Britten Water Filtration System

Senior Design Team 0G
Advisor: Tony Pinar
Sponsor: Britten, Inc

Michigan Tech

Senior Design Team 0G

- Team Members:
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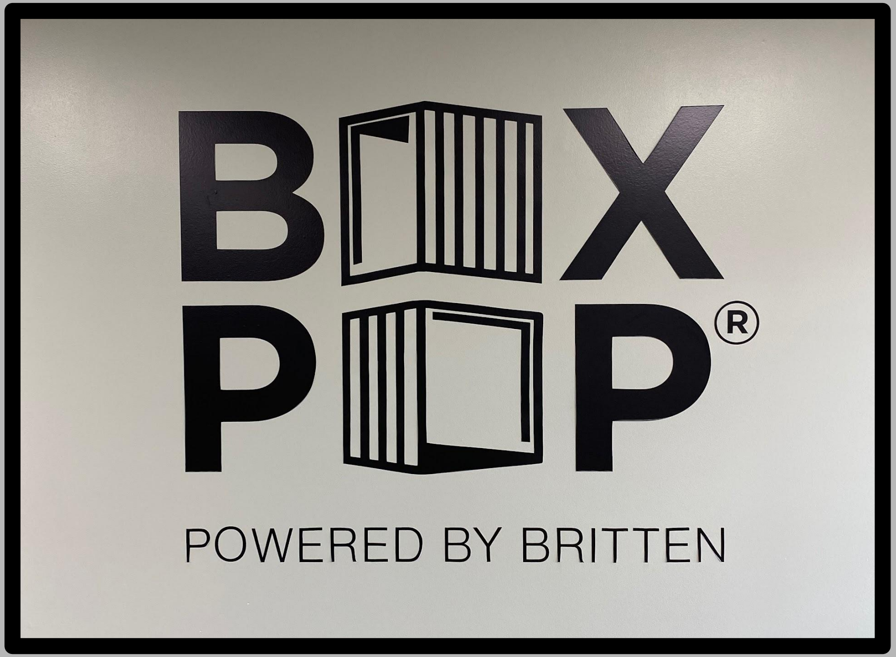
  - Matt Zambon (ME)
- Faculty Advisor:
  - Tony Pinar
- Sponsor Advisors:
  - Matt Egan
  - Nathan Bildeaux



Company Overview

- Britten, Inc.
  - BoxPop®
- Traverse City, MI
- Printing Company
- Custom Shipping Containers
- Founder: Paul Britten

Project Overview

- **Scope:** Develop a design for a water filtration system contained within a standard high cube 10 ft ISO container
- **Intent:** This product will be marketed and sold to developing regions, disaster recovery zones, and other markets where a safe potable water source is required
- **Original Budget:** $10,000*

Project Goals

- **Requirements**:
  - Intake for contaminated water and outlet for purified water
  - Option to be powered internationally, I.e. 50 or 60 Hz and common available voltage and an option for an onboard generator power source
  - Option for solar power with battery backup
- **Deliverables**:
  - Will provide Britten Inc with a complete design in the form of electronic documentation
  - Begin bench testing subsystems

Project Specifications

- 5,000 Gallon/Day Water Output
- Renewable Energy Source (Solar Panels)
    - Backup Generator
- Constrained to 8’ x 9.5’ x 10’ Container
- Water Filtration System
- Water Source 50 ft away
- 24/7 System

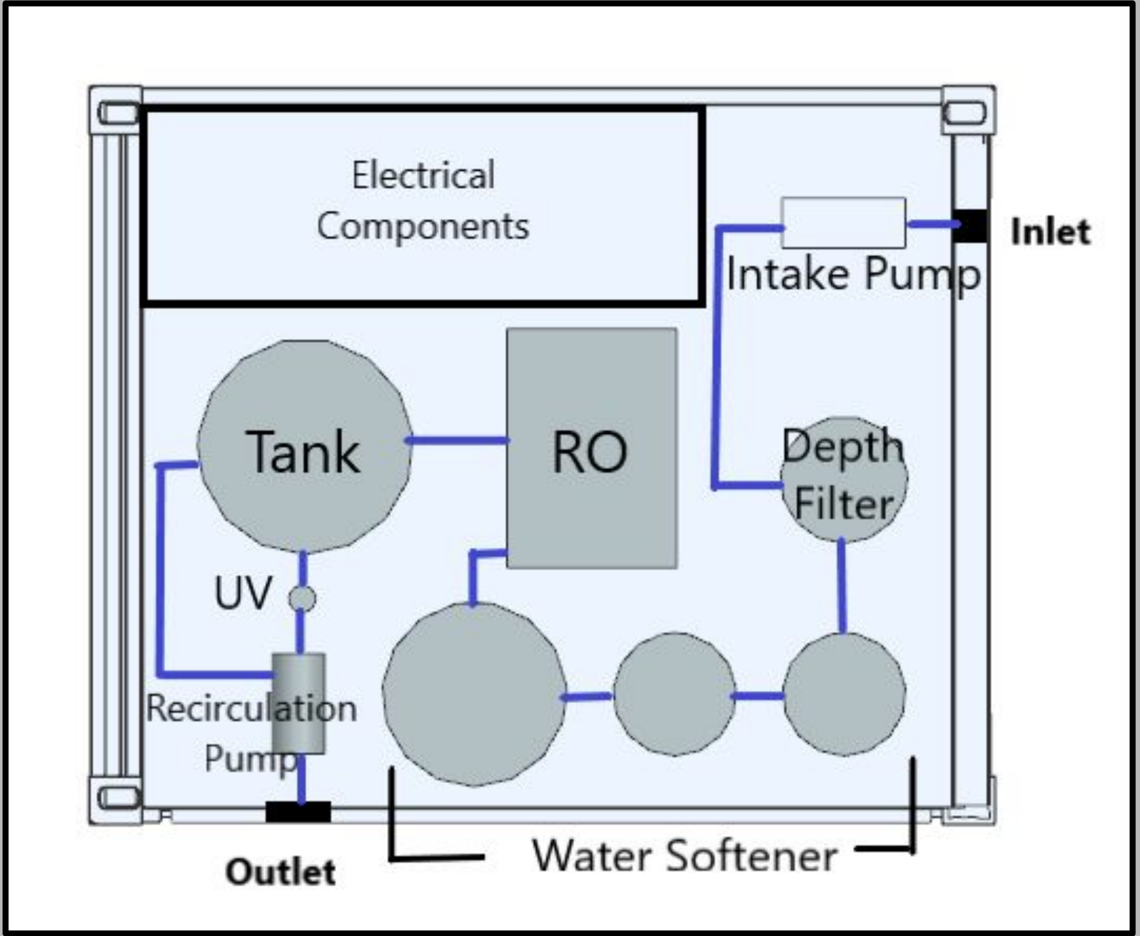
Standards

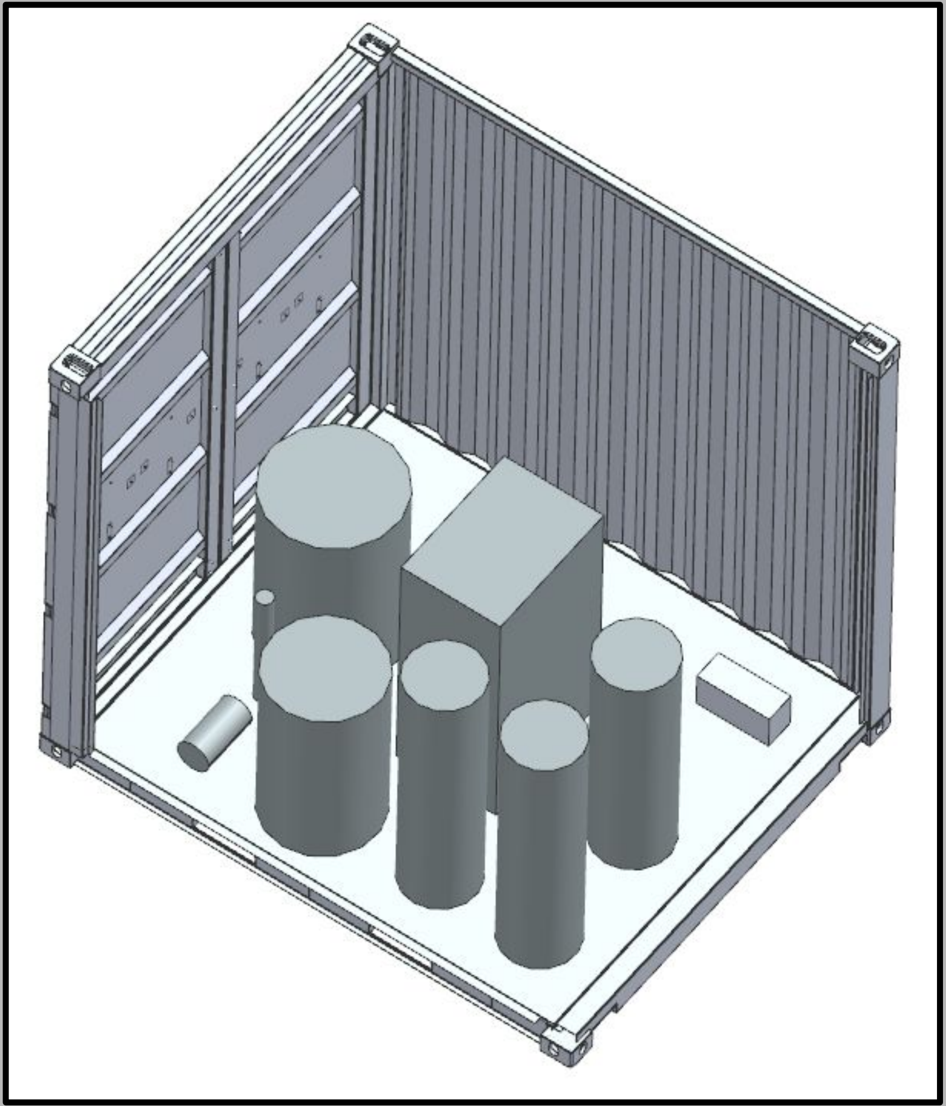
- **NSF/ANSI Standard 53** – Minimum Water Filtration Standard
- **NSF/ANSI Standard 58** - RO Treatment
- **2.1.3. MIL-STD-810** – Environmental Engineering Considerations and Laboratory Tests
- **UL 1741** – Inverters, Converters, and Controllers System Standards in Distributing Energy Resources
- **CSA C22.2** – Canadian Electrical Code Standard for Electrical Devices

Permits

- 5,000 Gallons/Day is a low volume so most countries will not have an issue
  - Only unless water scarcity is a concern
- Developing countries will have less regulations, and won't face much difficulty acquiring permits
- The most difficult part will be finding sources that aren't privately owned
- US will require the water to be tested ensuring it it safe to drink
- This will qualify as a permit for distribution
- Each state has different requirements for their water sources, but the process is fairly easy
- Even California's process is quite easy

Container Layout

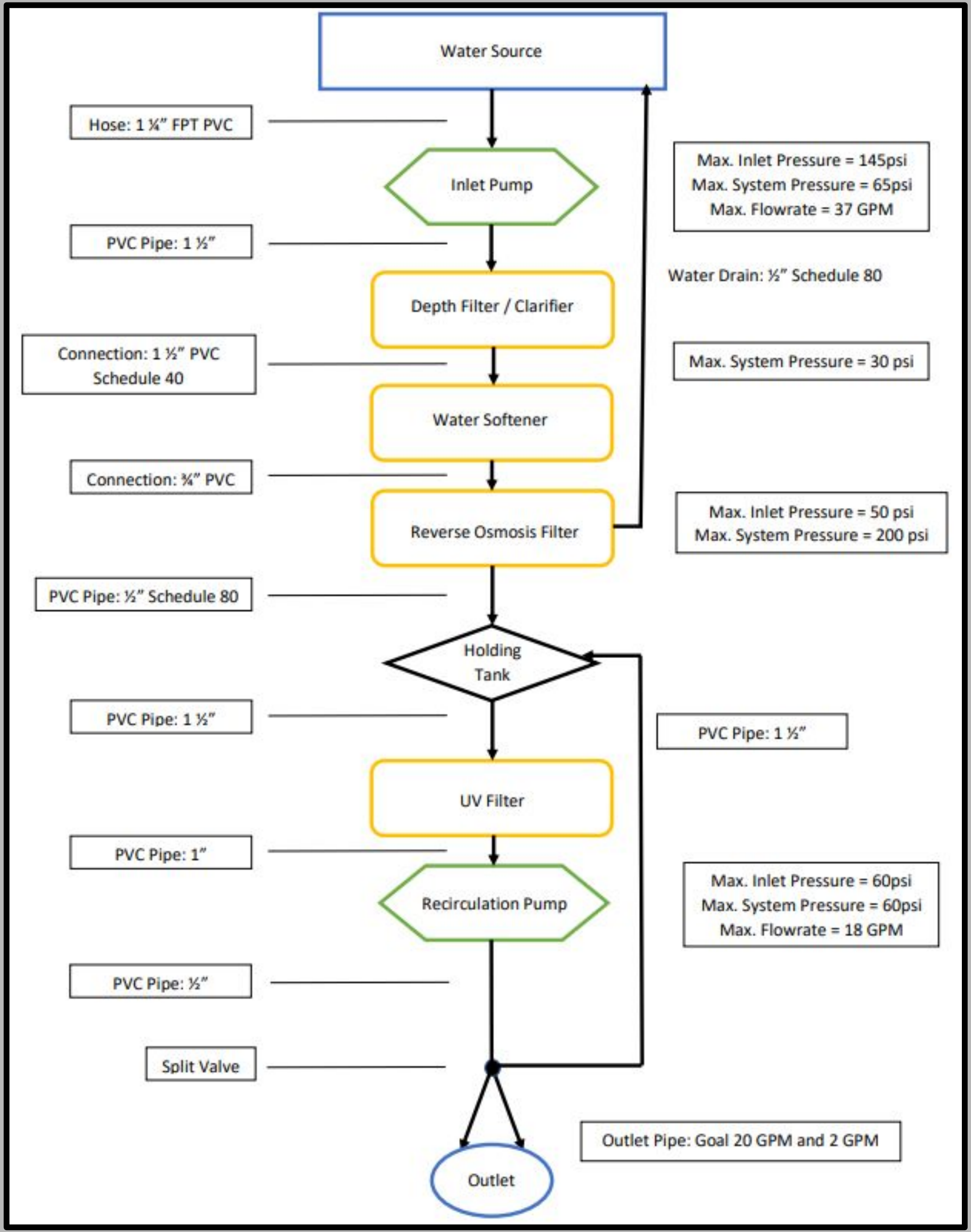




Water Subsystem

Water Flow Chart

- Water pumped into system from a natural source via inlet pump
- Two-system pre-treatment that leads to a Reverse Osmosis Water Filtration System
- Holding Tank
- Post-treatment UV Filter to be recirculated into tank
- Two outlets at different flow rates
- All piping connections are PVC



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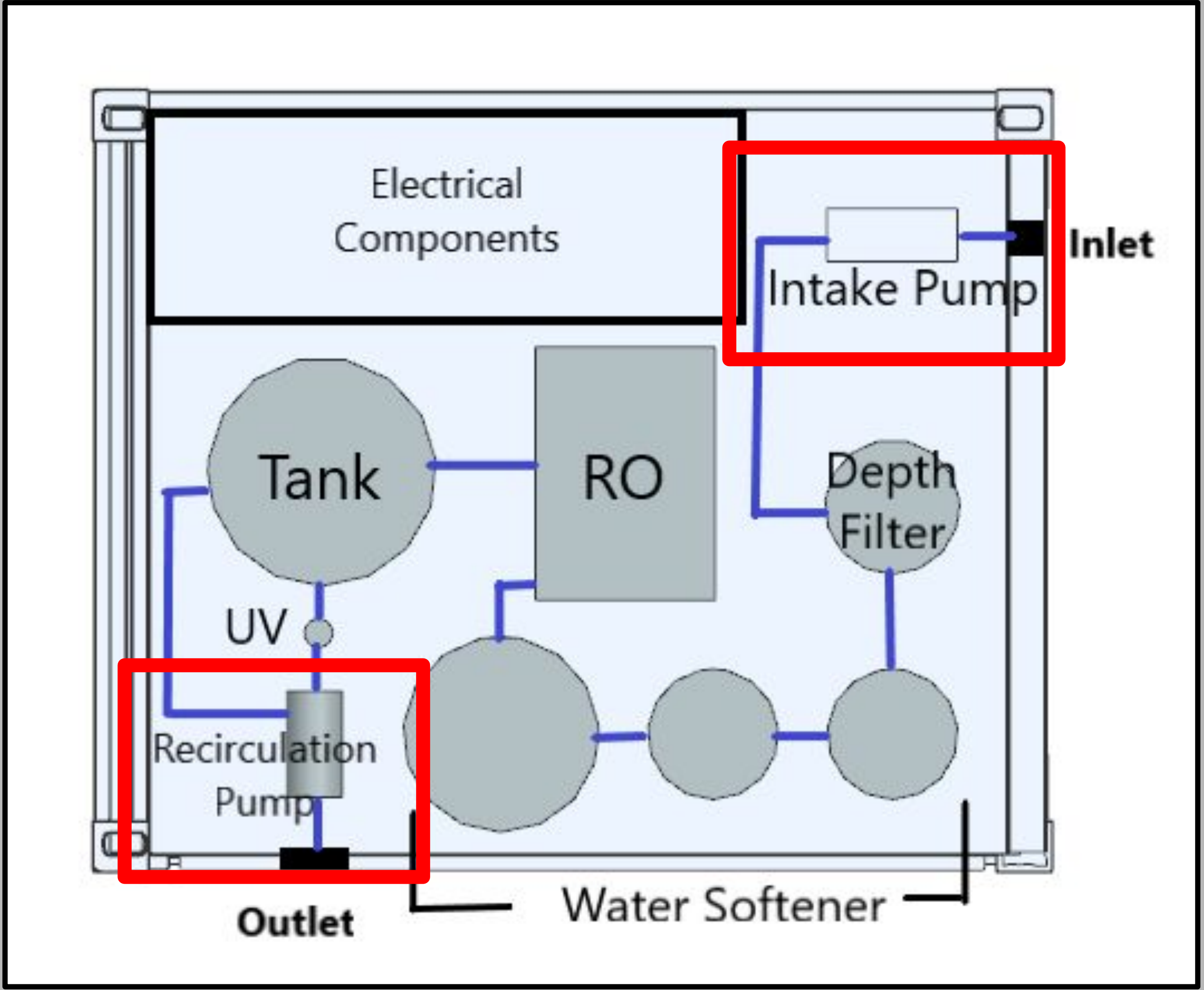
Intake Filter from Source

	Filter Size	Maintenance	Ease of Use	Required Depth	Price	Total
Weight	**2**	**2**	**1**	**2**	**1**	
Floating Pond	10	2	2	1	1	**29**
Centrifugal	4	4	4	4	5	**33**
Kleen Flo	9	8	9	7	9	**66**
Grainger Strainer	3	10	8	8	10	**60**
Mcmaster Carr Strainer	9	9	8	8	4	**64**

Pumps



Electrical Components
Intake Pump
Inlet
Tank
RO
Depth Filter
UV
Recirculation Pump
Outlet
Water Softener

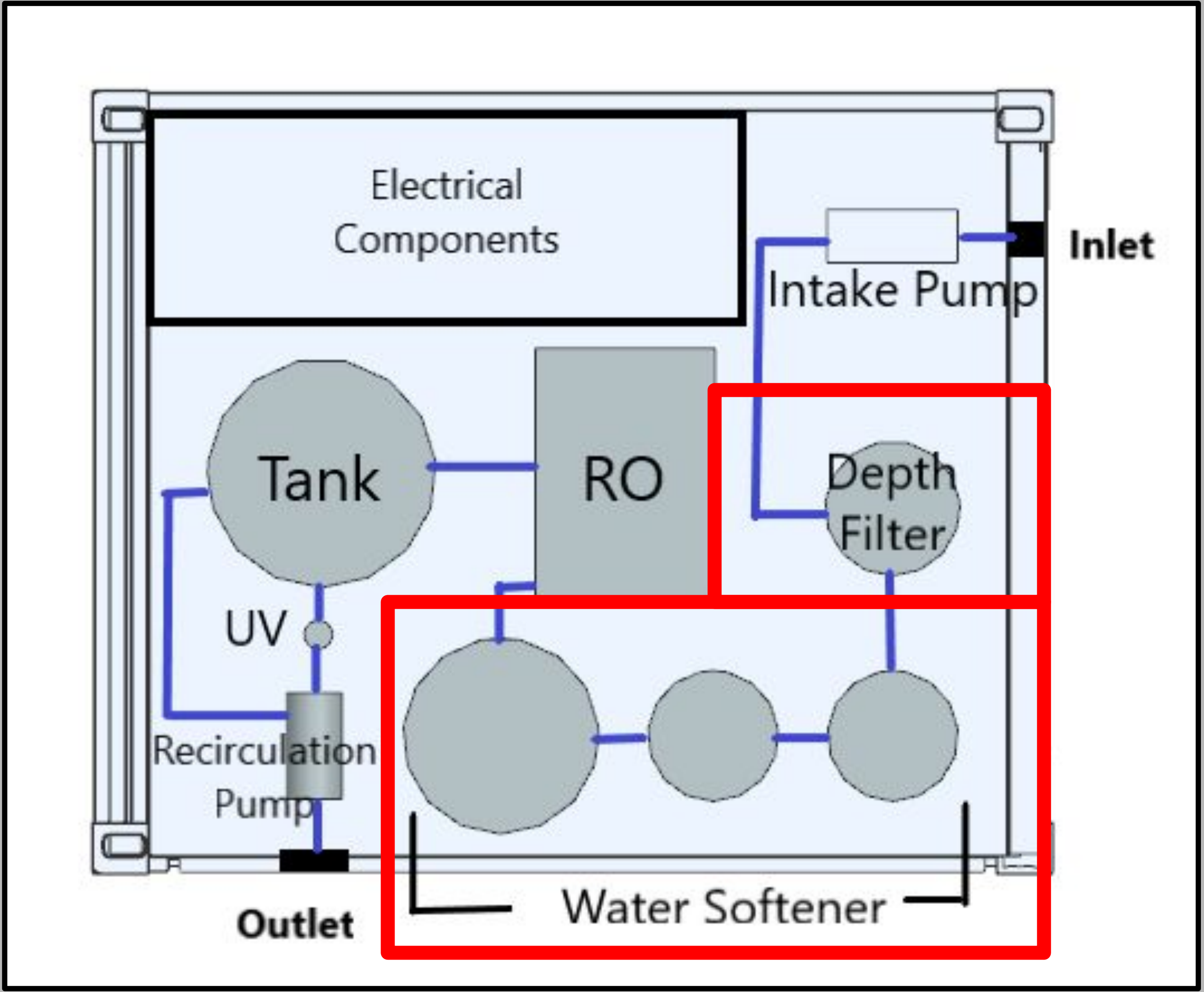
Intake and Recirculation Pump

	Durability	Maintenance	High Head Lift	Flow Rate	Power Consumption	Sound/Vibration	Cost	Total
Weight	**1.5**	**1**	**2**	**2**	**2**	**1**	**1**	**9.5**
Submersible	7	7	8	9	8	6	8	**81.5**
Centrifugal	9	6	9	8	9	5	7	**83.5**
Positive Disp	5	9	6	3	2	1	5	**44.5**
Utility	8	9	8	8	8.5	7	6	**83**
Jet	8	7	6	6	7	7	1	**65**

	Type	High Head Lift	Flow rate	Power Consumption	Price	Total
Weight	**2.5**	**2**	**2**	**2**	**1**	
Tsurumi Submersible	9	4.5	8	8	8	**71.5**
Goulds Centrifugal	10	10	8	6	2	**75**
RainFLo Diaphragm	4	3	1	10	10	**48**
Goulds Jet pump	6	4	6	7	1	**50**
Liberty Utility	9.5	8	5	8	7	**72.75**
RainFLo Centrifugal	10	10	8	7.5	6	**82**

Brand	Type	Power Consumption	Flow Rate	Total Head Lift	Cost
Finish Thompson	Centrifugal	0.18kW max	18 GPM	29 '	$245

Pre-Treatment System



Pre-Treatment Decisions Matrices

Sediment Depth Filter

Specs:
$1,958
11 GPM
120 °F
125 psi

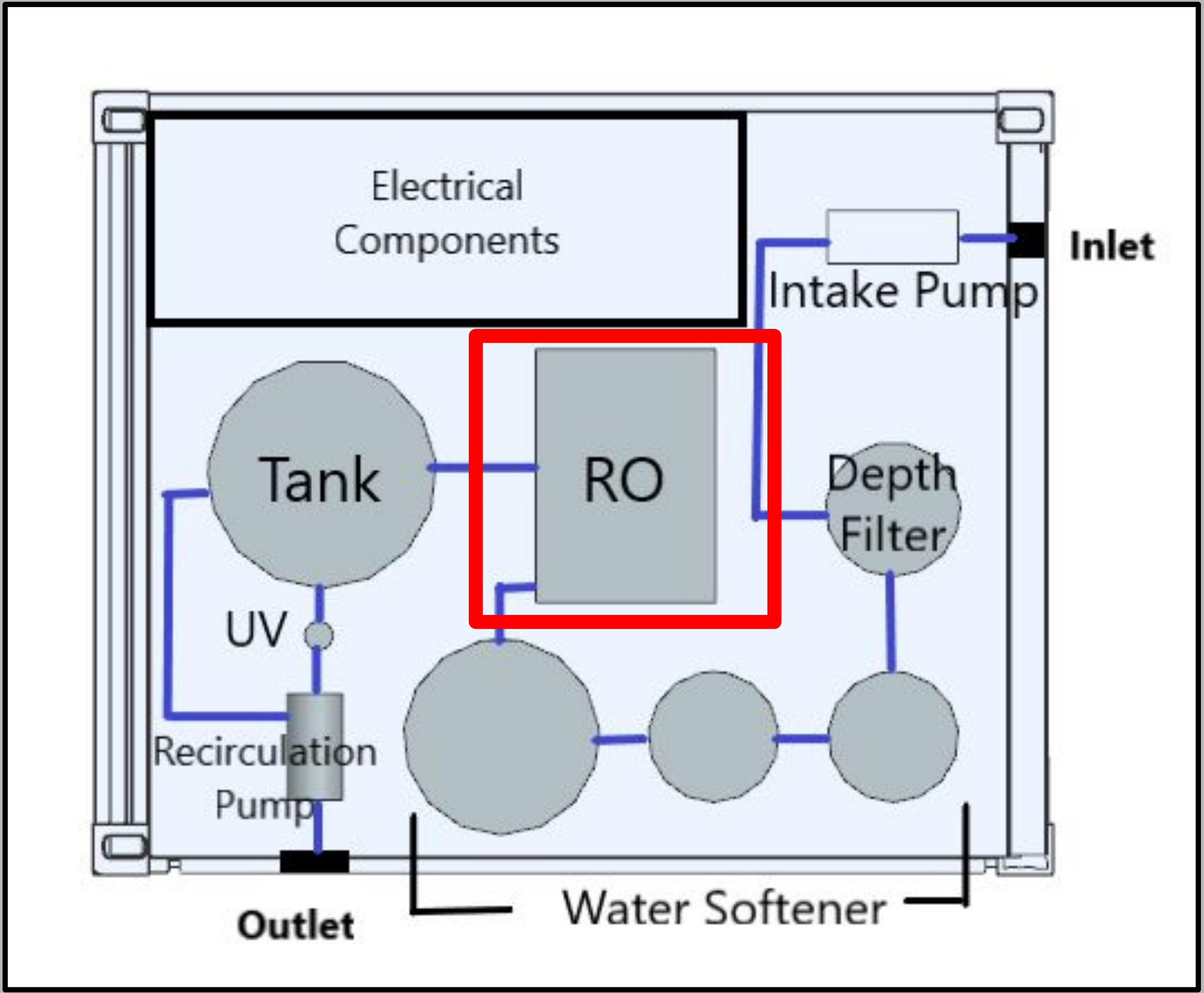
Category	Flow Rate	Media Volume	Max Temp	Max Pressure	Cost	Standardization	Total
Weight	**4**	**4**	**2**	**2**	**4**	**0.5**	
CW 5900-BT 1.5 CF	10	6.3	6	5	10	0	**127.0**
APEX WH-3010	10	8.3	8	1	10	0	**131.3**
Fleck 2510F-SED-200	6	8.3	8	10	9.5	0	**131.4**
US Water Matrixx	6	8.3	6	5	5.9	0	**102.9**
Culligan HE DF-14	8	10	10	10	7.3	10	**146.1**

Water Softener

Category	Flow Rate	Max Temp	Max Pressure	Grain Capacity	Cost	Total
Weight	**4**	**2**	**2**	**4**	**4**	
Fleck 2900	10	7.5	10	10	3.2	**127.8**
Fleck 9100	6.6	7.5	7.5	7.5	10	**126.5**
Softpro HE Excel Duplex	8.1	5	5	8.1	7.0	**113.0**
Culligan HET-090	8.3	10	7.5	9	5.9	**128.0**
Culligan HET-150	8.4	10	7.5	10	3.9	**124.1**

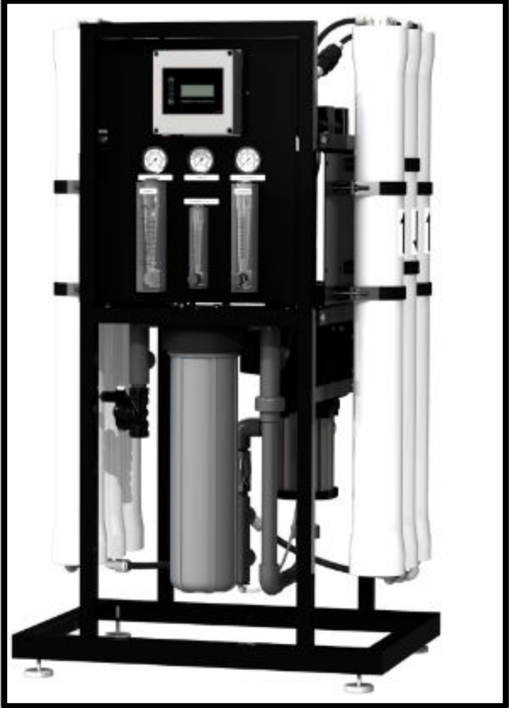
Specs:
$4,118
26.6 GPM
120 °F
125 psi
90,000 grains

Main Filtration System



Reverse Osmosis Decision Matrix

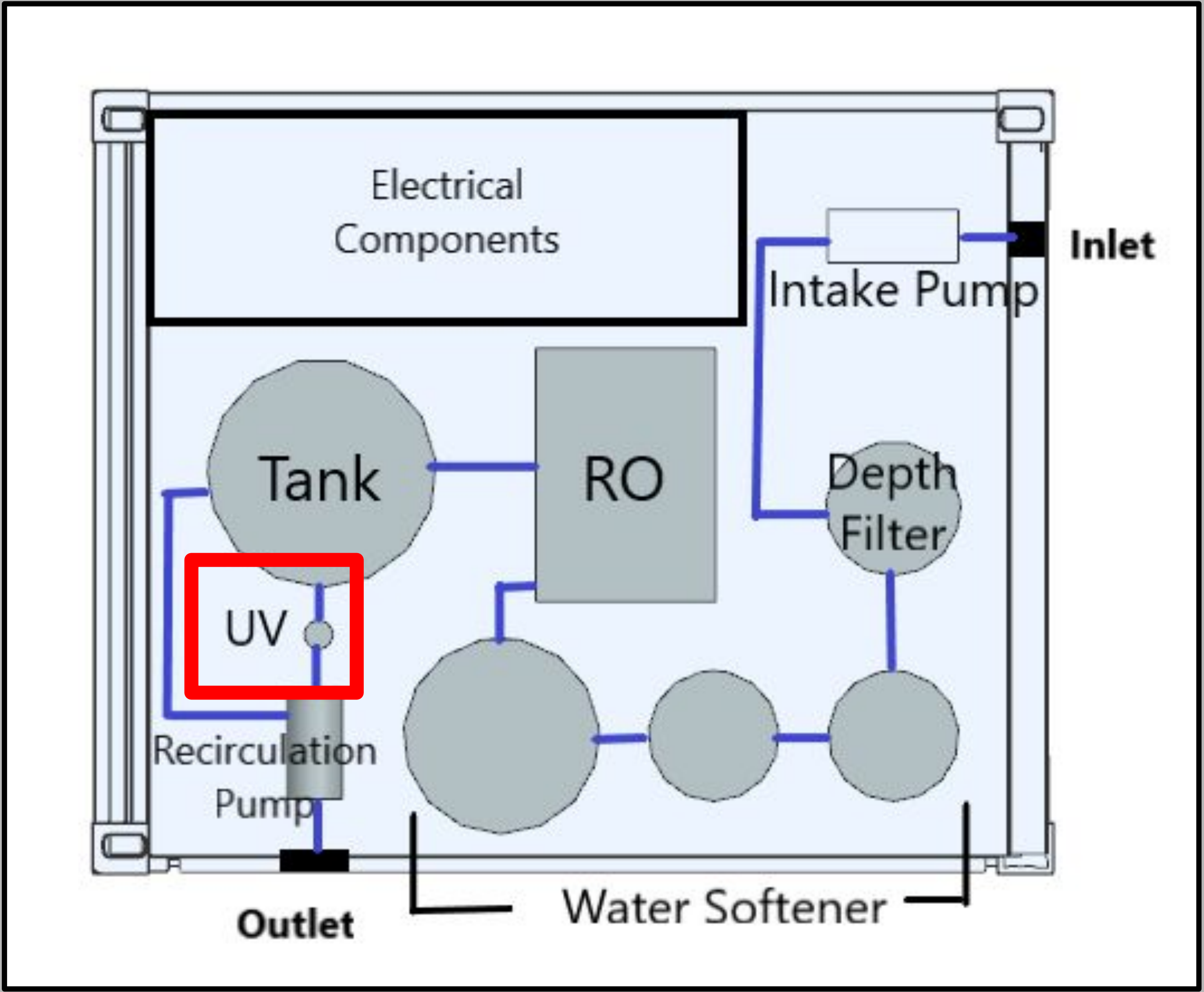
Company	Max GPD	Efficiency	Energy	Price	Length	Depth	Max TDS	Extras*	Total
Weight	**8**	**6**	**10**	**7**	**5**	**5**	**10**	**7**	
Applied Membranes	5	6.9	2	4.8	1	5.3	8	9	**31**
Culligan	5	7.5	8	4.5	10	6.7	10	9	**44.3**
RO Superstore	6.5	5.1	9	6.8	8.9	7.7	8	7	**43.2**
Crystal Quest	5	7.5	9	4.6	2.6	6.3	8	8	**38.8**
American Aqua	7	5.8	8	4.3	9.5	10	8	10	**44.8**



Specs:
$13,596
Input: 9.25 GPM
Output: 6.90 GPM
Energy: 1.49 kW
Max TDS: 2,500 ppm

*Extras is a subjective category that takes into account sensors, flowmeters, displays, and various other things that will enhance the RO system

Post-Treatment System

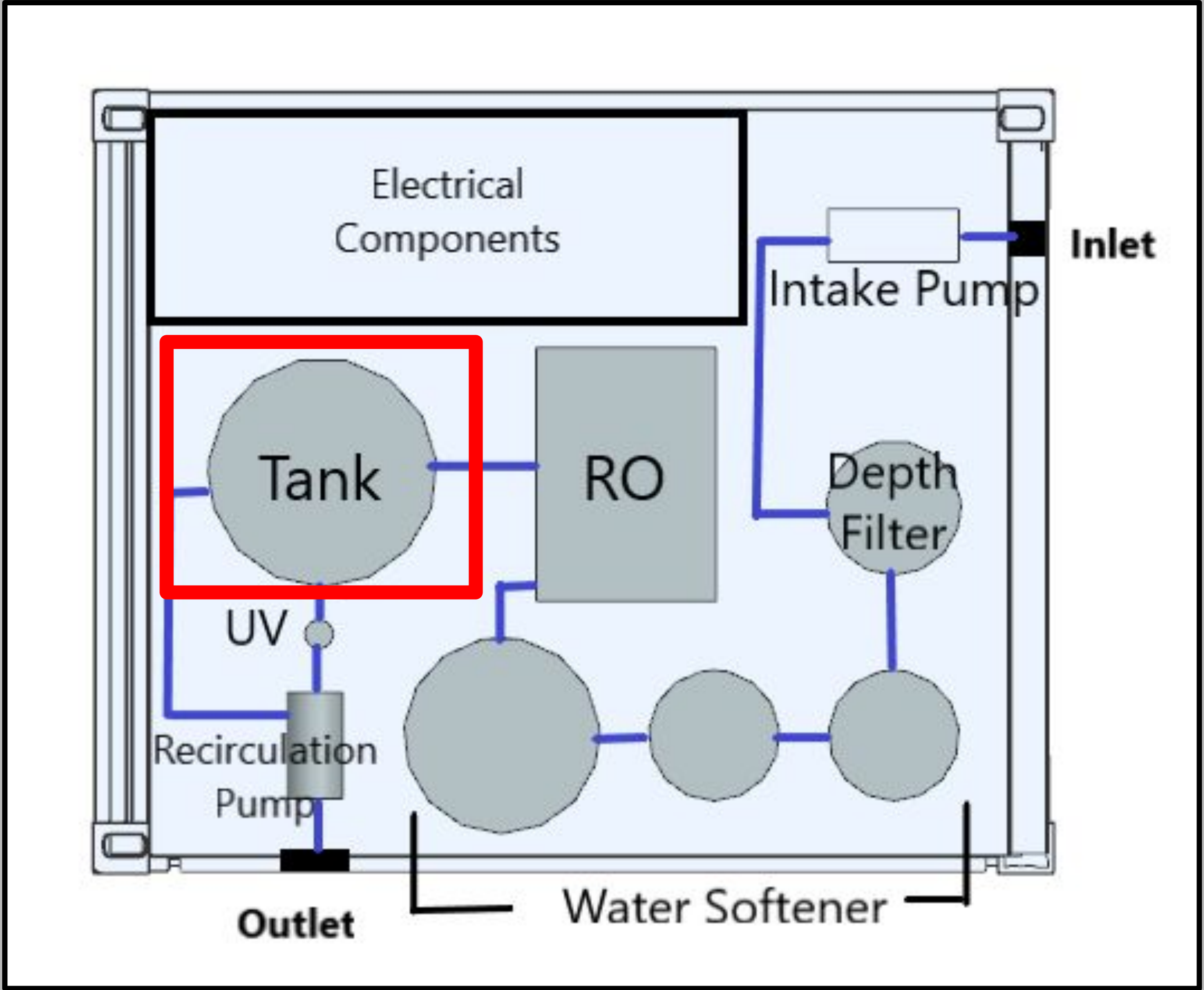


UV Post-Treatment Decision Matrix

Category	Flow	Price	Power	Minimum Psi	Max Psi	Total
Weight	**2**	**2**	**1**	**0.5**	**0.5**	
Sanitron S50C	5	5.1	9.7	5	5	**35.0**
Viqua VP600	10	6.3	8.6	10	10	**51.1**
Mighty PureMP49C	5	6.2	9.7	5	5	**37.0**
Polaris UV-24B	7	6.4	8.0	10	10	**44.9**
Viqua E4	6	5.6	7.6	10	10	**40.9**
Viqua UVMax G	4	0.9	5.0	1	5	**17.8**

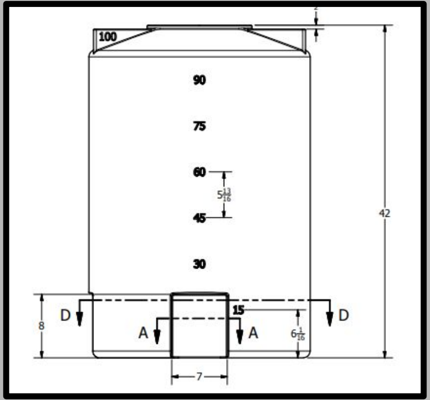
Specs:
$900
30 GPM
70 W
0-125 psi

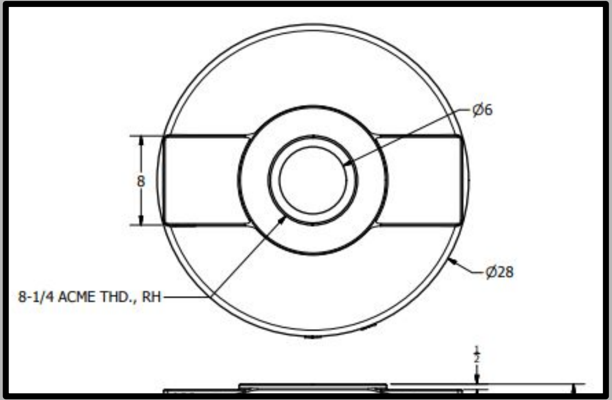
Holding Tank

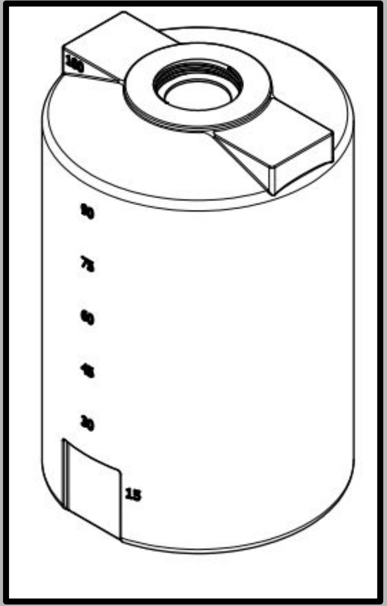


Water Tank Decision Matrix and Tech Drawing

	Corrosion Resistant	Safe for Drinking Water	Temp Resistant	Lifespan	Weight	Leak Resistant	Cost	Size	UV Light Resistant	Input Pressure	Final Weight
Weight	**2**	**2**	**1**	**1**	**1**	**2**	**1**	**1**	**1**	**2**	
Polyethylene	9	8	7	8	9	9	8	8	8	4	**108**
Stainless Steel	8	7	7	8	4	9	4	6	8	8	**101**
Fiberglass	9	5	4	4	8	3	3	7	2	5	**72**
Carbon Steel	6	7	8	8	3	8	3	6	8	8	**94**





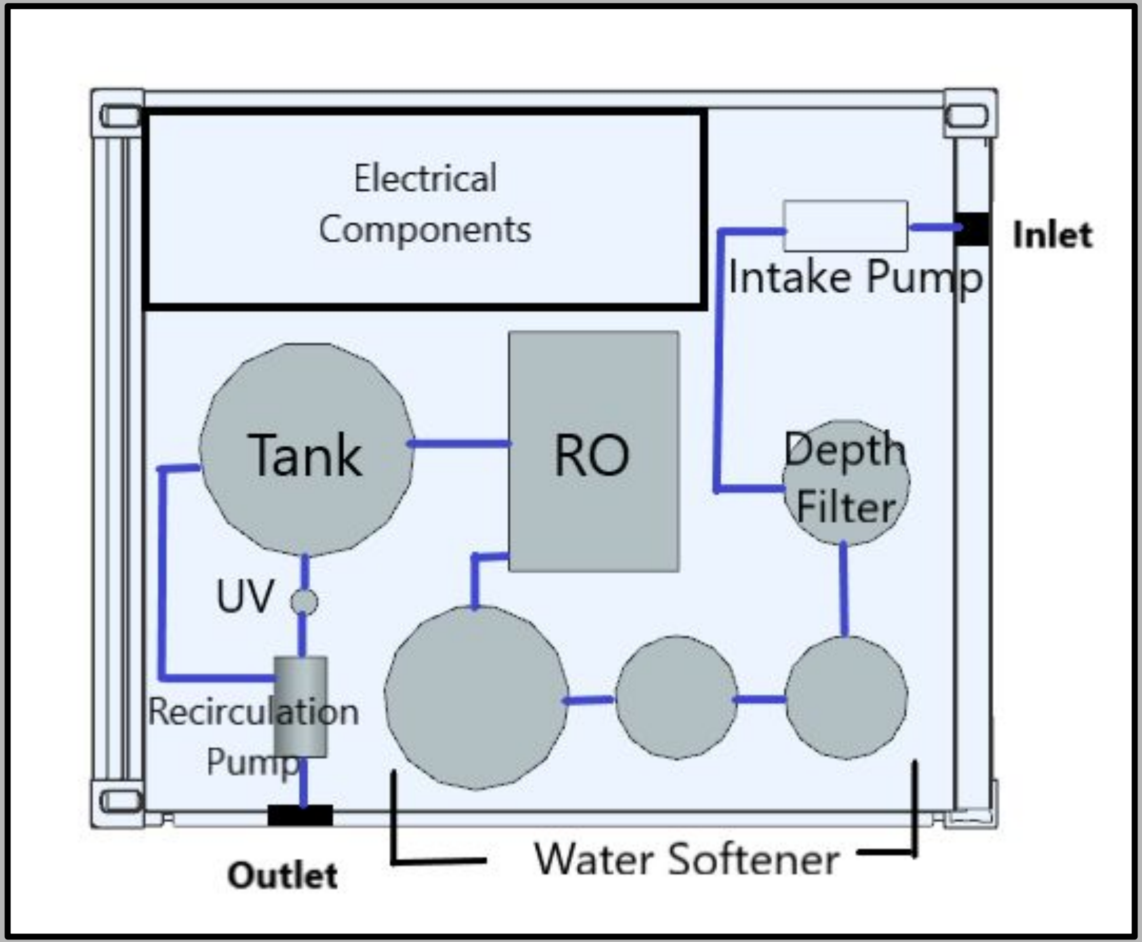


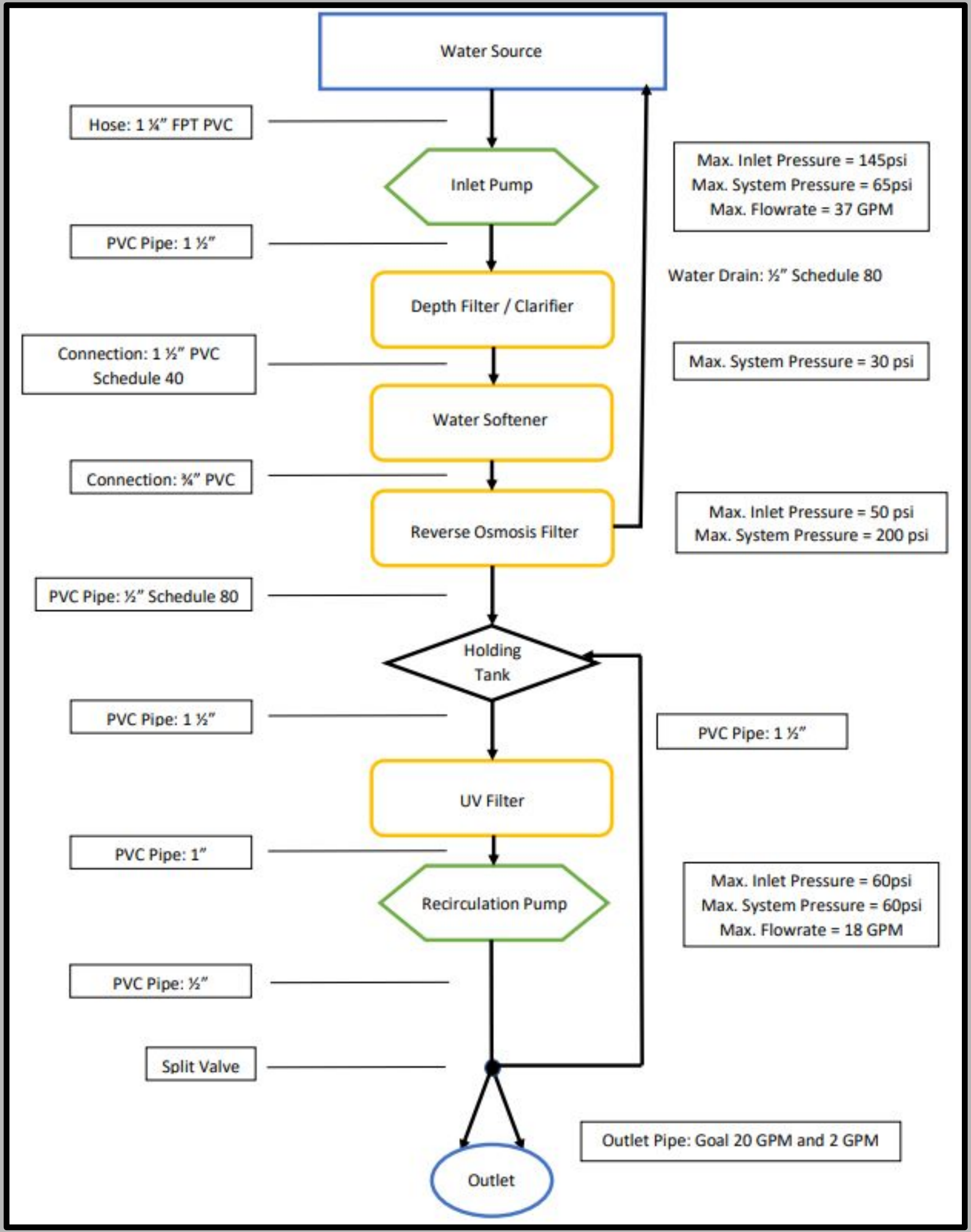
Pipes Decision Matrices

	Corrosion Resistant	Safe for Drinking Water	Temp Resistant	Lifespan	Weight	Leak Resistant	Cost	UV Light Resistant	Total
Weight	**2**	**2**	**1**	**1**	**1**	**2**	**1.75**	**1**	
Copper Pipes	9	9	9	8	5	9	6	7	**98.12**
Galvanized Steel	6	7	8	7	1	6	4	9	**74.03**
PVC	9	9	7	9	8	9	8	5	**102.42**
CPVC	9	8	7	9	8	9	6	9	**100.54**
PEX	9	7	8	9	9	6	10	3	**94.49**
Stainless Steel	8	9	9	9	1	9	3	8	**87.74**

Types: Schedule 80 & Schedule 40
Withstand High Pressure from RO
Common for Potable Water

Water Flow Overview

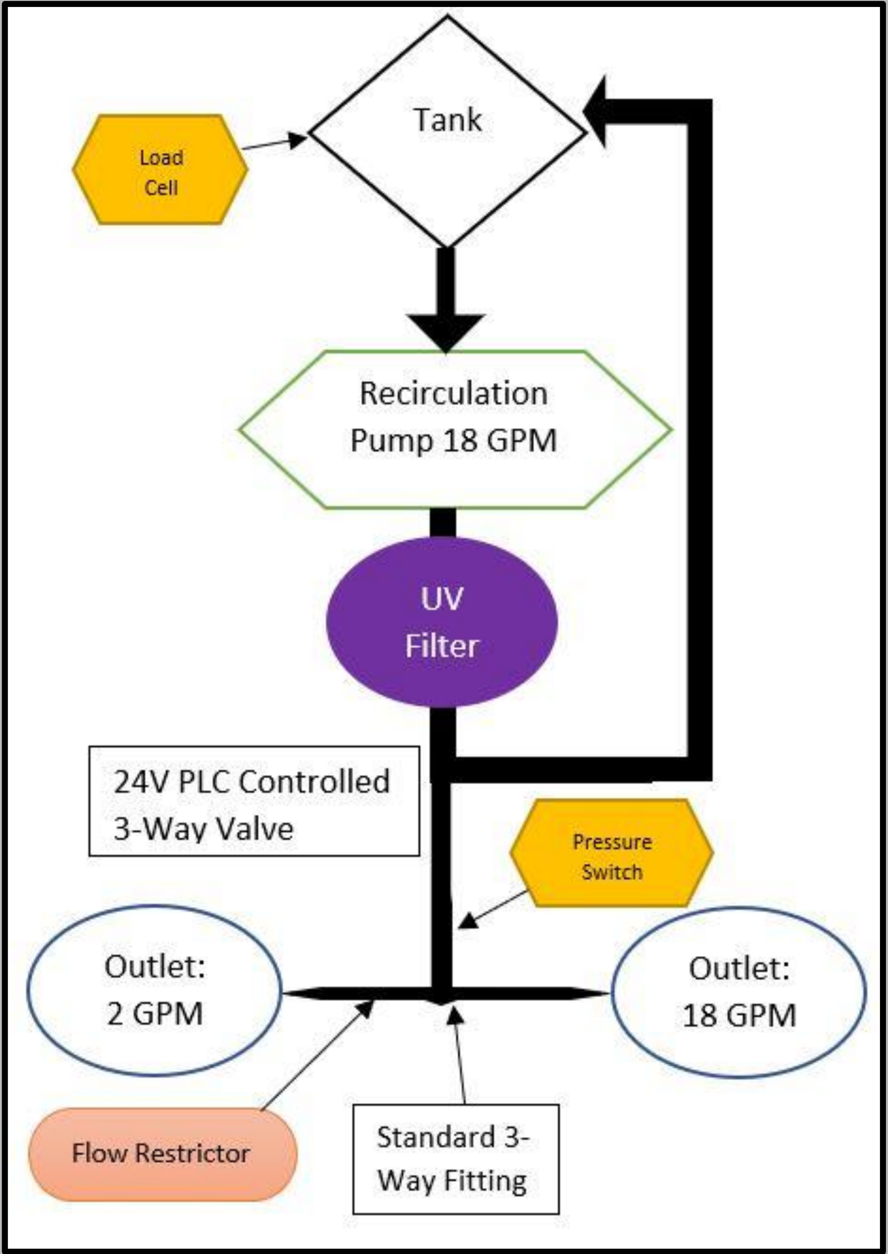




Water Outlet Testing

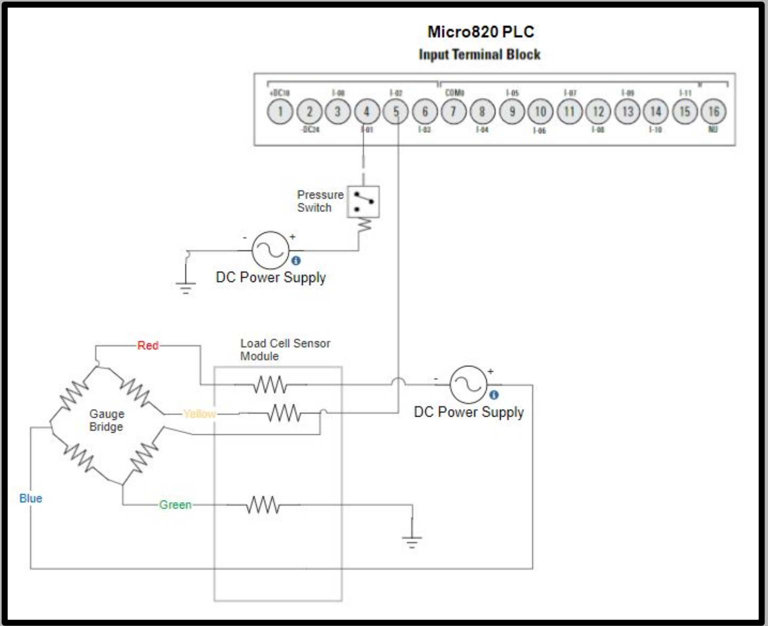
- Components to validate: Pump, UV filter, PLC, Belimo 3-way Valve, Pressure Transducer, Load Cell, and Flow Restrictor.
- Parameters to record: Volume, Water Condition, and Time.

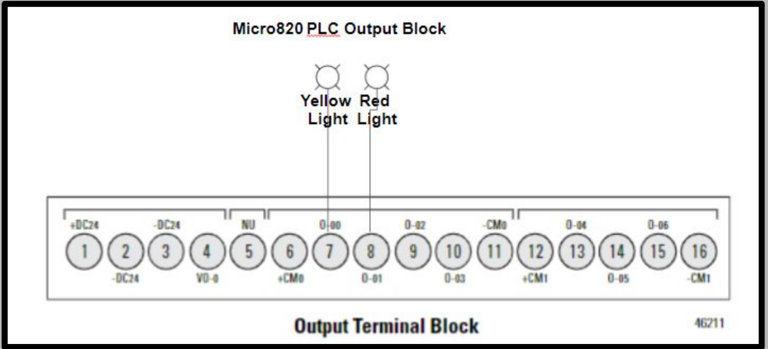
Water Testing Component	Quantity	Cost
UV system Viqua VP600 120V	1	$900.00
Finish Thompson DB4P Pump	1	$310.44
Belimo 3-Way Control Valve	1	$163.15
Allen Bradley Micro820 PLC	1	$200.75
Pressure Transducer	1	$52.40
Flow Restrictor 2 GPM 1/2"	1	$38.95
Water Test Strips	5	$27.95
1/2" MPT PVC Fitting	10	$0.99
1" MPT PVC Fitting	2	$3.59
1/2" FPT PVC Fitting	1	$0.99
1" FPT PVC Fitting	3	$1.59
1/2" PVC Tee fitting	1	$2.79
1/2" 10' PVC Pipe	1	$11.99
1" 10' PVC Pipe	1	$11.99
PVC Fitting Primer and Cement	1	$9.99
64 Gallon Trash Can	2	$80.00
Total		**$2,025.04**

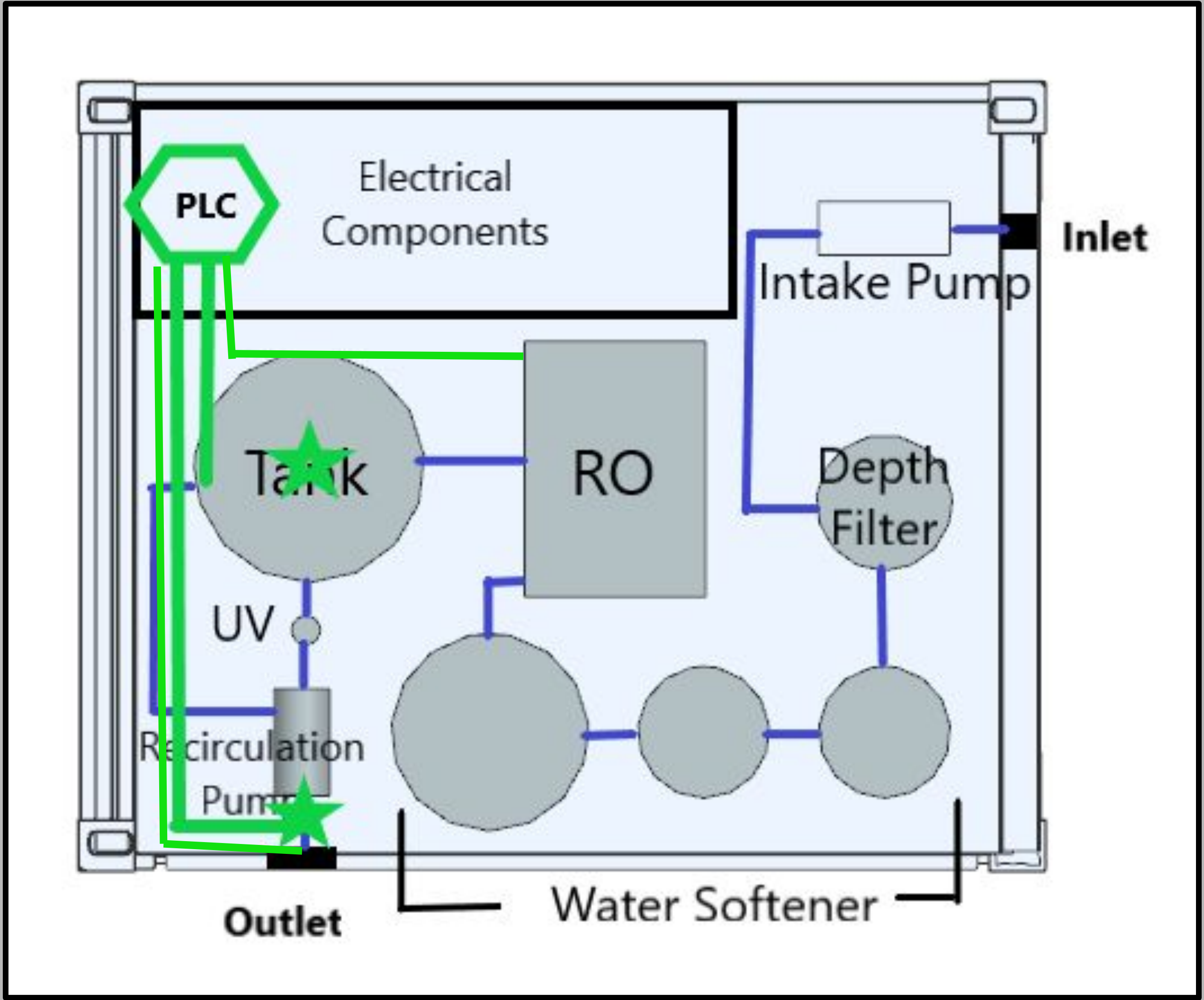


Control Subsystem

Controls Overview







*Green Star indicates location on sensor

Controls for R.O. System

R.O. is turned on when:

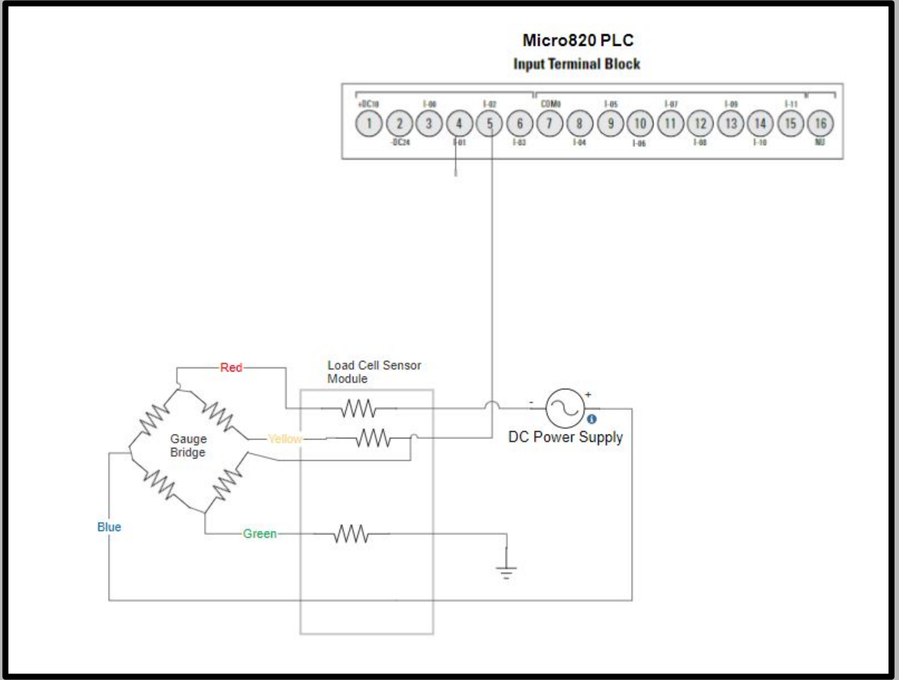
- Intake pump is in the water
- Water reservoir is below 80%
    - Remain on until 100% capacity is reached
    - Maintenance panel light turns on when tank is above 80%
- Battery level is above 10% of effective capacity

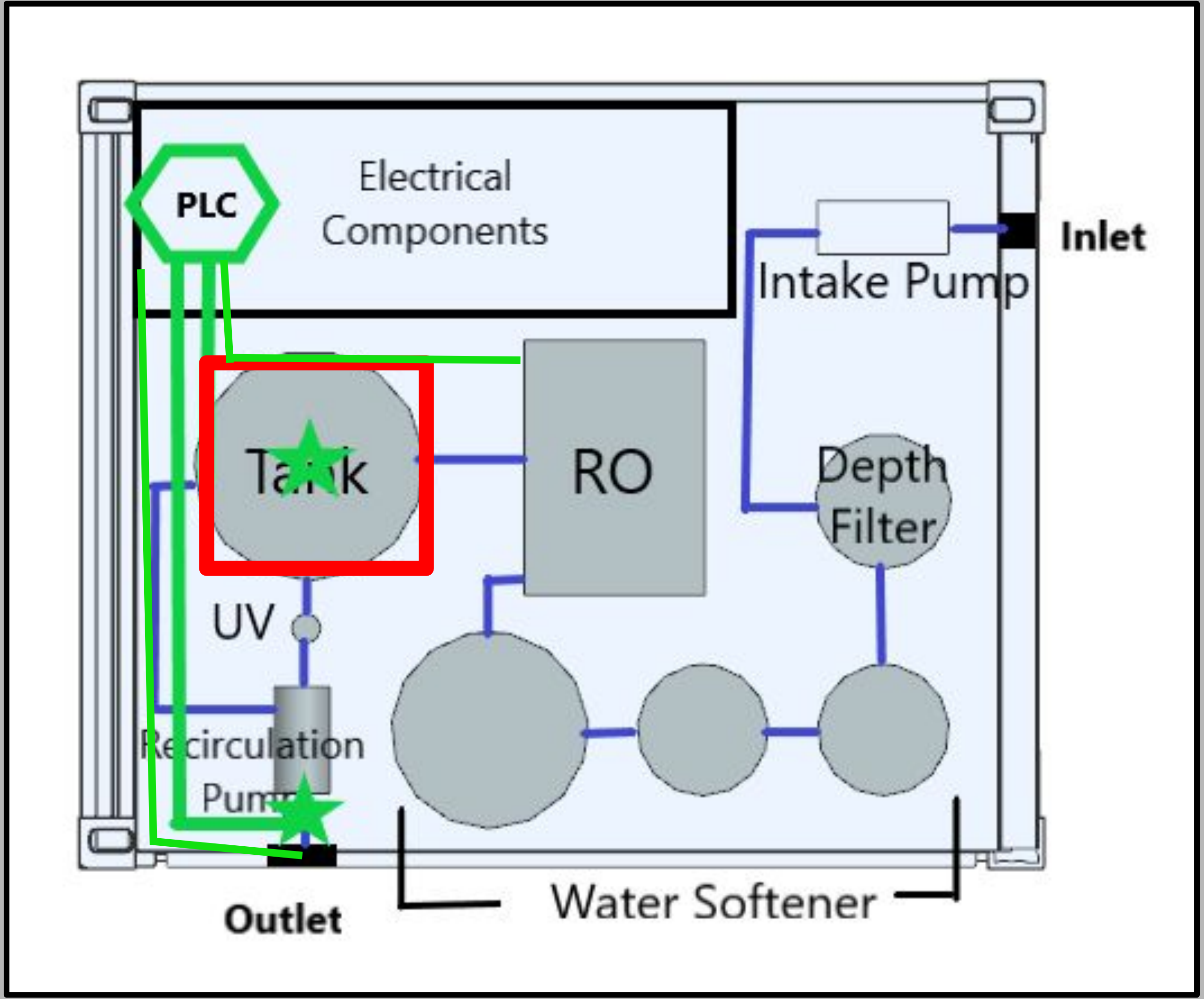
Controls for Recirculation

In Recirculation when:

- No user demand
- R.O. System is off
- Running only 20% of the time
    - 2 minutes out of 10 minutes
- Battery level is above 10% of effective capacity

Water Tank Sensor



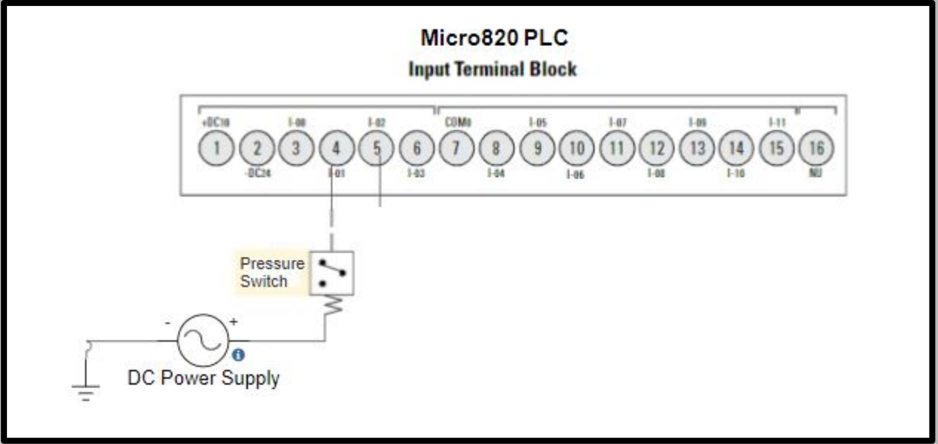


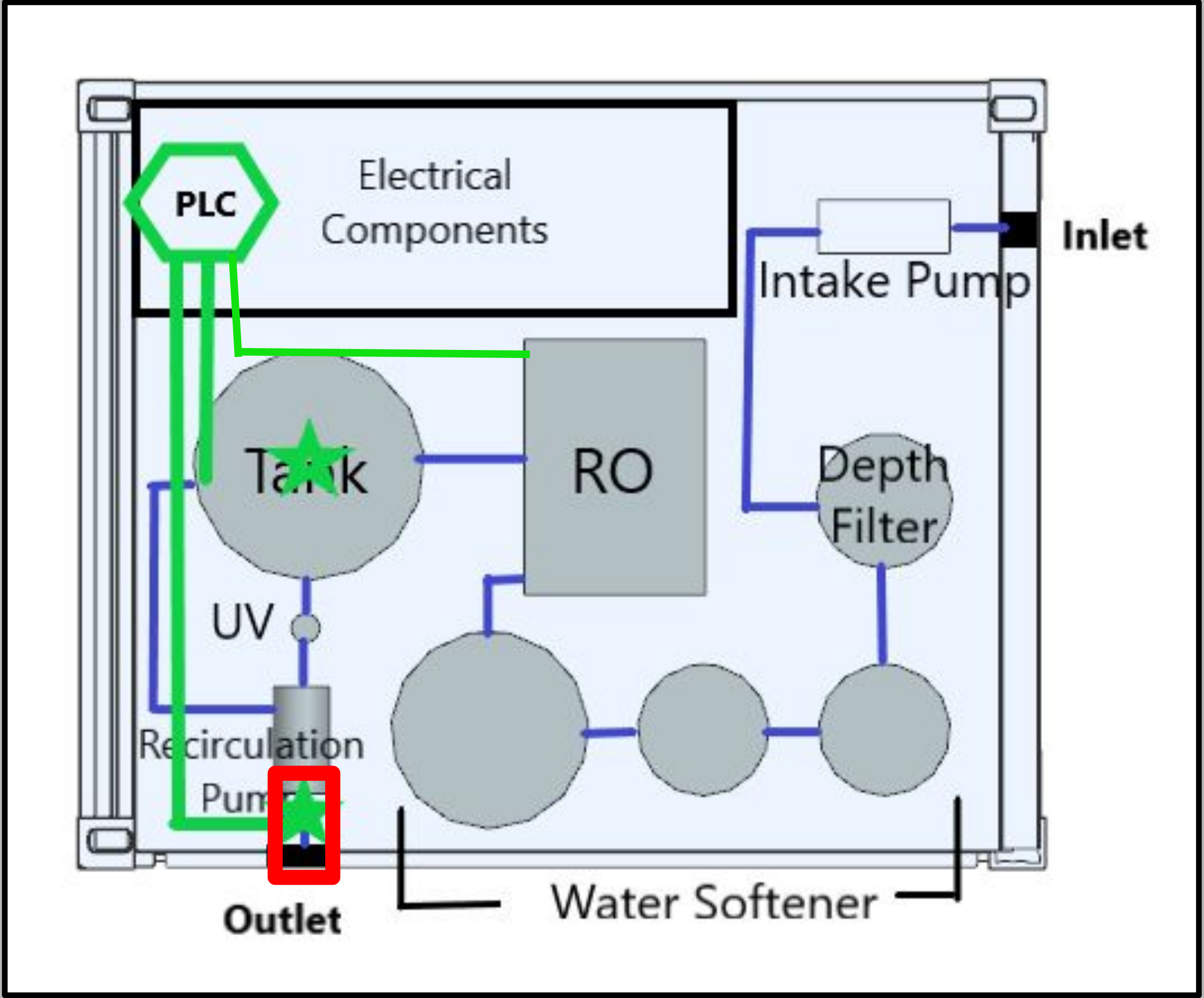
Water Tank Sensor Decision Matrices

	Process Pressure	Process Temperature	Corrosive Resistant	Accuracy	Cost	Lifespan	Size	Final Weight
Weight	**2**	**1**	**1**	**2**	**1**	**1**	**1**	
Capacitance Level Sensor (C)	7	7	3	5	8	4	7	**261**
Guided Wave Radar (C)	9	8	8	8	2	8	6	**273**
Vibrating Fork (P)	8	8	9	8	4	9	6	**289**
Float Switch (P)	8	8	7	6	6	7	5	**274**
Optical Level Switches (P/C)	8	8	6	8	9	5	9	**325**
Load Cell	8	8	9	8	7	8	9	**330**

	Operating Temp	Load Capacity	Corrosive Resistant	Accuracy	Cost	Lifespan	Size	Final Weight
Weight	2	1	1	2	1	1	1	
TE Connectivity FC2311-0000-1000-L	8	10	7	7	8	8	8	454
Honeywell Low Profile Load Cell Model 3132 Series	9	10	8	9	2	9	8	443
SMD2094-1000 S400 Button Load Cell	6	10	7	8	4	8	8	413

Pressure Sensor

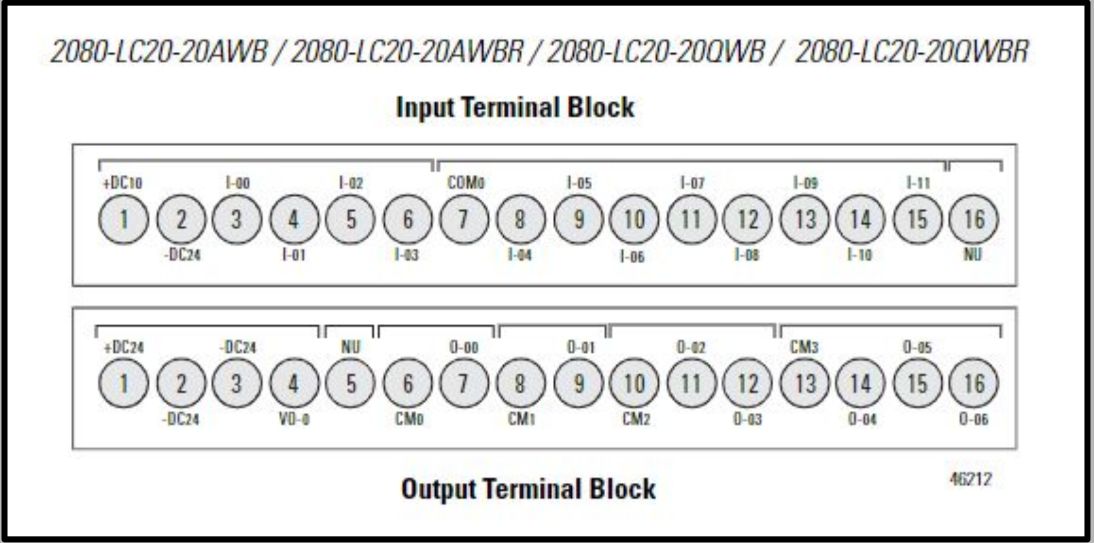


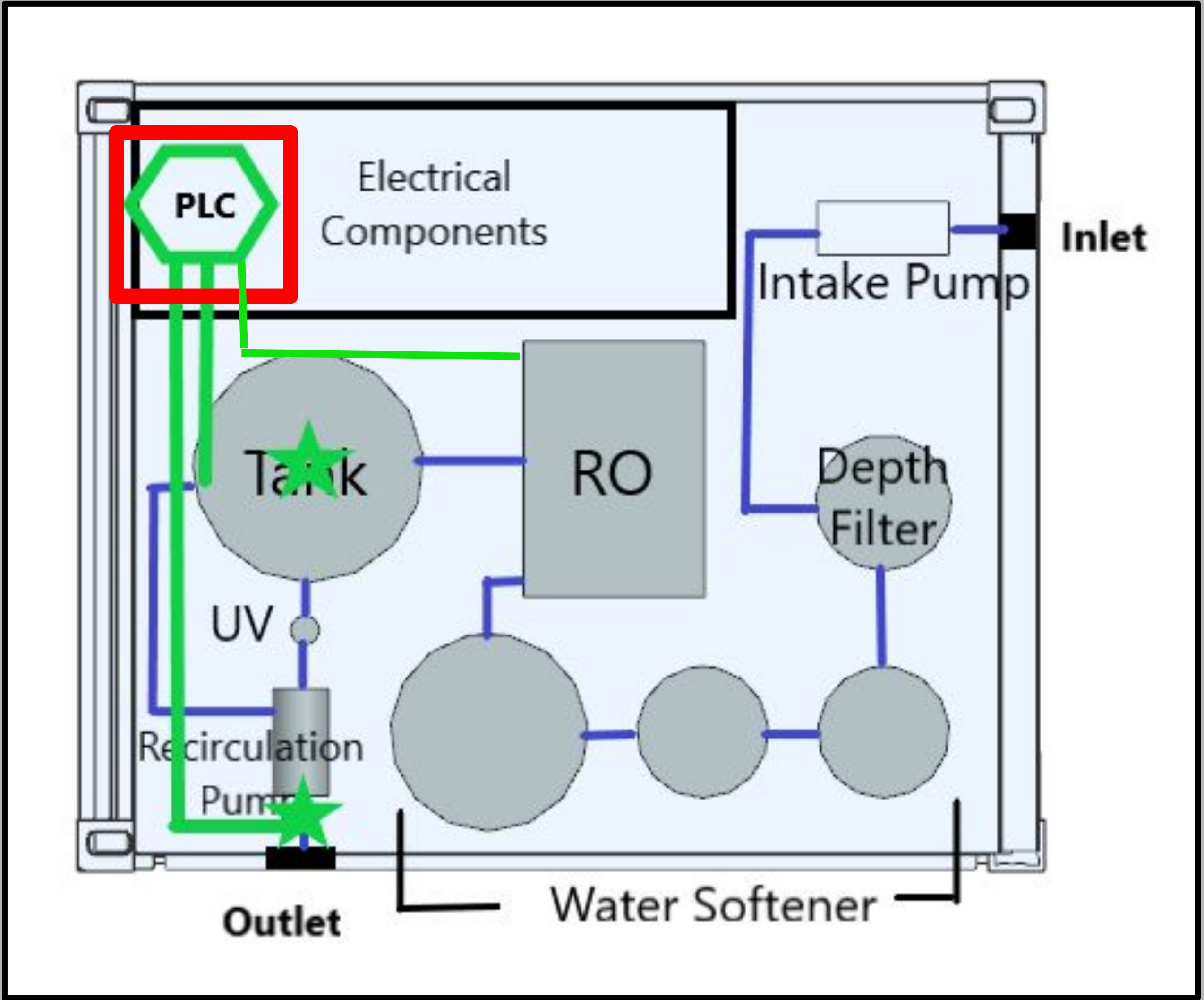


Pressure Sensor Decision Matrix

	Pipe Size	Accuracy	Pressure Range	Cost	Lifespan	Process Temp	Final Weight
Weight	**2**	**2**	**1**	**2**	**1**	**1**	
TE Connectivity M32JM-000105-100PG	9	8	9	8	7	7	**388**
ProSense Mechanical Pressure Switch MPS25-1C-D100D	9	6	7	7	7	8	**353**
OEM Style, Compact Pressure Transmitters with Mini DIN	9	7	8	6	7	8	**362**
Honeywell MIP Series MIPAN1XX100PSAAX.	9	9	9	9	7	8	**411**

PLC


2080-LC20-20AWB / 2080-LC20-20AWBR / 2080-LC20-20QWB / 2080-LC20-20QWBR
Input Terminal Block
Output Terminal Block
46212


PLC
Electrical Components
Inlet
Intake Pump
Tank
RO
Depth Filter
UV
Recirculation Pump
Outlet
Water Softener

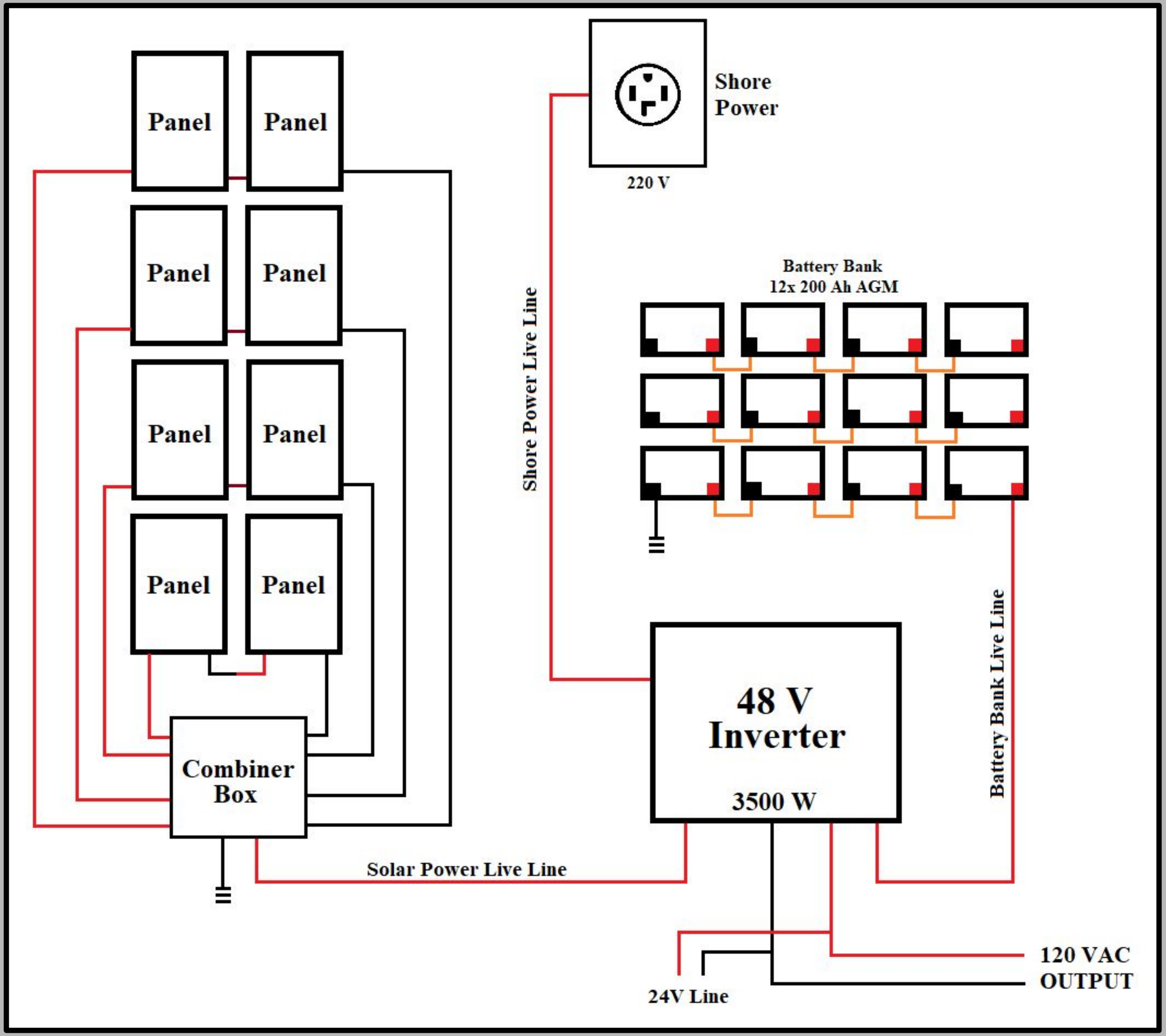
PLC Decision Matrix

	Size	I/O Capability	Price	Expansion Potential	Supportability	Power Consumption	Final Weight
Weight	**1**	**2**	**1**	**1.5**	**2**	**2.5**	
Micro 820	10	7	10	7	8	10	**85.5**
MicroLogix 1100*	9	8	9	10	10	8	**89**
MicroLogix 1400	7	9	6	10	10	4	**76**
Simatic S7-1500	8	10	5	9	6	4	**68.5**

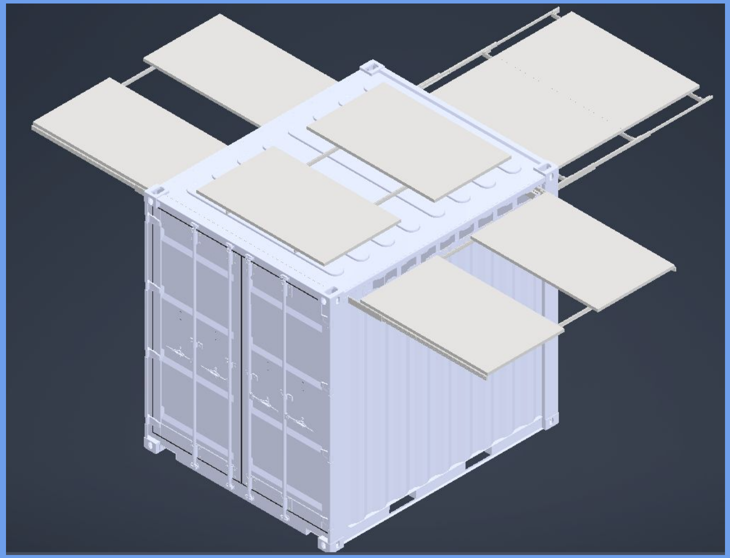
*The PLC was changed from the MicroLogix 1100 to the Micro 820 as the MicroLogix 1100 has been End of Lifed

Electrical Subsystem

Electrical Overview



Solar Panel Mounting

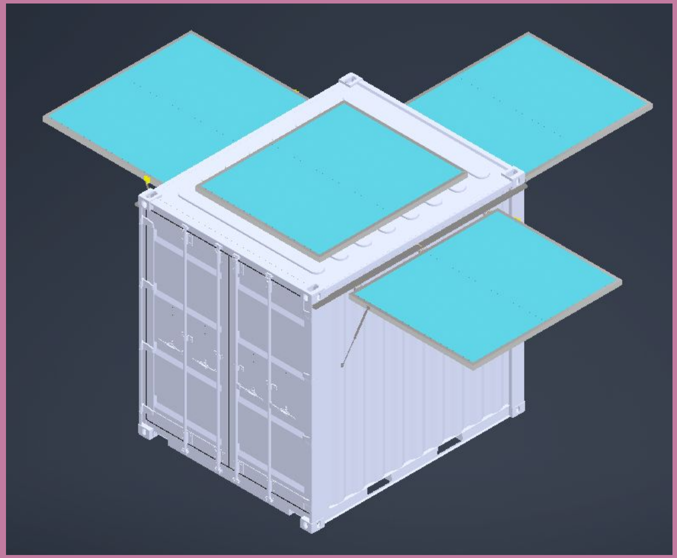


Design 1

Sliding Rails

Design 2

Hinge Mount, Heavy



Design 3

Hinge Mount, Light

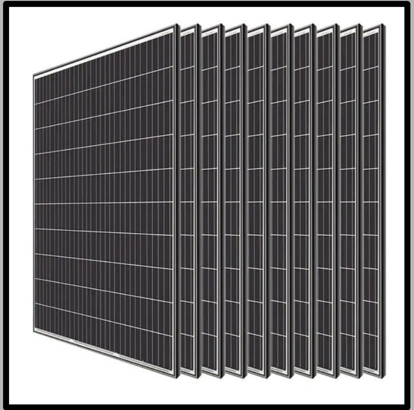
Solar Mounting DFMEA

Item/ Function	Potential Failure Mode	Effects of Failure	Severity	Causes/ Mechanisms of Failure	Prevention Controls	Occurrence	Detection Controls	Detection	RPN
Solar Rail Deployment									
Solar Panels	Panel Fracture	Panels not operable	8	Environmental Damage	Require deployment away from natural hazards	4	Allow for easy contact with technicians in case of system failure	3	96
Sealing Door	Dry and stiff rubber	Dust and moisture inclusions allowed	5	Hazardous Environment	Study rubber preservation	2	Regular maintenance schedule	5	50
Sliding Rails	Grit accumulation	Panel Deployment more challenging	4	Grit accumulation	Require rails to be cleaned before putting panels away	7	Regular maintenance schedule	5	140
Mounting Beam	Shear Failure	Panel Detachment	9	Improper weight distribution	Material load analysis	1	Allow for easy contact with technicians in case of system failure	5	45
Structural Support	Shear Failure	Panels collapse into container	10	Improper weight distribution	Material load analysis	1	Allow for easy contact with technicians in case of system failure	5	50
Hinged Solar Deployment									
Solar Panels	Panel Fracture	Panels not operable	8	Collision during shipping	Require isolated shipping	5	Visual inspection of container upon delivery	2	80
			8	Environmental Damage	Require deployment away from natural hazards	4	Allow for easy contact with technicians in case of system failure	3	96
Door Seal	Dry and stiff rubber	Dust and moisture inclusions allowed	5	Hazardous Environment	Study rubber preservation	2	Regular maintenance schedule	5	50
Gas Shocks	Stiff piston	Panel Deployment more challenging	4	Collection of Grit	Ensure piston rod cleaning before folding away	7	Regular maintenance schedule	3	84
Door Hinges	Stiff Hinges	Panel Deployment more challenging	4	Rust or grit in hinges	Hinge Lubrication	3	Regular maintenance schedule	5	60

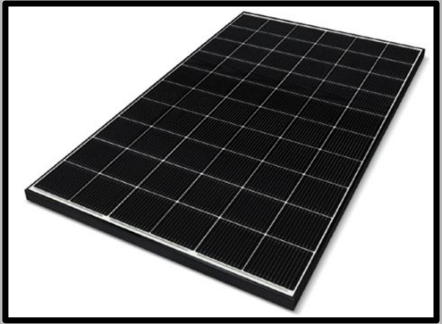
Solar Panel Decision Matrix

	Wattage (W)	Size (in²)	Weight (lbs)	Kit or Single Panels	Cost	Software Provided	12 Hour runtime capable	Total
Weight	2	1.5	1	1	2	1	2	
Renogy 320 W Package	9	3	3	9	1	8	9	**62.5**
Inverter Store 480 W Panels	1	7	6	9	4	1	1	**38.5**
ECO-WORTHY 300 W Panel Kits	8	5	6	9	2	1	9	**61.5**
Solar Kits 100 W Package	2	6	9	9	5	1	5	**52**
Solar Kits 300 W Panels	6	6	8	9	4	1	7	**61**

Based on availability, this decision was later changed to the LG NeON 2 panels for our testing setup at MTU, full build will use the Renogy panels



Renogy 320W



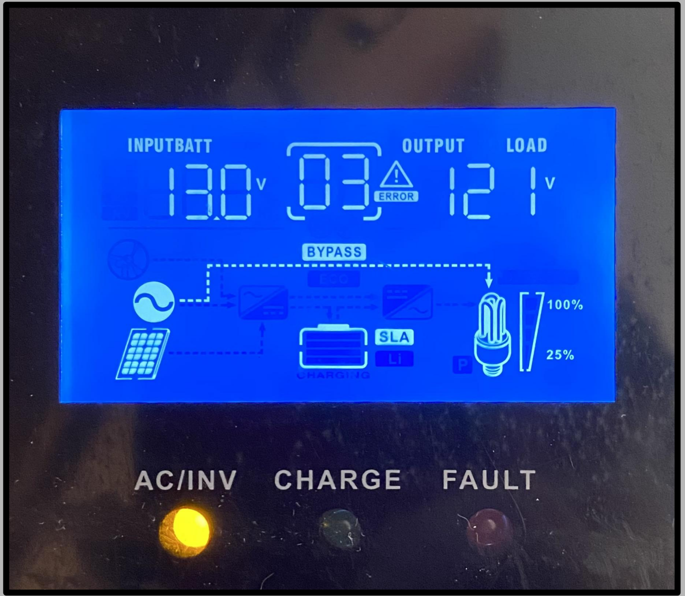
LG NeON 2

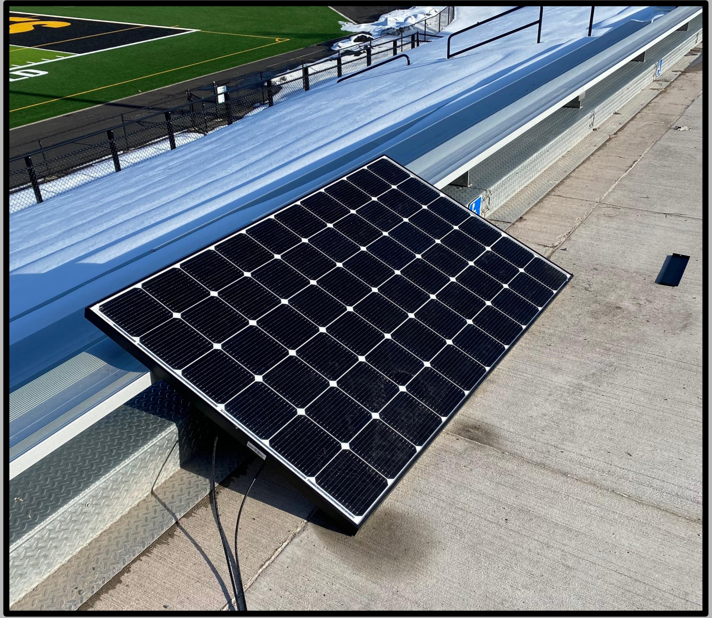
Solar System Testing

- Tested around 8 PM in moderately clear weather
- 17.54% efficiency
- 149.5W* of power

*On a day where Houghton got 503.3 Wh/m^2 of solar irradiance

Component	Expected/Nominal Value
Inverter Input	110 VDC
Inverter Output	120 VAC
Inverter Charge Volt	40-60 VDC
Inverter Charge Amp	0-80 A
Inverter Freq.	50-60 Hz
Inverter Switch Time	10 ms
1x Solar Panel Prod.	380 W/hr
8x Solar Panel Prod.	2800 W/hr
Panel Efficiency	21%
1x Battery Storage	200 Ah
4x Battery Storage	800 Ah
1x Battery Out Volt	12 V
4x Battery Out Volt	48 V





Renogy Batteries

- Using 12 200Ah batteries with 3 balancers
  - Total capacity of 28.8 kWh
  - System requires 26.4 kWh per day (12 hour runtime)
  - With an operating temperature of between 32 and 122 degrees Fahrenheit, they can operate in most climates

Inverter

- 48V Inverter/Charger drives our power delivery system
- Three different power routes for our application:
  - No PV, Grid Power straight to output
  - PV to Batteries, Grid Power to output
  - No Grid, PV or batteries to output

Project Management and Financials

Project Cost

Item	Cost	Tax + Shipping?	Power Cost (kW)					
10' Shipping Container	$7,500.00	Y	0		**Total:**	**$63,707.62**		Actual Price
Shipping Container Mods	$1,740.00	-	0		**Total Pwr (kW):**	**3.272**		Reasonable Guess
R.O. System	$13,596.00	N	1.5					Not as sure
Pre-treatment	$6,076.00	N	0.122					
Intake Pump	$688.95	Y	1.2					
Outlet Pump	$310.44	Y	0.18					
UV System	$1,125.00	Y	0.07					
Water tank	$800.00	Y	0	Updated - Shipping increased				
Solar Components	$10,155.80	No Tax	0					
Solar Mounting	$6,308.43	N	0					
PLC	$207.00	N	0.2					
Generator (gasoline)	$700.00	N	0					
Labor (Bill @ $95)	$11,400.00	-	0	120 Man Hours				
Miscellaneous	$2,000.00	N	0					
Sensors/Valves	$1,000.00	N	0					
Electrical	$100.00	N	0					

Solar Cost Breakdown and Testing Cost

Item	Total Quantity	MTU Quantity	Unit Cost [Total]	Unit Cost [MTU]	Provider
380 W Solar Panel	8	2	$ 319.50.00	$ 388.00	Renogy / LG
48V 3500W Solar Inverter	1	1	$ 899.99	$ 899.99	Renogy
12V 200 Ah AGM Battery	12	4	$ 439.99	$ 439.99	Renogy
Quad Enclosure Fuse Box	1	1	$ 59.99	$ 59.99	Renogy
Solar Combiner Box	1	1	$ 109.99	$ 109.99	Renogy
Battery Balancer	3	0	$ 65.45	$ -	Victron Energy
4AWG Battery Interconnect Cables	9	3	$ 12.99	$ 12.99	Renogy
10AWG Solar Panel Connectors	8	4	$ 24.64	$ 24.64	Renogy
Solar Circuit Breakers	4	4	$ 15.75	$ 15.75	Northern Arizona Wind & Sun
Panel Mount Breaker	1	1	$ 28.58	$ 25.58	Amazon
500A Battery Monitor w/ Shunt	1	0	$ 99.99	$ -	Renogy
			Total Build Cost	**Total Testing Cost**	
			$ 10,155.80	**$ 3,832.04**	

Michigan Tech

Water Bench Testing Cost

Item	Cost	Total Cost
Output Pump	$258	$2,097
PLC	$250	
UV System	$954	
3-Way Valve	$163.35	
Load Cell	$300	
Assorted Plumbing/Electrical	$100	

Britten’s Next Steps

- Heating and cooling solutions
- Manufacturing full prototype
- Developing full production line and product deployment
- Project lifecycle support

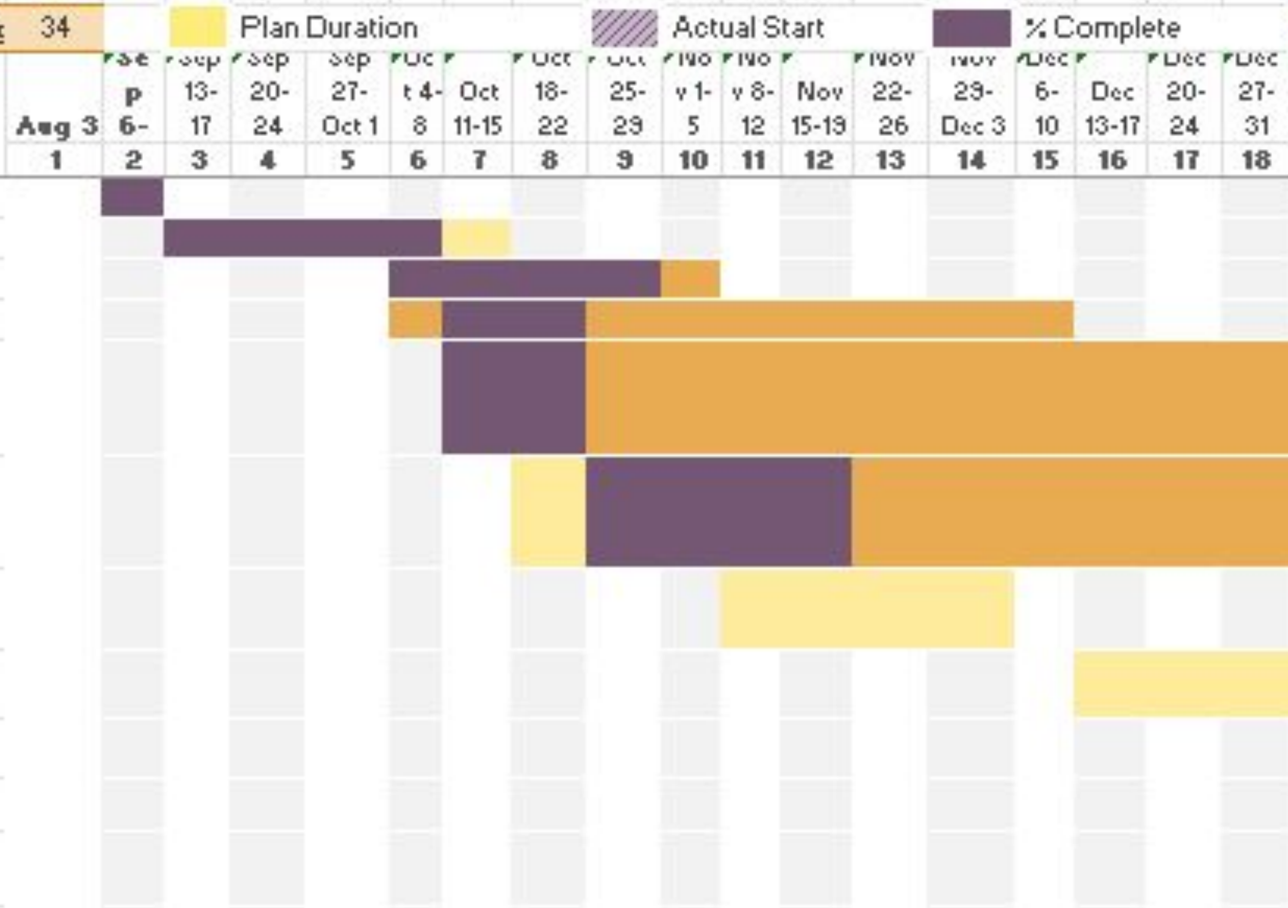
Team Operations

- Team Lead - Nika Orman
- Communication Lead - Matt Zambon
  - Team Internally Communicates via Text Group Chat
  - Team Communicates with Britten via Email
- Financials - Nick Hoffbeck
- Safety Manager - Luke Schloemp
- Weekly Meetings - In Person 11:30-2:00 pm Tuesday and Thursday in EERC
- Shared Google Drive for Collaboration and File Storage

Gantt Chart Semester 1

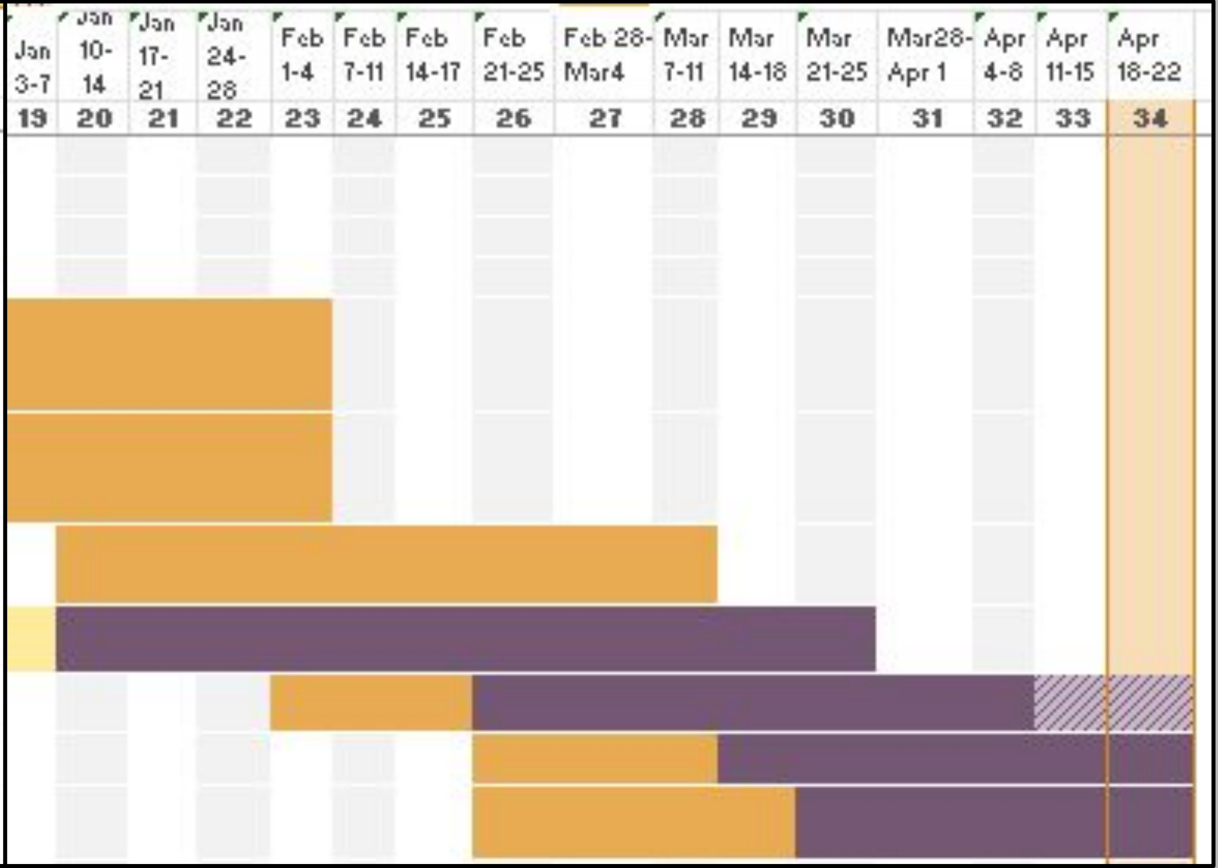
Select a period to highlight at right. A legend describing the charting follows.

ACTIVITY	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
Preliminary Research	2	1	2	1	100%
Parts Research	3	5	3	4	100%
Budgets	6	4	6	5	100%
Verify Parts	7	2	6	10	100%
Individual Parts' CAD Drawings	7	2	7	17	100%
Container Layout (Pre-Fabrication)	8	5	9	15	100%
Purchasing	11	4	20	9	100%
Subsystems	16	15	20	11	100%
Benchtesting	26	10	23	8	60%
System CAD	29	8	26	5	80%
Maintanence Manual	30	5	26	5	90%



Gantt Chart Semester 2

ACTIVITY	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
Preliminary Research	2	1	2	1	100%
Parts Research	3	5	3	4	100%
Budgets	6	4	6	5	100%
Verify Parts	7	2	6	10	100%
Individual Parts' CAD Drawings	7	2	7	17	100%
Container Layout (Pre-Fabrication)	8	5	9	15	100%
Purchasing	11	4	20	9	100%
Subsystems	16	15	20	11	100%
Benchtesting	26	10	23	12	90%
System CAD	29	8	26	12	100%
Maintanence Manual	30	5	26	12	100%



Individual Contributions

Kyle Clow: Water Purification System, Competing Product Review, Patent Review

Nick Hoffbeck: Shore Power, System Control, Standards Research, Prototype Costs

Evan McKenzie: Solar Panels, Panel and Battery Wiring, Logo, Iron Filter

Nika Orman: Water Tank, Sensors, Gauges, Connectors, Gantt Chart, Management

Luke Schloemp: Standards Research, UV system, Solar Panel Deployment, Structural

Gabby Sgambati: Preliminary Research, Pipes, Patent Review, Water Pre-Treatment

Matt Zambon: Communication Lead, Pumps, Water Rights, Water Outlet Testing

Acknowledgements

- The team would like to acknowledge and express our gratitude towards all the faculty who helped us throughout this project

<u>Advisors and Faculty:</u>

Dr. Tony Pinar

Dr. Paul Bergstrom

Dr. Andrew Gross

Dr. Brian Barkdoll

Dr. David W. Watkins

Trever Hassell P.E.

Christopher Morgan P.E.

John Lukowski

Dr. Christopher Middlebrook

<u>Sponsors</u>:

Britten, Inc

Nathan Bildeaux

Matt Egan

Questions?