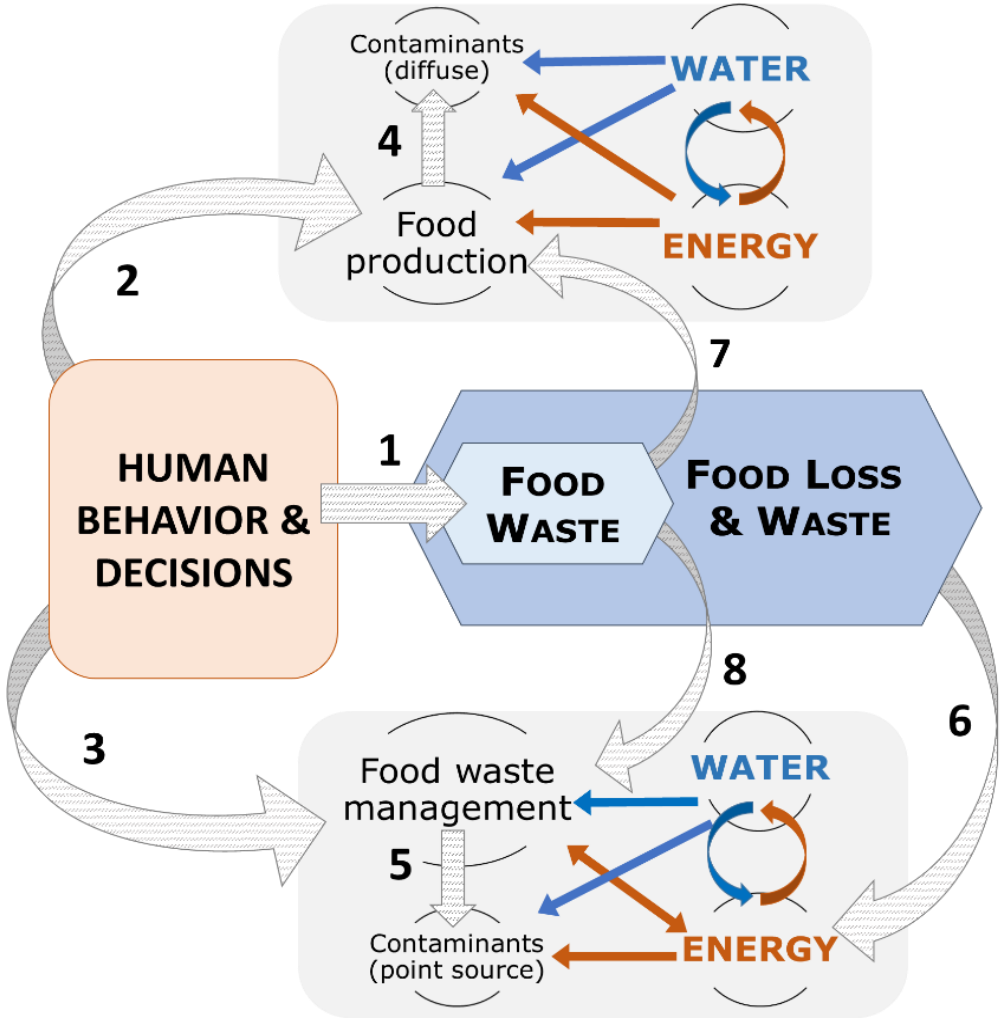
(1) Consumer choices lead to food waste, a subset of food loss and waste.

(2) Water and Energy are consumed in the production of wasted food.

(3) Water and Energy also consumed, energy may be produced, in food waste management.

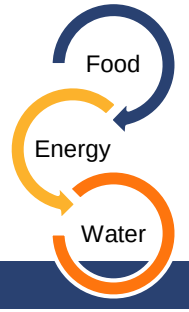
(4) Remediation of pollution is associated with both producing and managing wasted food (4 and 5 respectively).

When less food is wasted, more food is available without the need for increased agricultural production (7), and there is less food waste and food waste contamination to be managed (8).



Kelly M. Kibler, University of Central Florida

WEF impacts associated with producing wasted food



As extrapolated from known production costs :

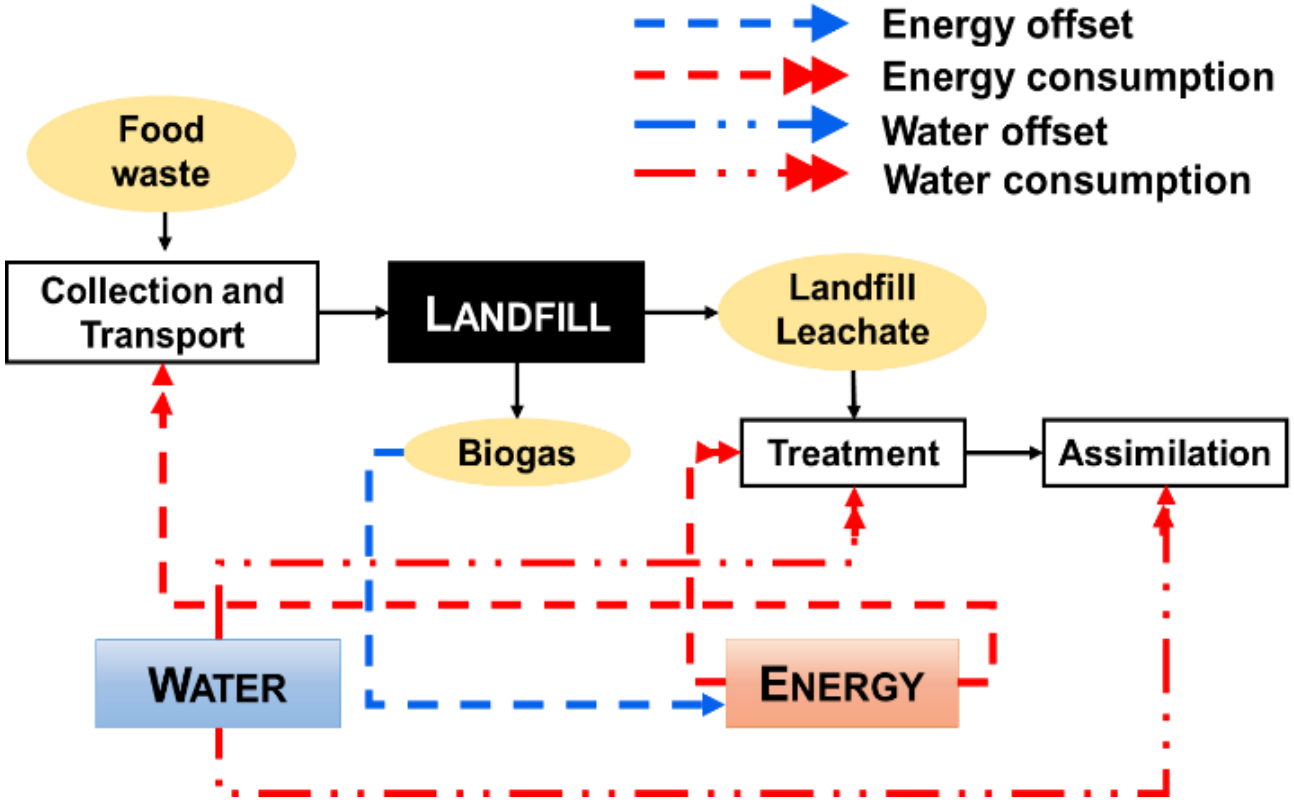
WATER

- **1-7%** of water used for agricultural production used to produce wasted food.
  - Annual per capita water footprint (i.e. sum of blue, green, grey water *sensu* Hoekstra et al. 2009) of agricultural production in the United States is ~2,400 m^3 (Hoekstra and Mekonnen, 2012)
  - Annual per capita water use in global production of food that is wasted ~27 -162 m^3 (Kummu et al. 2012, FAO 2013).

ENERGY

- **2%** of annual energy consumption in US is dedicated to production of wasted food (Cuellar and Webber, 2010)
- Energy dedicated to US food production range from 8 to 16% of annual energy consumption (Heller and Keoleian 2000, Pimentel and Pimentel 2003, Canning et al. 2010, Cuellar and Webber, 2010).

WEF impacts associated with managing wasted food



In a landfill pathway:

Energy is consumed

- In collection and transport of food waste from residential/commercial locations to landfill
- In treatment of landfill leachate

Energy is offset

- In generation of biogas (if collected and used)

Water is consumed

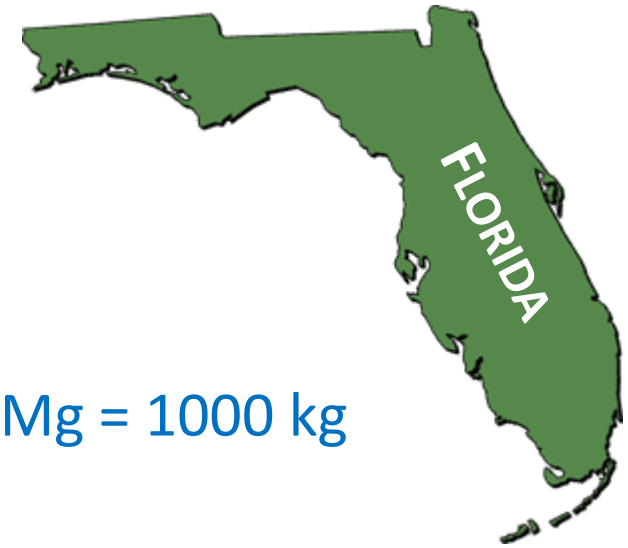
- In Treatment and assimilation of landfill leachate.

Kibler et al. 2018
https://www.sciencedirect.com/science/article/pii/S0956053X18300151

Water and energy footprints of landfilled food waste: A Florida case study

System boundary conditions:

- Florida geographic boundary, 21.5 million people
- 9.5 x 10^5 Mg of food waste sent to landfills annually
  - About 54% of total food waste generated is landfilled (FDEP 2014).
- 13% of landfills in Florida collect landfill biogas (USEPA 2016)
- Regulatory water quality standards for biochemical oxygen demand (BOD) and total ammonia nitrate (TAN) in receiving waterbodies of 20 mg/L (FDEP, 2016) and 8.75 mg/L (Bloetscher and Gokgoz 2001), respectively



1 Mg = 1000 kg

Water and energy footprints of landfilled food waste

Energy balance to estimate the fluxes of energy associated with landfilling food waste, Eq. 1 :

$$\mathbf{E = E_P - (E_C + E_T + E_L)} \qquad \mathbf{Eq.\ 1}$$

Where:

$\mathbf{E}$ = net energy (kWh/Mg)

$\mathbf{E_P}$ = energy produced by landfill gas (kWh/Mg)

$\mathbf{E_C}$ = energy consumed in food waste collection (kWh/Mg)

$\mathbf{E_T}$ = energy consumed in transport of leachate to a WWTP (kWh/Mg)

$\mathbf{E_L}$ = energy consumed in leachate treatment (kWh/Mg)

Water and energy footprints of landfilled food waste

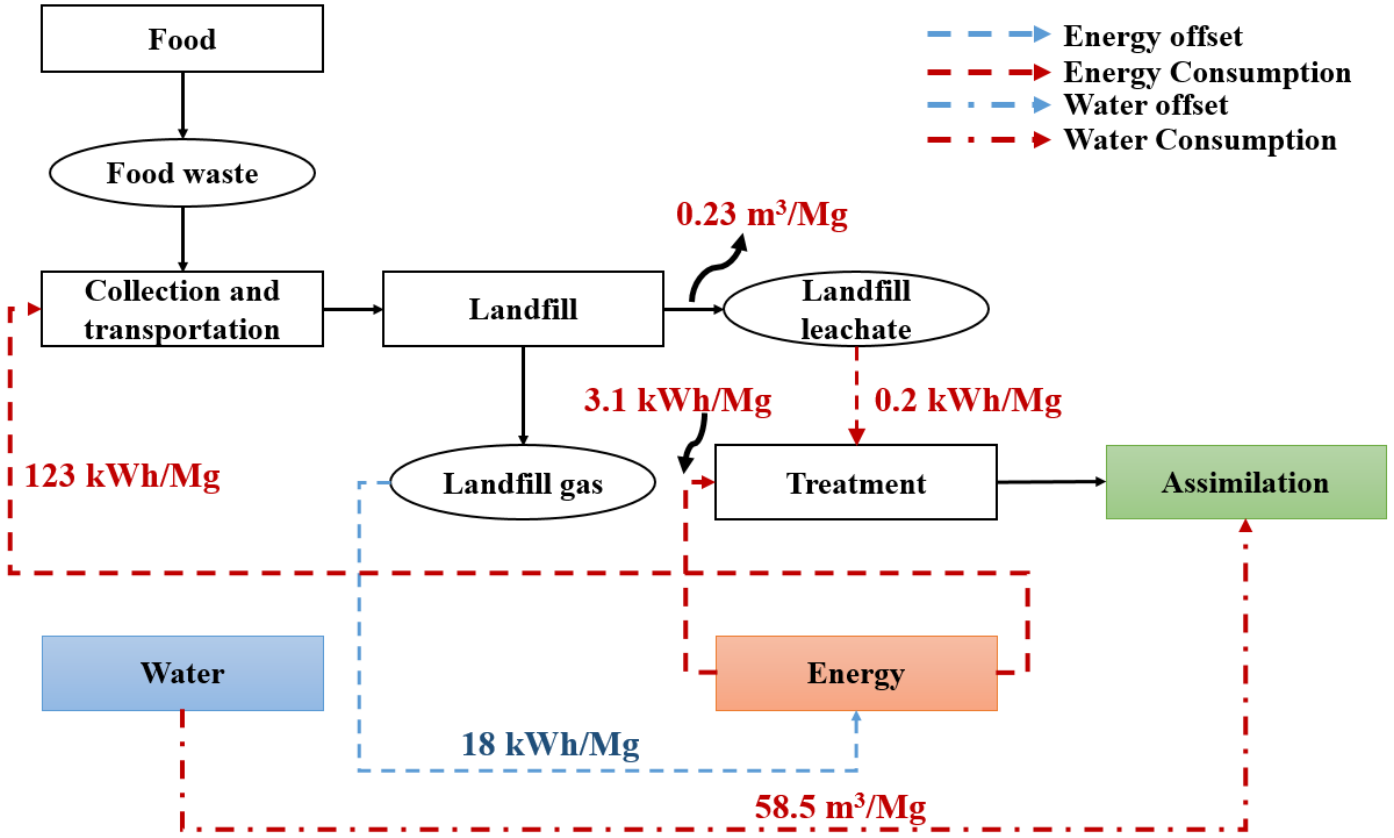
Mass balance to estimate volume of water needed to assimilate contamination attributable to food waste in treated leachate, grey water footprint (WF_{Grey}, m^3/Mg) (Hoekstra et al. 2009, Hoekstra et al. 2011, Morera et al. 2016), Eq. 2 :

$$\mathbf{WF_{Grey}} = \frac{\mathbf{Q_{MSW,T}}(\mathbf{C_{L,i}} - \mathbf{C_{max,i}})}{(\mathbf{C_{max,i}} - \mathbf{C_{background,i}})} \qquad \mathbf{Eq.\ 2}$$

Where:

$\mathbf{Q_{MSW,T}}$ = discharge rate of treated leachate (m^3/Mg)
$\mathbf{C_{L,}}\boldsymbol{i}$ = permitted concentration of contaminant *i* in wastewater discharge (mg/L)
$\mathbf{C_{max,}}\boldsymbol{i}$ = maximum allowable concentration of contaminant *i* in the receiving waterbody (mg/L)
$\mathbf{C_{backgorund,}}\boldsymbol{i}$ = background concentration of contaminant *i* in the receiving water body (mg/L)

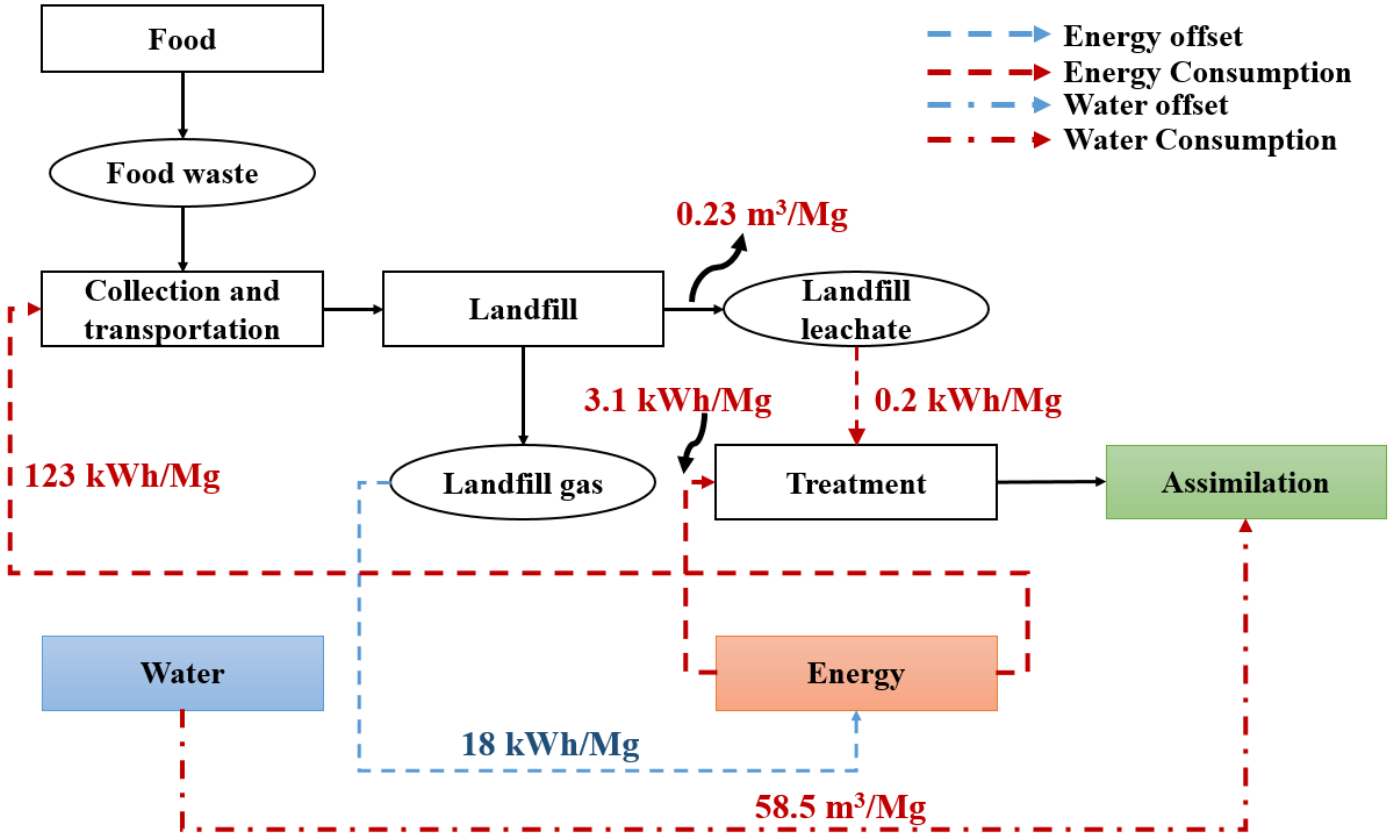
Results: Water and energy footprints of landfilled food waste



Each Mg landfilled food waste consumes **net 108.4 kWh** of energy

- In Florida, a total annual energy cost of 110 million kWh
- 0.05 % of Florida's total energy generation in 2014 (US EIA, 2016),
- 0.03% of Florida's total residential energy consumption (US EIA, 2016)
- or around 2% of Florida's 2014 renewable energy production (US EIA, 2016)
- If every landfill collected LFG, total energy cost could be reduced to 32.4 million kWh

Results: Water and energy footprints of landfilled food waste



58.5 m^3 of clean water is needed to assimilate pollution from each Mg landfilled food waste.

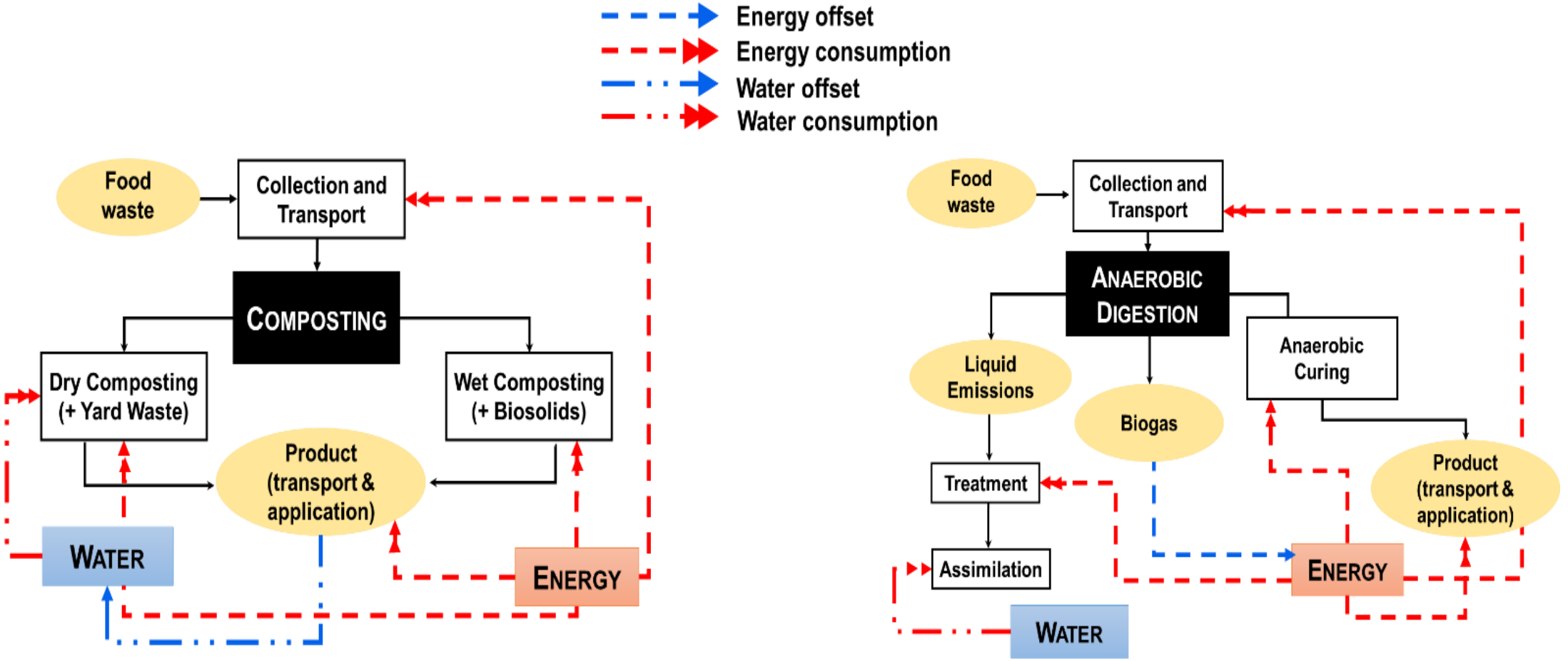
- In Florida, a total annual water cost of 58 million m^3
- 0.67% of the per capita water consumption in Florida (440m^3 in 2012, USGS, 2016)
- and 0.65% of the total freshwater withdrawn in Florida in 2012

Summary of potential wasted food production costs vs. waste management costs

	Production of wasted food	Management of wasted food
Water	27 -162 m^3 per person per year	4 m^3 per person per year
Energy	2% annual consumption	0.04% annual consumption

Assuming food waste is landfilled, landfill gas utilization is low (Florida levels) and leachate from landfill is treated prior to release.

How would the WEF nexus respond under different food waste treatment technologies?



Kelly M. Kibler, University of Central Florida

How would the WEF nexus respond under different food waste treatment technologies?

Can human food waste offset feed grains for animals?

- Recoup energy and water savings in both production (offset feed grains) and potentially waste management
- Can this be combined with other food waste treatment technologies to optimize WEF impact?

Thank you for your attention!

Food
Energy
Water

UCF

Questions?

Out of time? Please email me!

Dr. Kelly Kibler
University of Central Florida
Department of Civil, Environmental & Construction Engineering and
National Center for Integrated Coastal Research
http://ecohydraulics.weebly.com
kelly.kibler@ucf.edu

References

- Canning, P., Charles, A., Huang, S., Polenske, K. R., Waters, A. (2010). Energy Use in the U.S. Food System; U.S. Department of Agriculture, Economic Research Service.
- Cuellar, A. D., and Webber, M. E. (2010). Wasted Food, Wasted Energy: The Embedded Energy in Food Waste in the United States. Environmental Science & Technology, 2010, 44 (16), pp 6464–6469
- Food and Agriculture Organization of the United Nations (2013). Food wastage footprint; Impacts on natural resources. Summary report. ISBN 978-92-5-107752-8.
- Heller, M.C., Keoleian, G.A., 2000. Life Cycle-Based Sustainability Indicators for Assessment of the US Food System, vol. 4. Center for Sustainable Systems, University of Michigan, Ann Arbor.
- Hoekstra, A. Y., Chapagain, A. K., Aldaya, M. M., & Mekonnen, M. M. (2009). Water footprint manual: State of the Art 2009. Water Footprint Network, Enschede, The Netherlands.
- Hoekstra, A. Y., & Mekonnen, M. M. (2012). The water footprint of humanity. Proceedings of the national academy of sciences, 109(9), 3232-3237.
- Kibler, K. M., Reinhart, D., Hawkins, C., Motlagh, A. M., & Wright, J. (2018). Food waste and the food-energy-water nexus: A review of food waste management alternatives. Waste Management.
- Kummu, M., De Moel, H., Porkka, M., Siebert, S., Varis, O., & Ward, P. J. (2012). Lost food, wasted resources: Global food supply chain losses and their impacts on freshwater, cropland, and fertiliser use. Science of the Total Environment, 438, 477-489.
- Pimentel, D., Pimentel, M., 2003. Sustainability of meat-based and plant-based diets and the environment. Am. J. Clin. Nutr. 78 (3), 660S–663S.