Breaking taboos in sanitation - it's all about beneficiation

Kartik Chandran
Columbia University

Dealing with the sanitation nexus: The need for disruption

SIWI World Water Week, August 6th, 2017

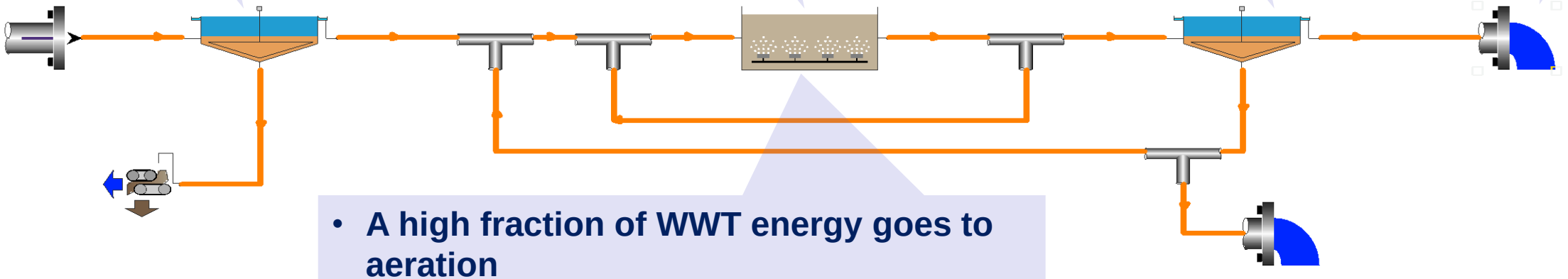
Brief overview of biological sewage treatment

Solids, inerts separation

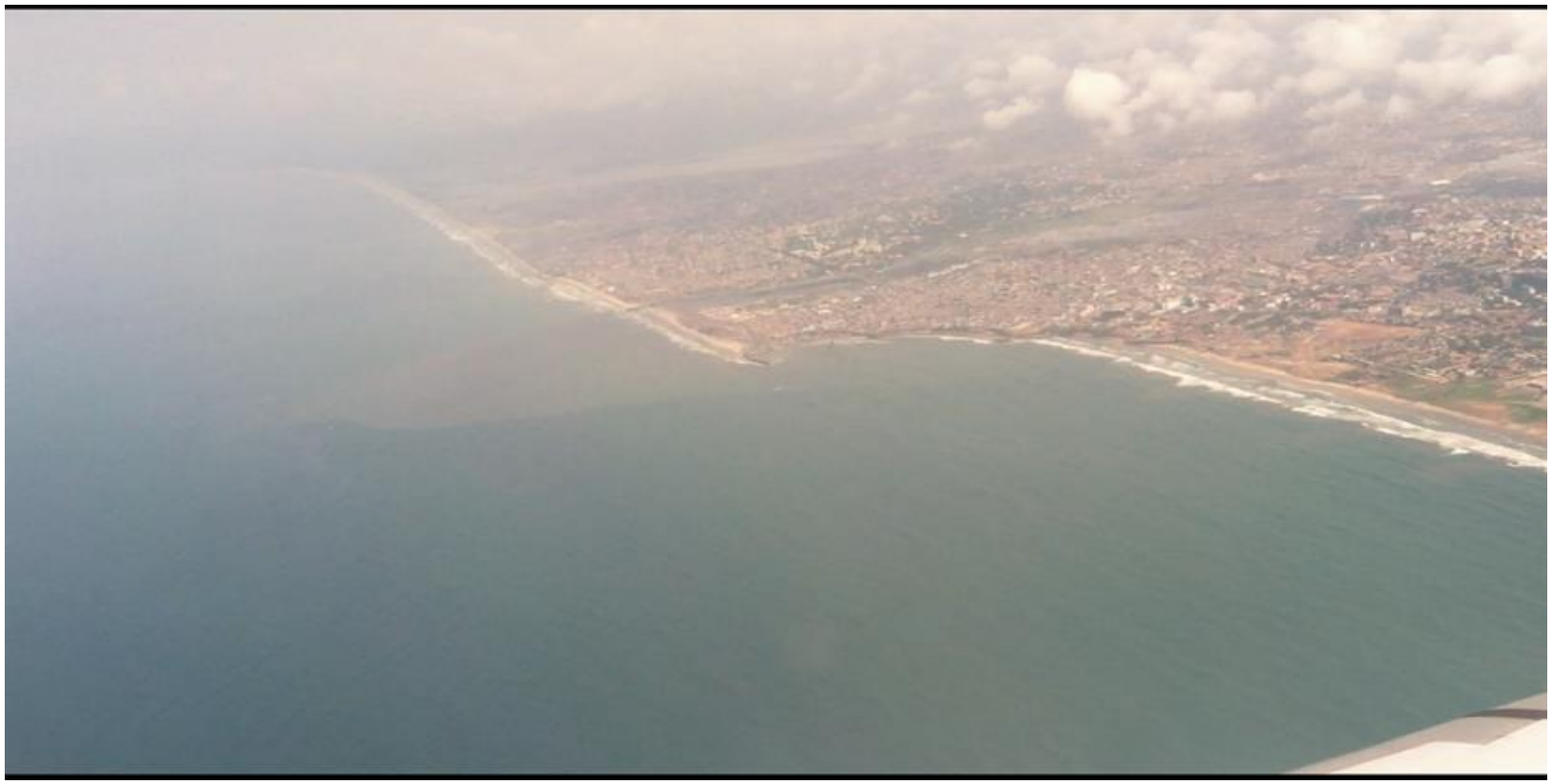
Aerobic C &N removal

Recycle of bacteria

Disinfection and discharge



- **A high fraction of WWT energy goes to aeration**
- **$MM in organic chemical purchase**
- **Bacteria could produce unwanted products (N_2O)**



	Energy consumed annually (tera tons oe)	Energy consumed annually for water (assuming 3%, tera tons oe
USA	2.4	0.07
Ghana	0.01	?

The potential for beneficiation and recovery

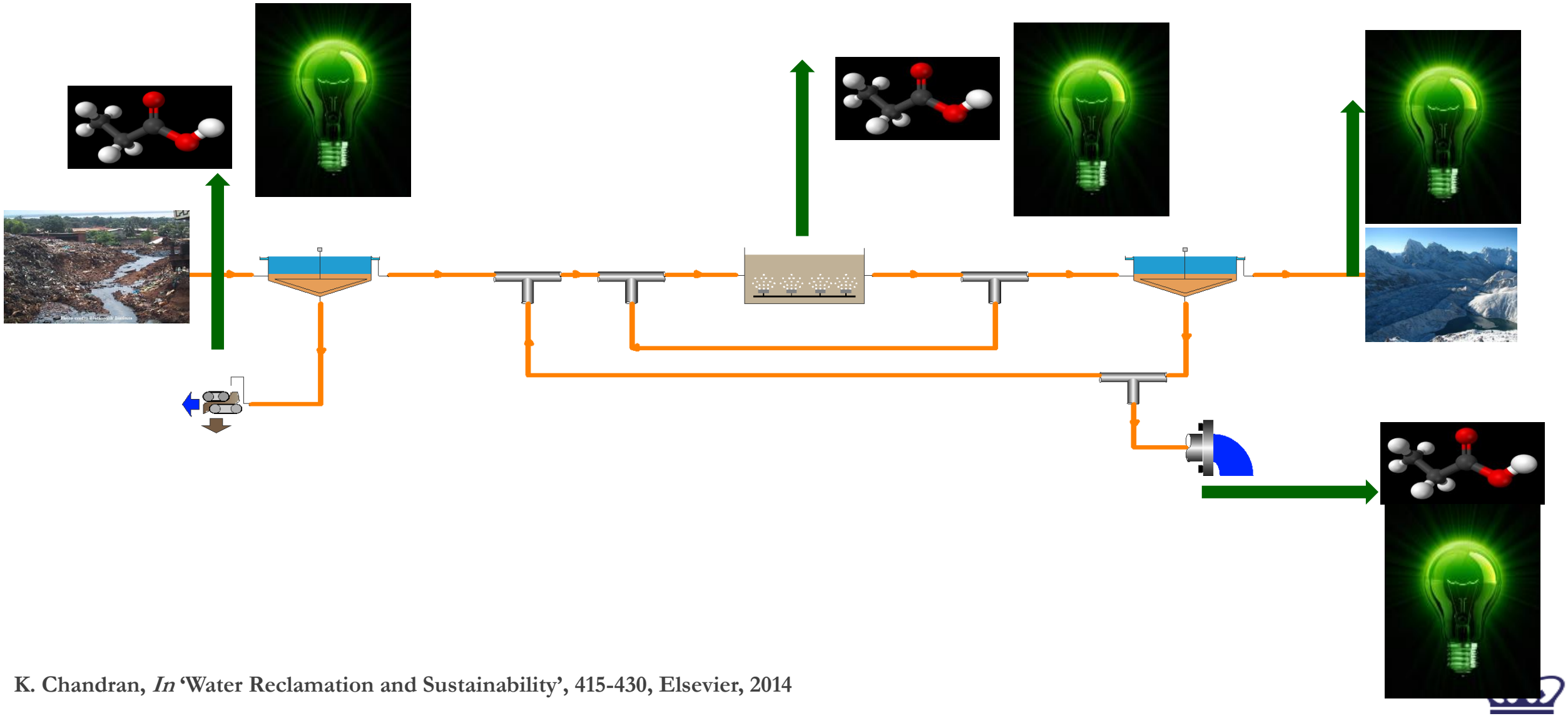
- Distributed (networked) treatment in NY
- Flow: 1.2 billion gallons per day
  - 1860 tons of organic carbon per day
  - 280 tons of N(-III) per day
  - 60 tons of P(+V) per day

Energy self-sufficiency in sanitation and wastewater treatment?

Energy present	Energy needed
~ 2500 kWh/MG	~2500 kWh/MG

- Assuming 34% conversion of organic matter to methane and electricity
- Assuming 'conventional' BNR
- Can 'import' carbon
  - Not at the expense of excessive nutrient discharges

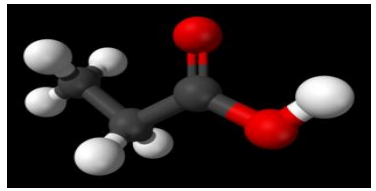
Shifting to Engineered Resource Recovery from 'Waste' Streams

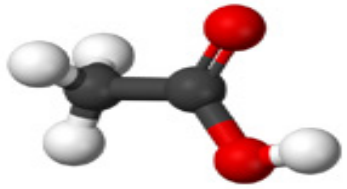


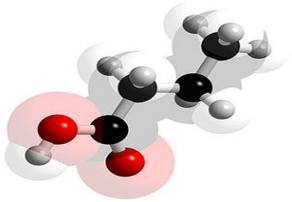
K. Chandran, *In* 'Water Reclamation and Sustainability', 415-430, Elsevier, 2014

Potential for C-recovery is immense, but…

Biofuels







Commercial chemicals

Fertilizer

… needs to address a higher objective

Internal use of VFA for enhanced BNR

Dual-Phase Digestion and Fermentation of AS

PDS fermentation and storage at 26th Ward WPCP in New York City, 2002

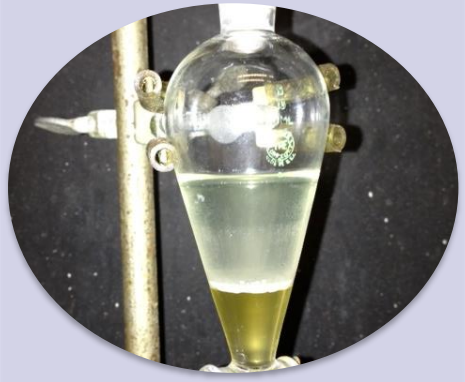
- Fermentation of PDS to produce VFA
  - Used mainly for denitrification
  - Kinetics higher than MeOH

Lipid Production from 'waste'organics

Organic waste

Anaerobic fermentation to produce volatile fatty acids (VFA)

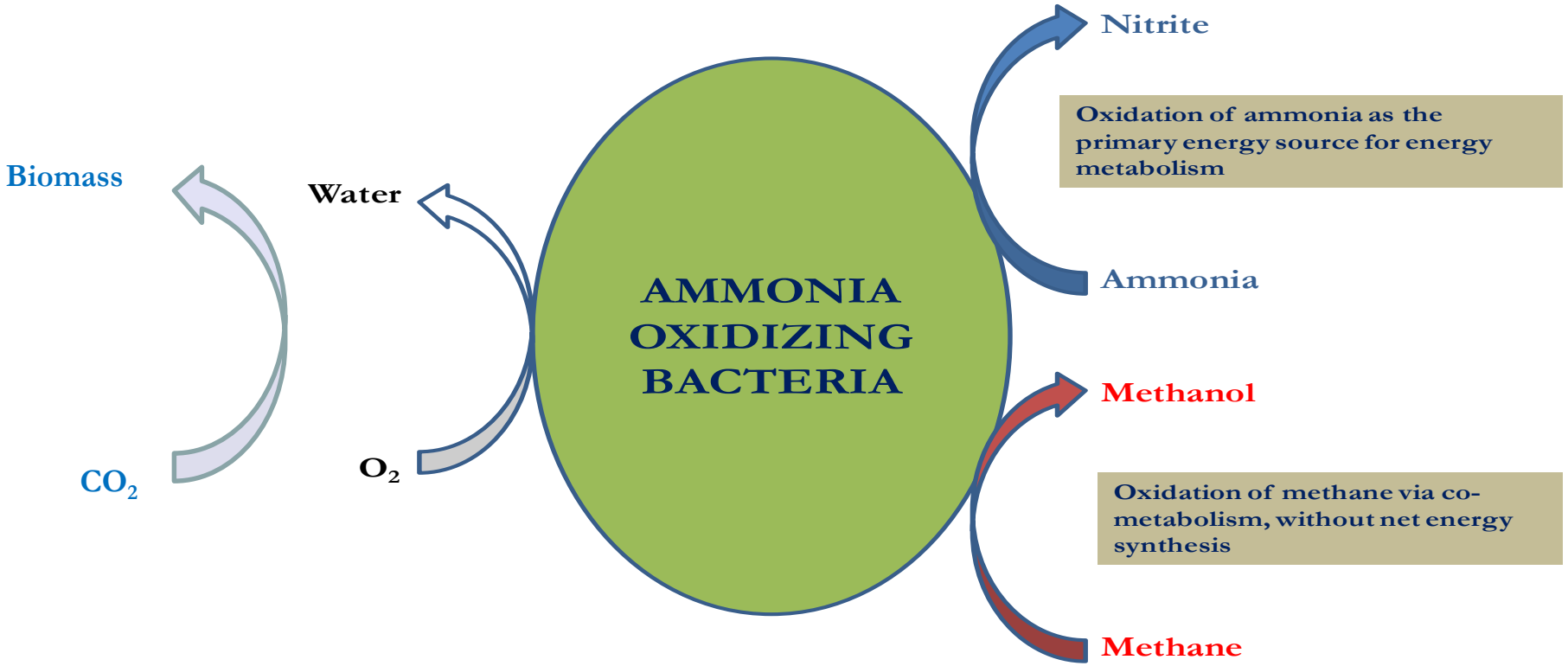
Convert VFA to lipids



Harvest and extract lipids

Convert lipids to …

From Greenhouse Gas to Green Fuel

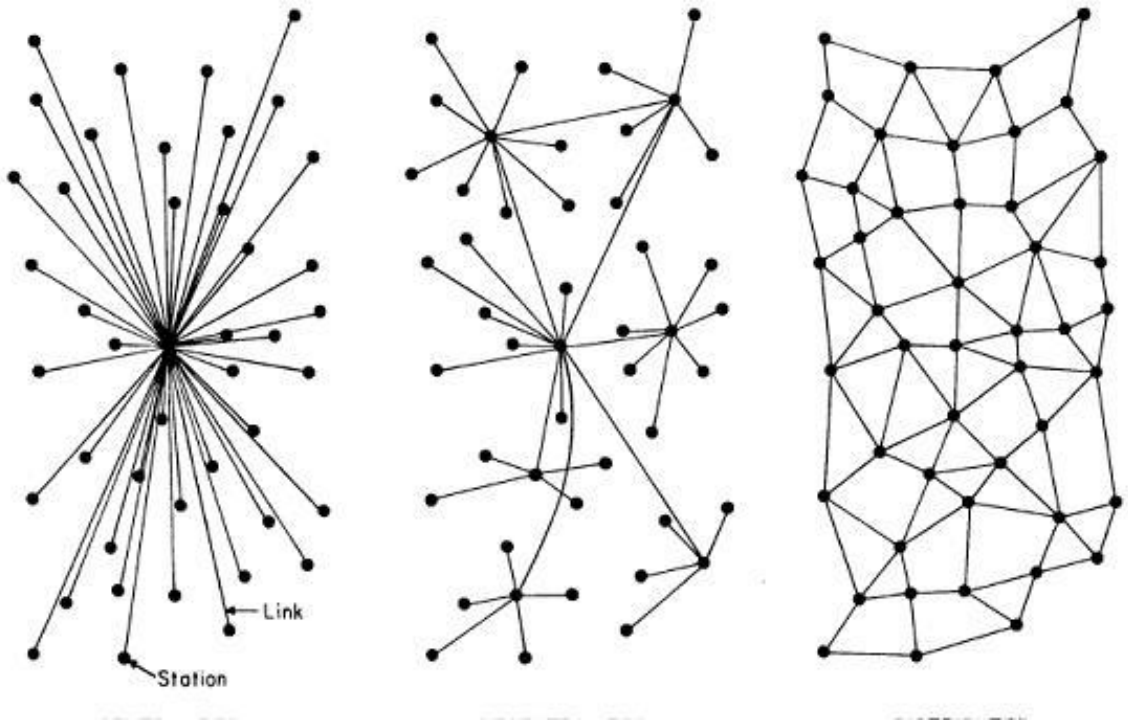


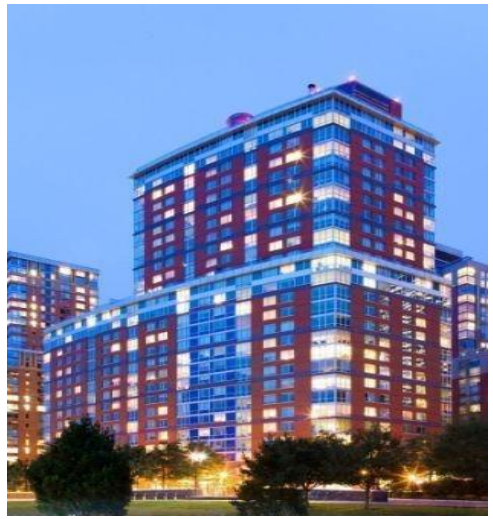
- Upcycling CH_4 to chemicals for 'internal' use

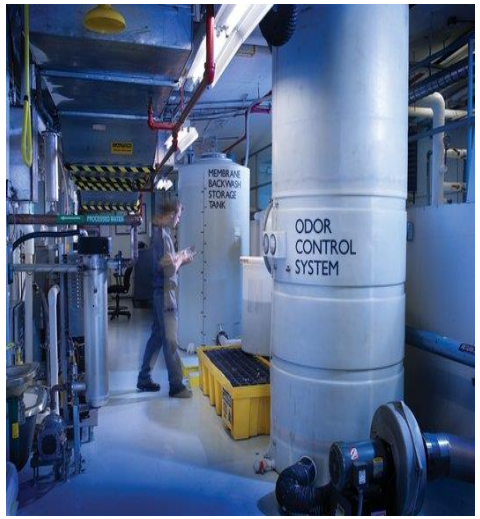
Taher and Chandran, ES&T, 2013

De-centralized infrastructure in future cities

water +x







- Scaling down recovery of water, energy and nutrients

~350
new inventions from Columbia research each year

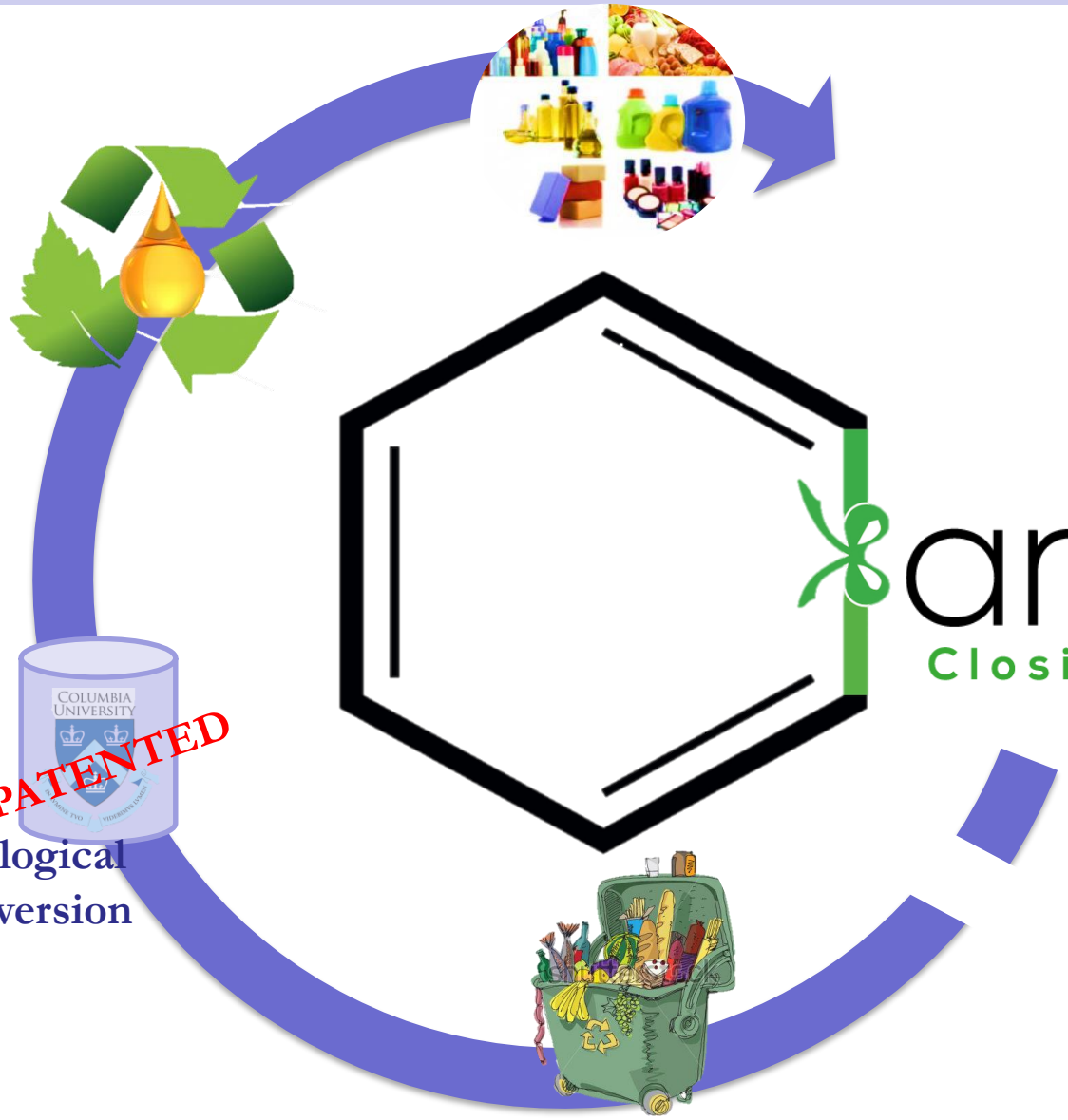
Columbia Technology Ventures

100+
licenses & options

20+
start-up companies

Millions
in licensing revenue

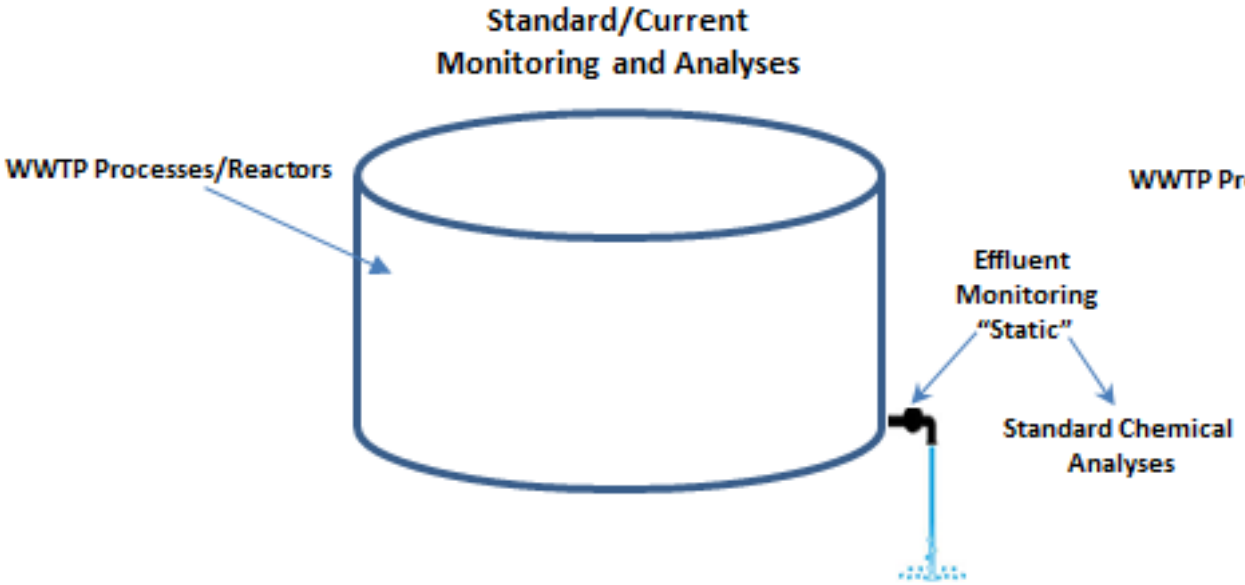
Carbocycle

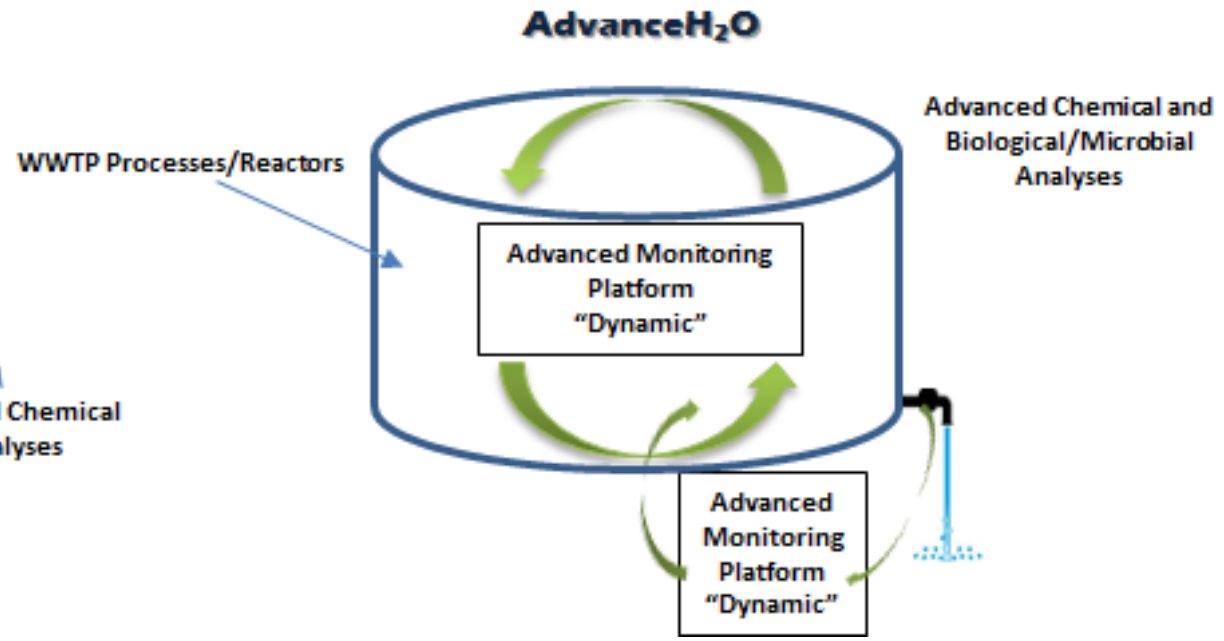


arboCycle

Closing the Carbon Loop

Advance H2O





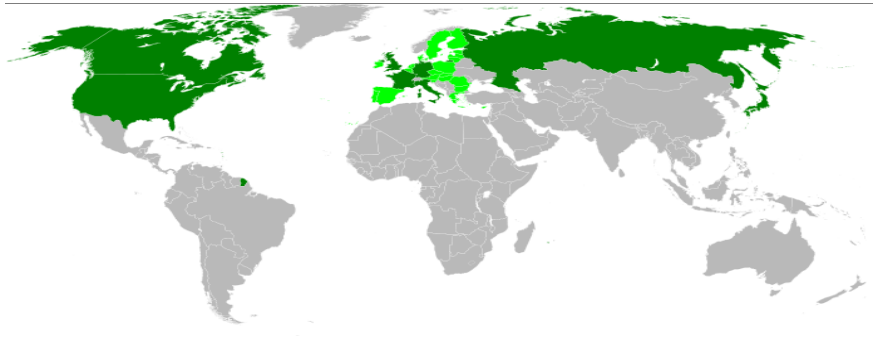
NSF I-Corps, NYSERDA Powerbridge

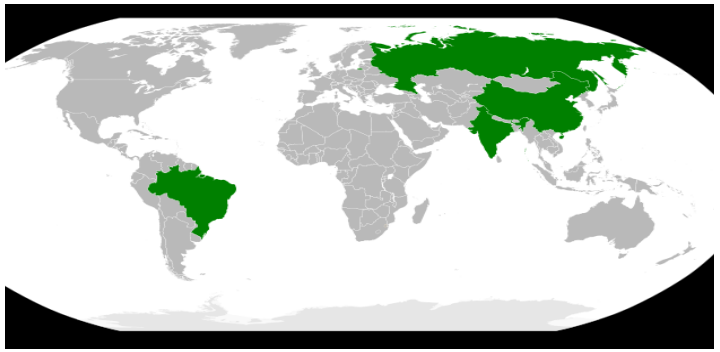
Acknowledgements

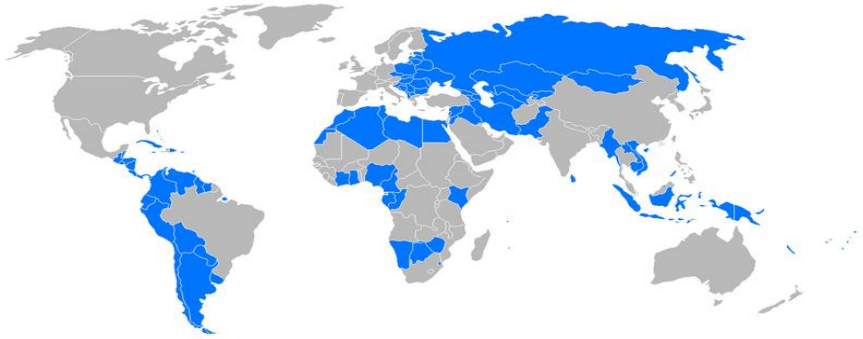
Bill & Melinda Gates Foundation, National Science Foundation, NYSERDA, WE&RF Paul Busch Award

Shashwat Vajpeyi, Justin Shih, Ato Fanyin Martin, Edris Taher, Yu-Chen Su, Young Lee

Linking resource recovery to other challenges

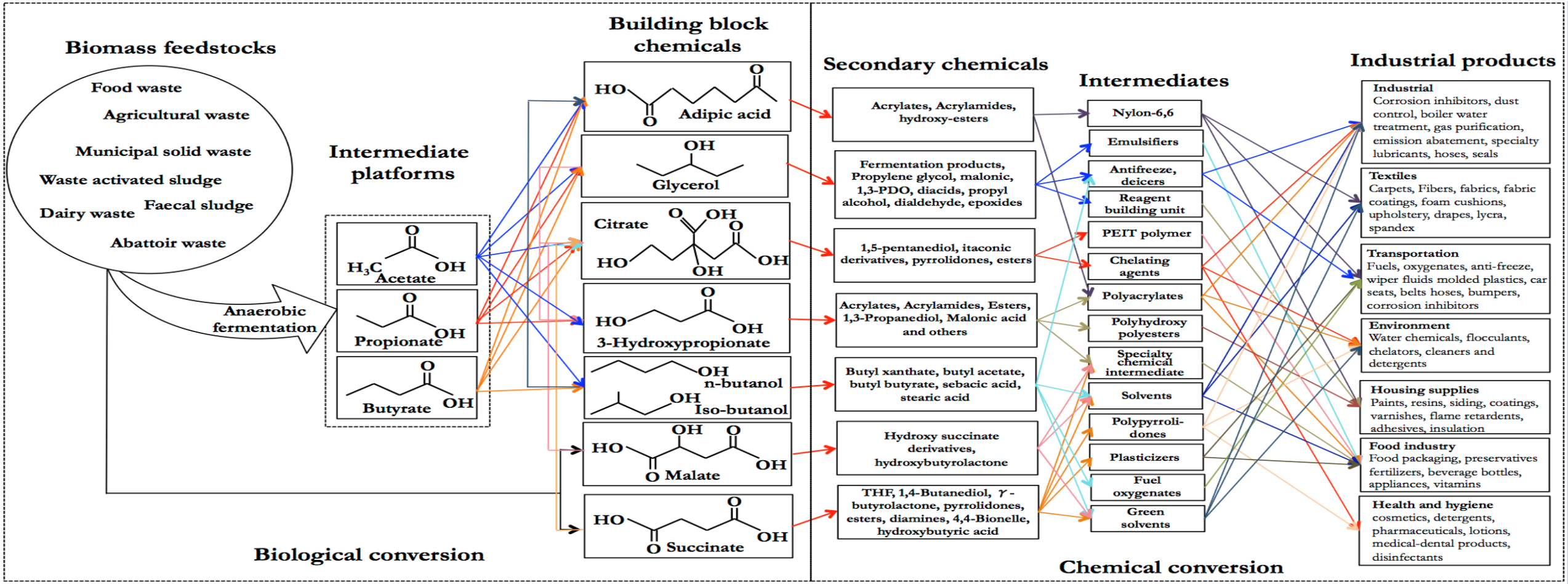






Food security	Food security	Food security
Technology and engineering	Technology and engineering	Technology and engineering
Recover C-energy	Recover C-energy	Recover C-energy
Recover P	Recover P	Recover P
Recover N	Recover N	Recover N
Disinfection	Disinfection	Disinfection

Potential for C-recovery is immense, but…



… needs to address a higher objective