



Getting Started in Water Circularity: How To Really Achieve 90% Water Savings

February 28, 2024



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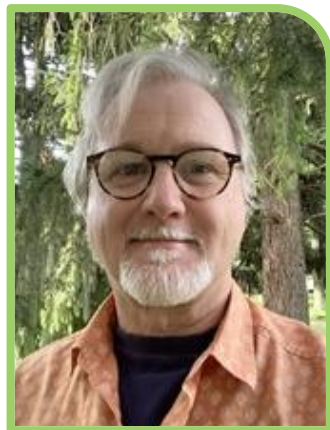


United States
Department of
Agriculture

Natural Resources Conservation Service



Today's Experts



Rob Eddy, M.S.



Kyle Lisabeth



A division of



Andy Lee

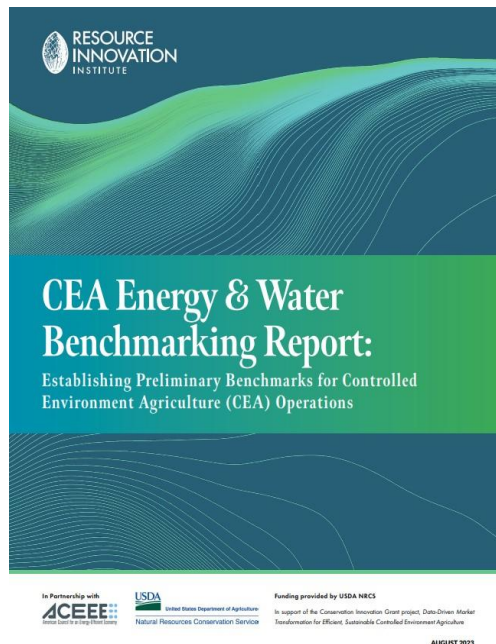
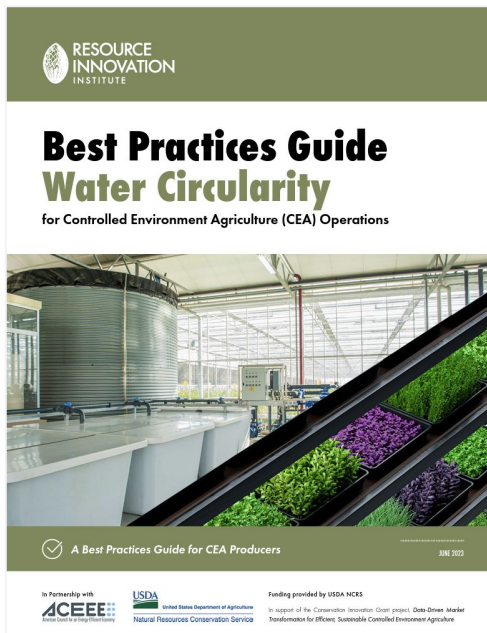


About RII

- Objective, data-driven, not-for-profit, public-private partnership funded by USDA and DOE
- Founded 2016 in Portland, Oregon
- Benchmark grower production and resource efficiency with our Powerscore platform
- Establish working groups from industry, government and academia to develop Best Practices Guides
- Webinars, workshops, articles, training for industry



CEA Water Circularity Resources

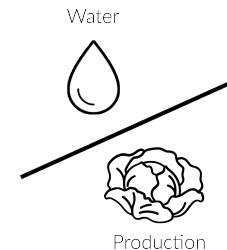
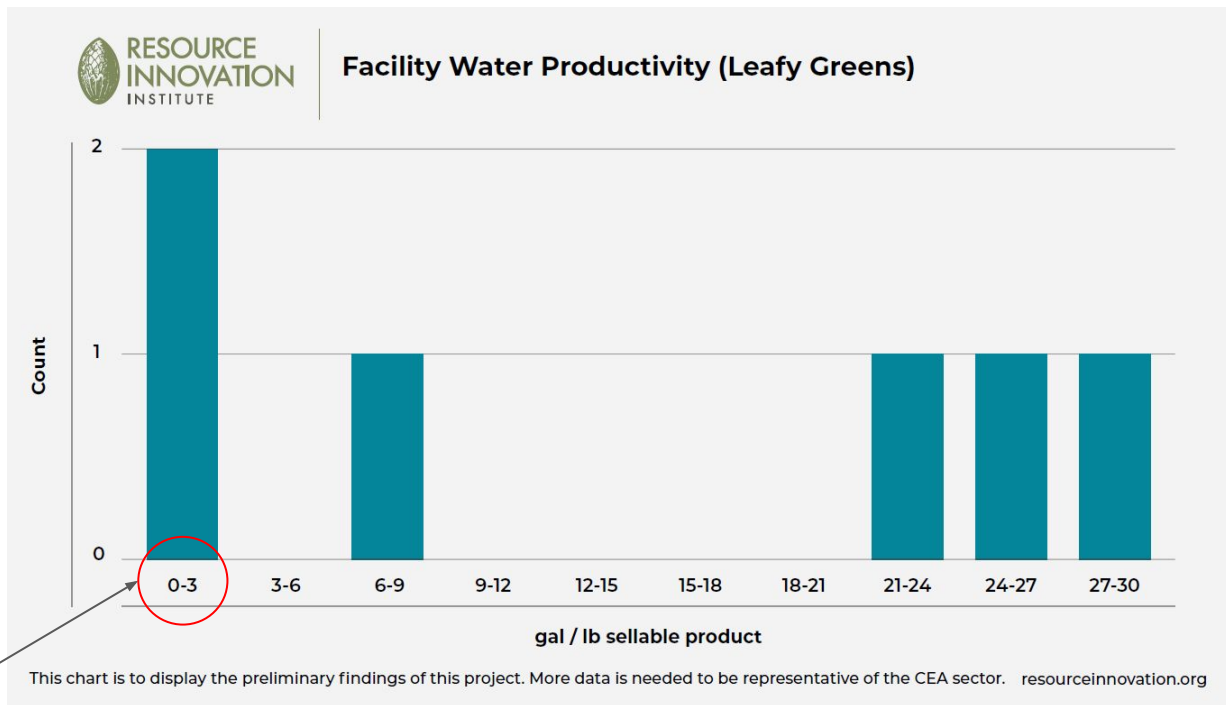


Best Practices Guide Featuring contributions from 15 Working Group member companies

Benchmarking Report Featuring annual resource consumption and productivity of twelve producers growing a variety of crops in greenhouse and indoor facilities across the US.

Access the reports for free on the [RII catalog](#)

Benchmarking Report Highlights



90% savings over field

Water Waste in CEA Operations

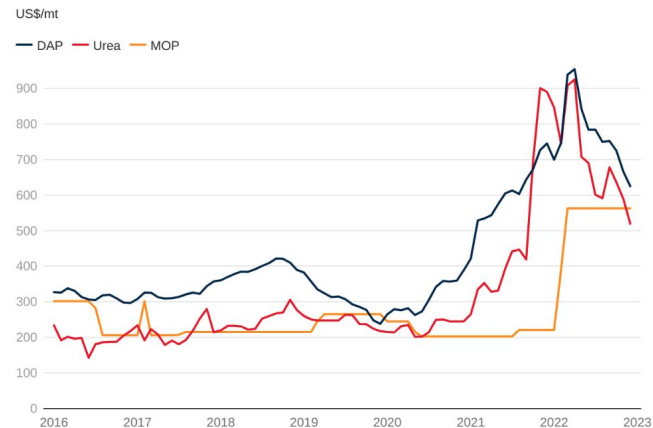
Priority Rank	Type of Water Waste	Relevant To All Facilities	Potential High Waste Volume	Release Causes Environmental Harm	Potential Crop Damage	Substitute for RO Water	Potential to Improve ROI on Treatment Costs	Difficult to Remediate
1	Over Irrigation and Leaks	X	X	X	X		X	
2	Irrigation Leachate	X	X	X			X	
3	Pesticide Drench/ Overspray	X		X				X
4	RO Reject Water		X					X
5	Evaporative Cooling Pad Bleed-Off		X					X
6	Condensate		X			X		
7	Washdown Water	X						X
8	Blowdown Water							X

Economic Rationale For Reducing Water Consumption

Reducing irrigation water has been shown to reduce fertilizer costs by **40%-50%**

CEA producers report ROI in as little as **two years** due to fertilizer cost reduction

Fertilizer prices



Note: DAP = diammonium phosphate, MOP = muriate of potash, mt = metric ton. Last observation is December 2022.

Source: Bloomberg; World Bank.

Reducing Irrigation Waste in Hort Substrate Culture

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Staal Plast

Netafim

Reducing Irrigation Waste by Weight Scale Measurement

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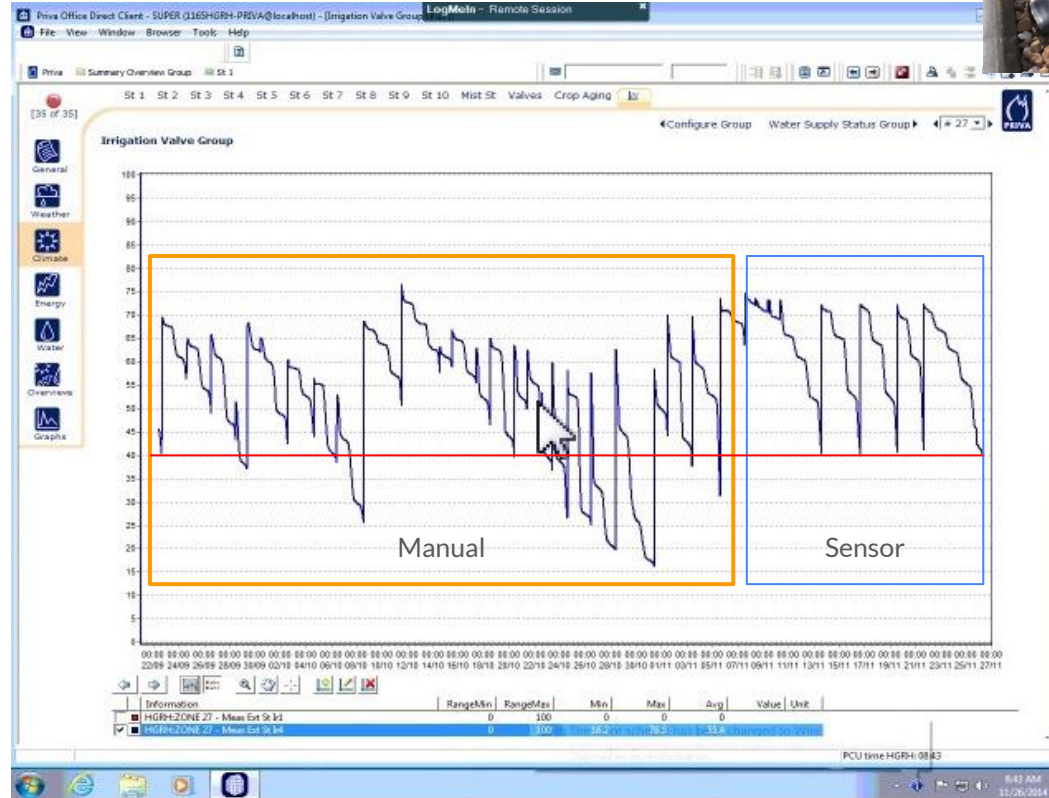


Powerplants Australia



Drain Sensors (volume, EC)

Reducing Irrigation Waste by Water Content Sensing



Reducing Irrigation Waste by Water Content Sensing

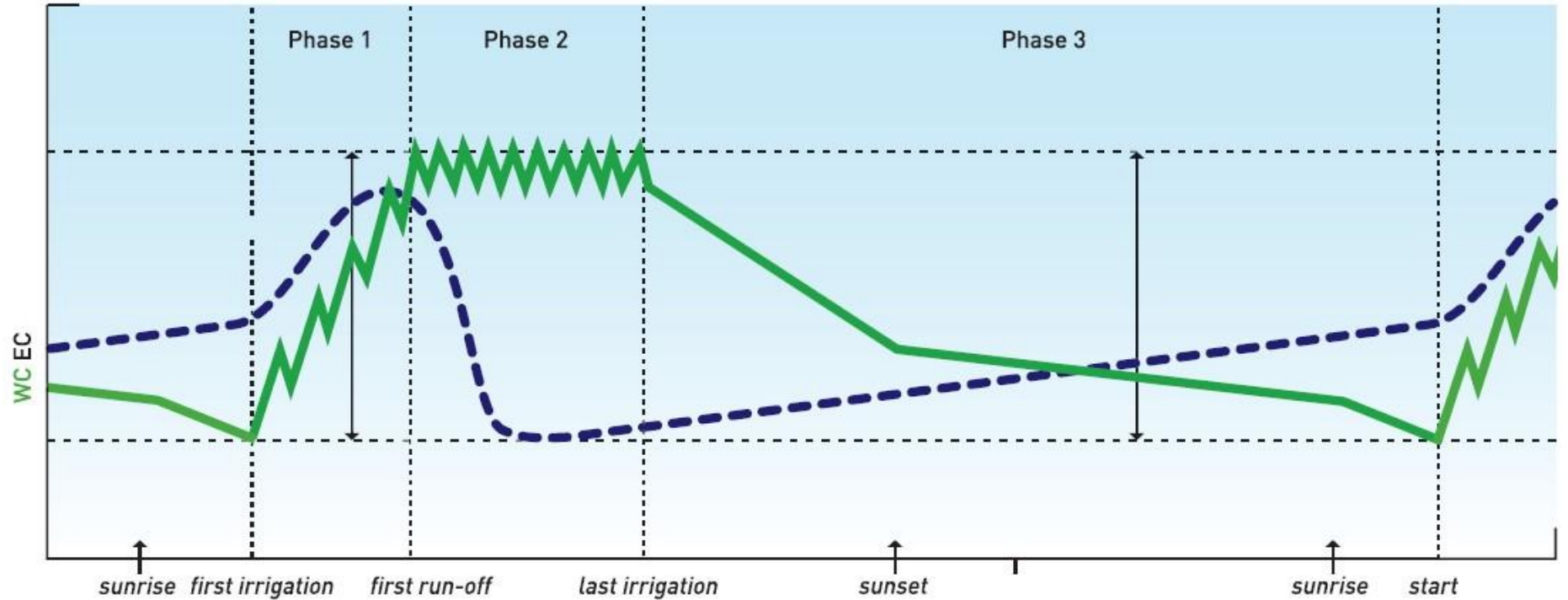
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Image credit: Grodan

Sensor (WC and EC)

24-hour cycle for stone wool irrigation



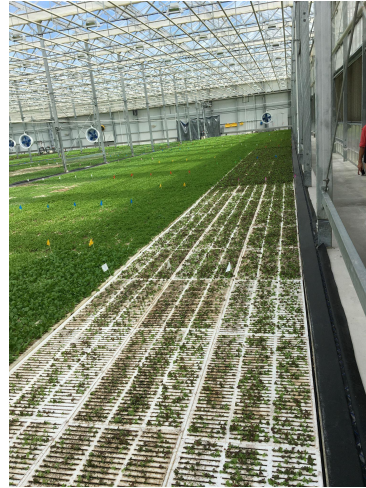
Reducing Irrigation Waste by Using Recirculating Systems

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Urban Ag News

Nutrient Film Technique



Raft Culture



Deep Water Culture



Climapod.com

Aeroponics



Plenty

Vertical NFT/Aeroponics

Water Treatment: Physical, Chemical and Biological

Table 9. Comparison of existing physical water treatment systems.¹⁰

Physical Water Quality Treatment Systems									
Technology	Notes	Pre Treatment Required	Treatment Range					Footprint	Cost
			Solids / organic material	Pathogens	Microbiota	Agg / flocculation	Resistant to		
Filtration - Coarse	Sand separation, GAC filter, ball filter, cartridge filter	No, though may be required	✓						
Regd Media Filters	Regd GAC filter, Diatomaceous Earth, Activated Carbon	Coarse filtration	✓		Media dependent				
Hardness Filtration - Microfiltration	Removes particles up to 10 to 100 microns	Pre filtration	✓						
Hardness Filtration - Ultrafiltration	Removes particles up to 0.1 to 1 microns	Pre filtration	✓	✓					
Hardness Filtration - Nanofiltration	Removes particles up to 0.001 to 0.1 microns	Pre filtration	✓	✓					
Hardness Filtration - Reverse Osmosis	Removes particles up to <0.0001 microns	Pre filtration	✓						
Hardness Filtration - High Efficiency Reverse Osmosis	Multiple membranes may reject particles of various sizes	Pre filtration	✓						
UV-C Light	254 nm wavelength	Pre filtration							
Heat Pasteurization	63-82°F (16-22°F)								

10. Modified from: [Barnes, J. & Barnes, A. \(2018\). Water Quality Engineering: Principles and Practice. Elsevier.](#)

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Table 10. Comparison of existing chemical water treatment systems.¹¹

Chemical Water Quality Treatment Systems													
Technology	Notes	Pre Treatment Required	Treatment Range							Footprint	Cost		
			Solids / organic material	Pathogens	Microbiota	Agg / flocculation	Resistant to	Resistant Effect?	Resist Water Wastes?		Capital	Operating	
Chlorine	Control with chlorine formation when using in high concentrations	No Filtration	✓	✓			Some	✓	Minutes	++	Small	\$ - \$12	\$
Chlorine Dioxide		No Filtration	✓	✓			Some	✓	Minutes	++	Small	\$ - \$55	\$5 - \$55
Peroxyacetic acid	(PAA) is a combination of weak acid and hydrogen peroxide	No Filtration	✓	✓			Some	✓	Minutes	++	Small	\$	\$5 - \$55
ICA	Chlorine 2-10 ppm may damage filter	Softening	✓	✓									
Ozone		No Filtration	✓	✓									
Copper Ionization		No Filtration	✓	✓									
Peroxyacetic acid + UV	Synergistic Effect	No Filtration	✓	✓									
Peroxyacetic acid + Ozone	Synergistic Effect	No Filtration	✓	✓									

notes: ++ denotes more extensive control

Table 10. Suggested Water Treatment Options Prior to Discharge

Suggested Water Treat									
Resistant to Water Wastes / Regenerant									
UV	UV	UV	UV	UV	UV	UV	UV	UV	UV
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Table 11. Comparison of existing biological water treatment systems.¹²

Biological Water Quality Treatment Systems												
Technology	Notes	Pre-Treatment Required	Treatment Range					Resilience Score	Resilience Time	Resilience Effect	Project Water? Water?	Indicator: Washburn W?
			Solids / organic material	Pathogens	Microbiota	Agg. / flocculation	Resistant to					
Slow Sand Filter			✓	✓		Partial						Indicator: Washburn W?
Constructed Wetlands			✓	Variable	✓	Variable						Indicator: Washburn W?
Flowing Treatment Wetlands	Can be applied to existing stormwater ponds		✓	Variable	✓	Variable	✓					Indicator: Washburn W?
Wasteway Bioreactors			✓	✓	✓	Some	Only					Indicator: Washburn W?
Hybrid Treatment Systems			✓	✓	✓	✓	Only					Indicator: Washburn W?

12. Modified from: [WQET, J. & Barnes, A. \(2018\). Water Quality Engineering: Principles and Practice. Elsevier.](#)

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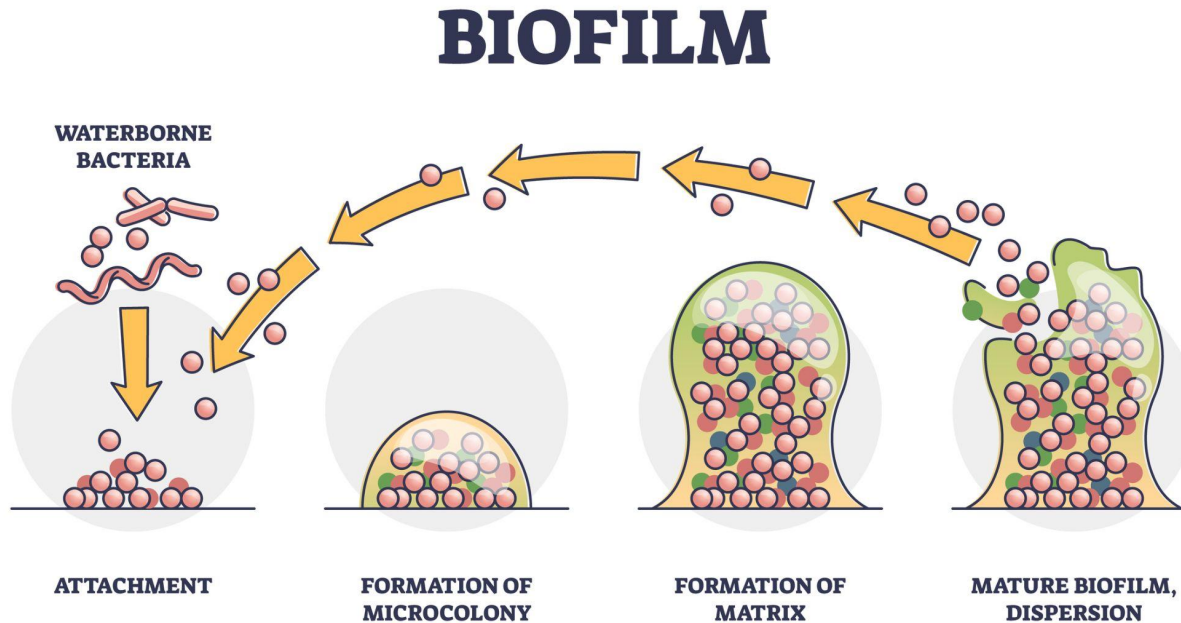


Suggested Water Treatment Options Prior to Discharge												
Department Water Quality Objectives: Turbidity, Capacity, Total Solids, Color, and Land, Water and Federal Regulations												
	Biological Growth	Hardness	Iron and Manganese	Oil and Grease	Pathogens	Resistant to Chlorination	Resistant to Disinfection	Resistant to UV	Resistant to Ozone	Resistant to Chlorine Dioxide	Resistant to Heat	Resistant to Other
End of Pipeline Location, Pre-discharge Wastewater or Conveyance Water	✓	✓	✓	✓	✓							
Sanitation Wastewater Water		✓	✓	✓	✓							
Regrind Water												
Preprocessor Cooling Water off	✓	✓	✓	✓	✓							
Cooling Tower Blowdown	✓	✓	✓	✓	✓							

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WQET UNIVERSITY 101 FACILITY TOUR

Your approach will be layered: filtration, instantaneous and residual controls
One example: cartridge filter, UV-C light, ozone



Control options:

- Ozone
- ECA-water
- Peroxyacetic acid
- Chlorine dioxide
- Nanobubbles

Alternative Water Source: HVACD Condensate

Research published in 2020 showed condensate water recovery accounted for 67% of the annual water demand for lettuce in a vertical farm



Source: Pacak, A., Jurga, A., Drag, P., Pandelidis, D., & Kaźmierczak, B. (2020). A Long-Term Analysis of the Possibility of Water Recovery for Hydroponic Lettuce Irrigation in Indoor Vertical Farm. Part 1: Water Recovery from Exhaust Air. Applied Sciences, 10(24), 8907.

Alternative Water Source: Rainwater

Metrolina Greenhouses in Huntersville, NC has been reclaiming rainwater for more than 20 years. They do not draw on the local water table.

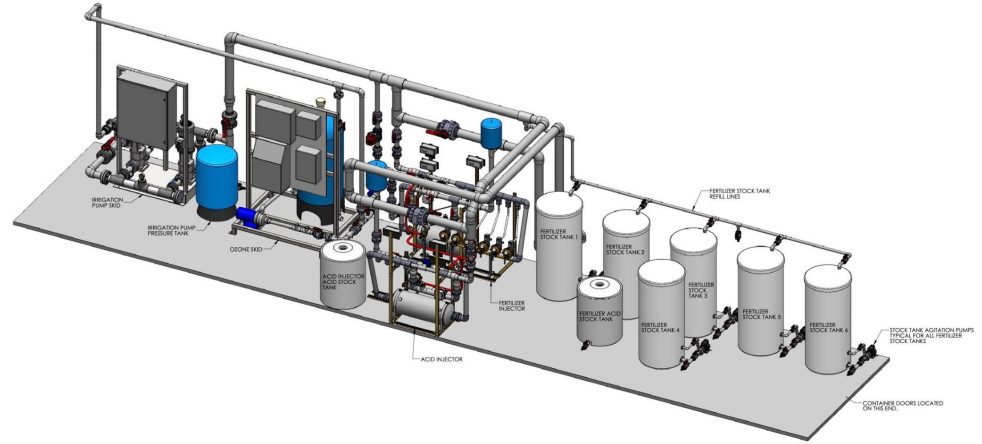


Water Treatment Equipment and Storage

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Silver Bullet



Dramm Corporation

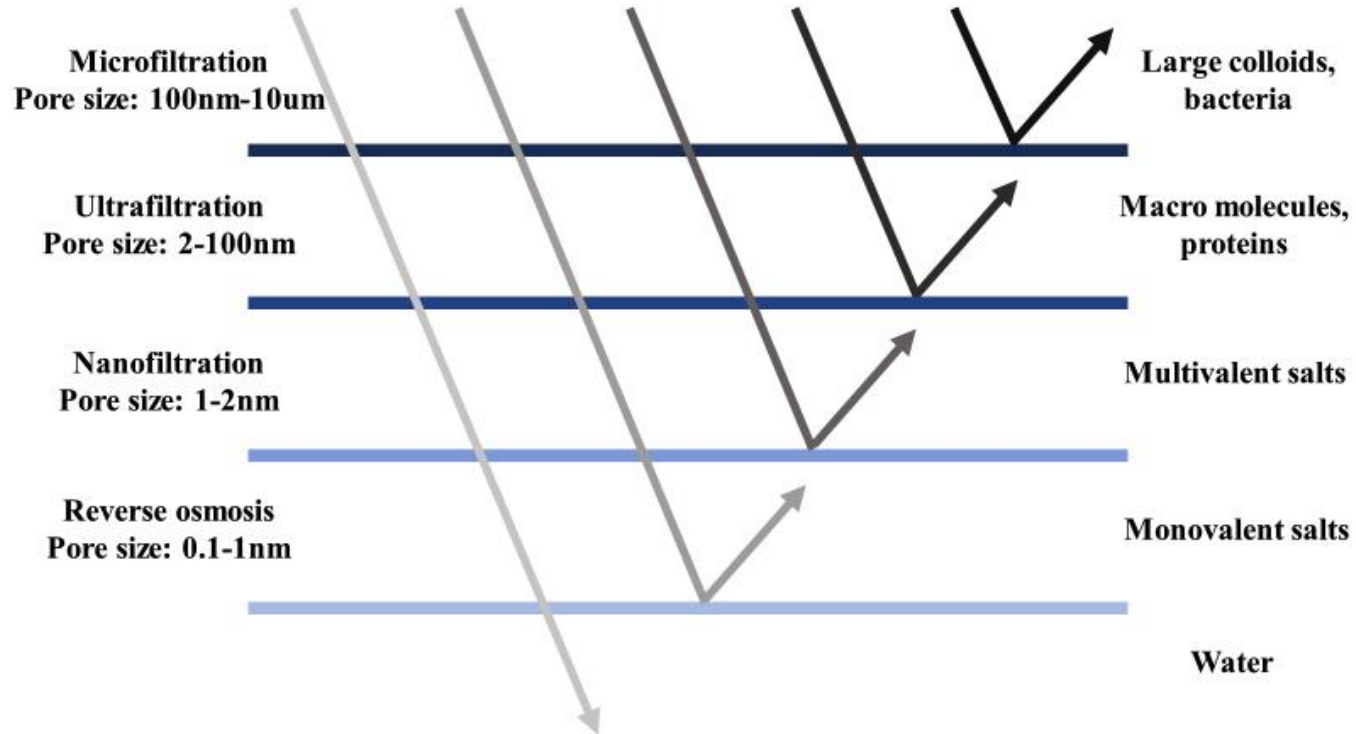


Priva and Grodan

A wide-angle photograph of a large-scale indoor hydroponic growing facility. The space is filled with long, parallel rows of leafy green plants, likely lettuce, growing in a controlled environment. The ceiling is high and industrial, featuring a complex network of metal trusses, numerous bright LED grow light fixtures, and large circular fans for ventilation. The walls are made of translucent panels, and the overall atmosphere is one of a modern, high-tech agricultural production space.

Discussion Audience Q & A

Membrane Filtration





**THANK YOU
USDA NRCS!**



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Discussion questions

1. Kyle, I've heard you say that assessing your source water is how to get started in water circularity. How does that kind of assessment impact planning, sizing etc?
2. Andy, as a grower moves toward recirculating irrigation water, what water quality issues do they need to monitor more closely than before?
3. Kyle, how does biofilm impact water quality, and does it impact facility design?
4. Andy, what are some examples of water or fertilizer waste you've seen in greenhouses or indoor farms? Especially the ones that the grower was not aware of or was not addressing?
5. Kyle, Ultra filtration and RO are hot topics right now in water remediation. Can you explain the difference/similarities?
6. Andy, are precision irrigation models like the one you showed us for tomato being developed for other CEA crops?

Water Use Efficiency by Production Method

Production Method	Country	Product water use (L/kg)	Product water use (gal/lb)
Open field, general	Israel, Spain, Turkey	100-300	12-36
Open field, drip irrigation	Israel	60	7
Greenhouse, unheated plastic	Spain	40	5
Glasshouse, unheated	Israel	30	4
Greenhouse, regulated ventilation, plastic	Spain	27	3
Glasshouse, advanced controls, CO ₂	Netherlands	22	3
Glasshouse, advanced controls, CO ₂ , closed hydroponic system	Netherlands	15	2
Closed Greenhouse, advanced controls, CO ₂ , closed hydroponic system	Netherlands	4	0.5
Greenhouse, evaporative cooling	Mexico	Estimated: 100	Estimated: 12

An Often Overlooked Source of GH Water Waste...

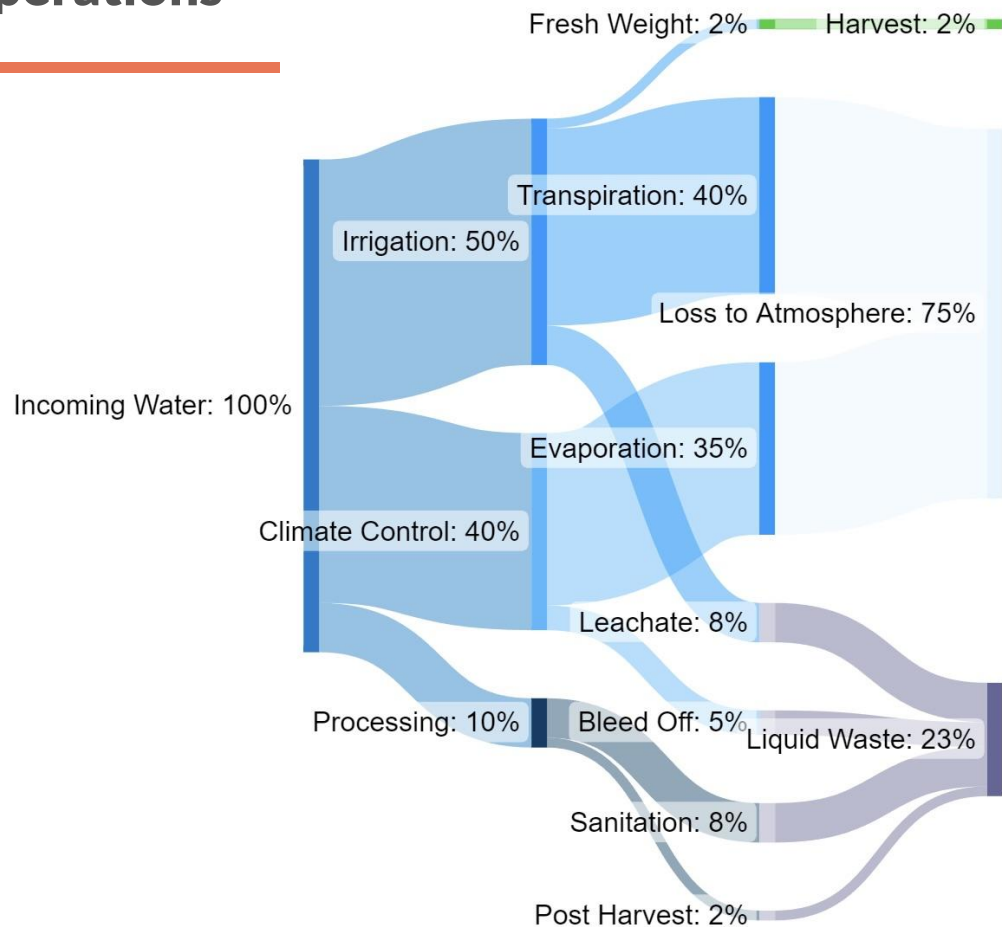
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Glasshouse, advanced controls, CO ₂ , closed hydroponic system	Netherlands	15	2
Closed Greenhouse, advanced controls, CO ₂ , closed hydroponic system	Netherlands	4	0.5
Greenhouse, evaporative cooling	Mexico	Estimated: 100	Estimated: 12

Modified from Nederhoff, Elly & Stanghellini, Cecilia. (2010).



Fate of Water in CEA Operations

Standard Greenhouse



Biological Remediation

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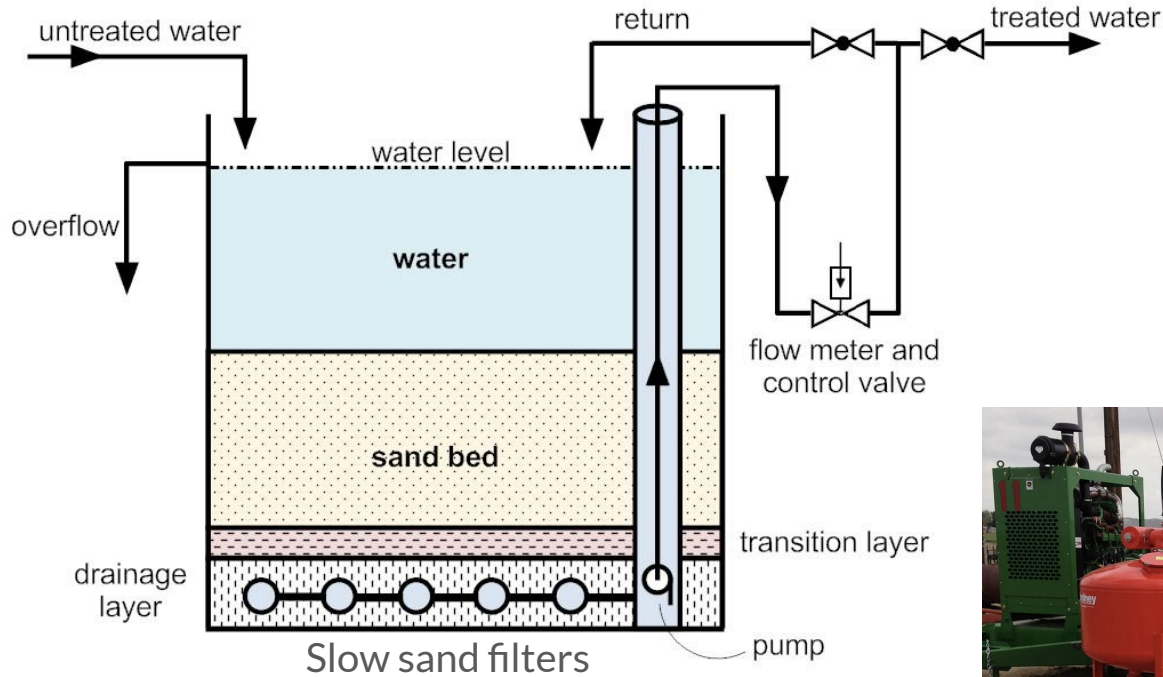


Image credit: Netafim, Inc.

Containerized
slow sand filters

Putting It All Together

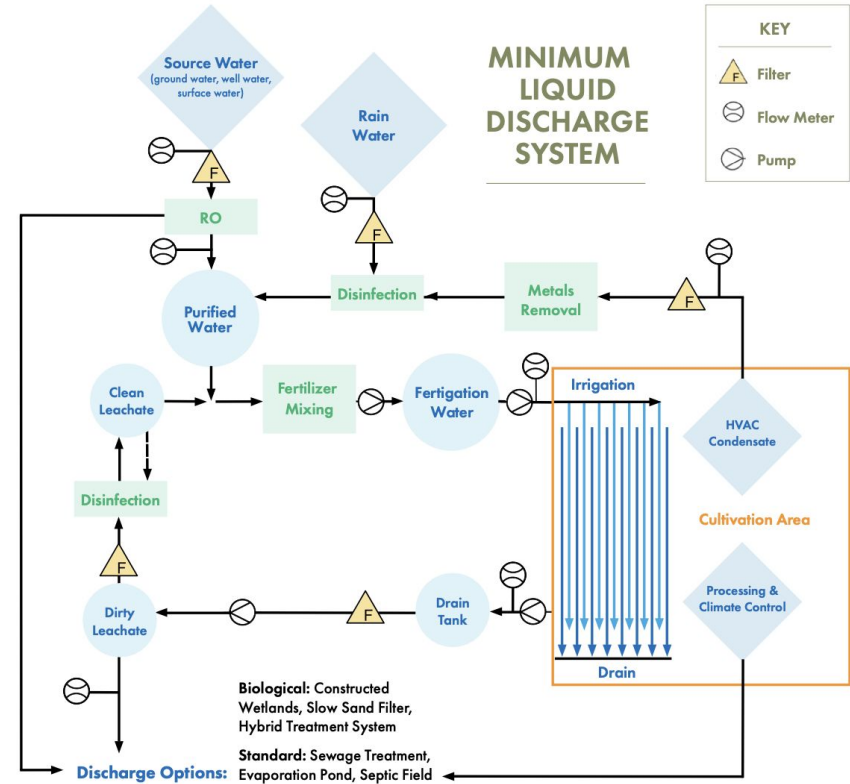
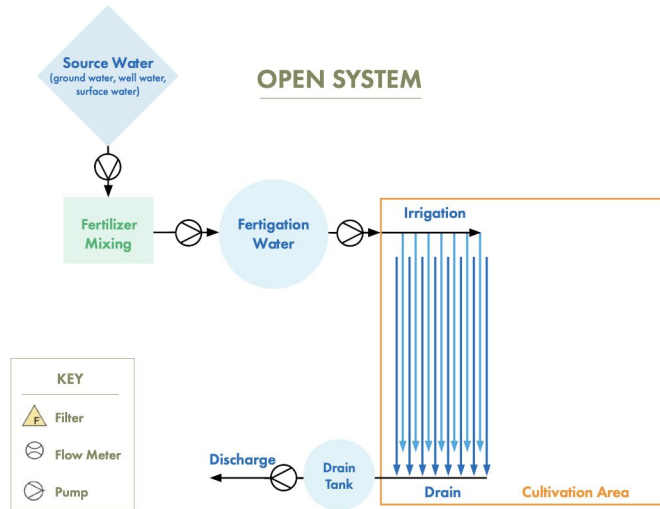


Table 10. Comparison of varying chemical water treatment systems.⁷⁷

Chemical Water Quality Treatment Systems														
Technology	Notes	Pre Treatment Required	Treatment Range						Reaction Time	Residual Effect*	Reject Water Waste?	Footprint	Costs	
			Solids / organic material	Pathogens	Nutrients		Agri - chemicals	Controls Biofilm					Capital	Operating
					N	P								
Chlorine	Caution with chloramine formation when using in fertigation solutions	Pre-filtration	✓	✓			Some	✓	Minutes	++		Small	\$ - \$\$	\$
Chlorine Dioxide		Pre-filtration	✓	✓			Some	✓	Minutes	++		Small	\$ - \$\$\$	\$\$ - \$\$\$
Peroxyacetic acid	(PAA) is a combination of acetic acid and hydrogen peroxide	Pre-filtration	✓	✓			Some	✓	Minutes	++		Small	\$	\$\$ - \$\$\$
ECA	Chlorine 2-10 ppm may damage lettuce	Softening	✓	✓				✓	Minutes	+		Small		
Ozone		Pre-filtration	✓	✓			Some	✓	Minutes	+		Medium	\$\$\$	\$
Copper Ionization		Pre-filtration		✓					Hours	++		Small	\$\$\$	\$
Peroxyacetic acid + UV	Synergistic Effect	Pre-filtration	✓	✓			Some	✓	Minutes	++		Medium	\$\$\$\$	\$\$\$ - \$\$\$\$
Peroxyacetic acid + Ozone	Synergistic Effect	Pre-filtration	✓	✓			Some	✓	MInutes	++		Medium	\$\$\$\$	\$\$\$ - \$\$\$\$
Ozone + UV	Synergistic Effect	Pre-filtration	✓	✓			Some	✓	Minutes	+		Medium	\$\$\$\$	\$\$
Deionization	Higher purity than typically needed	Pre-filtration and Reverse Osmosis to reduce cost	✓	✓	✓	✓	✓		Minutes		+++	Medium	\$\$\$\$	\$\$\$

* All technologies other than point treatments such as membrane filtration or UV have potential for phytotoxicity at high doses. Make sure to follow label and manufacturer recommendations on dose, monitoring, and maintenance.

⁷⁷ Modified from West, J., Huber, A., & Carlow, C. (2018). Water Treatment Guide for Greenhouses & Nurseries, Agriculture and Agri-Food Canada, and Fisher, P. (2020, February 18). Managing Water Quality and Biofilm for Indoor Production, Indoor Ag Science Cafe (episode 16). <https://www.youtube.com/watch?v=O7wVUUEd8>

Recycling Rain/Condensate

Quality level	EC (mS/cm)	Na (ppm)	Cl (ppm)	Suitability for hydroponics	Suitable use
1	< 0.5	< 34	< 53	++	Suitable for all crops
2	0.5 - 1.0	34 - 57	53 - 87	+	Some discharge required in recirculating systems
3	1.0 - 1.5	57 - 92	87 - 142	±	Not suitable for salt-sensitive crops or recirculated closed systems

Hydroponic producers commonly purify source water using reverse osmosis, with a typical 50% efficiency, meaning they create **1 gallon of brine waste for 1 gallon of purified water**.

High-efficiency RO units can increase efficiency to 85% or higher.

Alternatively, rainwater or HVAC condensate can be used as near-pure water sources.