Net Energy and Clean Water from Wastewater

ARPA-E Potential FOA

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ARPA-E Water-Energy from Wastewater Program

Case for Water-Energy from Wastewater

The “Box” For Energy-Water from Wastewater

ARPA-E Workshop Structure

Workshop on
"Energy & Clean Water From Wastewater"

Workshop Objectives

1. Obtain feedback from U.S. researchers, cognizant companies, and water associations as to the objectives and metrics to achieve net energy output and clean usable water from municipal and industrial wastewaters.
2. Identify promising technical directions with the potential to radically improve net energy exaction and clean water from wastewater, and identify key technical barriers.
3. Identify potential performers, and discuss teaming for system integration, and piloting for real wastewaters.

Workshop Context

Provide input as to how ARPA-E might structure an upcoming FOA so that an impactful 2-Phase 3 year program is created that complements existing DOE, EPA, and Federal research programs and accelerates promising ideas up the development ladder, so that a piloting stage in select small towns can start after 3 years.

Format

Focused breakout sessions with reports to the group

- Two tracks: Science & Techology and Implementaion & Translation
  - Four breakouts in each track. 15 minute "report out" by chair of each session

Joint Combined Methods Session

Overarching Goal of Program

1. Recover usable energy contained in wastewater to help renewably supply some of U.S. Energy needs.
2. Recover usable clean water from wastewater to:
   1. Reduce embedded energy cost needed to supply new water,
   2. Effectively increase water available for human use.
3. Reduce greenhouse emissions emanating from:
   1. Wastewater hydrocarbons,
   2. Energy used to treat and discharge wastewater,
   3. Energy used to transport and treat supply waters.
4. Increase American Competitiveness:
   1. Translating advances made in program to U.S. businesses
   2. Implementing and adopting new technologies by utilities, companies, govermental units, and other end users.

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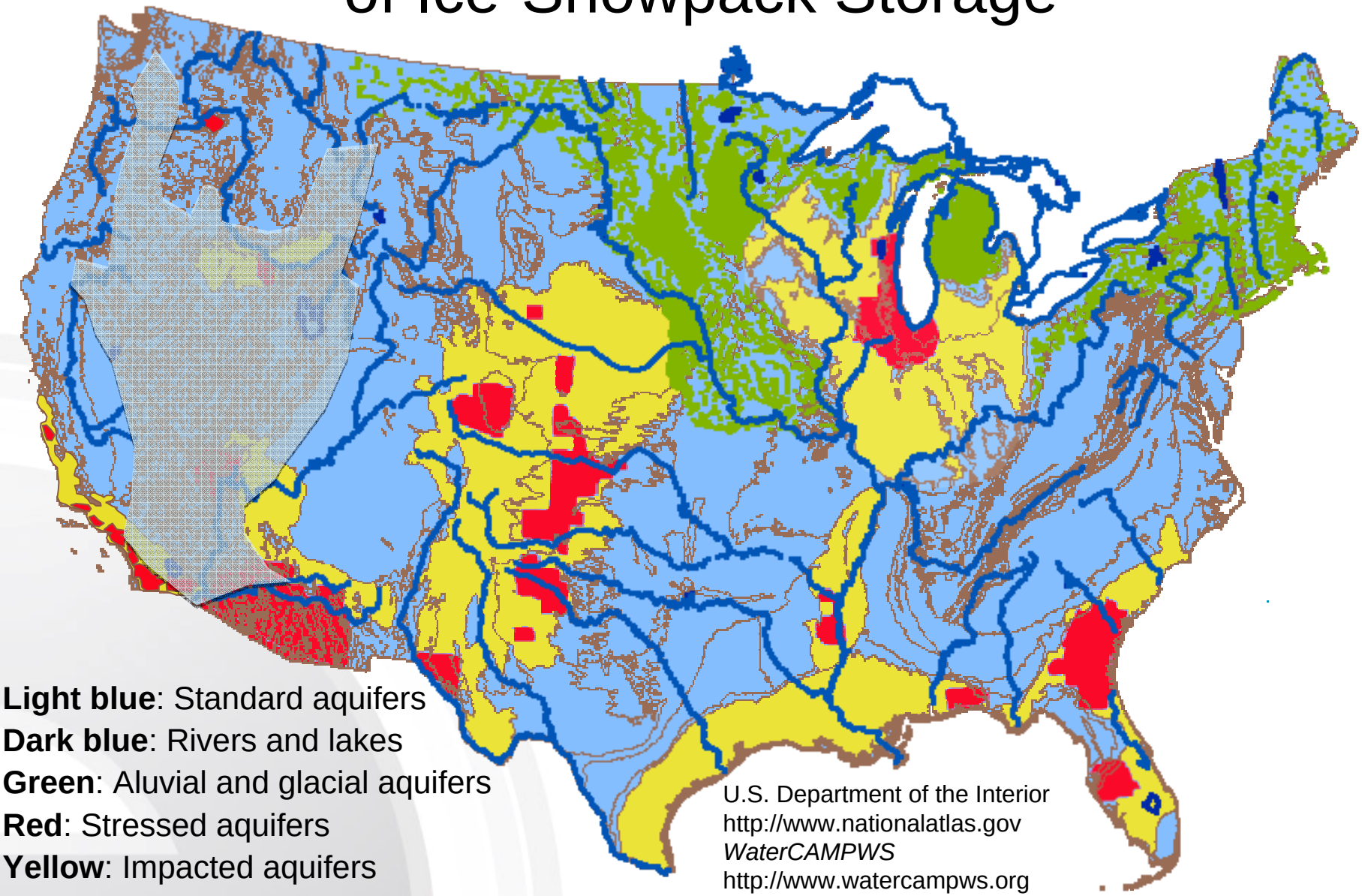
The Case For Water

- Will have large growth in demand on average, but many localities will see huge increases.
- Conservation alone cannot meet demand…not even rationing by 50% or more (at most a 2x increase).
- Need something that can increase effective supplies by many factors (3x, 4x, up to 100x)

Depletion of Groundwaters & Loss of Ice-Snowpack Storage

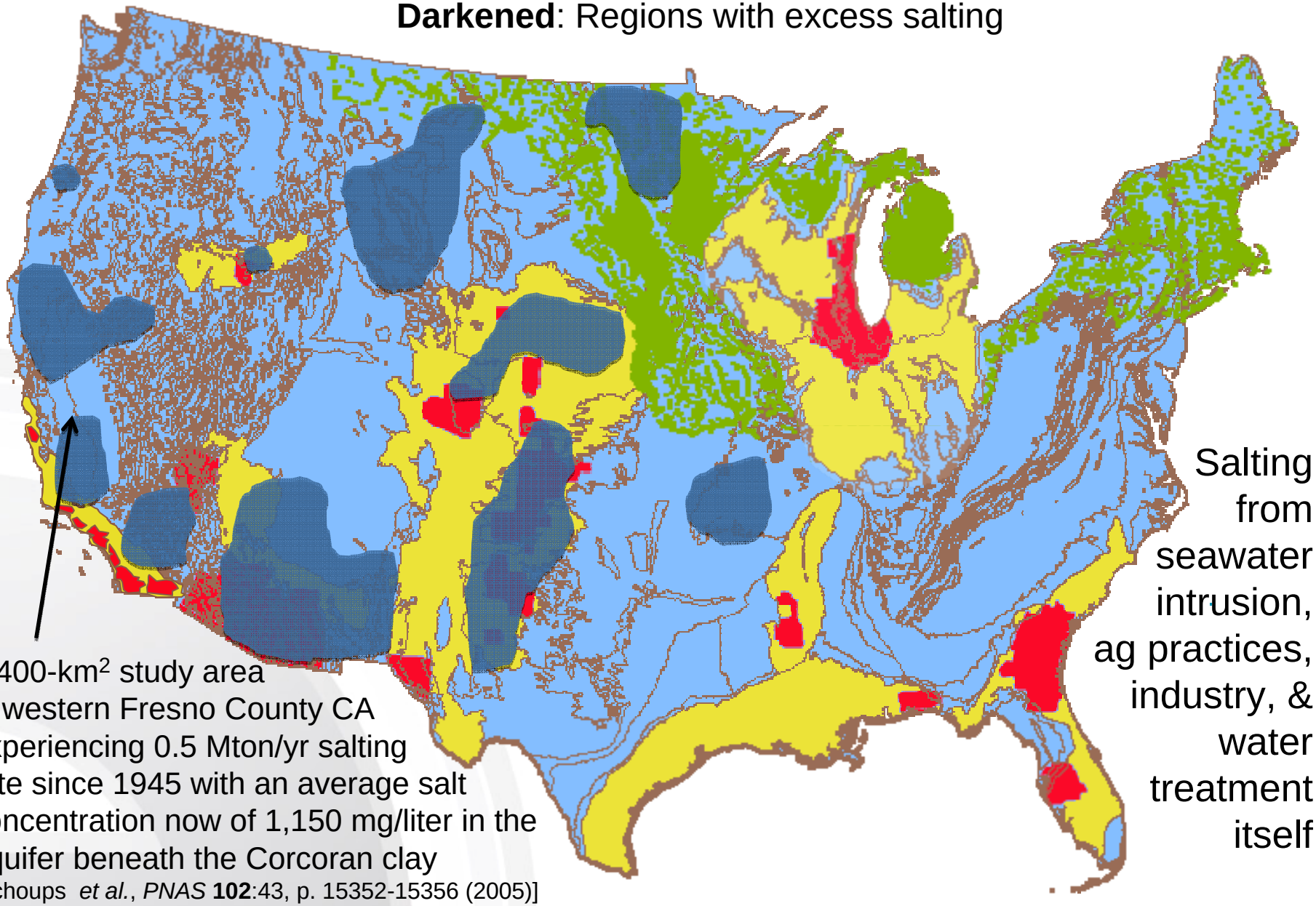


Light blue: Standard aquifers
Dark blue: Rivers and lakes
Green: Aluvial and glacial aquifers
Red: Stressed aquifers
Yellow: Impacted aquifers
White: Declining snowpack storage

U.S. Department of the Interior
http://www.nationalatlas.gov
WaterCAMPWS
http://www.watercampws.org

Salting Issues

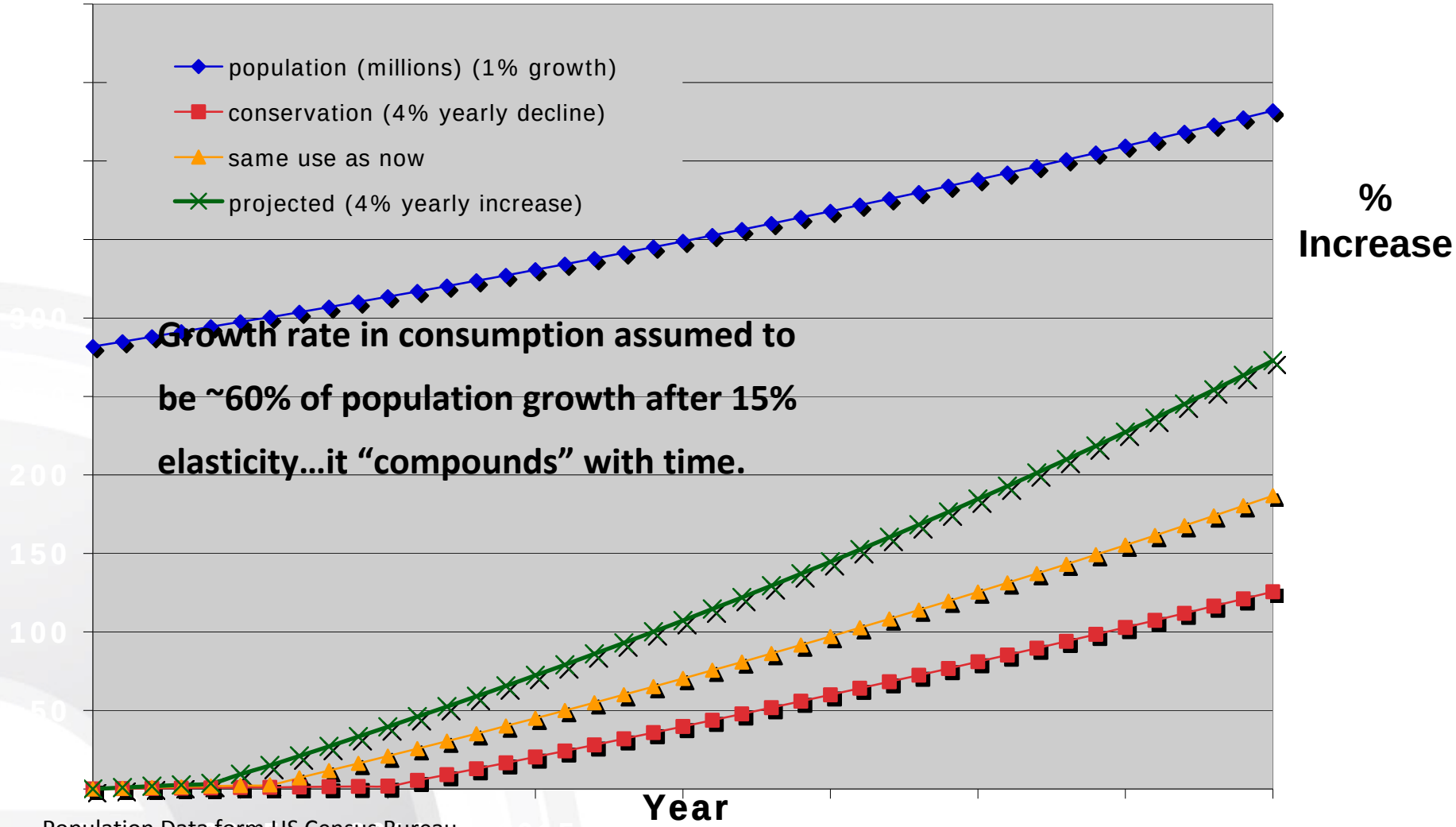
Darkened: Regions with excess salting



1,400-km^2 study area in western Fresno County CA experiencing 0.5 Mton/yr salting rate since 1945 with an average salt concentration now of 1,150 mg/liter in the aquifer beneath the Corcoran clay
[Schoups *et al.*, *PNAS* **102**:43, p. 15352-15356 (2005)]

Salting from seawater intrusion, ag practices, industry, & water treatment itself

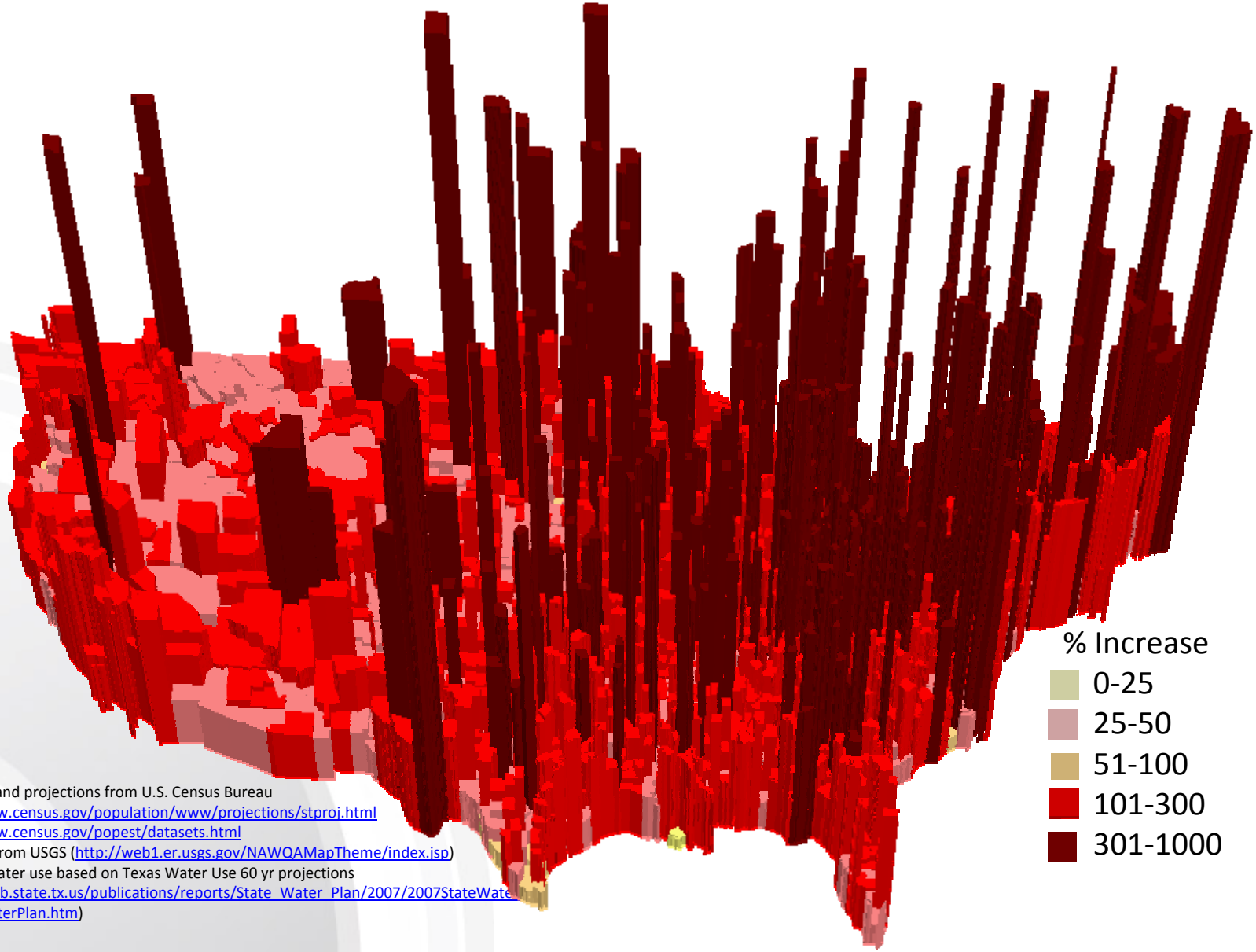
Water Use With Growth in Population



Population Data form US Census Bureau
The Blueprint 2030 forecast share of the revised United States population growth forecast from 2000 to 2030 was 1.14%

2030 Projected % Increase (since 2000)

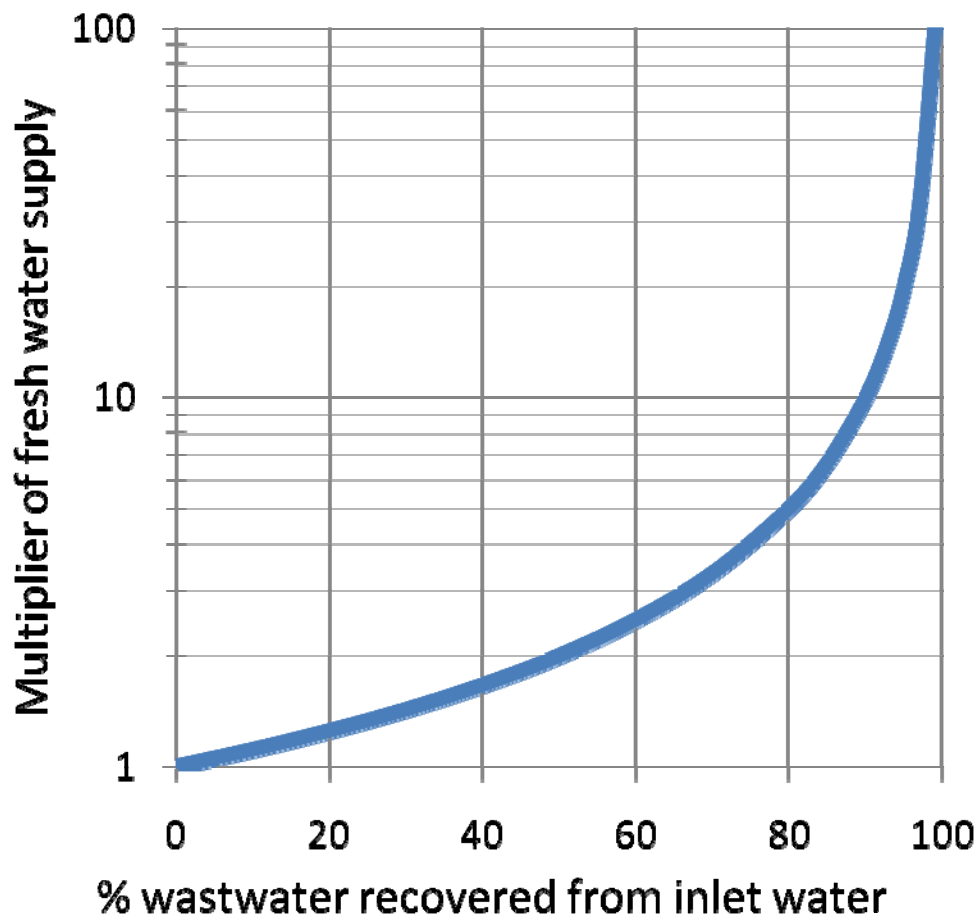
Averages don't tell the real story: Growth problems will be local.



Population data and projections from U.S. Census Bureau
http://www.census.gov/population/www/projections/stproj.html
http://www.census.gov/popest/datasets.html
Water Use Data from USGS (http://web1.er.usgs.gov/NAWQAMapTheme/index.jsp)
Projections for water use based on Texas Water Use 60 yr projections
(http://www.twdb.state.tx.us/publications/reports/State_Water_Plan/2007/2007StateWate
an/2007StateWaterPlan.htm)

Why Water Recovery?

- Only 10 to 30% of water actually consumed (70 to 90% returned) in municipal and industrial systems. Reuse can effectively increase supplies by 3.3x (70%) up to 100x (99%).
- Compare to conservation (50% reduction gives a 2x gain). Conservation of consumed (evaporated) water when combined with reuse can get to 90+%



What is "Clean Usable Water"

- We need water that can be used for most all uses. It has to be safe (pathogen and toxic compound free), low in dissolved solids (salts) and suspended solids (solids). Does it need to be clean enough for intimate human contact?
- Currently reclaimed water ~ costs near desalination. If non-potable water, separate distribution system needed to realize gain.
- Can recharge ground water (as in Orange county & coming to San Diego). There, the water undergoes tertiary treatment, followed by RO…at a cost more than $\$1/m^3$.
- But how to make it affordable? Instead of destroying energy content and using chemicals, extract energy and nutriments, which also equate to energy.

Why Municipal Wastewater?

- Municipal – Mixed suspended and dissolved solids, ranging from 100 ppm for combined sewers to 500 ppm for dedicated sanitary. How small a system can we go to recover energy and water?
- Industrial – Pharma, petrochemical, food, agribusiness, forest products, ranging from 1,000 to 100,000 ppm.
- Agriculture – Crop waste, cattle & swine (total solids is 7,210 mg/*l*, total volatile solid is 5122 mg/*l*), poultry wastes (total solids of 8,300 mg/*l*, and volatile solids in the amount of 5,400 mg/*l*).

Strength of Waste in ppm {mg/liter, g/m³}	Energy Content {Joule/liter, kJ/m³}
1	25.6
10	256
100	2,560
1,000	25,600
10,000	256,000
100,000	$2.56\ 10^6$

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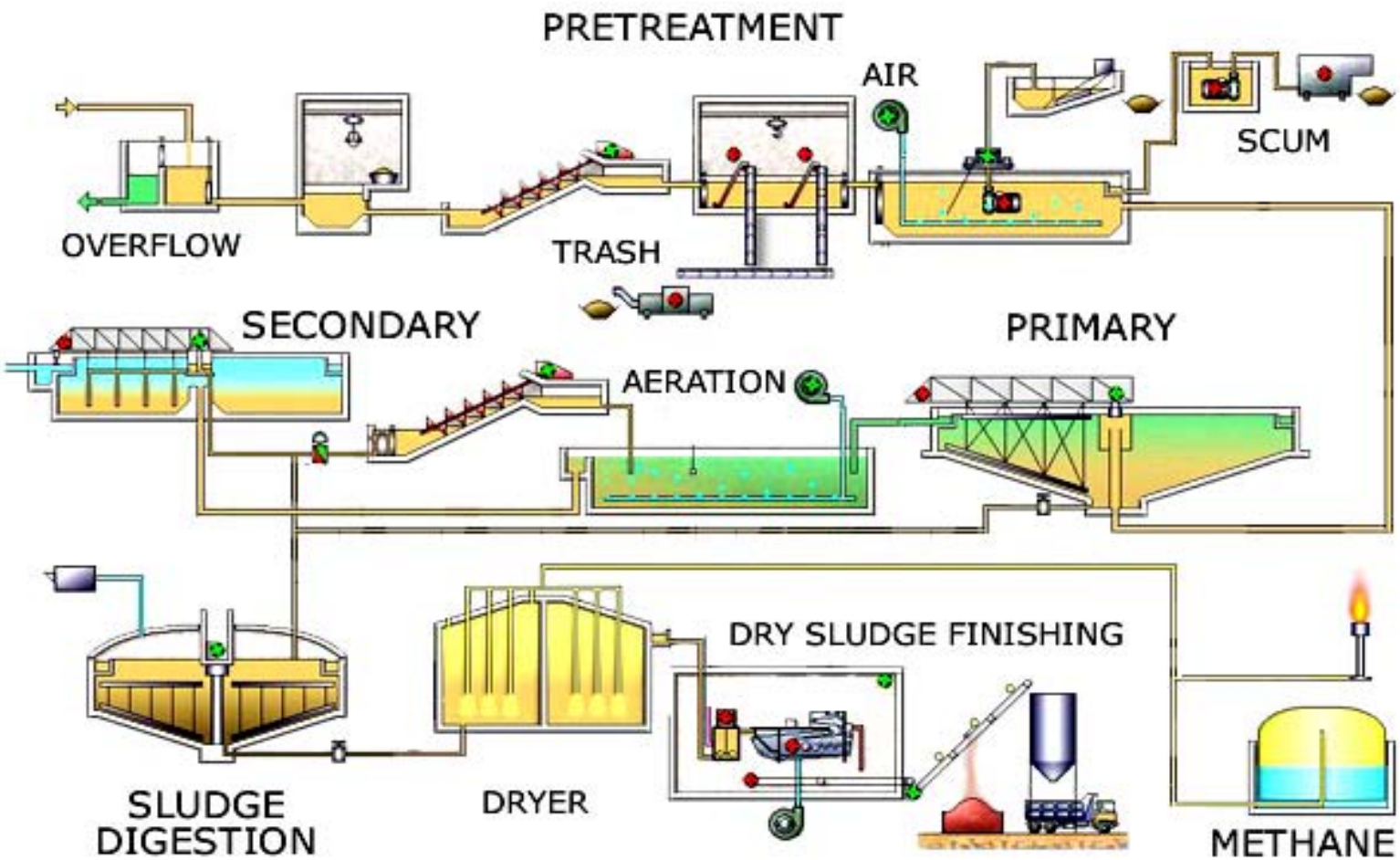
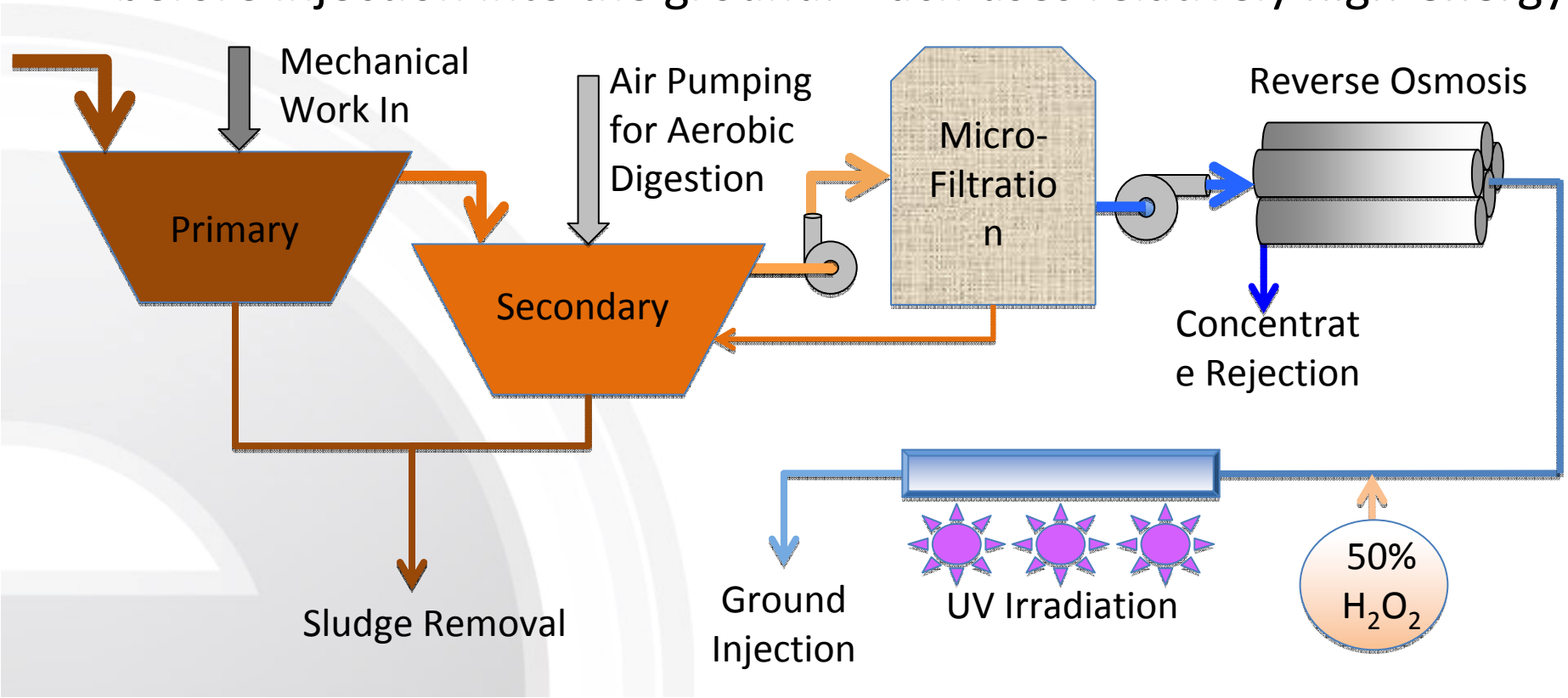
Current Treatment & Energy Method

- Energy and water recovery in an secondary treatment plant. Many points of energy inputs and losses.



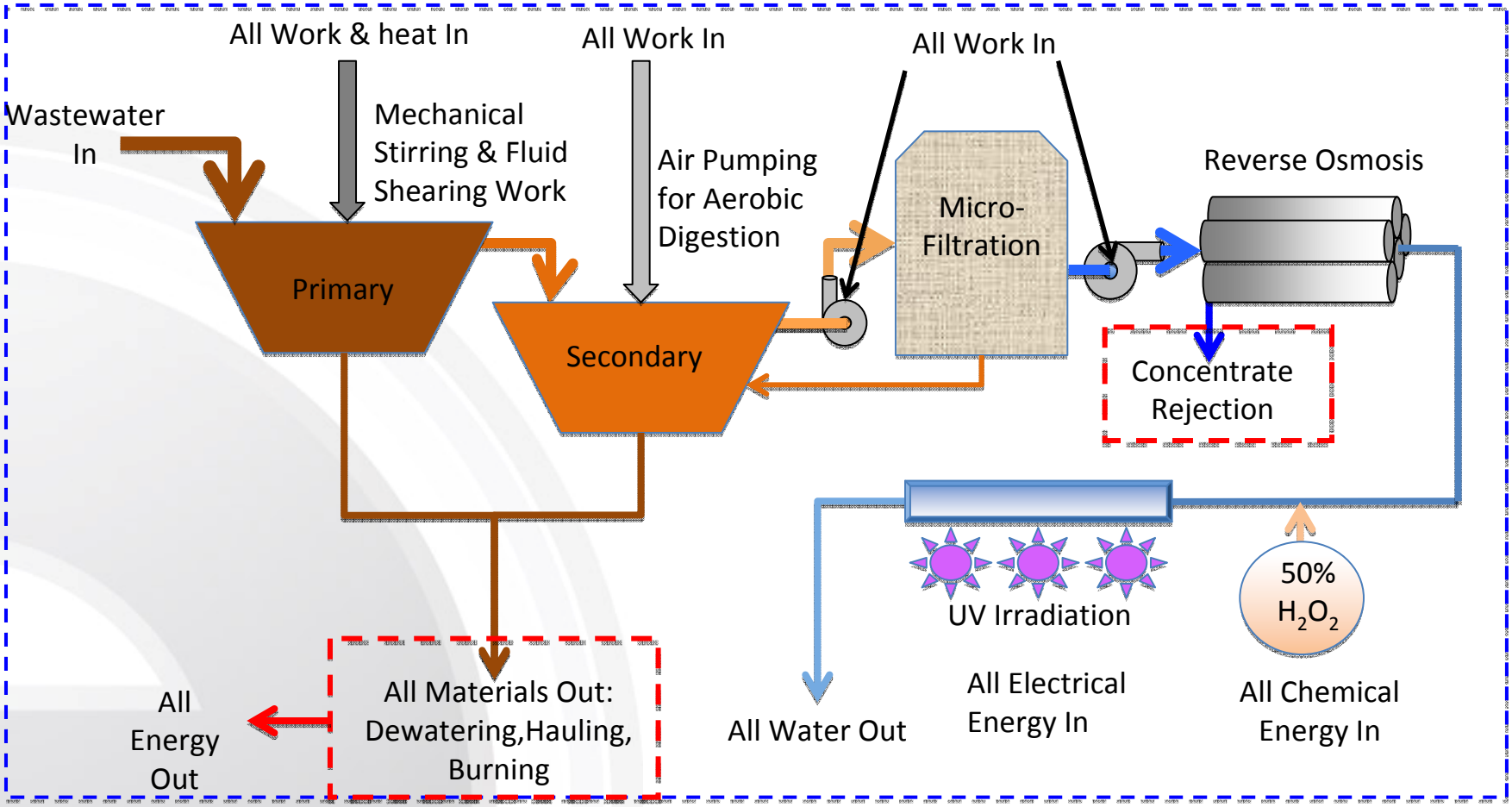
Current Advanced Clean Water Reuse

- Water produced by the Groundwater Replenishment System for the Orange County Water District first comes from the effluent of a primary and secondary wastewater treatment plant. It is then purified using state-of-the-art microfiltration, reverse osmosis, ultraviolet light and hydrogen peroxide treatment techniques, before injection into the ground. Each uses relatively high-energy.



Achieving Net Energy & Clean Water Output

- How we draw the control volume matters. If one only draws the volume around the sludge out, one can show net energy generated. But if one accounts for all inputs and outputs from the sourcewater to the output, it is much harder.



Balances

- Want to account for **all** inputs and outputs from the processes developed: Energy, chemical, input and output streams (i.e. wastewater in (chemical and thermal), clean and discharge water out (chemical and thermal), sludge out (chemical and thermal), chemicals in and out, mechanical and electrical work in and out).
  - We need to put an energy value on all inputs and outputs! Nothing gets a free ride (i.e. ozone, chlorine, ammonia, HCl, NaOH, nutrients, sludge to landfill,…) . We need total lifecycle analysis on sustainablity.
- Want to account for **all** change in greenhouse gases from the processes developed (i.e. amount of organics remaining in sludge discharged, savings from converting to usable net energy, chemicals used or saved, nutrients recovered, embedded enegy avoided, electrical to primary energy multiplier, quality of discharged water)
  - We need to put a GHG value on all processes of the system. Need the total cycle analysis to determine sustabability of the technology adopted.

Problem with Recovering Energy: Water!

- Water content does not add to energy
  - Need to extract energy from multiphase waste at cost per kW-hr that is competitive with other sources of energy.
- Dewatering waste takes energy
  - Taking it all the way to dry mass takes a lot of energy (latent heat of evaporation ~2,260 kJ/kg of water content)
- Solids and volatiles complicate dewatering…different methods needed.
  - Settling (cheap, but slow and limited in performance), flocculation (leaves chemical residual), spinning (capital intensive), vacuum stripping (energy-capital intensive), evaporation (very energy intensive)
  - Clear liquor and/or mineral residuals still needs processing.

More Problems to Overcome

- Heating of lots of water takes lots of energy
  - Higher temperatures typically mean higher kinetics and higher yields, but higher quality heat is needed, and thermal management to control direct and available work losses.
- Solids contain clays, hard salts, sulfur compounds, etc.
  - Ash and minerals reduce conversion (thermal, chemical, and biological) efficiencies. Minerals retained and foul. Foulants interfere with membrane separations, and catalyst processes.
- Wastewater highly variable
  - Large variations in water content, temperature, pH, protein, fats, salts, & carbohydrates. Contains toxic industrial compounds, household cleaners, oils, tars, and everything that goes down a drain, as well as antibiotics that can be retained or kill beneficial microbes. Variations are temporal and seasonal.

More Problems to Overcome

- Pathogens in abundance
  - Even non-potable water needs to be pathogen-free to be used in most applications, even if not for intimate human contact. Most dangerous are viruses, which can pass through most normal membranes. Some can survive temperatures > 100°C.
- Small toxic compounds pass through many processes
  - Small molecules pass through membranes and as volatiles. Many logs (up to 6) reduction needed.
- Long retention times typically needed
  - Slow rates for conversion typically mean large, expensive systems are needed. Capital intensive.

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Workshop Structure

1. **Science and Technology Track**

   In this track, we want to try establish the ***metrics*** that *can possibly be achived* to extract energy *and* clean water from municipal (low strength) wastewater. What are the scientifically possible metrics w.r.t. amounts and cost, and what are the technologies we should invest in that might achieve those metrics?

   1.Clean water from wastewater

   1. Metrics and technologies

   2.Energy (nutrients) from wastewater

   1. Metrics and technologies

This track is to inform ARPA-E as to what S&T to invest in that can revolutionize simultaneously obtain clean water and energy (nutrients/minerals) from wastewater.

Workshop Structure

2. Implemention and Translation Track

In this track, we want to try establish the ***metrics and objectives*** that *need to be achived* to extract energy *and* clean water from municipal (low strength) wastewater in order for the technologies to be considered for adoption.

1.Energy and clean water from wastewater

1. Metrics and objectives

2.Translation in practice: Metrics, outcomes, piloting, barriers and solutions

1. Barriers and solutions for implementation

This track is to inform ARPA-E as to what is needed for the S&T that might be invested in so that the technology can be adopted and implemented, and translated into practice, while increasing American Competitivness.

Science and Technology Track

Morning

Clean Water from Wastewater- Group 1

Senate Ballroom Salon C

Jim Smith, US EPA NRML

Group 1: *Science and technological challenges to obtaining clean water from wastewater with more than an order of magnitude better performance than current technologies*

Clean Water from Wastewater- Group 2

Senate Ballroom Salon B

Benito Mariñas, University of Illinois

Group 2: *Emerging methods of deriving clean water from wastewater with associated metrics*

Science and Technology Track

Afternoon

Net Energy from Wastewater: Science and Technology Needed, with Associated Metrics- Group 1

Senate Ballroom Salon C

Mohamed Dahab, University of Nebraska

Group 1: *Science and technological challenges to obtaining energy from wastewater with more than an order of magnitude better performance than current technologies*

Net Energy from Wastewater: Science and Technology Needed, with Associated Metrics- Group 2

Senate Ballroom Salon B

William Horak, Brookhwaven National Laboratory

Group 2: *Emerging methods of deriving energy from wastewater with associated metrics*

Implementation and Translation Track

Morning

Energy and Clean Water from Wastewater- Group 1

Senate Ballroom Salon A

Eugenio Giraldo, American Water

Group 1: *Quality and costs needed for water to be reused from wastewater*

Energy and Clean Water from Wastewater- Group 2

Gallery Room

Sudhir Murthy, DC WASA

Group 2: *Barriers (Infrastructure, codes, permits, and requirements) and incentives needed*

Implementation and Translation Track

Afternoon

Translation into Practice: Metrics, Outcomes, Piloting, Barriers and Solutions- Group 1

Senate Ballroom Salon A

Cat Shrier, Watercat Consulting

Shadid Chaudhry, California Energy Commission

Group 1: *Metrics and outcomes needed for pilot demonstrations and implementation of technologies developed in program*

Translation into Practice: Metrics, Outcomes, Piloting, Barriers and Solutions- Group 2

Gallery Room

Joe Zuback, Global Water Advisors

Group 2: *Barriers to adoption and solutions needed for translation of technologies into practice*