Why Eco-Toilets?

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Hatchville Rd, Falmouth MA
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Likely trends / Implications

- **Climatic events / climate resilient infrastructure**:
  - –More intense storms, sewer overflows, outages
    - Pressure sewers, off grid systems more resilient
  - –Aging pop/tourists, more prone to diseases
    - e.g. legionellosis via water aerosols (etc.)
- **Energy & nutrient recovery / novel management**:
  - –Utilize energy value within 'wastes' / energy-heat recovery
  - –Revitalize agriculture / recycle of 'local' nutrients
- **Need to reduce greenhouse gases / source-sep**:
  - –Move less water over long distances, i.e. recycle, especially reuse within homes/buildings with renewable energy

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Clean Water Act (CWA)

- 40th Anniversary of the Clean Water Act (Oct 1972) from Federal Water Pollution Control Act (1948), to
  - –"restore & maintain the chemical, physical, & biological integrity of the Nation's waters"
    - interim goals for waters to be fishable & swimmable
- All national water discharges are unlawful unless authorized by a permit with baseline, across-the-board technology-based controls for **municipalities & industry**

Missing elements: Household discharges to the environment
One-water systems approach/narrative

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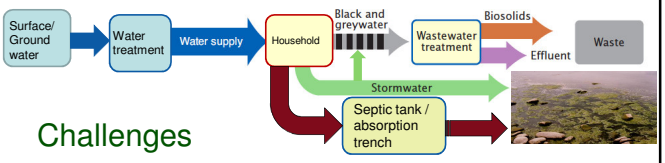
Current urban water system



Challenges

- US water services utilize ~3-7% of nation's electricity
- Aging water and wastewater infrastructure $trillions to maintain
- Insufficient nutrient and energy recovery + 3% GHG
- Not climate nor demographic resilient

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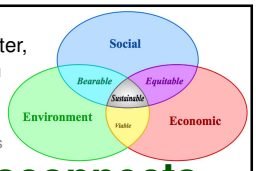
Bullitt Center, Seattle
$30m, office O_3-rainwater, PV power & foam-flush dry composting toilets (opens April 22, 2013)
Sian Kennedy, New York Times



There are many disconnects in the management of water

➢e.g. Energy & water use & who pays; most decisions are local; hard to adapt big systems

- ◆ Missing a whole-of-system consideration
- ◆ For future technology options it is all about resource recovery (energy, nutrients, H_2O)

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Core elements: water service sustainability

- We can not management the environment*, hence
  - –The need for adaptive-resilient water systems
- Ecosystem services are central societal needs
- Therefore, based on 'urban metabolism' to mimic that of nature, water services need to be framed around
  - –Resource recovery for public health protection

*Social-ecological systems are so complex that understanding them is still a faint hope; If you cannot understand something, "managing" it is problematic & precautionary principle of little value

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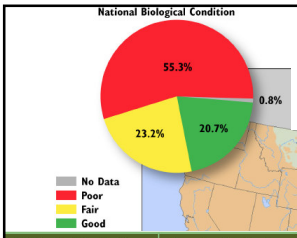
Bromley (2012) Ecology & Society 17(3): 43-50

U.S. EPA 2013 National Rivers and Streams Assessment 2008-2009

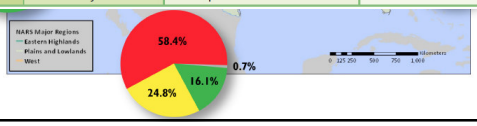


water.epa.gov/type/rsl/monitoring/riverssurvey

55% do not support healthy life

N, P & poor habitat major issues

Biological Indicators	Chemical Indicators	Physical Indicators	Human Health Indicators
▪ Benthic macroinvertebrates ▪ Periphyton (algae) ▪ Fish community	▪ Phosphorus ▪ Nitrogen ▪ Salinity ▪ Acidity	▪ Streambed sediments ▪ In-stream fish habitat ▪ Riparian vegetative cover ▪ Riparian disturbance	▪ Enterococci (fecal indicator) ▪ Mercury in fish tissue



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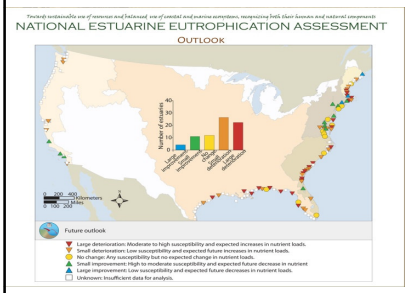
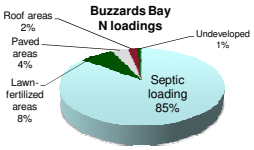
NE Coast Eutrophication



NOAA: Mid-Atlantic region, stretching south from Cape Cod - Chesapeake Bay, is the most impaired

http://ccma.nos.noaa.gov/publications/eutroupdate/

Excessive nutrient has caused massive blooms of marine algae along Cape Cod



Septic N major contributor to coastal eutrophication

http://buzzardsbay.org/bbpnitro.htm

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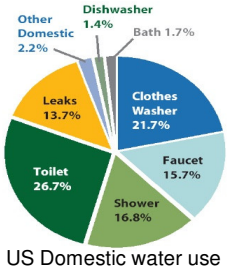
Global Issues: Water scarcity/climate change, urbanization & eco service loss

- For economic, ecosystem service & water scarcity points of view we need to reuse water and only treat so reuse water is
  - –Fit-for-purpose



US Domestic water use (AWWA/AwwaRF)

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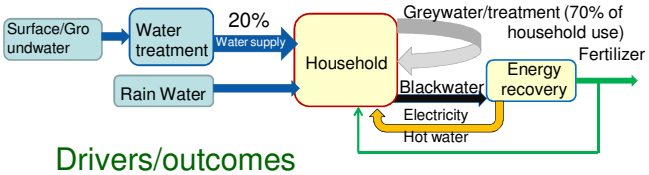
Hence, alternative system elements 'One-water' concept



Drivers/outcomes

- Need to reduce energy use plus GHG and nutrient emissions
  - ➢ Novel water, energy & nutrient recovery & management
- Climate & demographic resilient infrastructure
  - ➢ Decentralized, adaptable and antifragile

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Primary concern is public health

- CDC estimate waterborne disease costs > $970 m/y
  - –Addressing giardiasis, cryptosporidiosis, Legionnaires' disease, *otitis externa*, and non-tuberculous mycobacterial infections, causing over 40 000 hospitalizations per year,
  - ✦ >$780 m/y from gastrointestinal pathogens (incl. some via water)

Disease	$ / hospitalization	Total cost
Cryptosporidiosis	**$16 797**	**$45 770 572**
Giardiasis	**$9 607**	**$34 401 449**
Legionnaires' disease	**$33 366**	**$433 752 020**
NTM infection/Pulmonary	**$25 985 / $25 409**	**$425 788 469/ $194 597 422**

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Collier *et al.* (2012) Epidemiology & Infection 140:2003-2013

CWA narrative problems, how to make 208 planning better

- In the one-water paradigm
  - –we aspire to have no 'waste'
  - –trial, adapt, innovate – via civic engagement
- **Economics**: we do not price nor assess in planning:
  - –Recovery of resources – co-located for reuse
  - –Household water service financing, and how to integrate with centralized plans
  - –Value of ecosystem services

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Example solutions to allow

- Central financing entity that owns and maintains decentralized water services / with users' tax breaks
- Owners have options for type of service, which may include:
  - Urine storage &/or septic retro and pump-out – fertilizer payment
  - Greywater treatment on-site using PV power for use in garden, toilets, clothes washing
  - Blackwater sewer connection – with community useable hot-water heating and/or energy credits
- Municipally-owned reactive barriers for enhanced denitrification for groundwater N removal & phosphorus sorption

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Building codes and responsibilities

- **Reuse of rainwater & greywater not allowed**
- **Hence need demonstration ordinances**
  - Missing experience, training & validation:
    - Iconic demonstration sites (local experience) could provide that, along with 'green plumber' training, but no yet mandated
    - Adaptive practice requires more flexibility
      - While protecting humans & ecosystems

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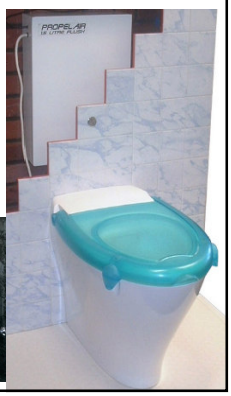
Example toilet & greywater options

Graywater treatment

Urine-diversion toilet

Foam-flush toilet



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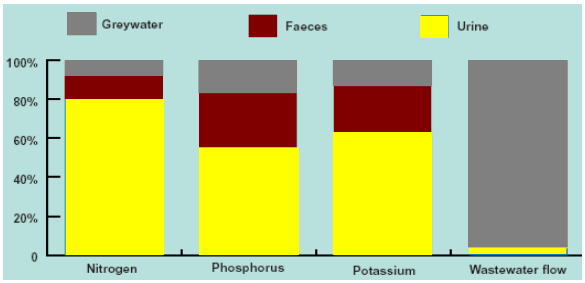
Why divert the urine?



- Use as a plant fertilizer

– Normal nitrogen application (80-100 kg/ha)
≡ 10-40 tonnes of urine/ha is needed

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Urine storage tank (264 gal) & Aquatron solids separator + composter

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Engineering principles

- Use of specific process-oriented tools (e.g. LCA, NPV, MRA) to aid in sustainability assessments, and
- Water-fit-for-purpose/resource-recovery decision support systems to aid stakeholder involvement

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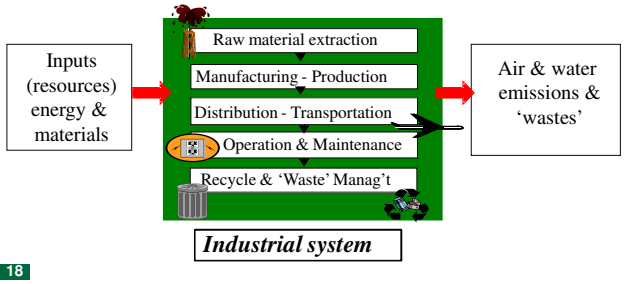
Life-cycle assessment (LCA)

LCA is the systematic analysis of environmental impacts from products/services during their entire life-time



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Life Cycle Inventory

Unit processes	Data sources
Water services including water extraction, treatment and supply	water utility datasets, peer reviewed articles, ecoinvent database
Composting toilet, low-flush toilet, urine diversion toilet	pilot studies, peer reviewed articles
Blackwater collection, digestion and energy recovery	ecoinvent database, peer reviewed articles, EPA Coeat Model
Greywater collection, treatment and reuse	ecoinvent database, peer reviewed articles
Rainwater harvest and use	ecoinvent database, peer reviewed articles

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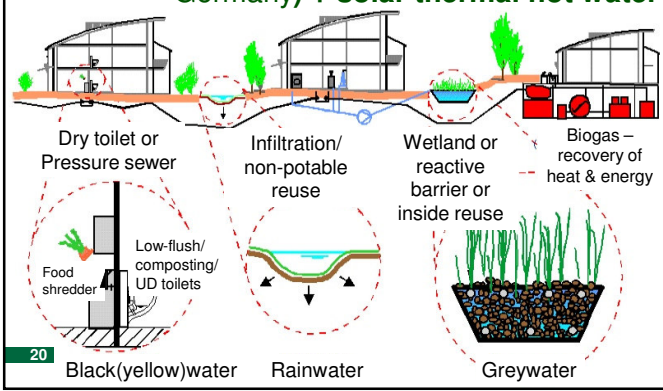
Example system (based on Lübeck, Germany) + solar thermal hot water



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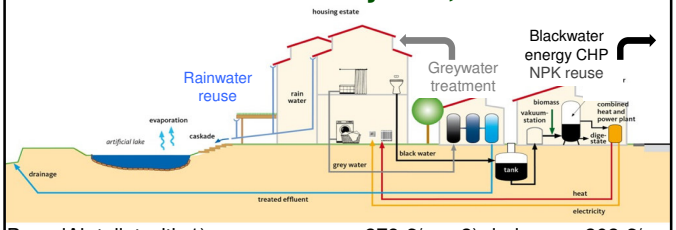
Future municipal water services: HAMBURG WATER Cycle®, Jenfelder Au



PropelAir toilet with 1) pressure sewer: 278 €/p·y; 2) drainwave 262 €/p·y
3) drainwave + pump out clusters of households 274 €/p·y
4) conventional gravity sewer 302 €/p·y (Kinstedt MSc, Hamburg)

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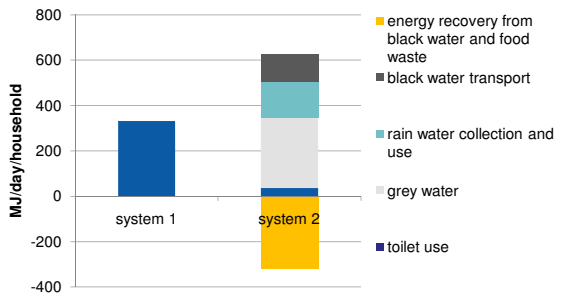
Preliminary LCA results for energy use

1: municipal water supply +composting toilet + greywater via septic tank

2: lowflush toilet+blackwater-energy + greywater reuse + town & rainwater use



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Solar-powered septic retrofit that generates hydrogen & electricity

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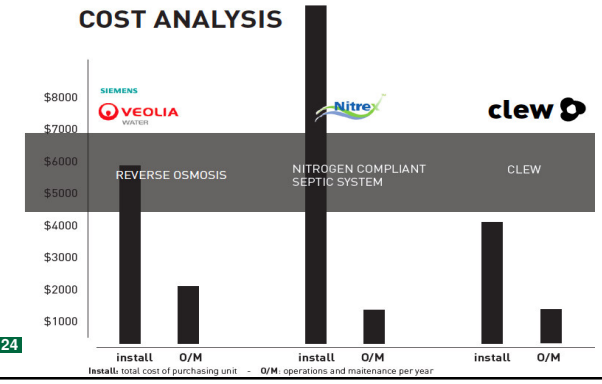
Caltech CLEW system (<$5000)



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Caltech CLEW comparison

REVERSE OSMOSIS	NITROGEN COMPLIANT SEPTIC SYSTEM	CLEW
+ best filtration	+ very effective	+ clean processing
- energy intensive	- expensive	+ energy neutral
- high maintenance	- consistent use	+ no filter
- expensive	- high maintenance	+ cost effective

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Summary

- Sustainable water services = resilient & adaptable systems
- Based on resource recovery (so economically driven change)
- Need new metrics for public health / wellbeing assessment
- Need 208 planning to provide for an adaptive compliance process

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Waste of energy in the water sector

- US water services utilize ~3-7% of nation's electricity
  - Drinking W 1500 kWh/MG + Waste W 1200 kWh/MG
  - i.e. some 100 billion kWh/y = 16 avg coal-fired power plants
  - ≅embedded energy in food/fecal residuals in sewage
- However household energy use – 14% for hot water
  - i.e. heating water more important energy issue
  - 3rd highest use after household heating (29%) & cooling (17%)

www.eia.doe.gov/emeu/reps/enduse/er01_us.html

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Urine-diverting toilets

- WM-Ekologen model DS
- Other models have combine vacuum system or dry fecal collection with urine diversion.
- BB Innovation & Co. model Dubbletten
- gives 3.3 - 3.6 g N / L

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