Sustainable Winemaking and the Design of Sustainable Wineries

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Outline

- Sustainable Winemaking Practices
  - Winemaking Practices, Wine Transfers, Tank Cleaning
  - Energy, Water, Carbon and Chemistry Footprints
- The Design of Sustainable Wineries
  - Less Energy and Water Intensity Practices
  - Storage vs On-Demand Systems
  - Fermentation Carbon Dioxide Capture
  - Advanced Above Ground Passive Barrel Spaces
  - Wireless data, Prediction of Demand and System Loads
  - The Self-Sustainable Winery at UC Davis
  - Off the Power and Water Grids

Sustainable Winemaking Practices

Non-Residue Treatments
Out of Tank Treatments
Recovery and Multiple-Use of Water
and Green Cleaning Chemistry

Current Practice	Non-Residue Alternative
Cation Exchange Clays Bentonite(s)	Regenerable Adsorption Column MacroPrep 50S Immobilized Tannin Column
Protein(s) Casein, Gelatine, Albumen, Isinglass MannoProteins	Immobilized Protein Column PVPP Column
Tartrate Crystal Inhibitors Gum Arabic Carboxy methyl cellulose Meta-Tartaric Acid	Fluidized-Bed Crystallizer with KHTa Recovery
Tannin Extracts	Oak Piece, Seed Columns
Alginates Ferrocyanide	

Out of Tank Treatment Alternatives

More Efficient Contacting
Less Wine Loss, Microbe and Oxygen Exposure
Less Wine Movement and Treatment
A Tank Transfer (= A Tank Cleaning)

Water Saving from In-Tank Treatments

Examples:

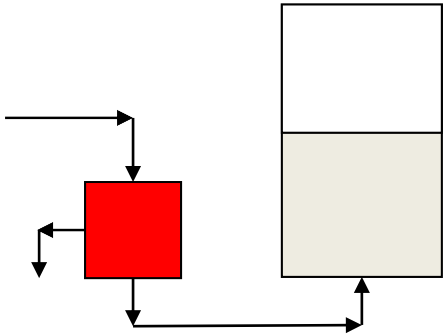
- In-line White Juice Flotation - Jameson Cells
- Protein Adsorption Columns - MacroPrep and others
- Fluidized-Bed Crystallizer for Potassium Bitartrate
- Phenol and Tannin Extraction Columns – Oak Pieces, Seeds
- In-Tank Blending Systems

Saves at least 4 tank washings for each White Wine

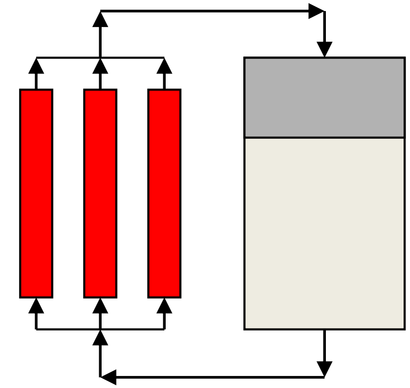
Saves at least 3 tank washings for each Red Wine

Sustainable Winemaking Practices

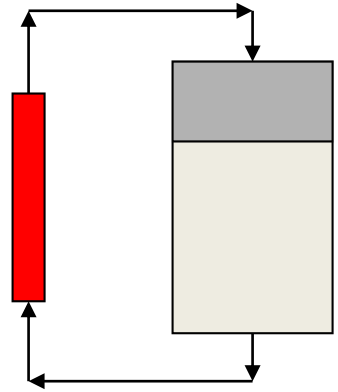
- Wine Movements and Tank Washing
  - Whites: Historical, Typical, Target
  - Reds: Historical, Typical, Target
- Barrel Racking Practices
  - Clarified Wine, No Ranking, Washing and Topping of Barrels
- External Tank Treatments
  - In-Line Flotation (White Juice), no settling or racking
  - MacroPrep Column for Protein (White Wine), no Bentonite
  - Adsorption Column for Phenols (Red Wine), no Proteins
  - Fluidized Bed for KHTa, KHTa recovery
  - Oak Piece, Seed Columns for Phenols
- Blending
  - In Tank Blending, no Blending tank



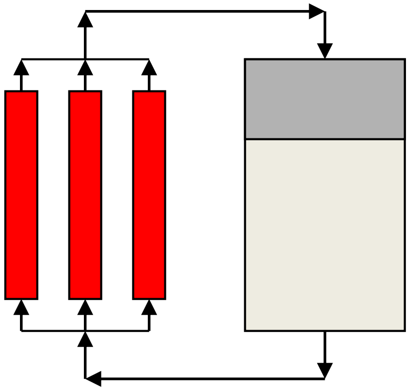
Flotation Cells



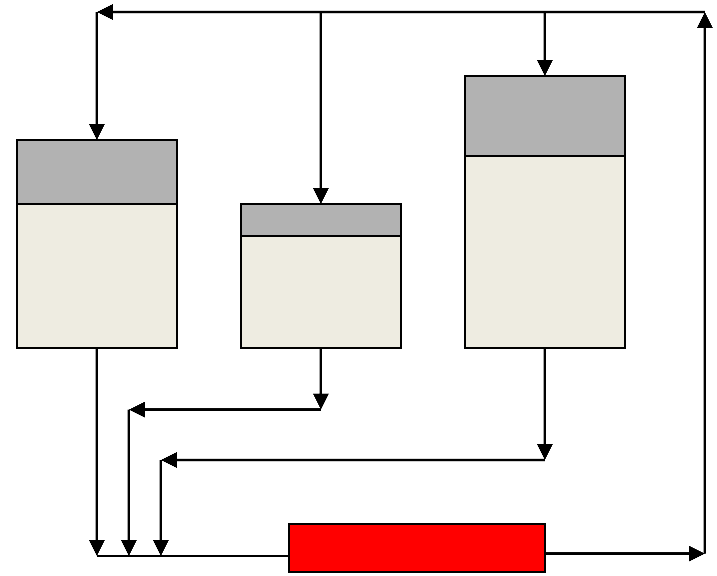
Protein Adsorption Columns



Phenol Extraction Columns



KHTa Fluidized Bed Columns



In-Tank Blending

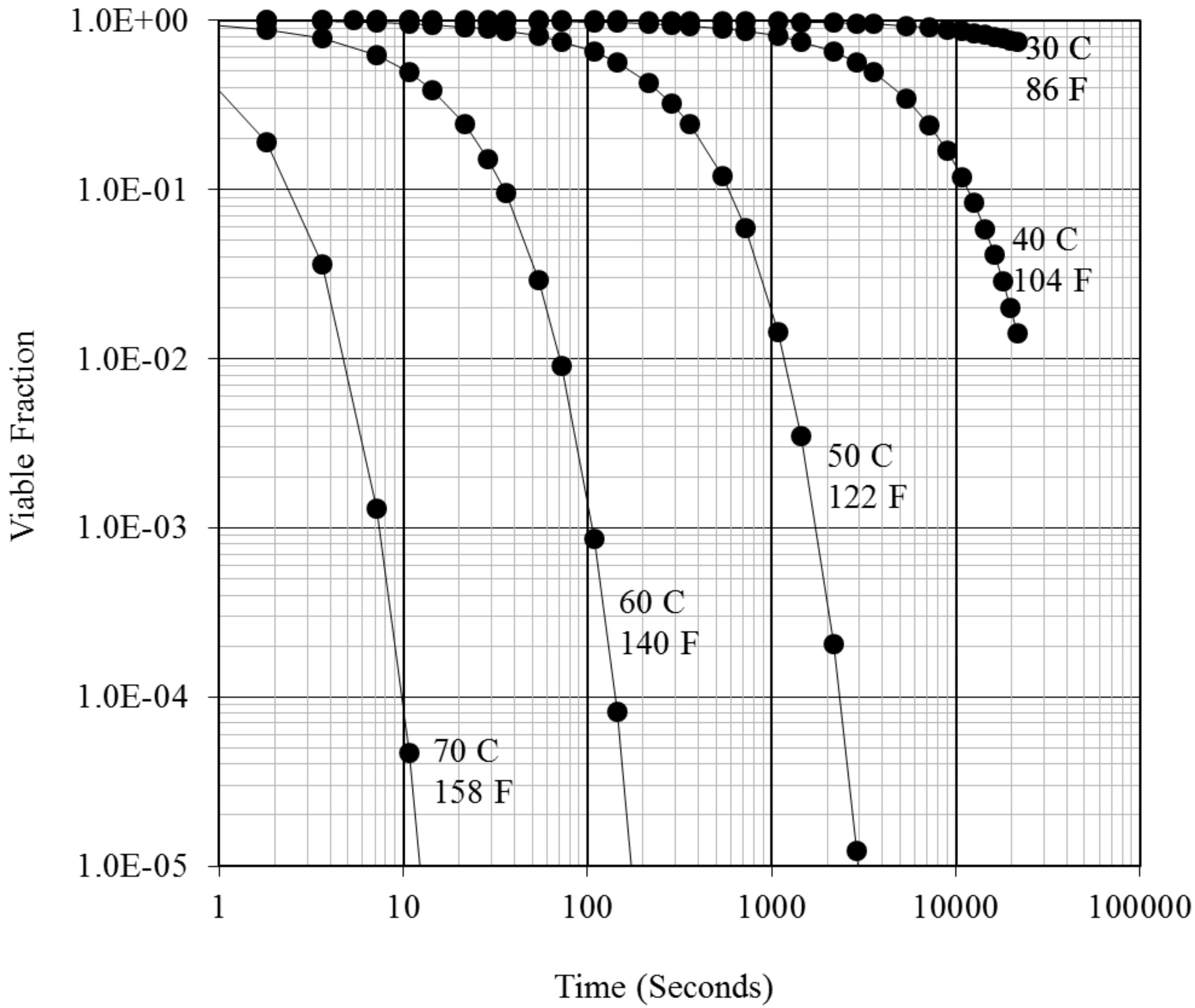
Alternative Cleaning Solutions

Potassium-based, multiple-use solutions
Elimination of Sodium, Phosphate, Chlorine, BOD and COD
80 to 90% Recovery each use
Soft water, Rainwater for Membrane life

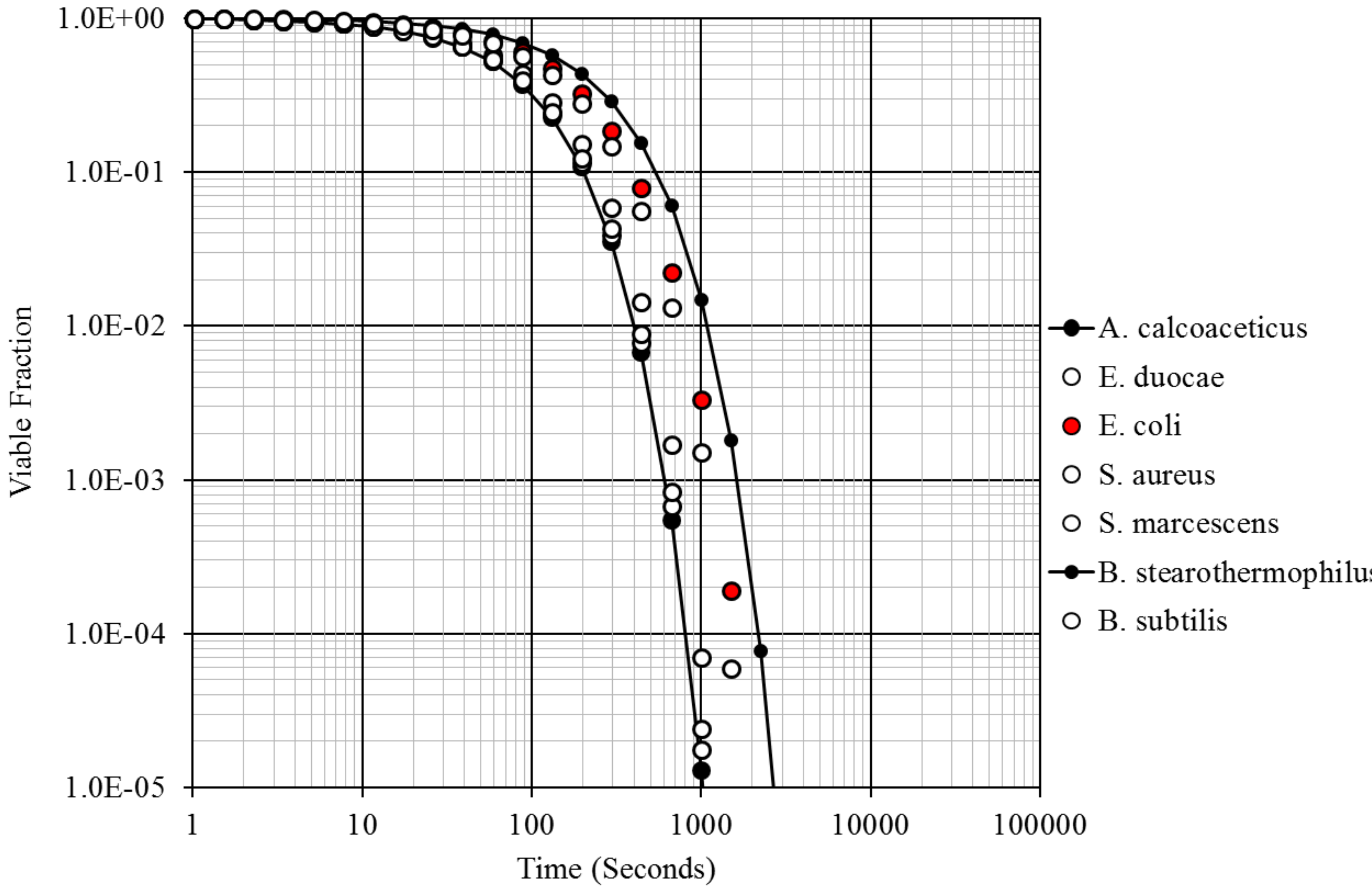
Clean-In-Place Buffer Solutions

Ambient, 5 Decade Reduction in ***E. coli***
Matched KOH/$KHSO_4$ 10 to 20 mM
All Monovalent ions for NF recovery
pH 7 discharge, no BOD or COD

Survival of *E. coli* in Hot Water, pH = 7.0



Survival of *E. coli* and others with 1% Hydrogen Peroxide, pH 2.3 and T= 20ºC



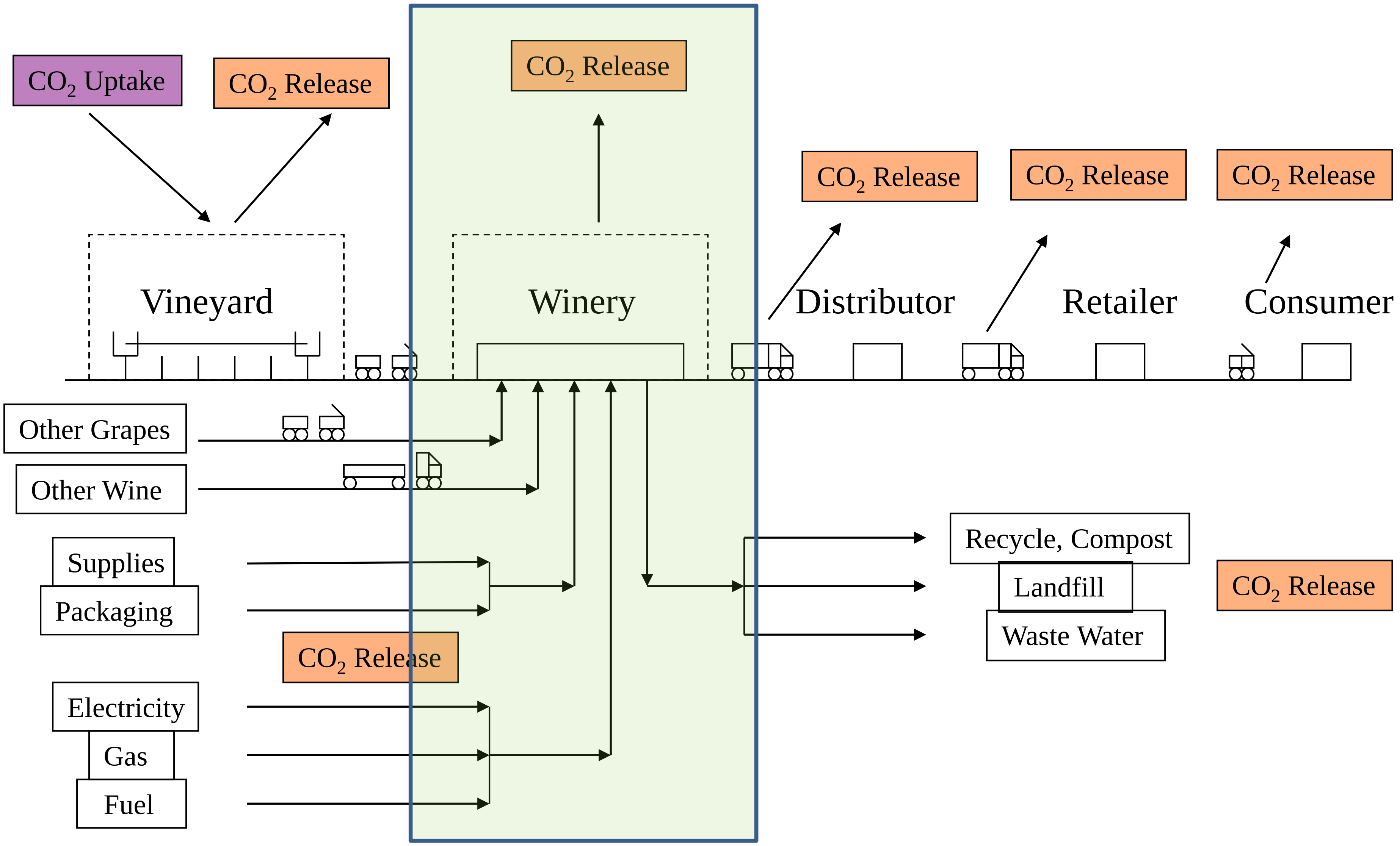
Recovery, Cycles and Volumes

Recovery	**0.90**			
Cycle #	**Initial Volume**	**Use Number**	**Makeup**	**Cum. Saving**
1	100.00	1.00	0.00	0.00
2	90.00	1.90	10.00	90.00
3	81.00	2.71	10.00	180.00
4	72.90	3.44	10.00	270.00
5	**65.61**	**4.10**	**10.00**	**360.00**
6	59.05	4.69	10.00	450.00
7	53.14	5.22	10.00	540.00
8	47.83	5.70	10.00	630.00
9	43.05	6.13	10.00	720.00
10	**38.74**	**6.51**	**10.00**	**810.00**
% Recovery	**90.00**		**90.00**	
Volume	**900.00**			
Makeup	**90.00**			
Saved	**810.00**			
# Uses	**6.51**			
Reduction Factor	**10.00**			

Carbon Dioxide Footprints

Fermentation Carbon Dioxide Emission
Capture and On-Site Sequestration

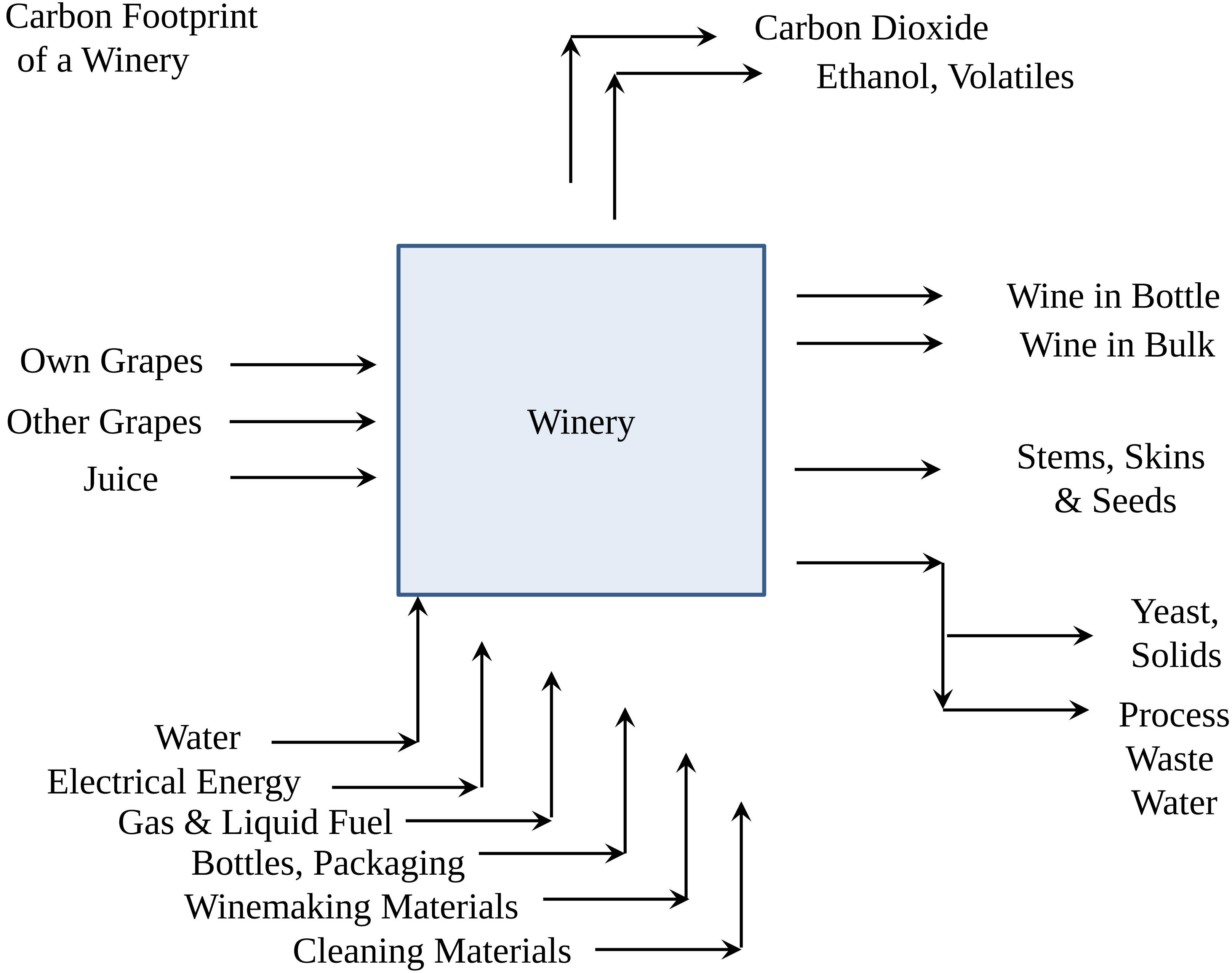
Carbon Dioxide Balance – Vine to Consumer



Carbon Dioxide Emissions from Fermentation

Largest Direct (Scope 1) Emission
Highest Concentration Release,
Ground Level and Ambient Temperature

The Carbon Footprint of a Winery



CO_2 Summary

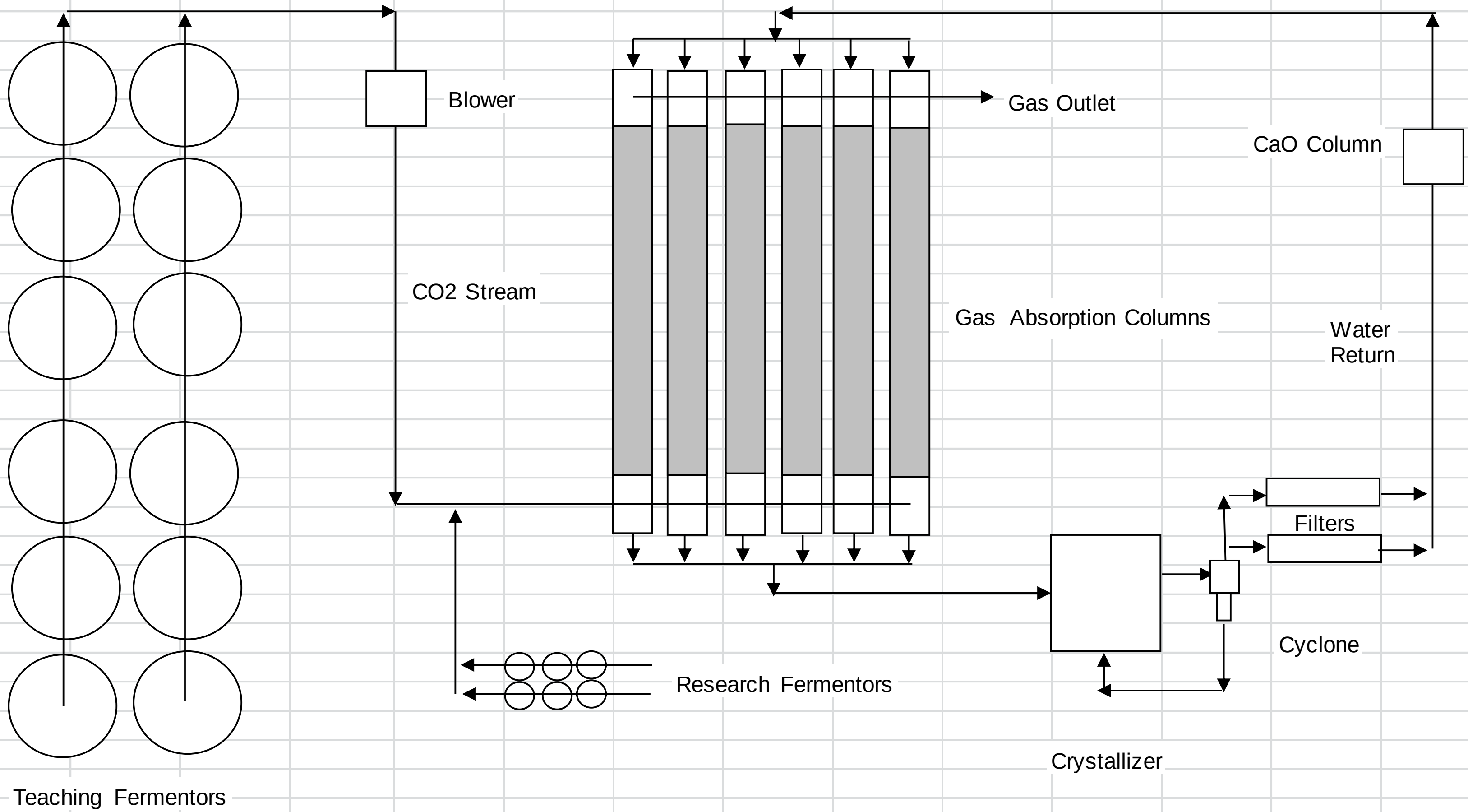
- Fermentation release:
  - 68 Kg/tonne of grapes
  - 60 L CO_2 per L of juice or 120 g CO_2 per L of juice,
  - 80 g CO_2 per 750 mL bottle

- Electricity at 550 g CO_2 per KWh
  - 65 g CO_2 per 750 mL bottle

- A new bottle
  - 454 g CO_2 per 750 mL bottle

Calcium Hydroxide Columns

- Precipitation as CaCO3
  - No energy-intensive phase change
  - No Vapor or Liquid Storage System
- A simple and safe storage form, $CaCO_3$ powder
- Saturated Lime Water, high CO_2 solubility
- Requires CaO (or $CaCO_3$)
- Requires Water, in a recirculation loop
- Multiple Columns in Parallel to handle flow variation
- First proposed in 2003…..



Blower
Gas Outlet
CaO Column
CO2 Stream
Gas Absorption Columns
Water
Return
Filters
Cyclone
Research Fermentors
Crystallizer
Teaching Fermentors

Footprint Reporting

Example: Pernod Ricard
One of the largest Wine and Spirits Companies in the world,

Thematic	Definition		Mesure Unit	Total Pernod Ricard 2009	2008	2007	2006	Mesure Unit		a) Ratio for 1 000L of distilled alcohol b) Ratio for 1 000L of finished product 2009	2008	2007	2006	G3 GRI Index
Volume Produced	Total production	a) distilled alcohol	kL	212,746	174,729	220,662	195,952	-	-	-	-	-	-	-
		b) finished product		1,228,829	1,166,177	1,185,449	1,145,225			-	-	-	-	-
Water	Total water intake		m³	8,540,794	6,710,552	7,605,066	7,182,064	m³/kL	a)	40.15	38.41	34.46	36.65	EN 8
									b)	6.95	5.75	6.42	6.27	
Energy	Total energy consumption		MWh	1,668,747	1,550,242	2,049,267	2,029,538	MWh/kL	a)	7.84	8.87	9.29	10.36	EN 3 EN 4
									b)	1.36	1.33	1.73	1.77	
	Among which: Electricity		MWh	272,080	218,929	246,290	237,968	MWh/kL	b)	0.22	0.19	0.21	0.21	
CO_2 Emissions	Direct CO_2 emissions (scope 1)		CO_2 teq	299,810	300,013	463,310	455,222	CO_2 teq/kL	a)	1.41	1.72	2.10	2.32	EN 16
									b)	0.24	0.26	0.39	0.40	
Cooling gases	Quantity of fluorinated gas in place		kg	20,499	20,249	20,480	14,394	-	-	-	-	-	-	EN 19
	Part of HFC in place among all fluorinated gases		%	27.2	23.7	19.9	23.6	-	-	-	-	-	-	
	Quantity of fluorinated gas released into the atmosphere		kg	2,940	2,297	2,330	NA	-	-	-	-	-	-	
	Part of fluorinated gas released into the atmosphere		%	14.34	11.34	11.38	NA	-	-	-	-	-	-	
Waste water	Volume of waste water discharged		m³	6,153,681	5,063,494	5,831,760	5,460,197	m³/kL	a)	28.93	28.98	26.43	27.86	EN 21
									b)	5.01	4.34	4.92	4.77	
Organic waste	Quantity of organic waste landfilled or incinerated		T	7,106	11,631	18,359	66,015	kg/kL	a)	33.40	66.57	83.20	336.89	EN 22
									b)	5.78	9.97	15.49	57.64	
Solid waste	Quantity of total solid waste		T	32,879	32,202	40,652	36,198	kg/kL	b)	26.76	27.61	34.29	31.61	EN 22
	Quantity of solid waste landfilled or incinerated		T	7,228	7,400	10,197	8,646	kg/kL	b)	5.88	6.35	8.60	7.55	
	Part of recycled solid waste		%	78	77	75	76	-	-	-	-	-	-	
Hazardous waste	Quantity of hazardous waste treated externally		T	515	349.8	432.2	363.5	kg/kL	b)	0.42	0.30	0.36	0.32	EN 24
Abestos	Quantity of waste containing abestos		T	30	265.0	205.0	336.0	-	-	-	-	-	-	EN 24
ISO 14001 certification	Number of certified sites		%	81	70	59	44	-	-	-	-	-	-	-
	Part of certified sites in total production		%	93	86	74	63	-	-	-	-	-	-	
Investments	Amount of investments for environment protection		€M	5.85	5.60	9.25	13.04	-	-	-	-	-	-	
Conformity	Environment-related fines or sanctions		Fines or Sanctions number	4*	0	0	0	-	-	-	-	-	-	EN 28

The Research Gap

Developing and adopting alternative technologies that enable fewer Tank Transfers

Shortage of Engineering Research and Development

The Design of a Self-Sustainable Winery

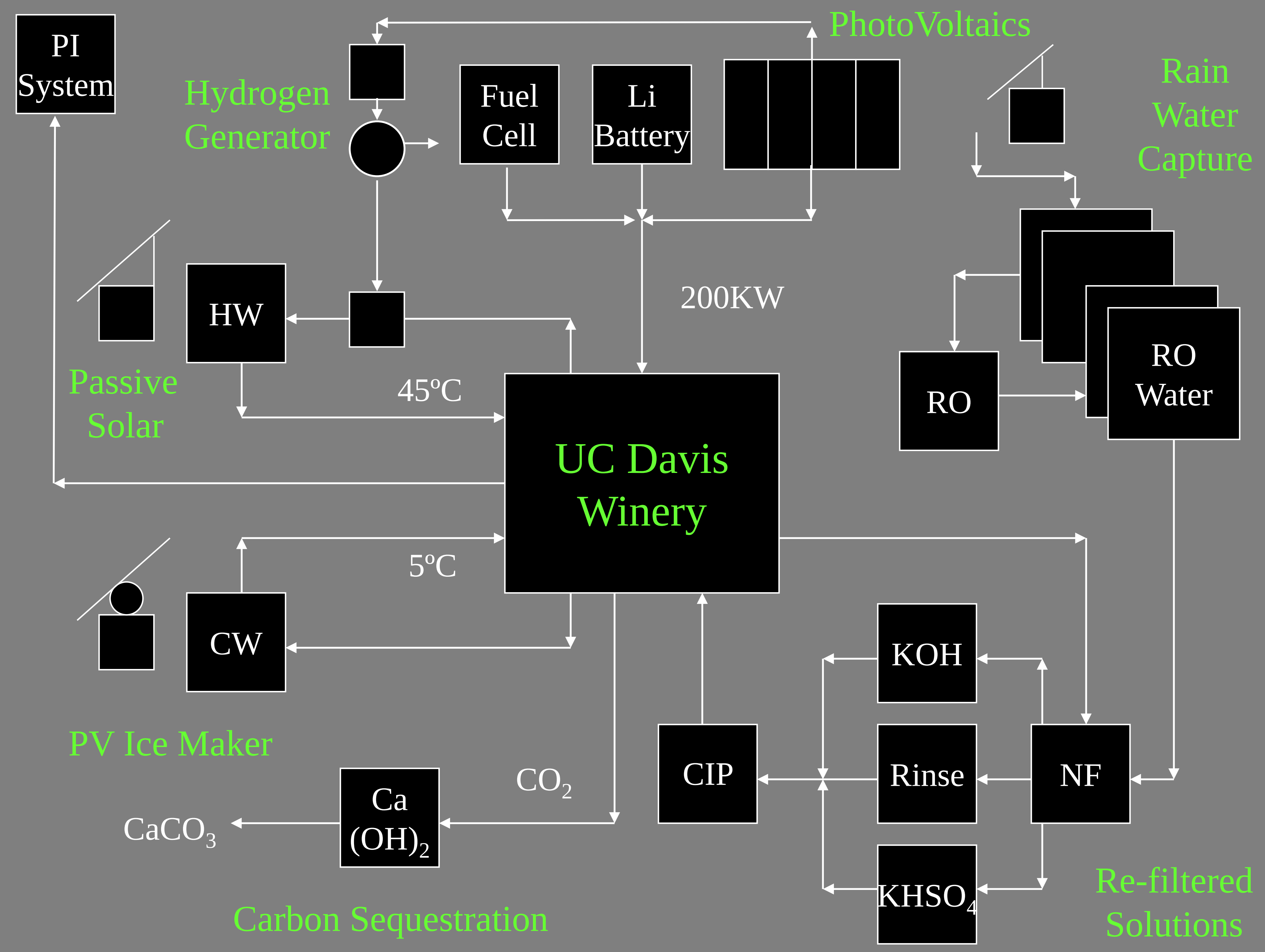
Onsite Energy and Water Capture, Off-Grid
Storage Systems for Energy, Water, Ice, Hot Water, Nitrogen and Compressed Air
Carbon Dioxide Capture and On-site Sequestration
Ambient Peroxide and Potassium-based Cleaning Chemistry
Recovery and re-filtration of Cleaning Solutions

Design of Sustainable Wineries -I

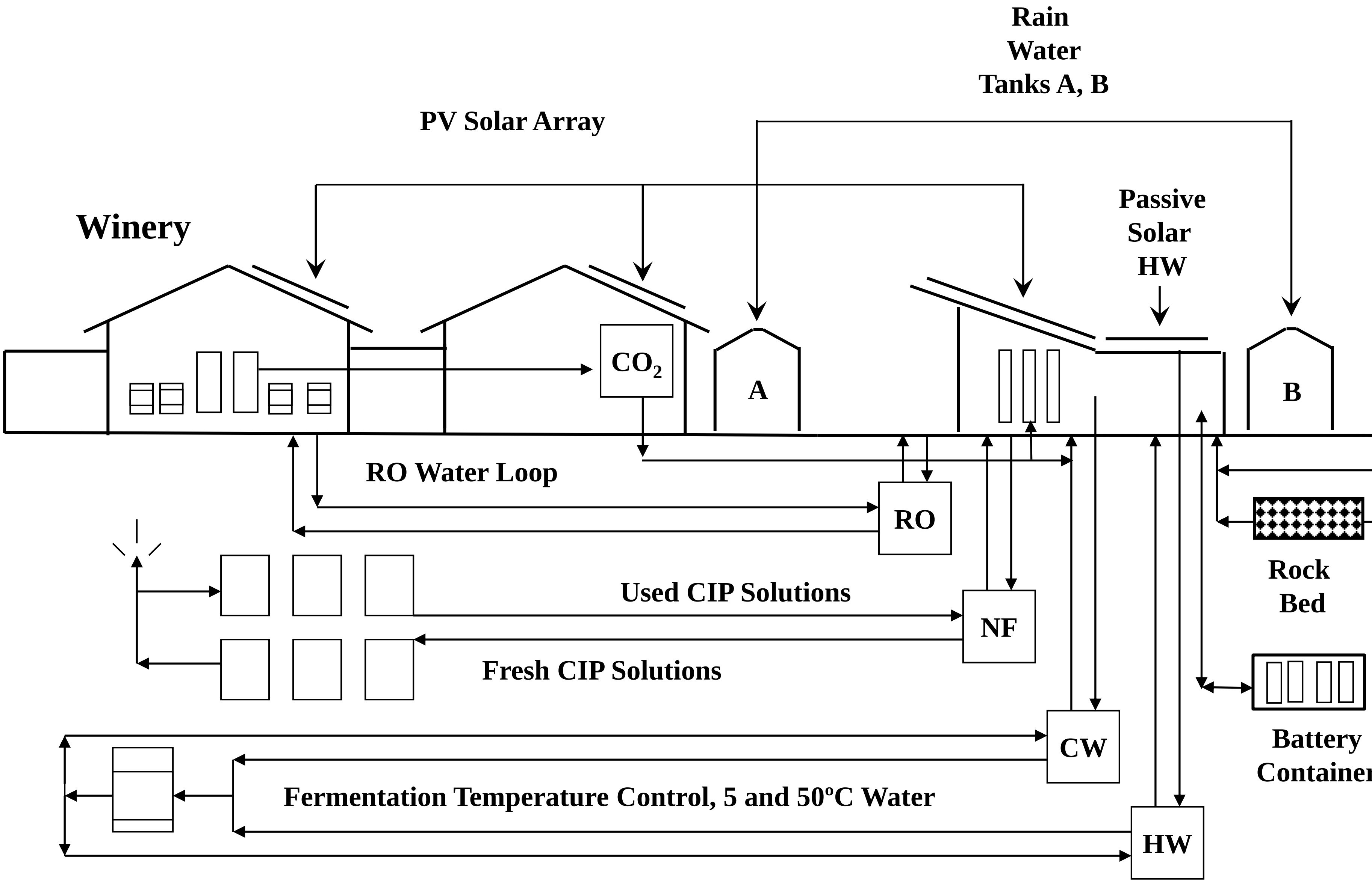
- Energy,
  - On-site PV, Wind and Passive Solar
    - Generation and Storage
  - Efficient Process Refrigeration, VSD compressors
    - Coolant at 5 C, no lower
    - Pulse Cooling in Jackets
    - Thermal Banking not On-demand Generation
  - Thermally Efficient, Passive Barrel Buildings
    - Night Air, Humidity control
    - High Thermal Insulation Envelope
- Water
    - On-site Capture, Storage, RO filtration
    - Capture Re-filtration of cleaning solutions, NF
    - Multiple Uses, 2, 3, 5 or 10 times

Design of Sustainable Wineries -II

- Carbon Dioxide Capture and On-Site Sequestration
  - Fermentation Capture and Sequestration
  - Capture from Release from Compost
  - Process Water Treatment
- Potassium-based Cleaning Chemistry
  - No BOD, COD demand from cleaning Chemistries
  - No Sodium or Phosphorous contributions to Discharge Water
- Elimination of Aerobic Treatments
  - Carbon Dioxide release
  - Nitrate formation
- On-site Generation and Storage:
  - High purity Nitrogen Gas
  - Hydrogen Peroxide as needed

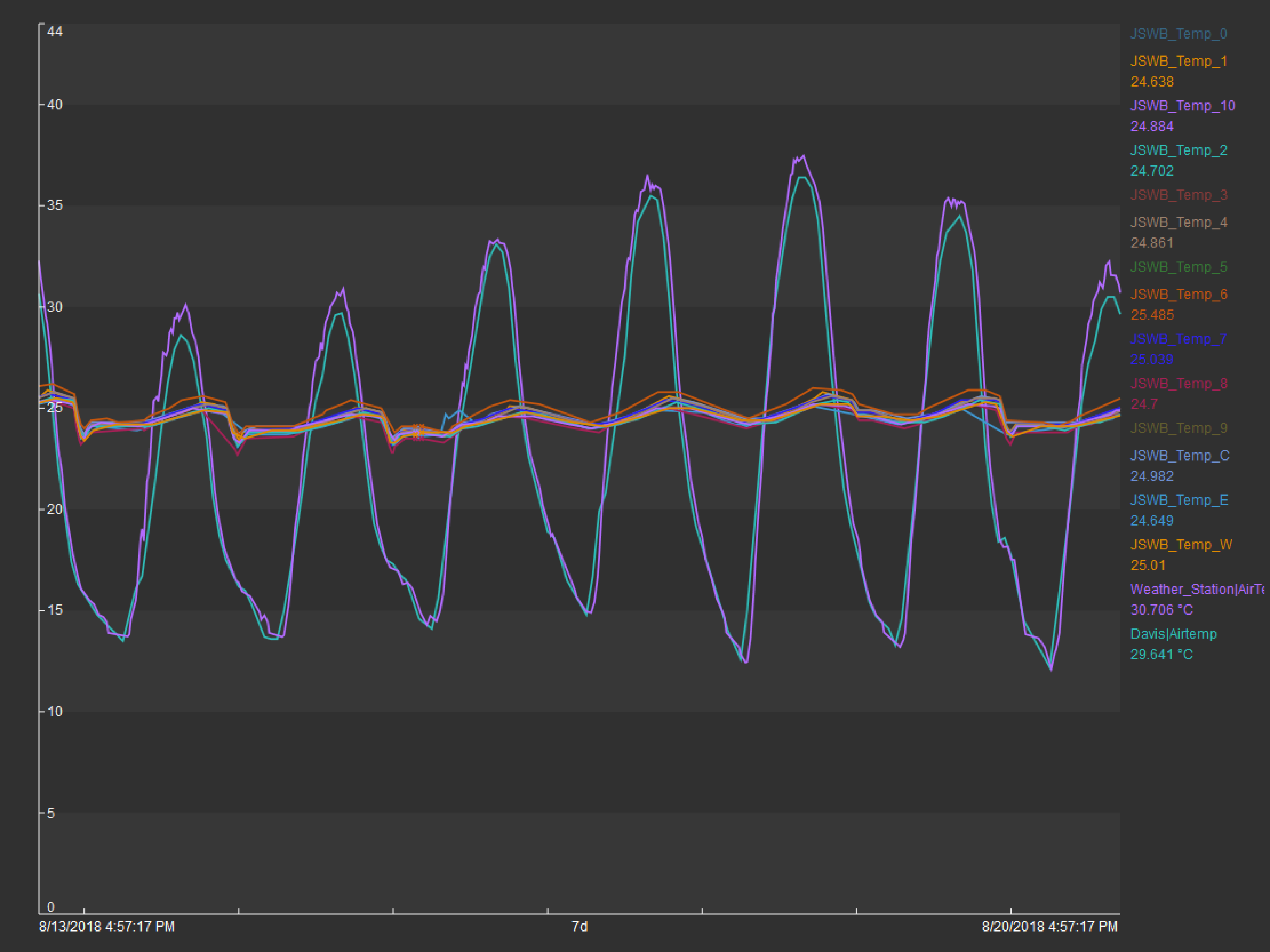

PI System
Hydrogen Generator
Fuel Cell
Li Battery
PhotoVoltaics
Rain Water Capture
Passive Solar
HW
200KW
45ºC
RO
RO Water
UC Davis Winery
5ºC
CW
PV Ice Maker
KOH
Rinse
KHSO$_4$
NF
CIP
CO_2
Ca $(OH)_2$
$CaCO_3$
Carbon Sequestration
Re-filtered Solutions

Utility Loops for the Self-Sustainable Winery

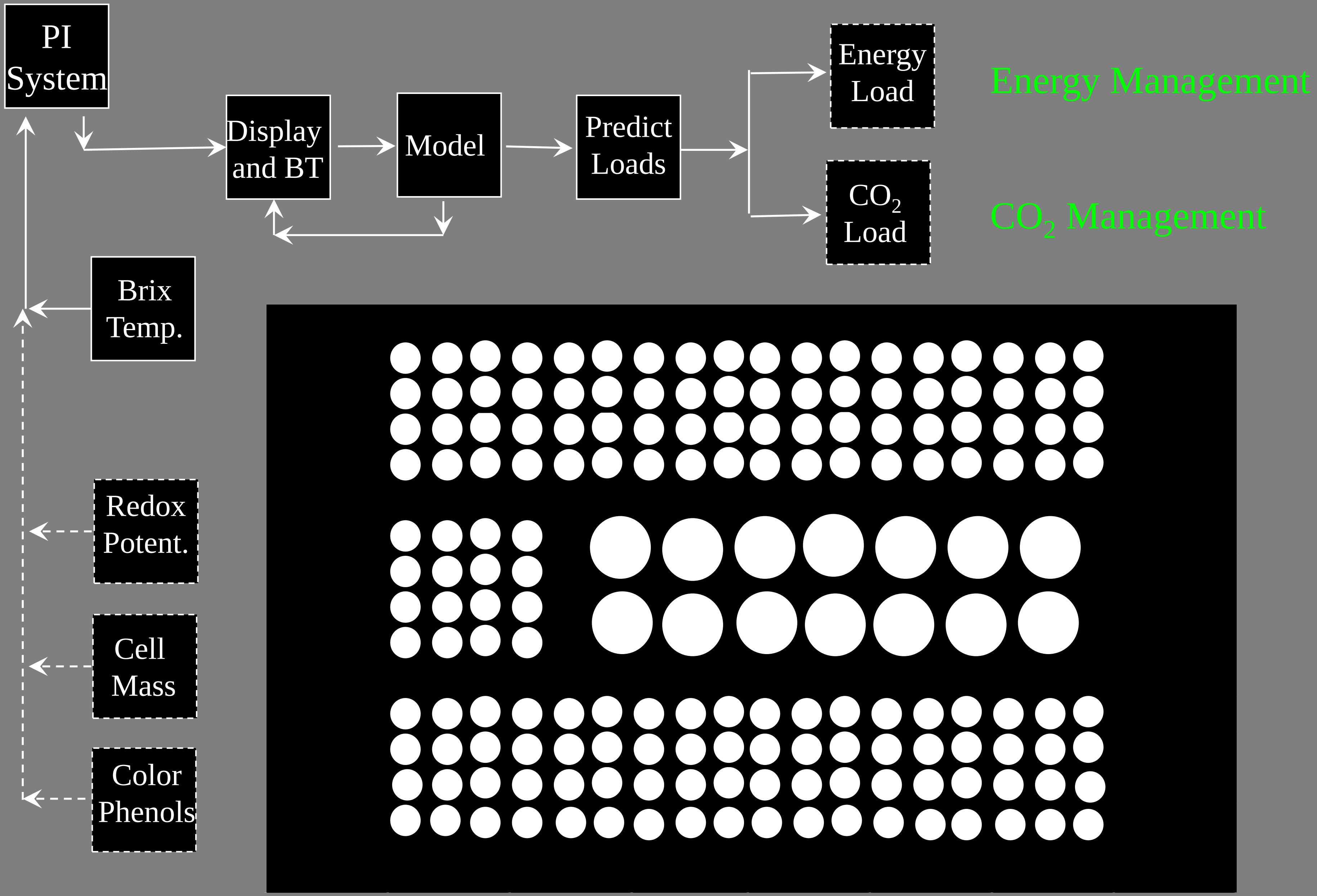


Passive Building Performance

The Jackson Building at UC Davis
Model Barrel Room
5 Rooms for Winery Systems
4 Rooms for System Projects

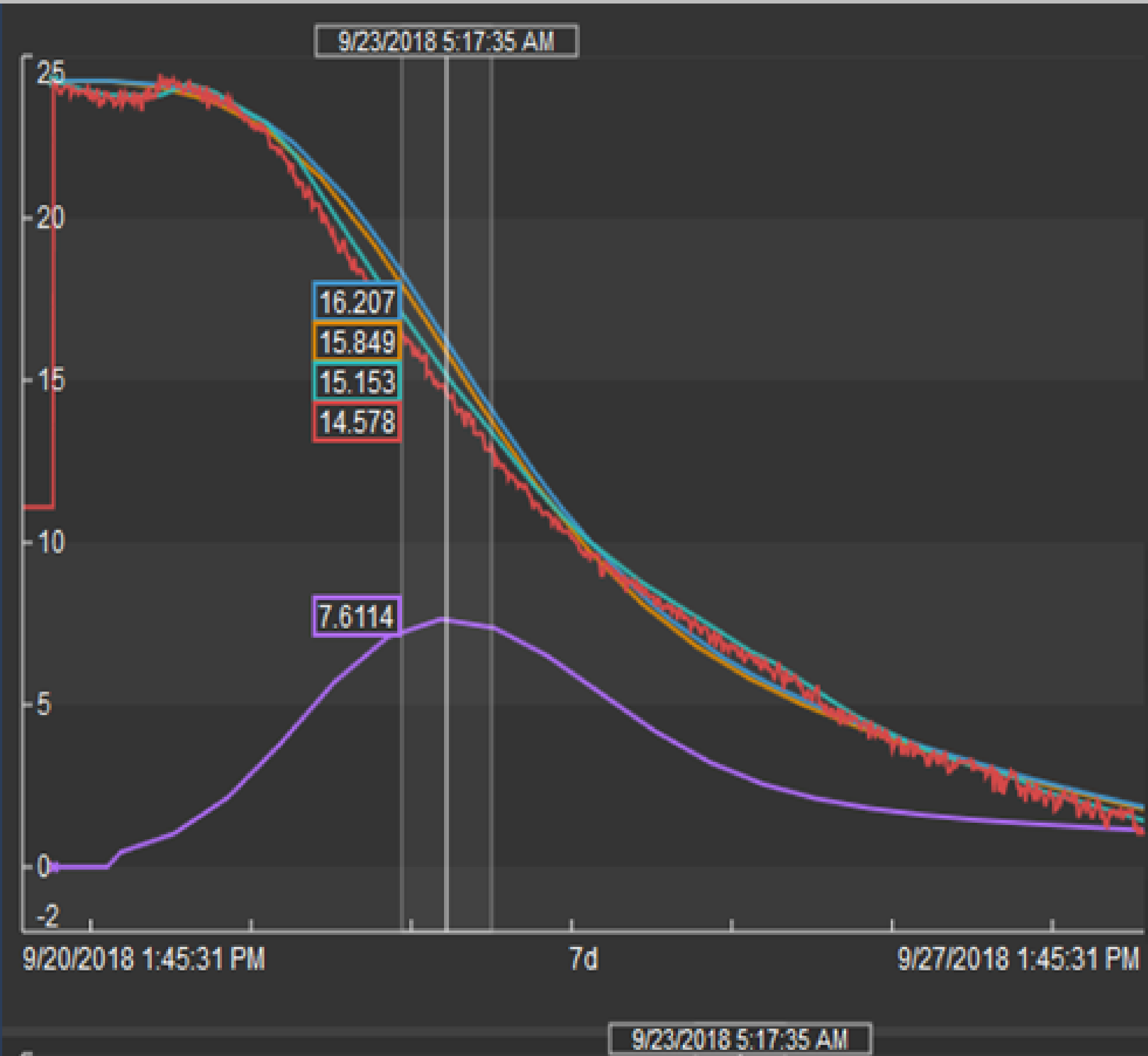

44
40
35
30
25
20
15
10
5
0
8/13/2018 4:57:17 PM
7d
8/20/2018 4:57:17 PM
JSWB_Temp_0
JSWB_Temp_1
24.638
JSWB_Temp_10
24.884
JSWB_Temp_2
24.702
JSWB_Temp_3
JSWB_Temp_4
24.861
JSWB_Temp_5
JSWB_Temp_6
25.485
JSWB_Temp_7
25.039
JSWB_Temp_8
24.7
JSWB_Temp_9
JSWB_Temp_C
24.982
JSWB_Temp_E
24.649
JSWB_Temp_W
25.01
Weather_Station|AirTe
30.706 °C
Davis|Airtemp
29.641 °C


DANGER



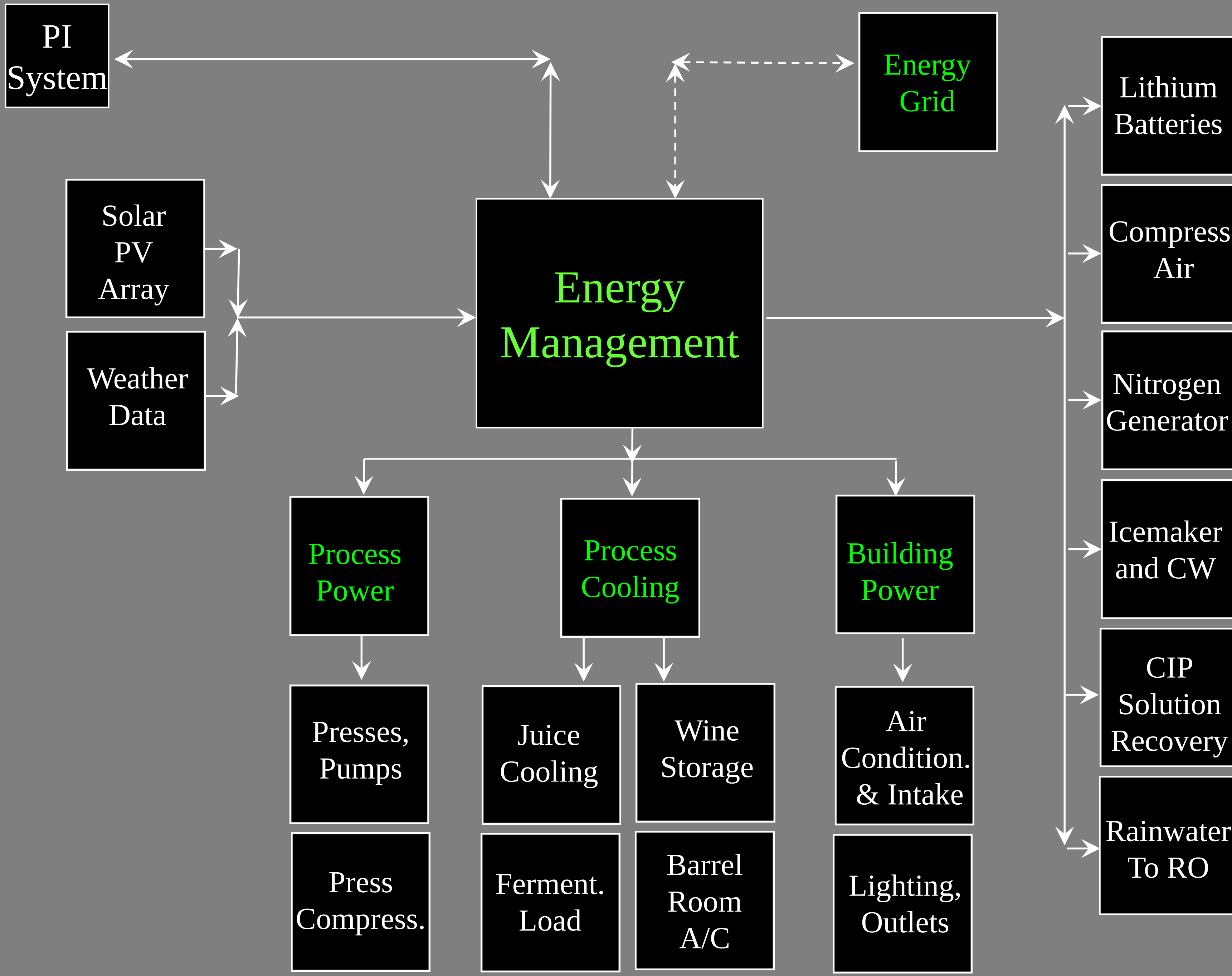
Fermentation Monitoring and Management Systems

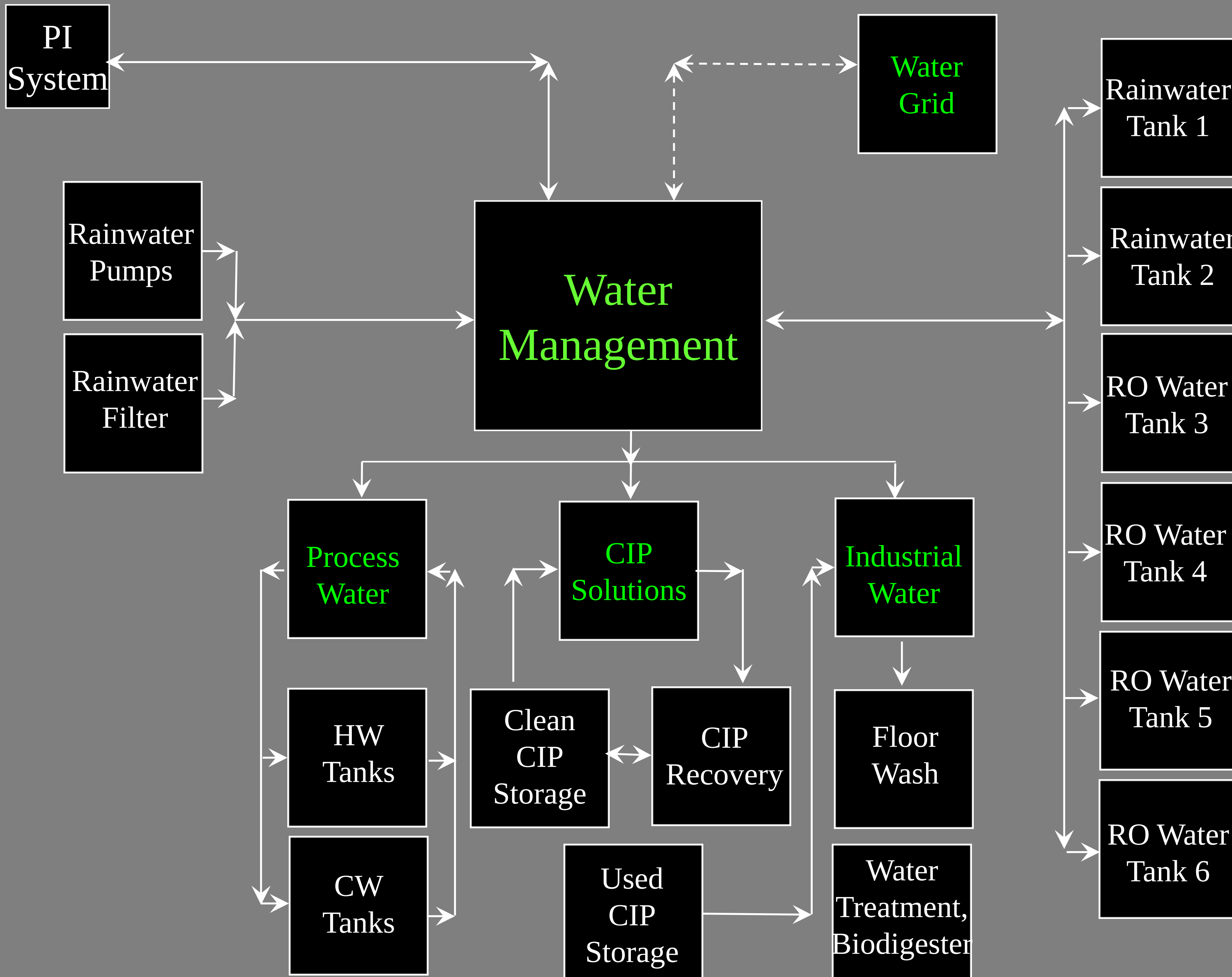
Wireless Brix and BT Redox

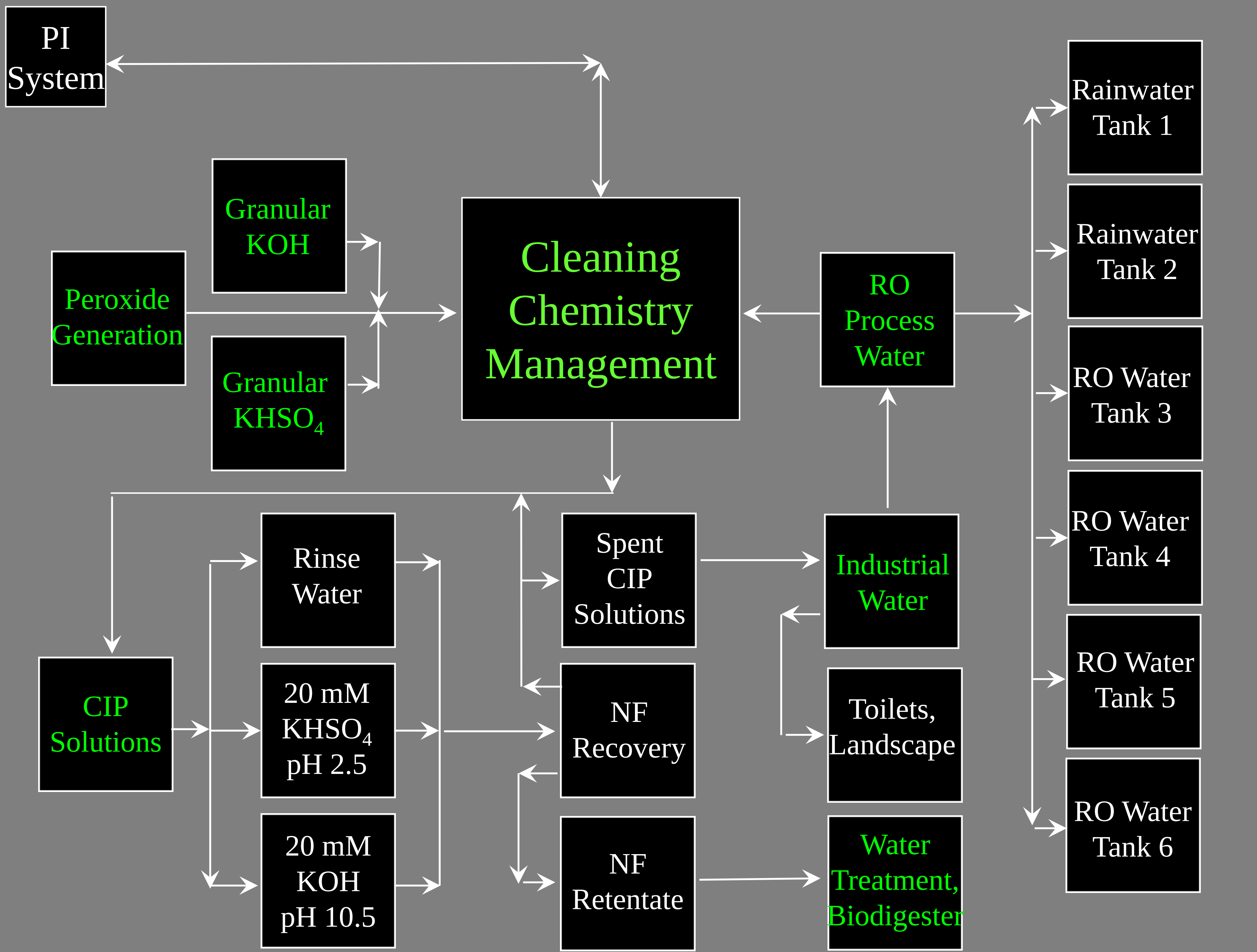


Name	Value
UFL.jcstest10_ETH-INHIB	0.025732
UFL.jcstest10_INIT-NITRO	0.00026591
UFL.jcstest10_LAG-TIME	8.0585
UFL.jcstest10_MAINTENANCE	0.04329
UFL.jcstest10_VIAB-CONST	28.972

Wireless Measurement, Modeling and Prediction


PI System
Energy Grid
Solar PV Array
Weather Data
Energy Management
Lithium Batteries
Compress. Air
Nitrogen Generator
Icemaker and CW
CIP Solution Recovery
Rainwater To RO
Process Power
Process Cooling
Building Power
Presses, Pumps
Press Compress.
Juice Cooling
Ferment. Load
Wine Storage
Barrel Room A/C
Air Condition. & Intake
Lighting, Outlets


PI System
Water Grid
Rainwater Pumps
Rainwater Filter
Water Management
Rainwater Tank 1
Rainwater Tank 2
RO Water Tank 3
RO Water Tank 4
RO Water Tank 5
RO Water Tank 6
Process Water
CIP Solutions
Industrial Water
HW Tanks
CW Tanks
Clean CIP Storage
CIP Recovery
Floor Wash
Used CIP Storage
Water Treatment, Biodigester


PI System
Granular KOH
Peroxide Generation
Granular $KHSO_4$
Cleaning Chemistry Management
RO Process Water
Rainwater Tank 1
Rainwater Tank 2
RO Water Tank 3
RO Water Tank 4
RO Water Tank 5
RO Water Tank 6
Rinse Water
Spent CIP Solutions
Industrial Water
CIP Solutions
20 mM $KHSO_4$ pH 2.5
NF Recovery
Toilets, Landscape
20 mM KOH pH 10.5
NF Retentate
Water Treatment, Biodigester

Acknowledgements

Organizing Committee
of the Sauvignon Blanc 2019 Conference

The Stephen Sinclair Scott Endowment
University of California, Davis
My Students and Colleagues