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Woods Institute 5th Anniversary Symposium

October 21, 2009

Woods Institute
for the Environment
Stanford University

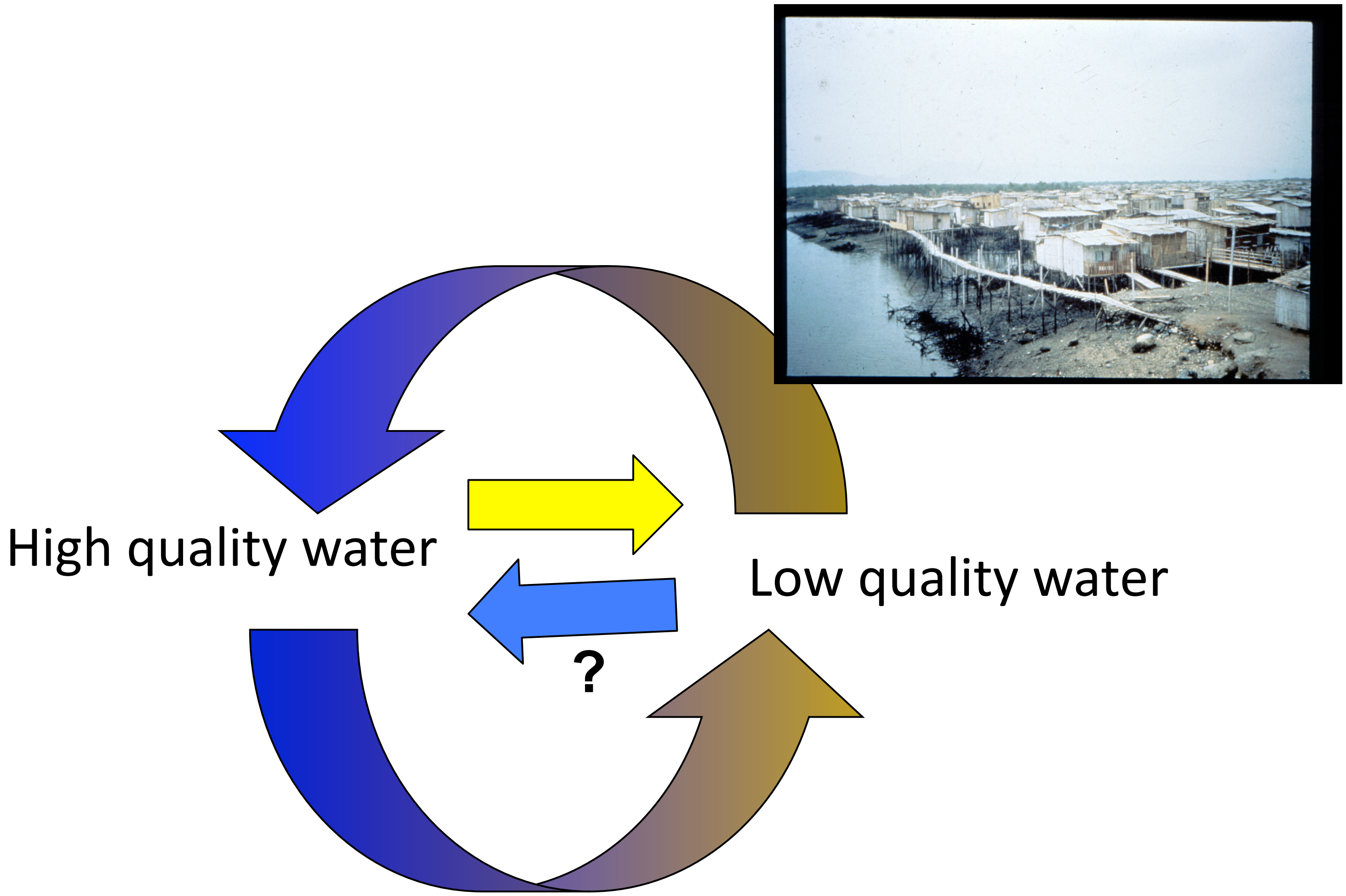
Collaborations initiated with Woods Institute funding

- Short-circuiting the H_2O cycle with Frank Wolak (Economics)

- Short-circuiting the C cycle with
Sarah Billington (Structural Engineering)
Curt Frank (Chemical Engineering)

- Short-circuiting the N cycle with
Brian Cantwell (Aeronautics and Astronautics)

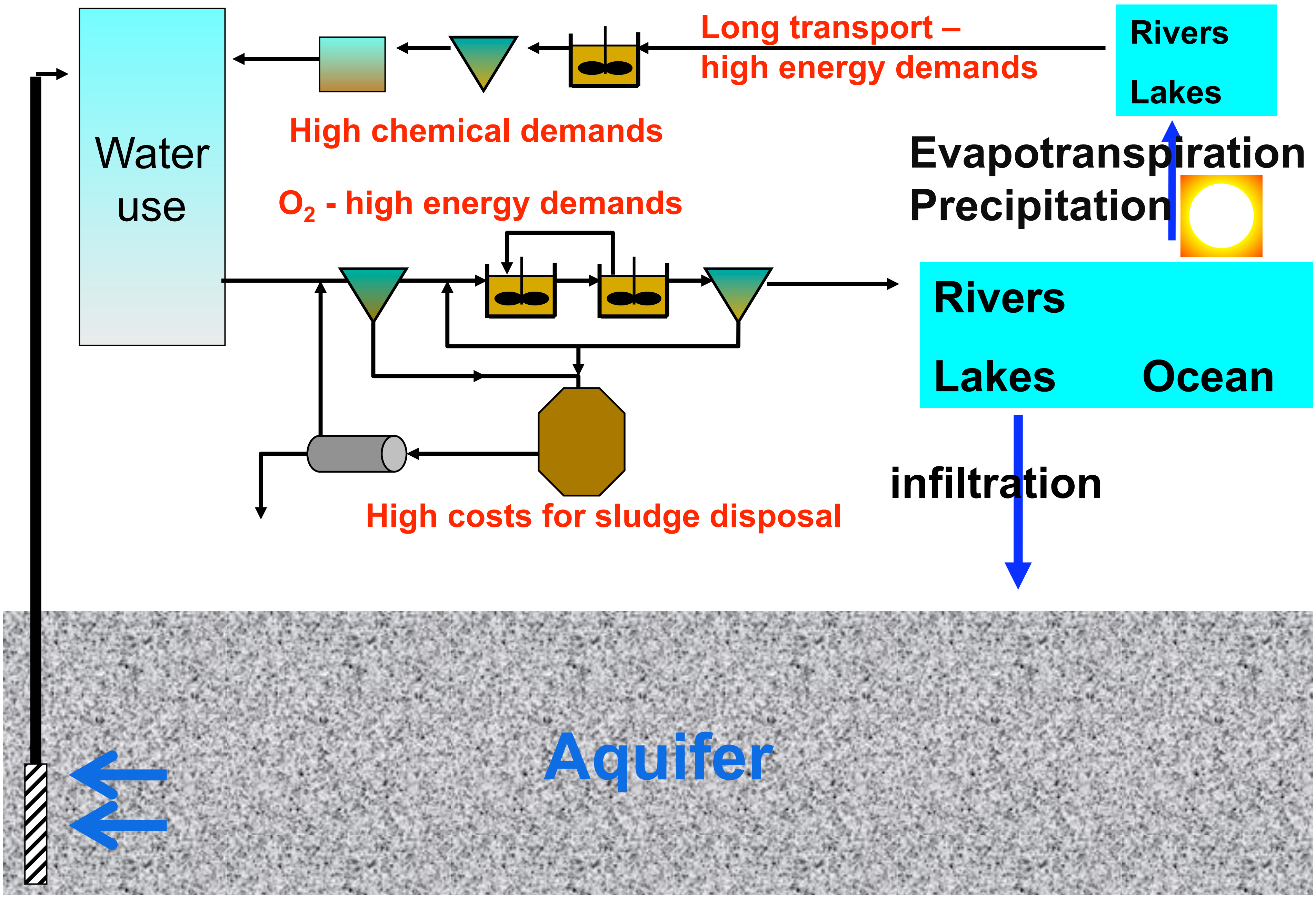
Short-circuiting the H_2O cycle



Low q

The water cycle

Can we improve it?



Products in wastewater

Components of wastewater:

- Water (99.9%)
- Biodegradable organics
- Nutrients (N and P)

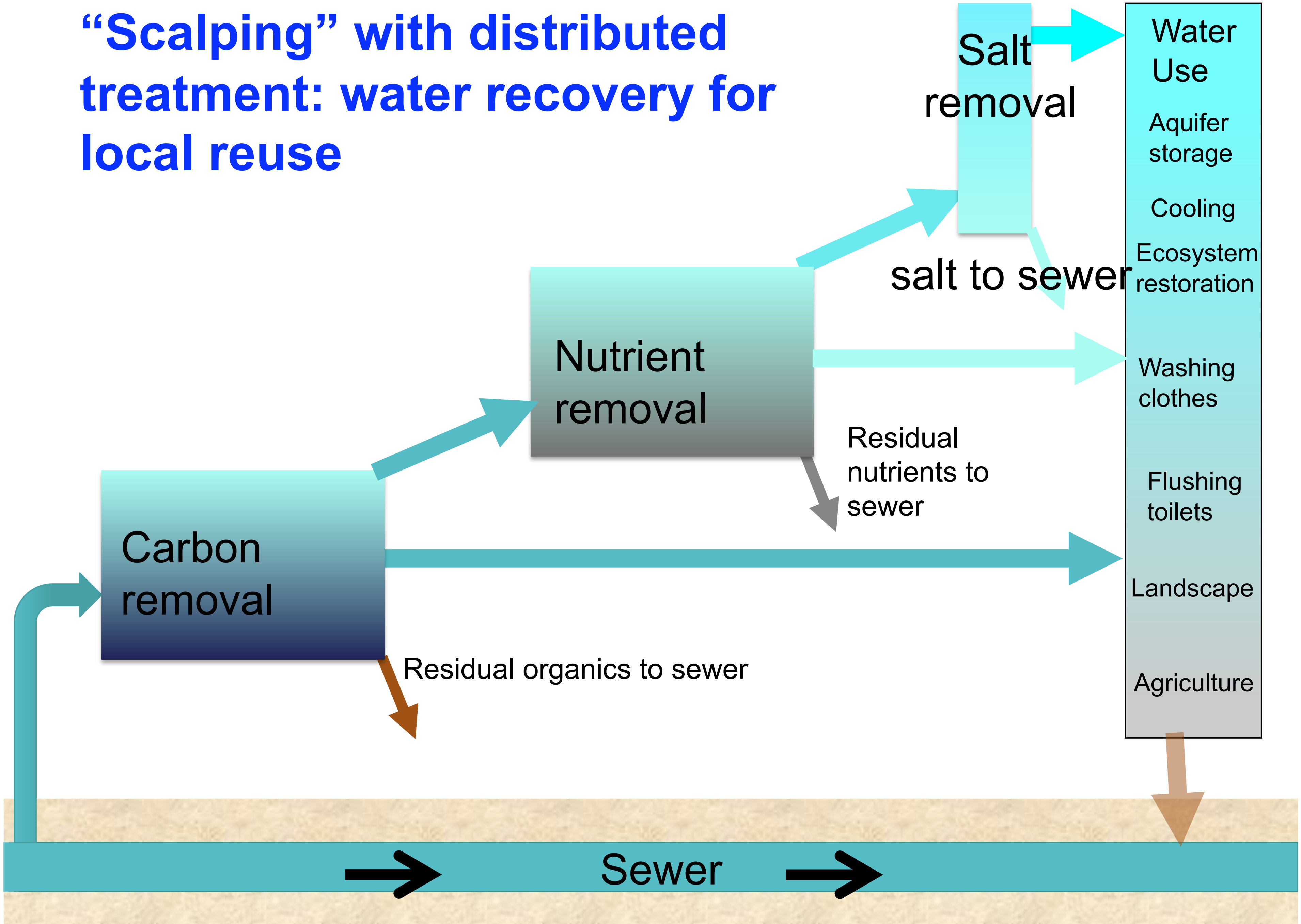
- Pathogens
- Salt
- Refractory organics

The value of wastewater resources

Resource	Per m^3	US $ per m^3	US $ per 1000 gal
Organic soil conditioner	0.10 kg	0.026	0.10
Methane	0.14 m^3	0.065	0.25
Nitrogen	0.05 kg	0.065	0.25
Phosphorus	0.01 kg	0.013	0.05
Water	1 m^3	0.325	1.20

From Willy Verstraete (2008)

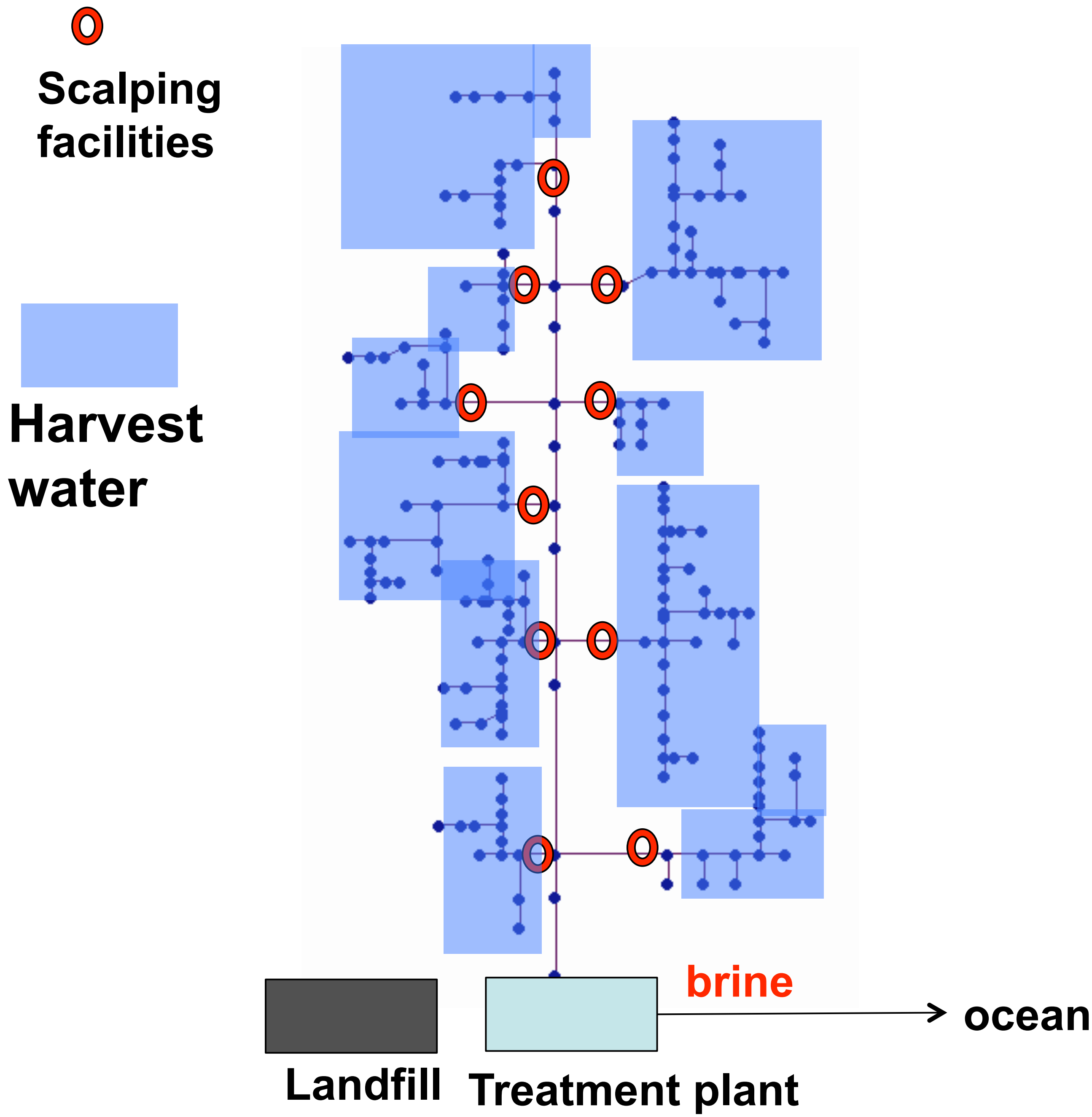
“Scalping” with distributed treatment: water recovery for local reuse



For the Stanford campus, “scalping” is a potential supply of non-potable water. Recovery of water at $1/1000 gallons would be a good goal.

Widespread “scalping” would change the composition of the water to be treated at the centralized facility.

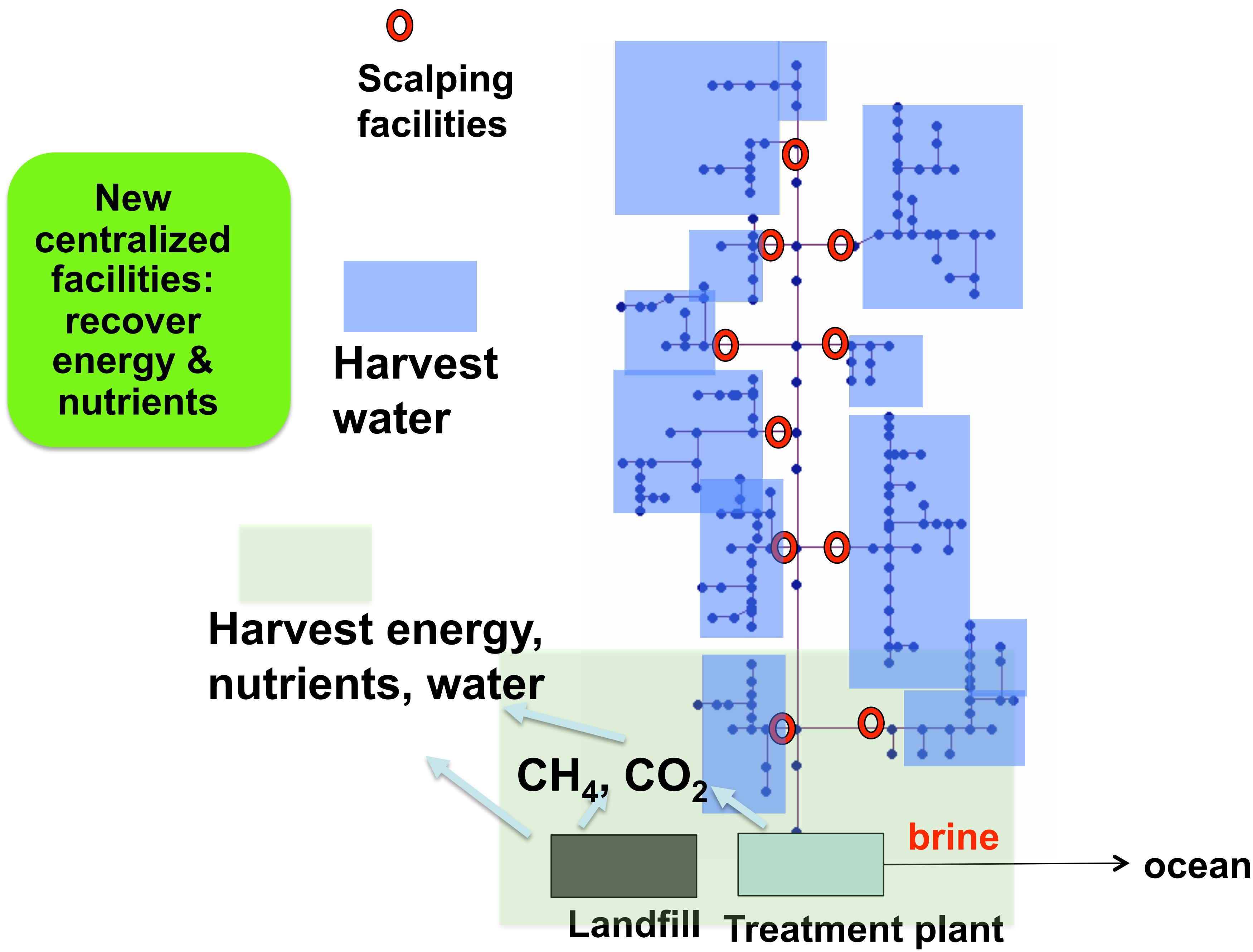
Distributed scalping facilities for local water reuse



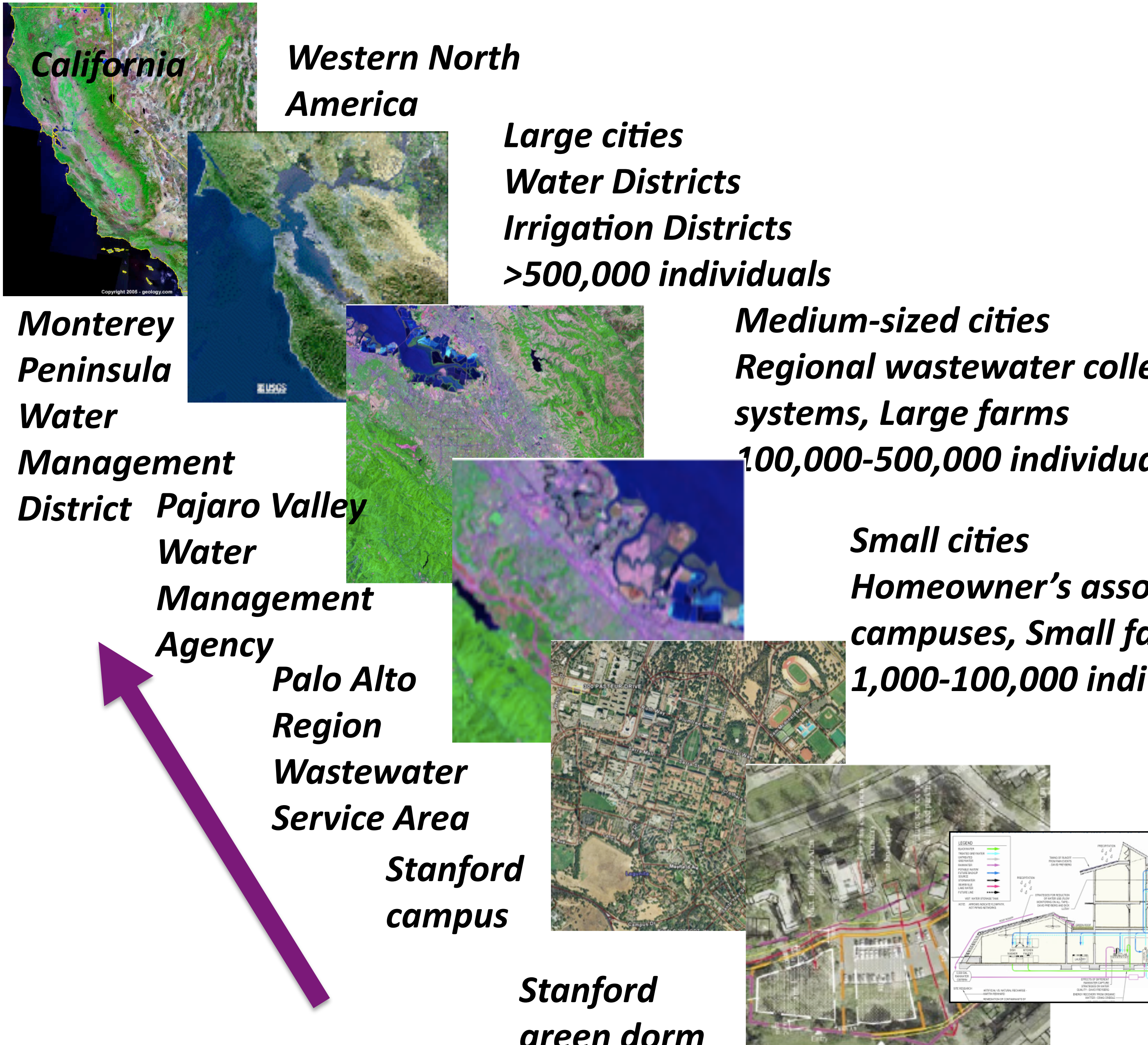
The value of wastewater resources at centralized facilities if 75% of the water is removed by scalping.

Resource	Per m^3	US \$ per m^3	US \$ per 1000 gal
Organic soil conditioner	0.40 kg	0.10	0.40
Methane	0.56 m^3	0.26	1.00
Nitrogen	0.20 kg	0.26	1.00
Phosphorus	0.04 kg	0.05	0.20
Water	1 m^3	0.325	1.20

Note: removal of three quarters of the water quadruples the \$/unit volume from the organics and nutrients in one m^3 of wastewater. Now the energy and nutrient value is equivalent to the value of the water.



New centralized facilities: recover energy & nutrients
Scalping facilities
Harvest water
Harvest energy, nutrients, water
CH_4, CO_2
brine
ocean
Landfill
Treatment plant



Western North America

Large cities
Water Districts
Irrigation Districts
>500,000 individuals

Monterey Peninsula Water Management District

Medium-sized cities
Regional wastewater collection systems, Large farms
100,000-500,000 individuals

Pajaro Valley Water Management Agency

Small cities
Homeowner's associations, campuses, Small farms
1,000-100,000 individuals

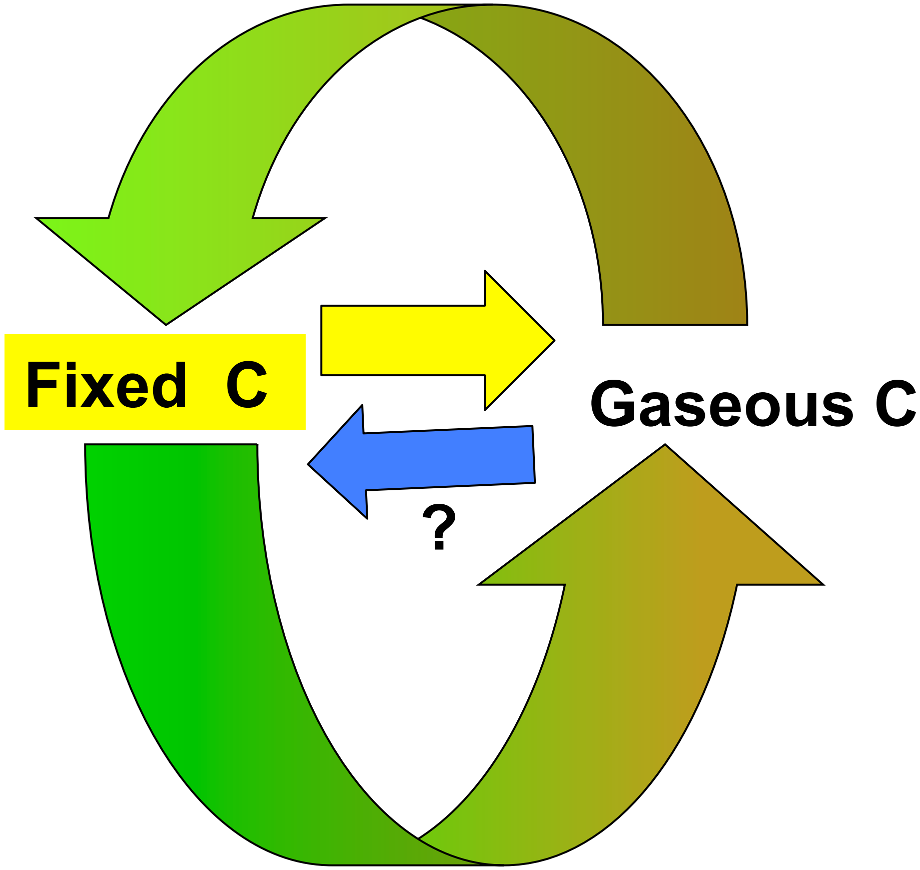
Palo Alto Region Wastewater Service Area

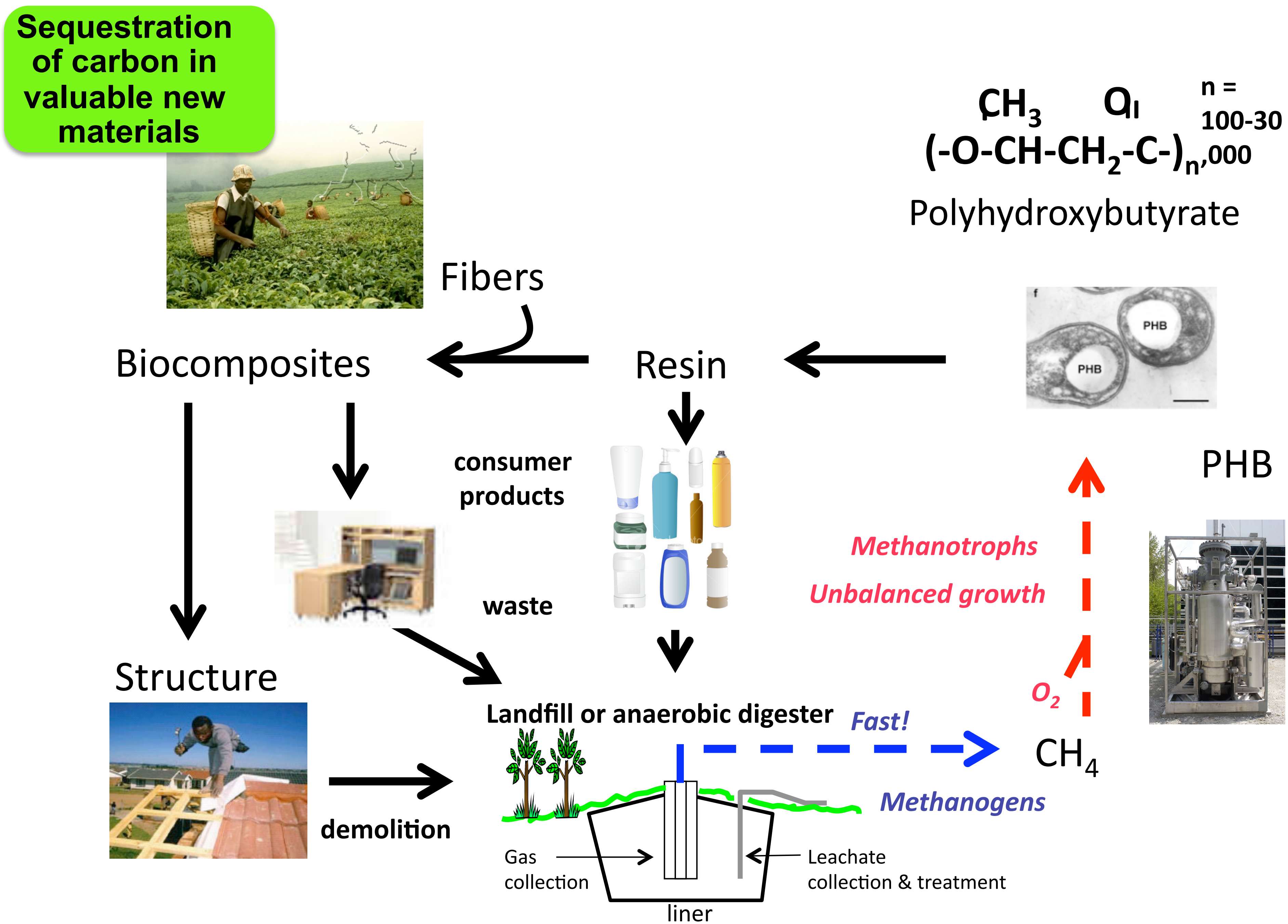
Stanford campus

Buildings (Hotels, Dorms, etc.)
10-1,000 individuals

Stanford green dorm

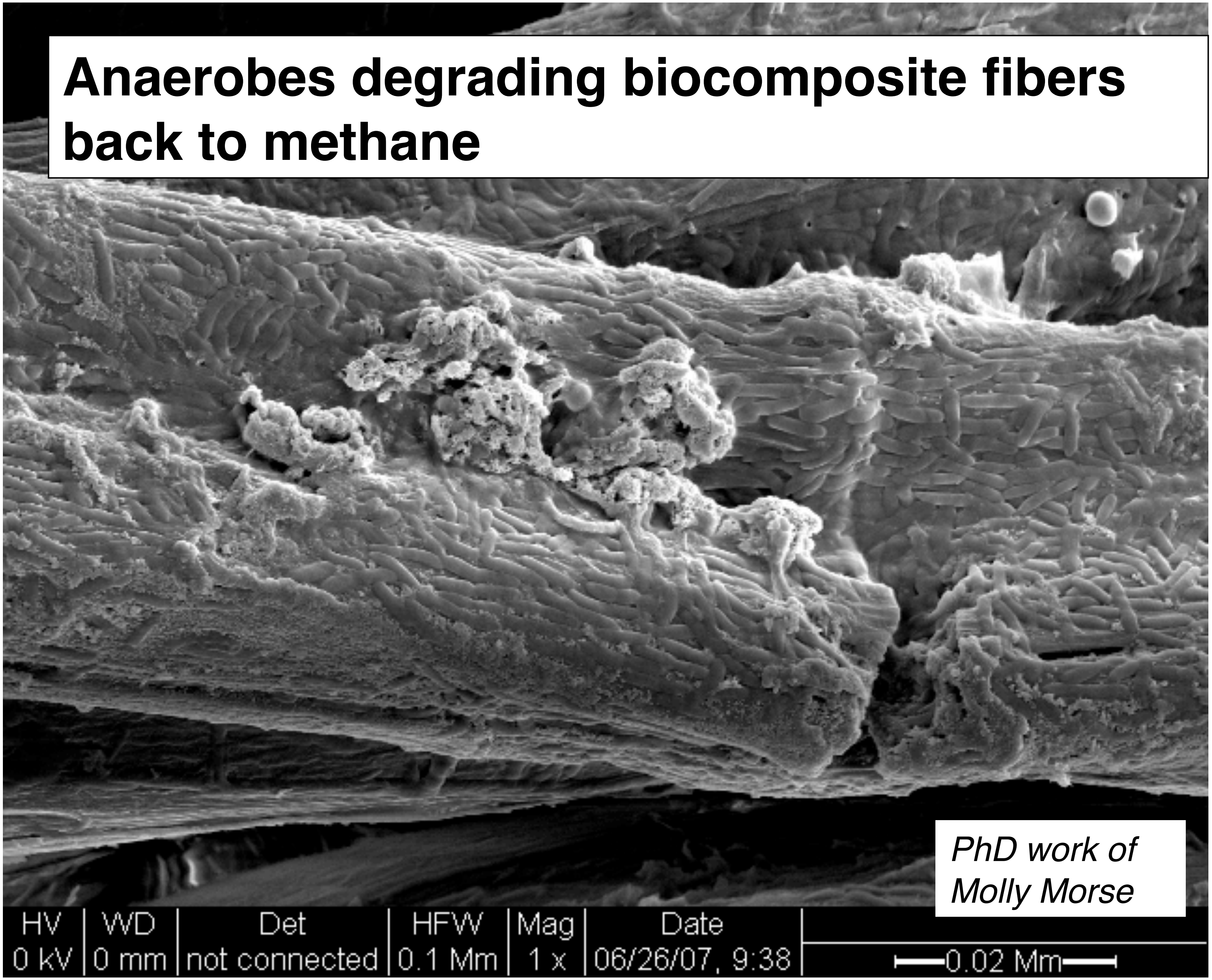
Short-circuiting the C cycle





Sequestration of carbon in valuable new materials
CH_3 O
$(-O-CH-CH_2-C-)_n$
n = 100-30,000
Polyhydroxybutyrate
Fibers
Biocomposites
Resin
PHB
PHB
PHB
consumer products
waste
Methanotrophs
Unbalanced growth
Structure
O_2
Landfill or anaerobic digester
Fast!
CH_4
Methanogens
demolition
Gas collection
Leachate collection & treatment
liner

Anaerobes degrading biocomposite fibers back to methane



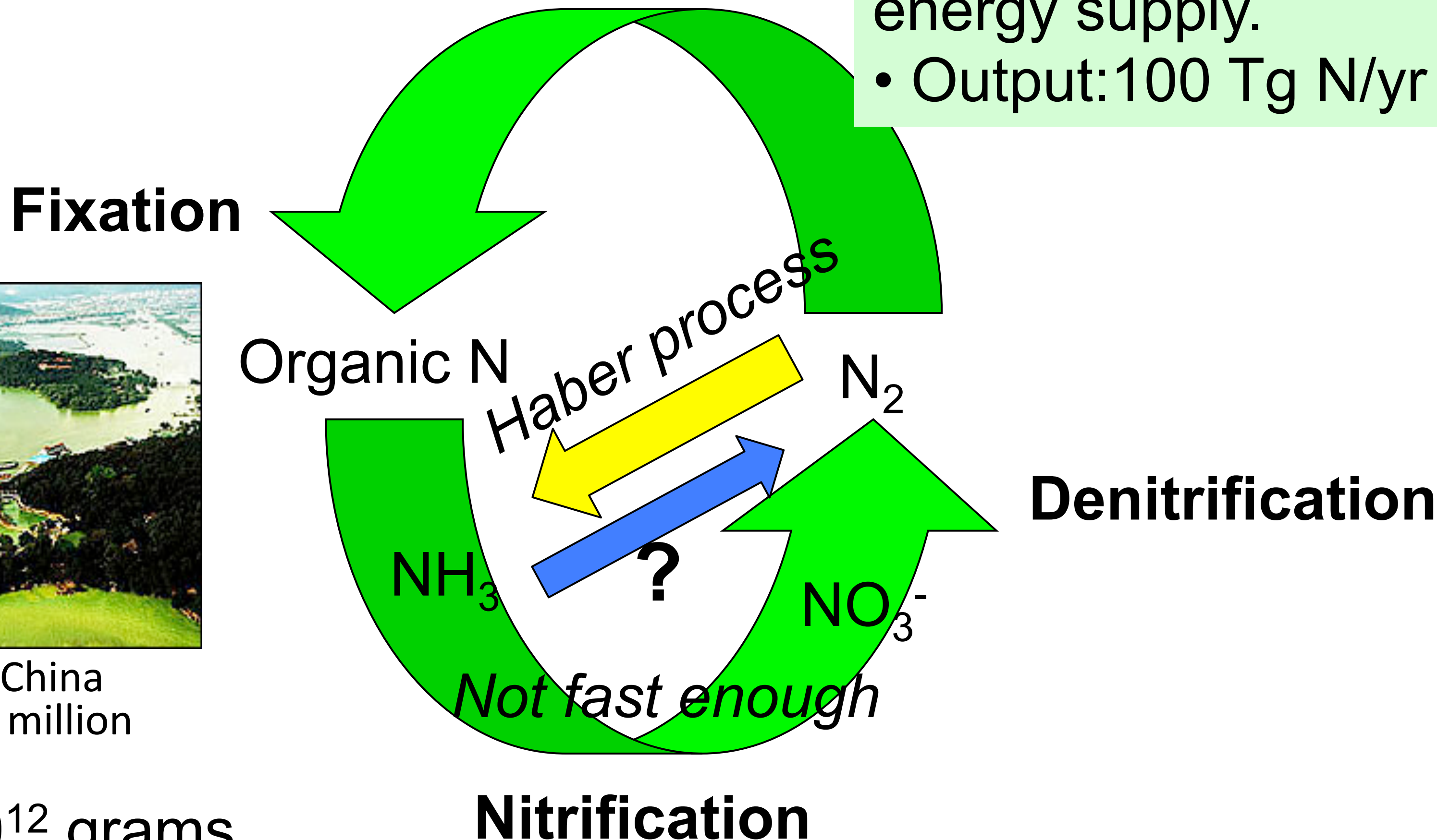
PhD work of Molly Morse

• The Nitrogen Cycle

The Haber Process:
$N_2 + 3H_2 = 2NH_3$

- Input: 1-2% of the world's annual energy supply.
- Output:100 Tg N/yr

Natural cycle spins at 130 Tg N/yr



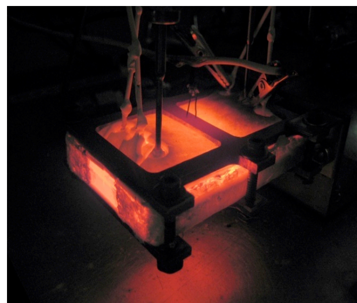
Lake Taihu, China
Supplies 30 million people

1 Tg = 10^{12} grams
10^6 tonnes = 0.001 Gt

Can nitrogen be converted to N_2 in a short-circuit cycle that generates energy?

Short-circuit nitrification with catalytic N_2O decomposition

N_2O decomposition cell (Scherson and Cantwell, 2008)



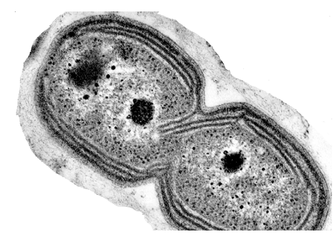
Serious greenhouse gas!

Nitrous oxide

$$0.5N_2O + 1.5H_2O$$

$0.75\ O_2$

NH_3



$$0.5N_2 + 0.25\ O_2$$

+ 41 kJ

Produces energy and saves oxygen!

Thank you.

For more information:

http://www.stanford.edu/group/evpilot/