NASA Water Recycling Technology Development

State of California / NASA Water Recycling Demonstration Project

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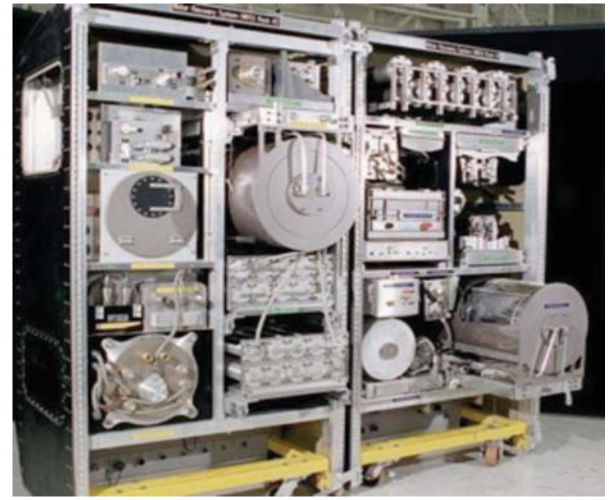
NASA Water Recycling Technology Development

ISS US Water Processing Assembly

- In operation since 2009
- Urine and condensate are recycled to drinking water
- Wastewater is recycled using distillation, adsorption, and oxidation
- Only true toilet to tap water recycling system in our Solar System



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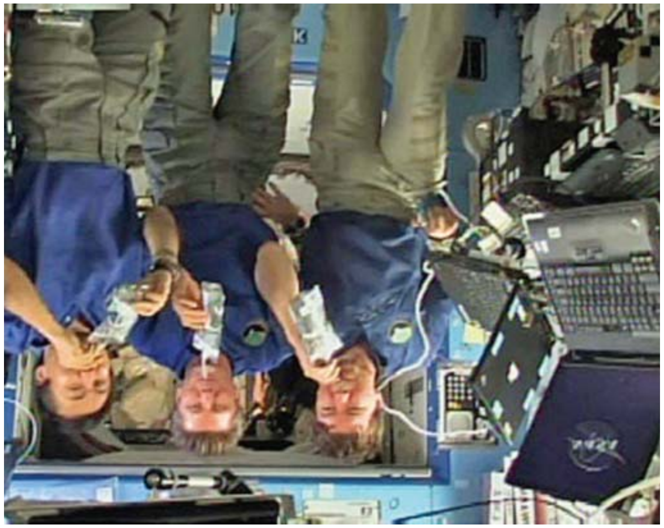


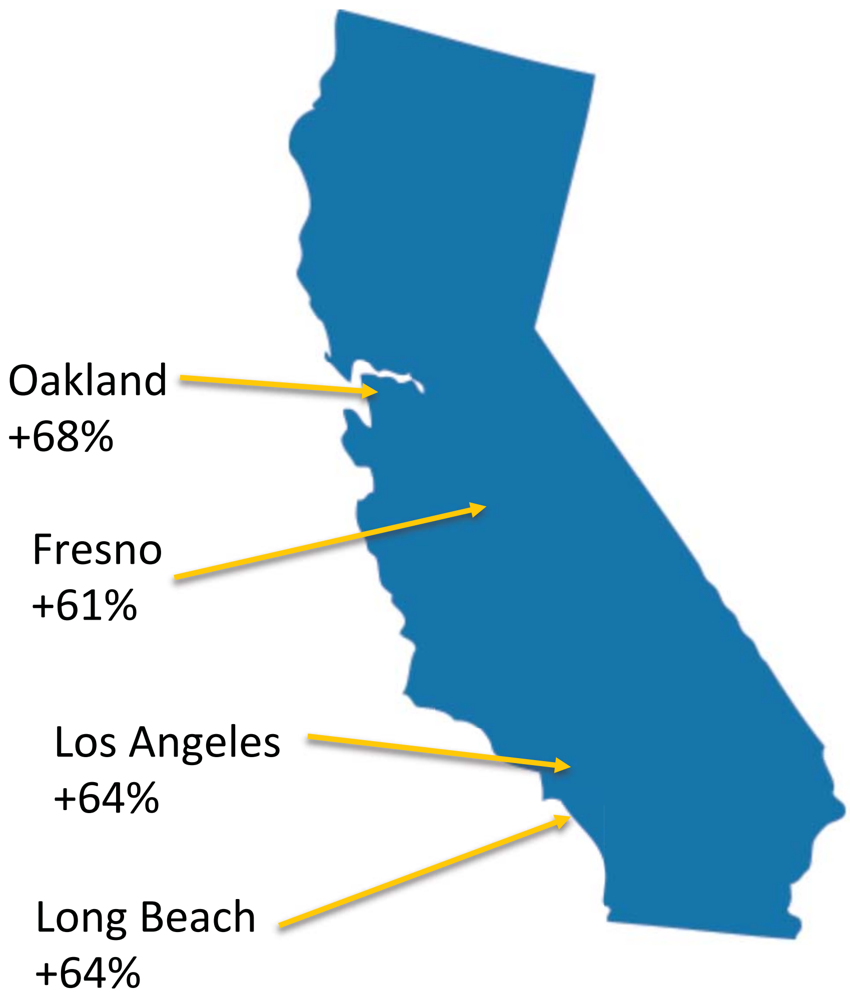
Impact of Water Recycling to State

1. The availability of water is impacting economic development and residents lives.
2. The environmental impact: About ½ of all rain water that falls on California is diverted to human use. This percentage will increase in the future. Blaine Hanson, Department of Land, Air and Water Resources, University of California, Davis
3. Water costs are one of the most inflationary commodities. This is a result of infrastructure replacement and maintenance costs.

Unfunded infrastructure cost estimates

	Water (next 20 year)	Sewer (next 10 years)
USA	$ 348 Billion	
CA	44 Billion	$45 Billion
Reference	EPA 2011 Drinking Water Infrastructure Needs Survey: Fifth Report to Congress.	The American Society of Civil Engineers (ASCE) *2013 California Infrastructure Report Card*

Rate of Inflation of water over the Last 12 Year



Inflation per 12 years	Inflation Per year
38%-70%	3%-6%
71%-89%	6%-7%
90%-129%	8%-11%
130% - 233%	11%-20%

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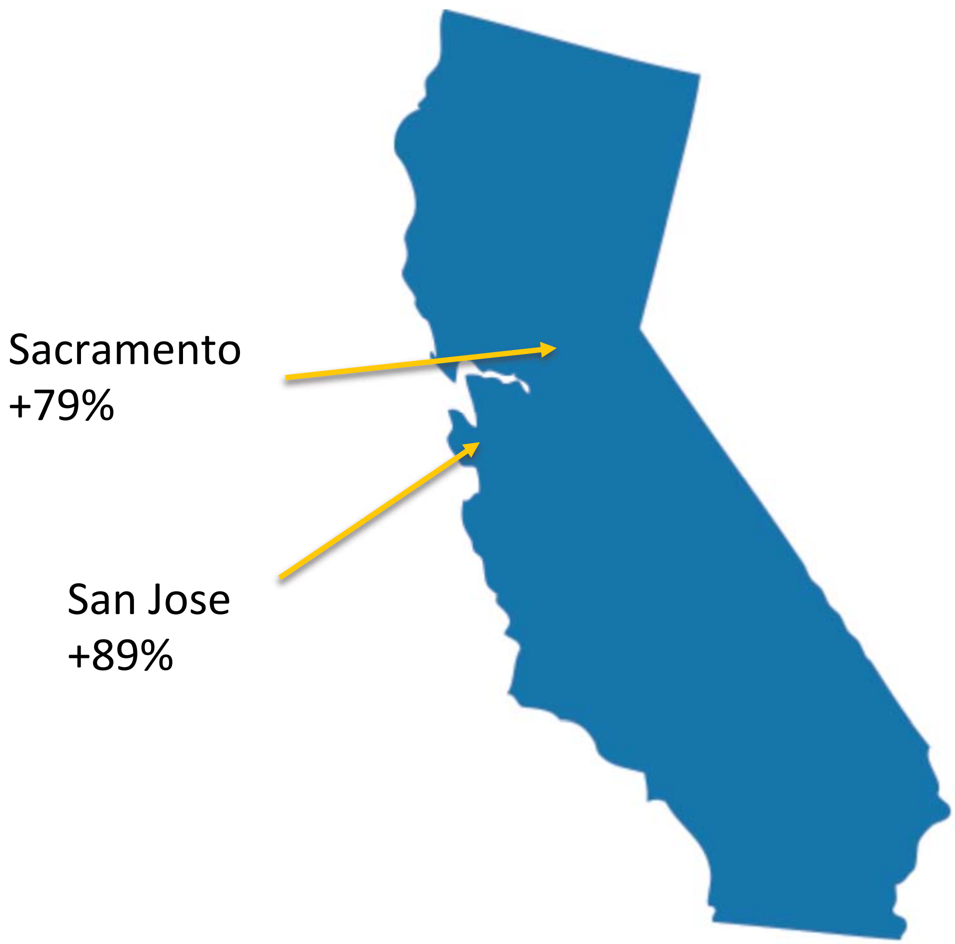

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Rate of Inflation of water over the Last 12 Year

Alameda County
+102%

Santa Cruz
+113%

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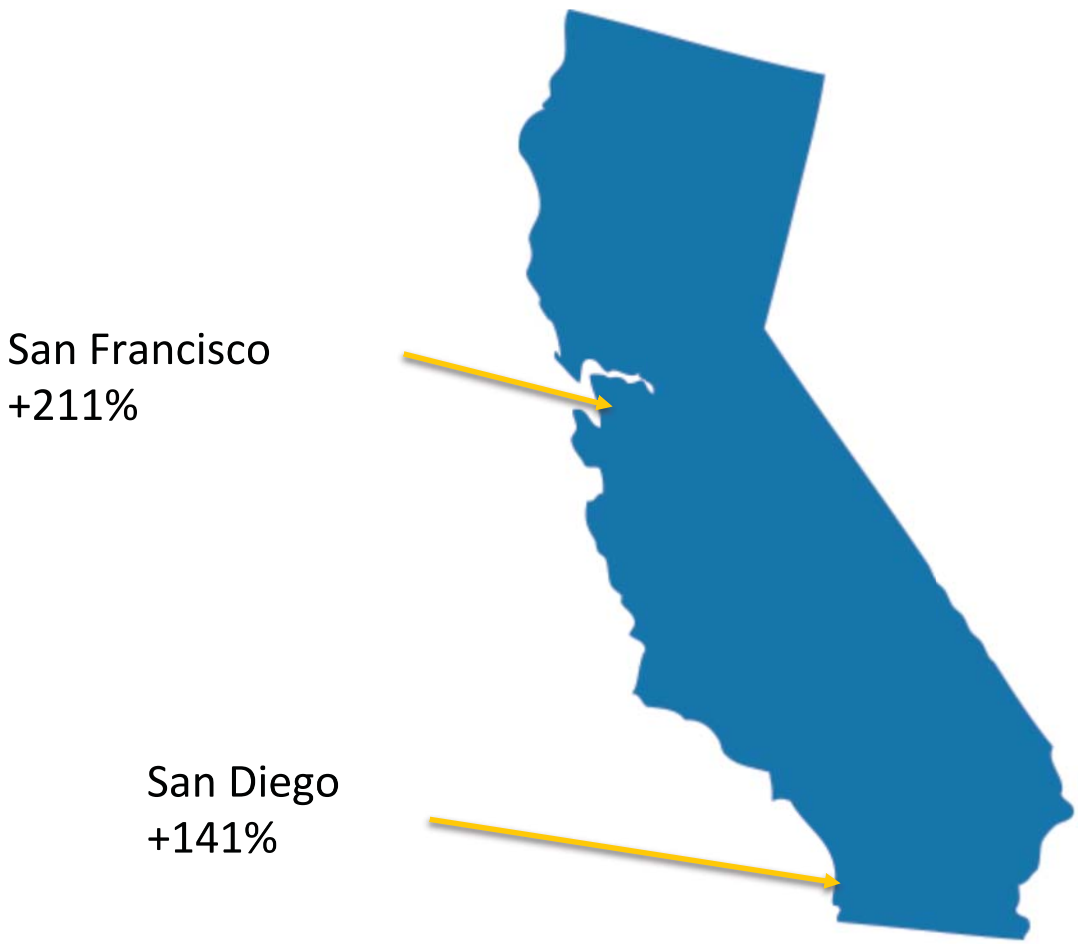

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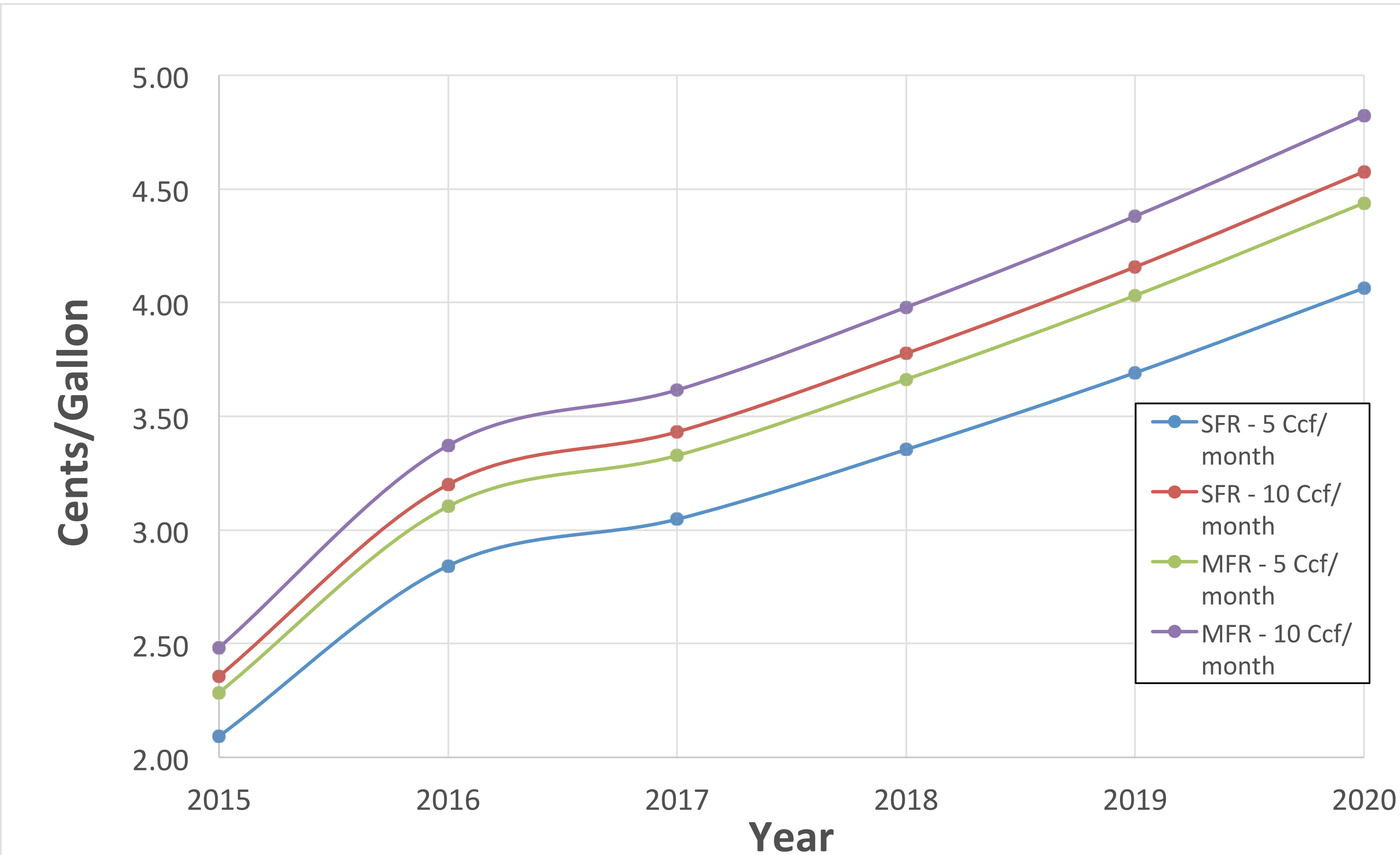
Cost Analysis using San Francisco Water and Sewage Data



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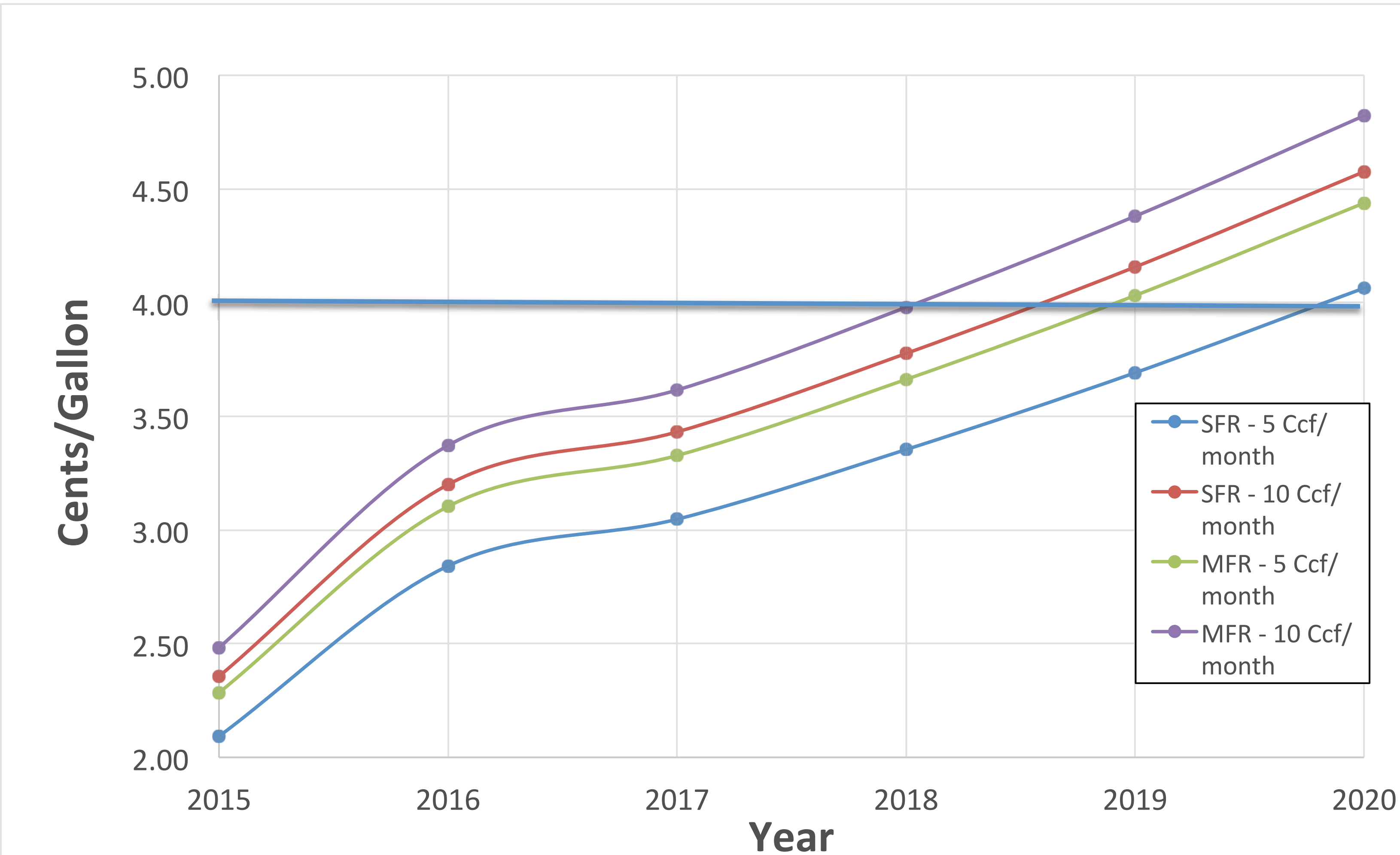
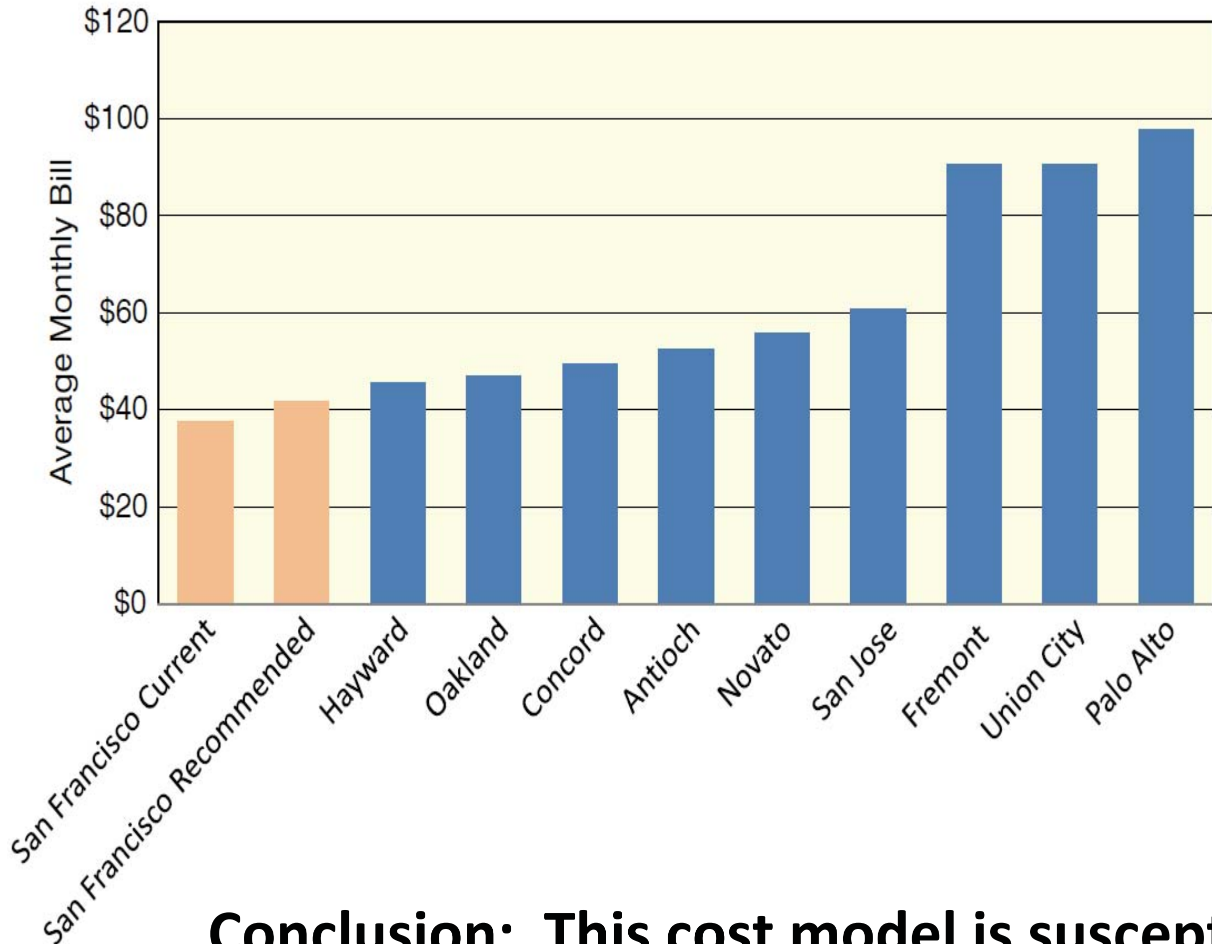


Comparison of SF Water Cost to Region and World Wide (2014)



Country	$/cubic meter
Germany	$1.91
Denmark	$1.64
Belgium	$1.54
Netherlands	$1.25
France	$1.23
UK - Great Britain & N. Ireland	$1.18
Italy	$0.76
Finland	$0.69
Ireland	$0.63
Sweden	$0.58
Spain	$0.57
United States	$0.51
Australia	$0.50
South Africa	$0.47
Canada	$0.40

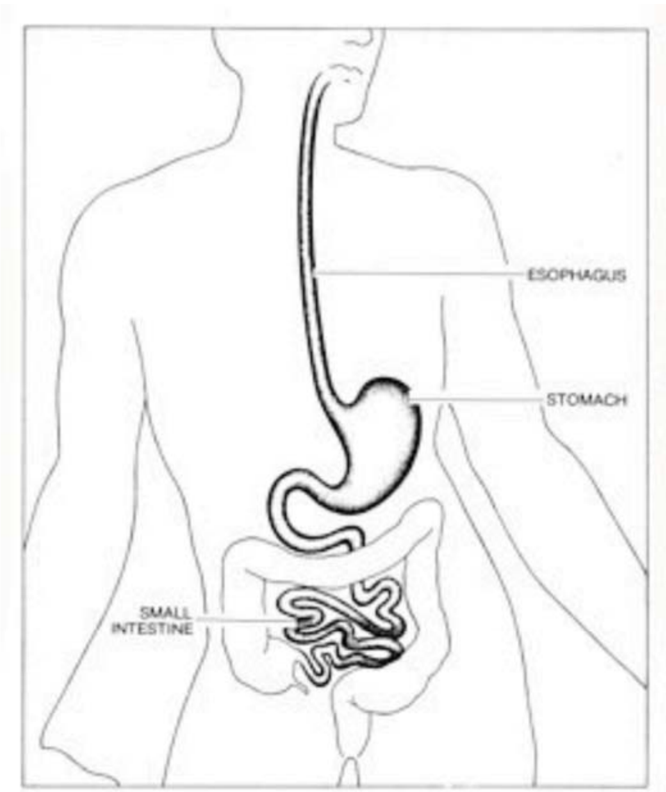
Conclusion: This cost model is susceptible to disruption from innovation and consumer empowerment.

Unbalanced Markets are Susceptible to Disruption Through Innovation

NASA Next Generation Life Support System (NGLS) Advanced Water Processor (AWP)

Forward Osmosis

Human Intestine Model

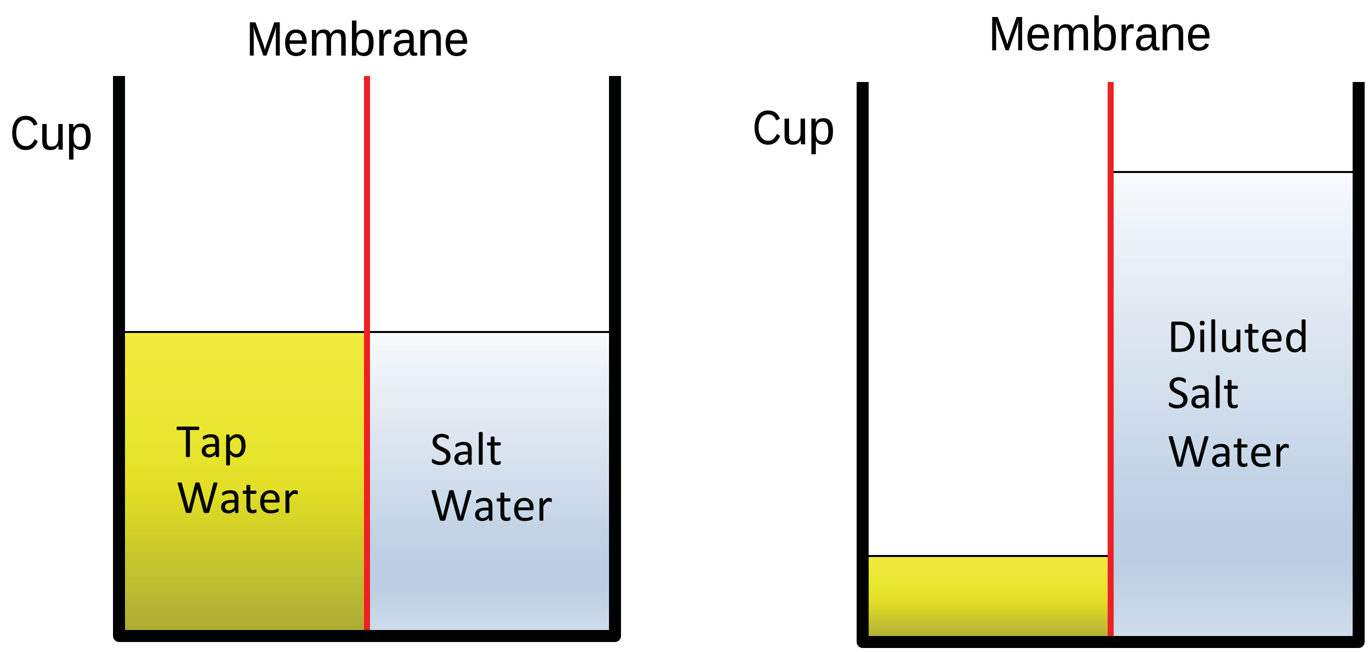


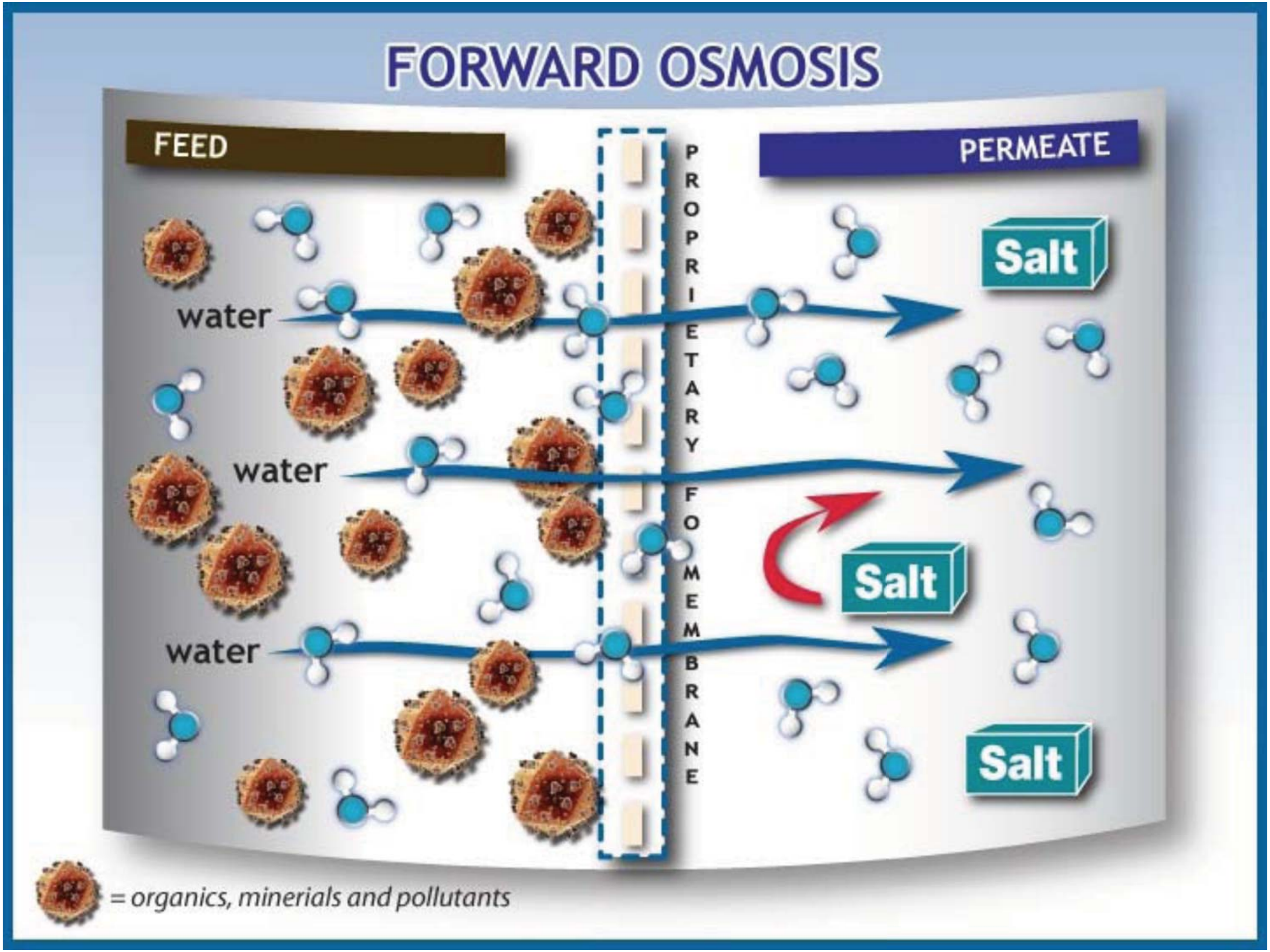
https://commons.wikimedia.org

Plant Root Zone Model

https://commons.wikimedia.org

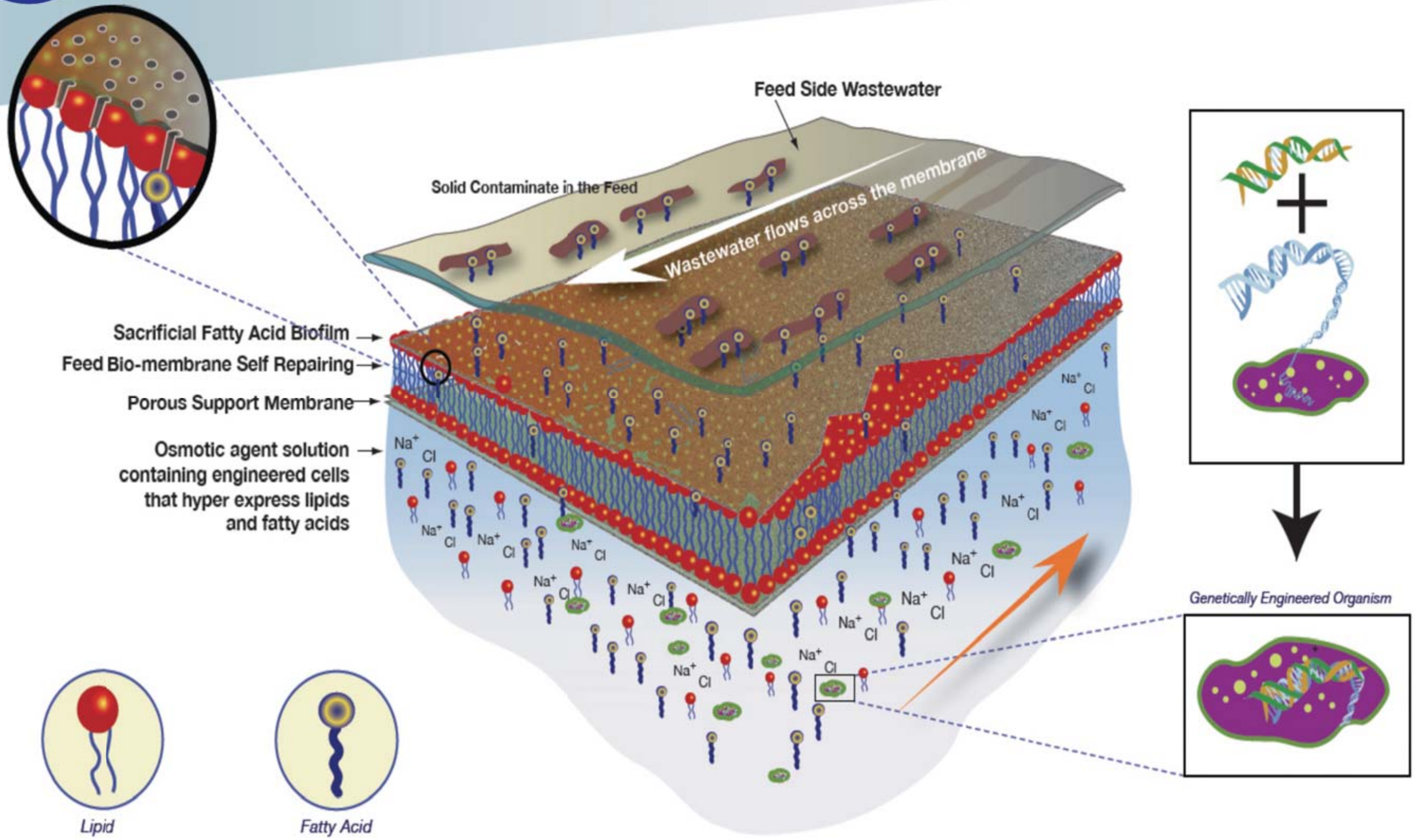
Forward Osmosis



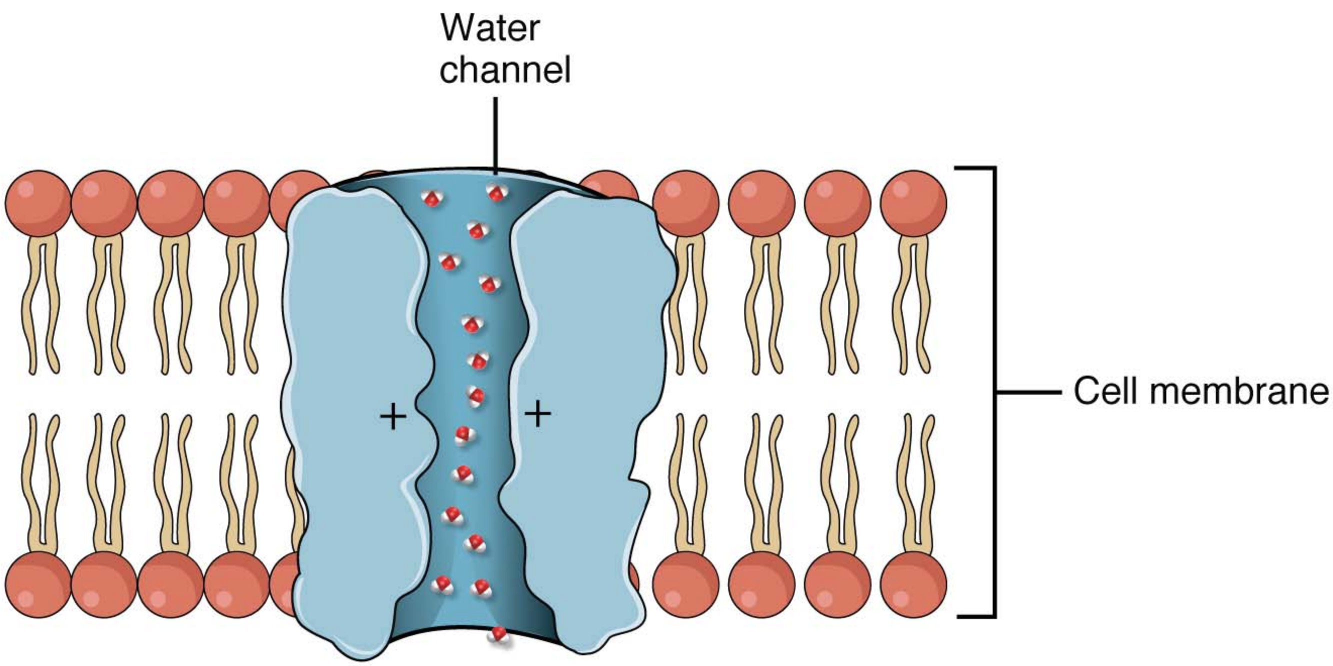


FORWARD OSMOSIS
FEED
PERMEATE
PROPRIETARY FO MEMBRANE
water
water
water
Salt
Salt
Salt
= organics, minerials and pollutants

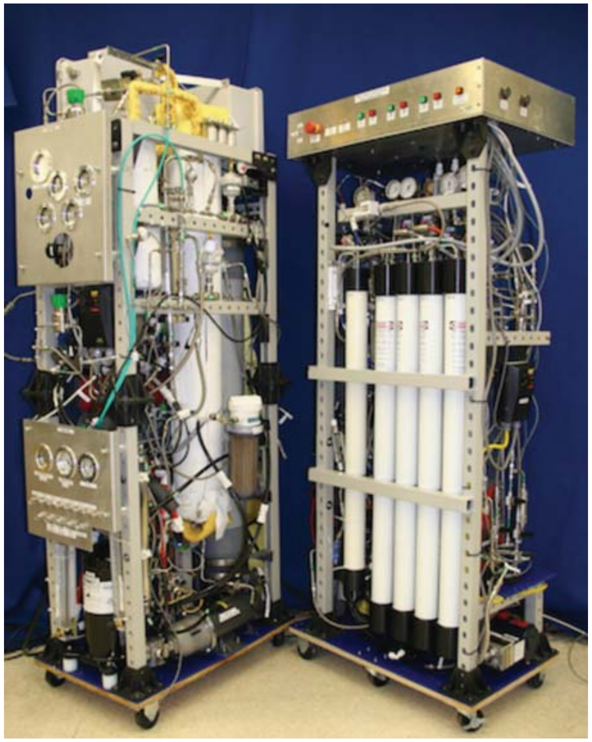
Bio-membrane



Aquaporin Membrane



NASA FO Systems



Direct Osmotic Concentration

Cargo Transfer Bag

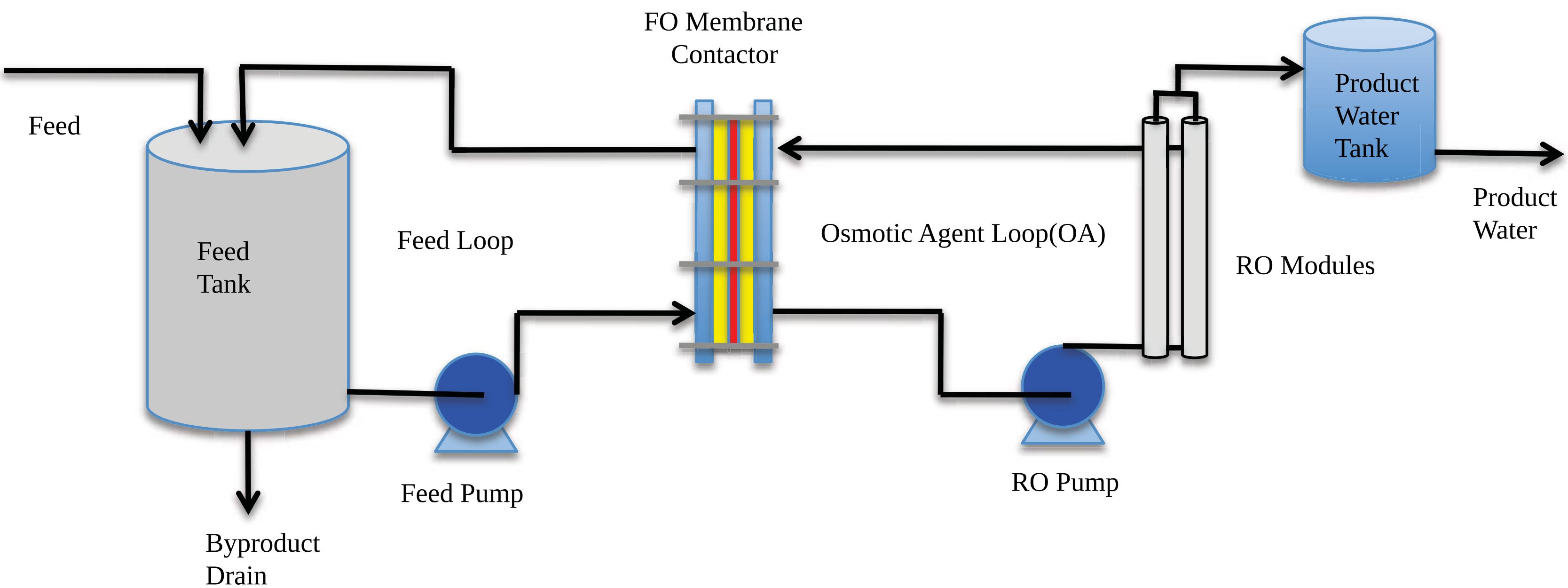
Osmotic Distillation

Forward Osmosis Secondary Treatment

Environmental Desalination

Personal Water Recycling System

Sustainability Base Gray Water Recycling System

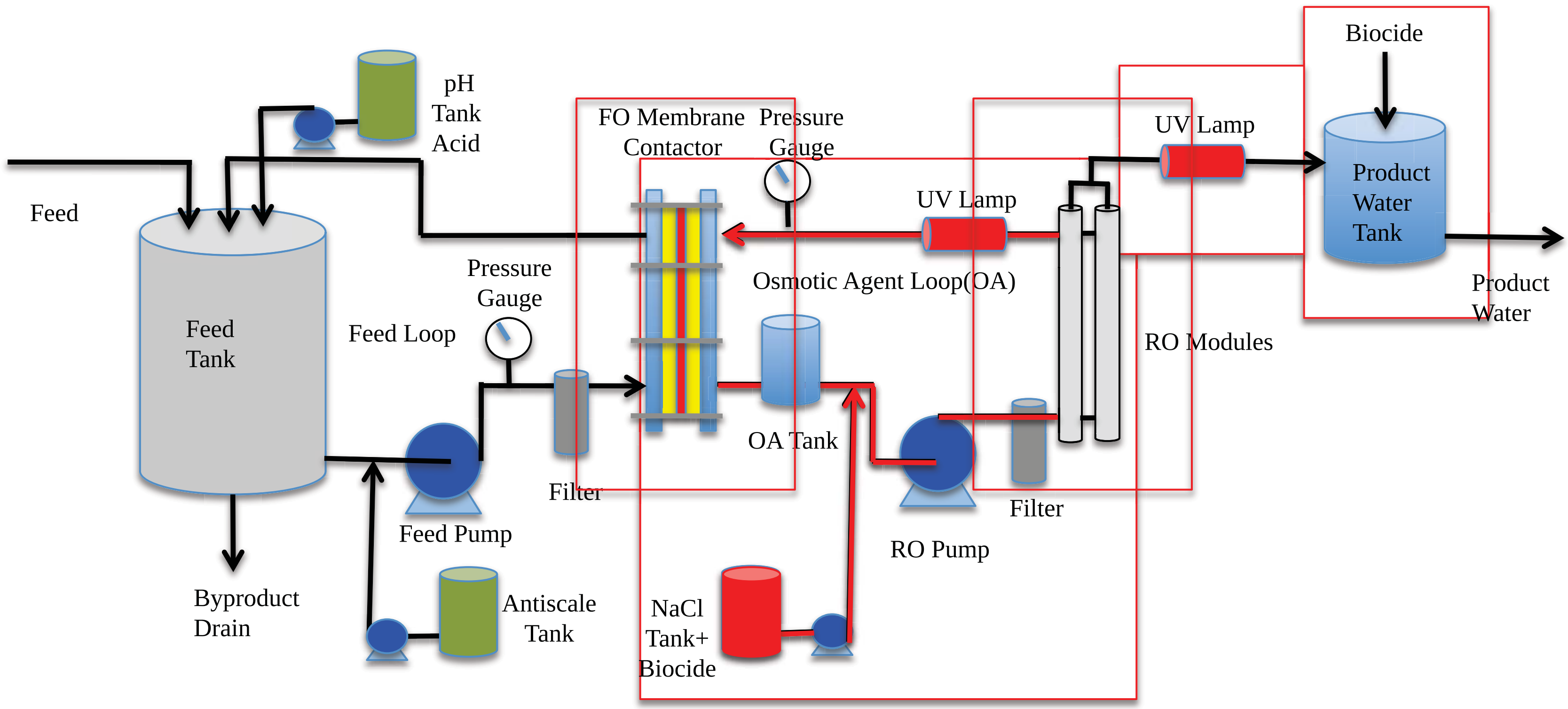


Army/NASA Forward Operating Base Gray Water Recycling System

Army Sustainability Logistics Basing Science and Technology Objective-Demonstration (SLB STO-D) Test at Ft. Devens, MA (Aug 6th through 17th 2016)

Fail-safe Design Considerations

- Level 1: FO membrane is a biological and chemical barrier
- Level 2: RO membrane is a biological and chemical barrier
- Level 3: UV product lamp will kill bacteria
- Level 4: OA loop uses a UV lamp and biocide to control bacteria and viruses
- Level 5: A biocide added to product to control bacteria and viruses



Transferring NASA Technology to Address Water Scarcity in California

It is one thing to say it is safe but its another to prove it is safe.

- Requires long-term operational testing.
- Requires statistically valid operational test that address both public health and human factors issues.

NASA approach

- Use fail safe systems and limit testing
- Small scale distributed systems (in home or in business) at an economical scale
- Produce potable water, even for non potable use
- Continually study human factors and health effects
- Develop systems designed to autonomously operate for extended periods
- Apply automation and predictive failure approaches to reduce operational costs

Empower the consumer to solve the consumers problems.

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State of California/NASA Water Recycling Demonstration Project

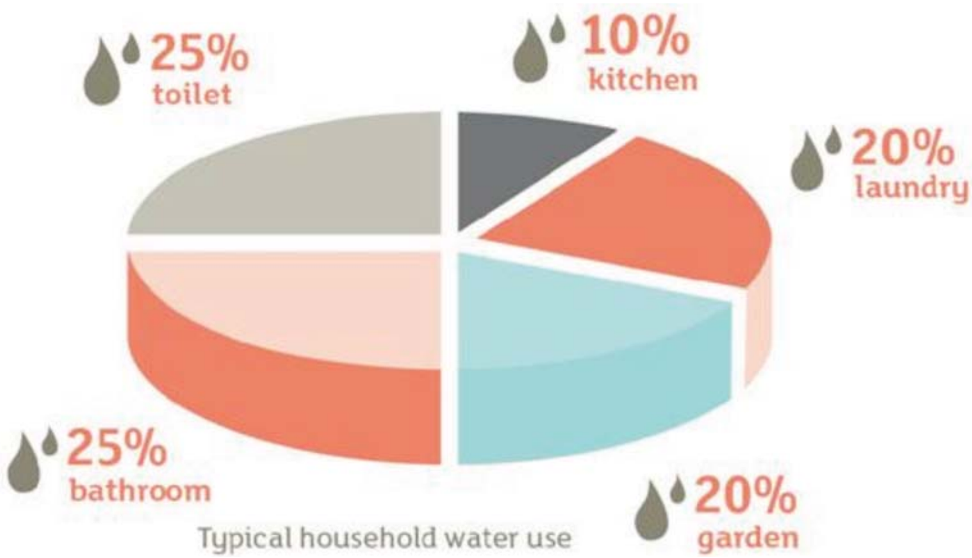
The objectives of the pilot project are to:

- Demonstrate the applicability of on-site greywater reuse for washing machines and toilet flush applications
- Evaluate recycled water quality performance and public health impact
- Evaluate consumer perceptions about recycled water and associated technologies
- Evaluate the economics of on-site consumer-scale water recycling
- Develop recommendations to inform regulations, policy, and product development pathways that will enable wide-scale adoption and of onsite water recycling

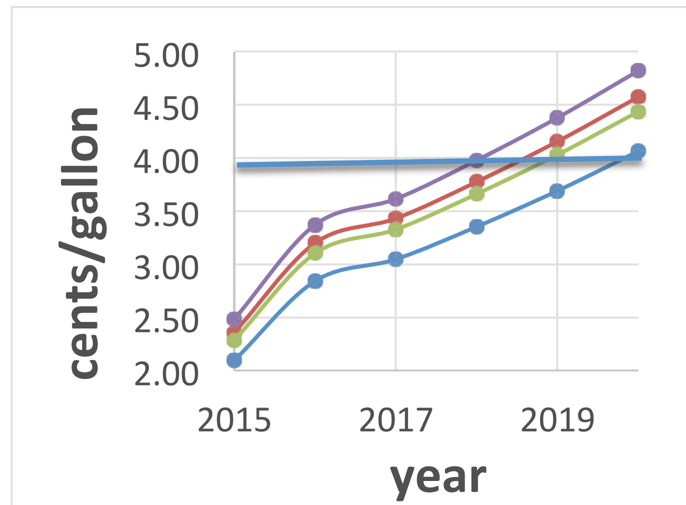
State of California/NASA Water Recycling Demonstration Project

- A collaboration between
  - National Aeronautic and Space Administration (NASA)
  - Research Triangle Institute (RTI)
  - Sustainable Silicon Valley
  - City of San Jose
  - Santa Clara County
  - Mercy Housing
  - Ecumenical Hunger Program
  - Others (TBD)

Why Graywater?



San Francisco Data



Target Consumer Solutions

Water Recycling Clothes Washer

- 90% water recovery
- Saves approximately 6000 gal/person year
- Low installation costs
- May not require a permit
- Does not require double plumbing

5 L/hr NASA Forward Osmosis System

Gray Water to Toilet

- 75-85% water recovery
- Saves approximately 7000 gal/person year
- Higher installation costs
- Will require a permit
- Double pluming required is limited to inside bathroom only

12 L/hr NASA Forward Osmosis System

Human Studies

Approach: To ensure that the research ethics, public health and the human factor aspects are addressed

This project will include oversight from the following review and technical advisory boards:

- An independent institutional review board (IRB) – to ensure research ethics and safety protocols are in place and to provide final selection approval for test sites
- An external human factors advisory board – to advise the team on best practices in studying the impacts of social, economic and political factors impacting technology adoption
- An external public health studies review board – to advise the team on best practices and correlative research surrounding public health impacts of water reuse

Demonstration Site Selection

Although the demonstration sites will ultimately be determined by the IRB Board, an initial identification of sites has included:

- A residential lodging facility at Moffett Field
- An office building at Moffett Field
- Several apartment complexes in San Francisco
- A community center in East Palo Alto
- A public/commercial space in San Jose
- A corrective facility in Santa Clara.
- Other TBD sites

The sites have been selected to draw users from different demographic settings and backgrounds and will therefore deliver insights to inform adoption strategies across a range of populations

Data Collection Protocols

These sites will involve demonstration, observation, and experimentation activities over a 36-month period aimed at delivering technology exposure, quality assurance, and user feedback on applications.

- *Demonstrating technical performance.* System performance will be monitored routinely, along with routine safety and operational checks.
- *Soliciting and analyzing user preferences.* Demonstration at site will involve experimental and observational studies using interviews, surveys, and user focus groups to gather user preferences related to system design, function, and cost. The user evaluation will involve data collection to gather insights across a range of demographic groups, and will document gender, age, income, and social and cultural variables in findings related to technology adoption. Survey protocols will be defined and disseminated across sites to ensure consistency in methods used across the sites. Instruments used in data collection will be implemented and designed consistently across sites, to bring broadly generalizable findings to the study.
- *Testing educational and product messaging.* Beyond just demonstrating the water products themselves, the test sites provide a venue for exploring public education about water reuse. Leveraging installations at each locality will allow for preparation and testing of education and product messages about water reuse as applied across the various appliances.

Impact

- Empower consumers to solve States water scarcity problems
- Future cost savings to users
- Provide tool for consumers to meet mandated water use reductions
- Municipality savings from differed infrastructure costs
  - Facility capacity enhancement displacement
  - Defer enhancement of distribution system
  - Transfer costs from municipality to the consumer
- Environmental benefits from reductions in State water diversions
- Enable development in water limited applications
- Generate commercial opportunities through private sector investment

Issues

1. State funding to Federal Laboratories

2. Mechanisms to address safety and regulatory issues associated with onsite reuse

3. Feedback to ensure needs of the State are meet