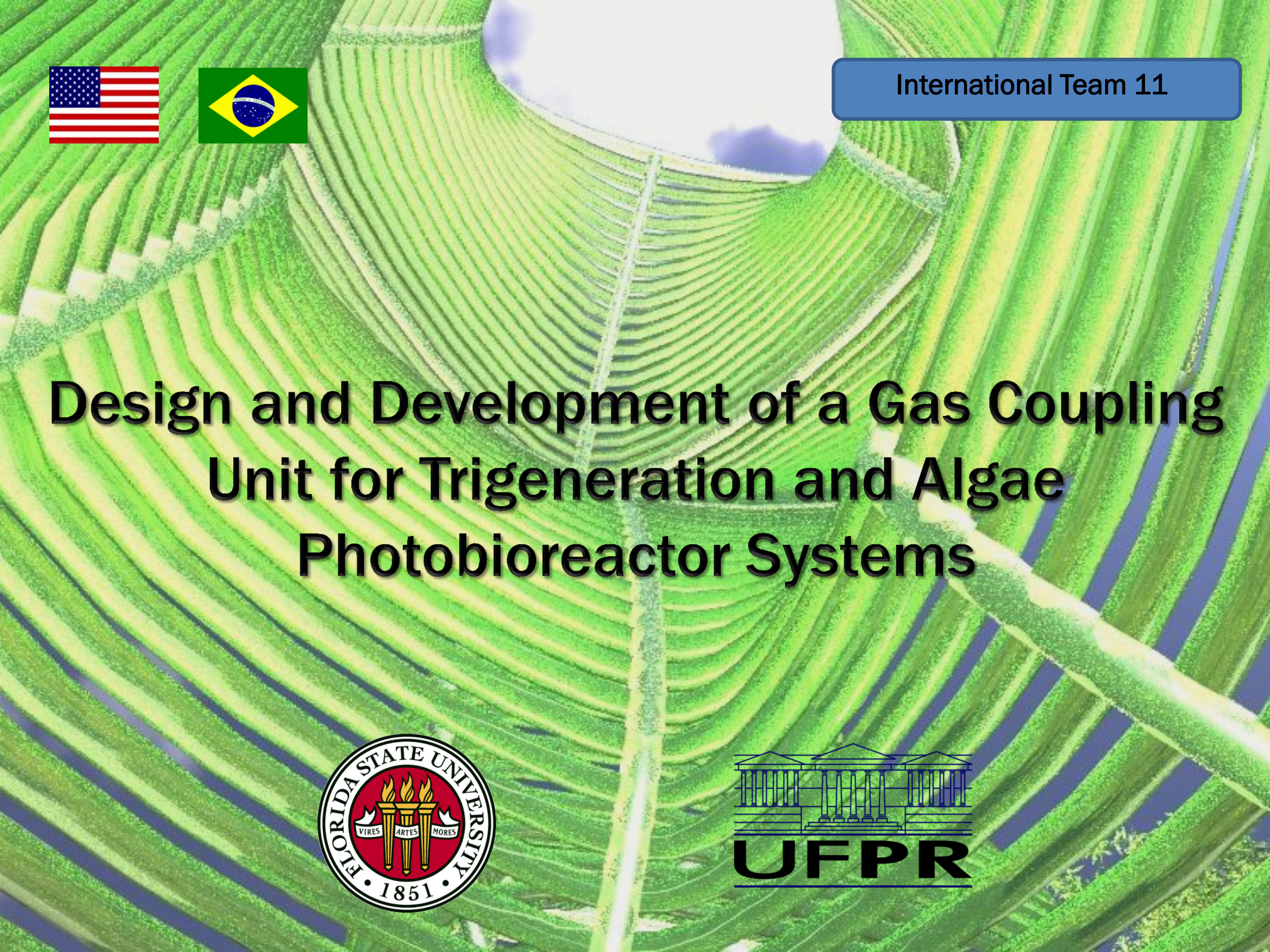

International Team 11

Design and Development of a Gas Coupling Unit for Trigeneration and Algae Photobioreactor Systems

FLORIDA STATE UNIVERSITY 1851

UFPR

International Team 11

Team

- **Supervisors**

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- **Co-supervisors**

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- **Students**

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[2] Federal University of Paraná

Biofuels

- Renewable sources
- Environmental impacts
- Tax exemptions
- “Greener” products & processes

- Europe:

1.9 billion liters of Biodiesel (2004)
4.9 billion liters of Biodiesel (2006)

- Brazil:

2% Biodiesel in Diesel Fuel (2009)
5% Biodiesel in Diesel Fuel (2012-2013)

Biodiesel

- Can be made from plants (vegetable /algae oils) or animal (animal fat)
- To produce biodiesel, the oil is removed from the plant and is mixed with alcohol (or methanol) then stimulated by a catalyst

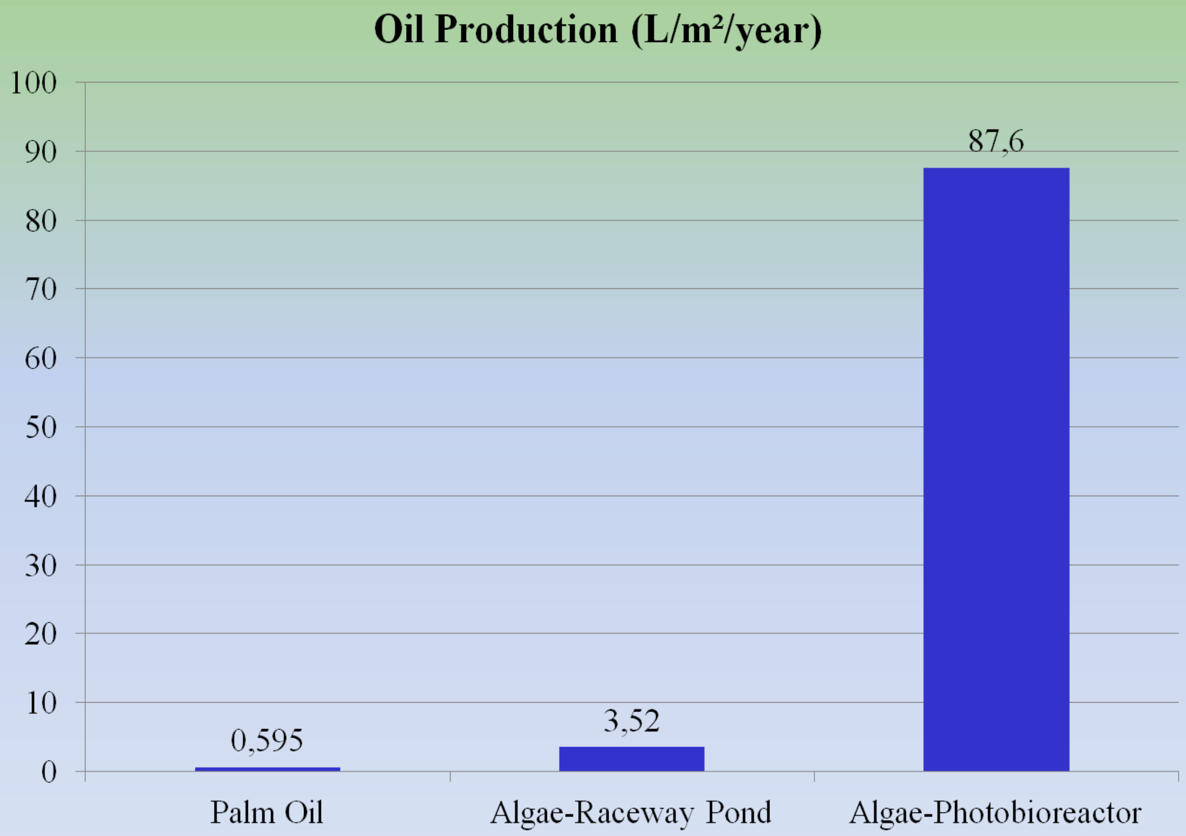
- Vegetable oils:
  - Corn
  - Soy
  - Canola
  - Palm
  - Coconut

- Algae oils:
  - Schizochytrium sp.
  - Nannochloropsis sp.
  - Chlorella sp.

- Animal fats:
  - Yellow grease
  - Chicken fat
  - By-products of Omega-3 fatty acids production from fish oil

Biodiesel

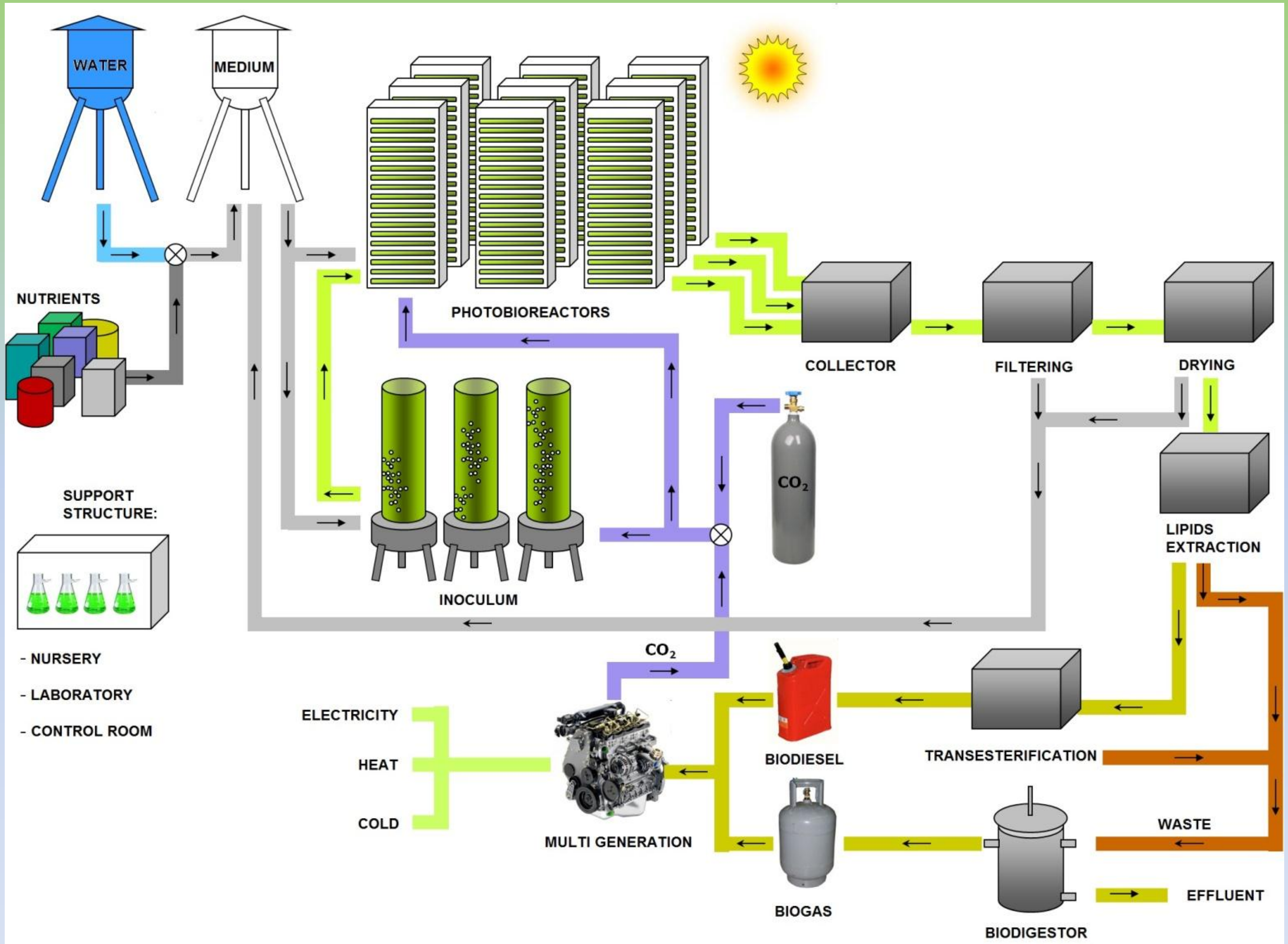
- Biodiesel production from different raw materials



- **Comparison Criteria:**
- 20% lipid content present in the algae
- Density of the bio-diesel produced has a density of 800kg/m^3

NPDEAS

International Team 11



What is LCA?

International Team 11

- Cradle-to-Grave approach
- Greener Products and Processes
- LCA can be performed using software (Simapro 7.3)

Photobioreactor LCA

International Team 11

- Study the environmental impacts in the construction (materials used, energy consumption, transport, packaging)

Data Acquired

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Materials	Volume (m^3)	Density (kg/m^3)	Weight (kg)	Energy (kWh)
Water	9.380474974	1000	9380.474974	N/A
Steel	0.3305	7850	2594.425	N/A
Paint	0.032	1198	38.336	N/A
Concrete	5	2400	12,000	N/A
Transparent PVC	0.7688366	1300	999.48758	N/A
Brown PVC	0.199154735	1300	258.9011552	N/A
Packaging (Brown PVC)	1.078	689	192.231	N/A
Packaging (Transparent PVC)	0.279	689	742.742	N/A
Paint Containers	X	X	2.36	N/A
Tank	X	X	35	N/A
Phosphorus	X	X	0.25	N/A
Magnesium	X	X	0.075	N/A
EDTA	X	X	0.05	N/A
Zinc	X	X	0.0000882	N/A
Pumps	X	X	X	7,323.36
Compressor	X	X	X	4,079

Analysis

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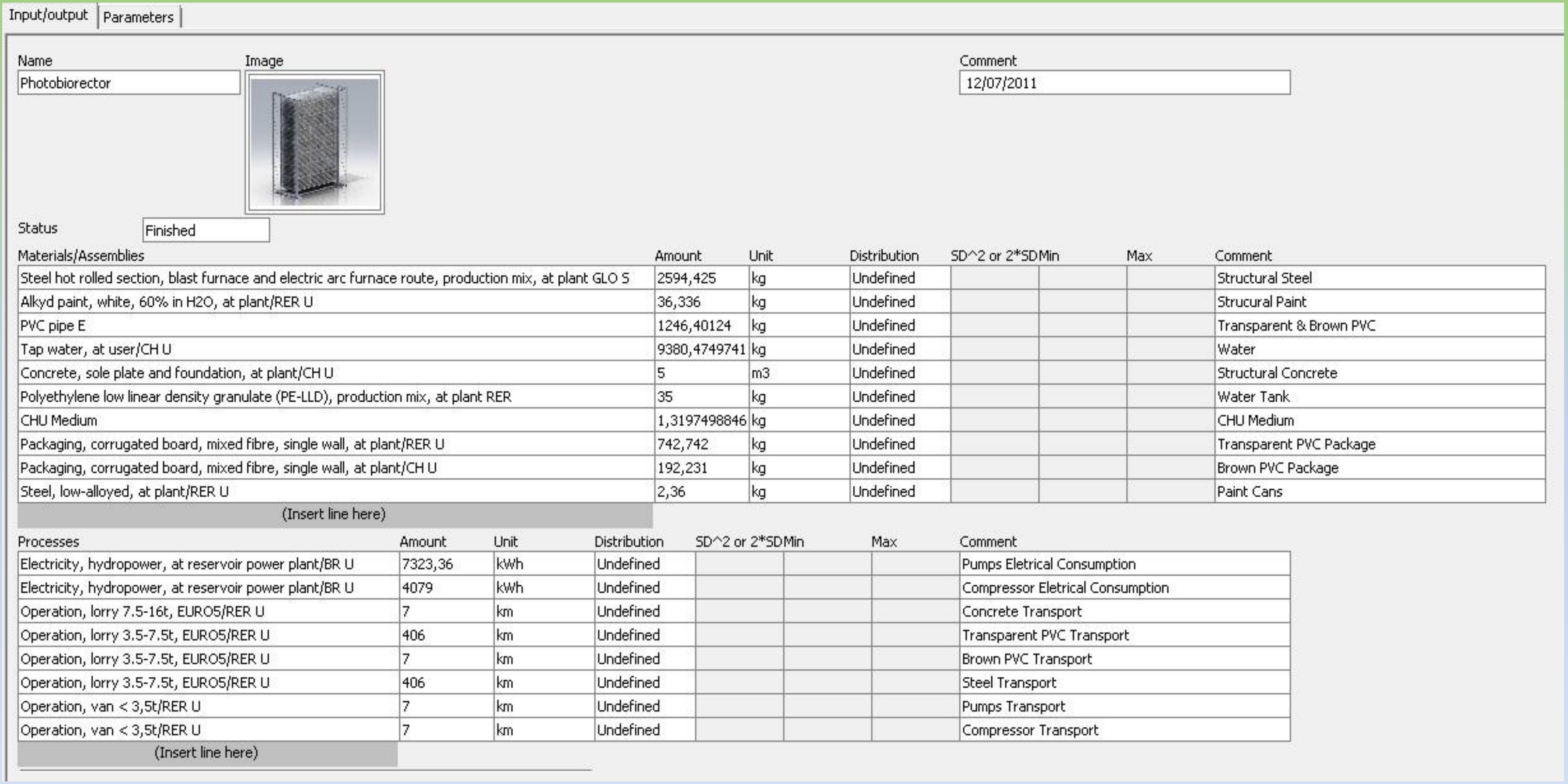


Name: Photobiorector

Image

Comment: 12/07/2011

Status: Finished

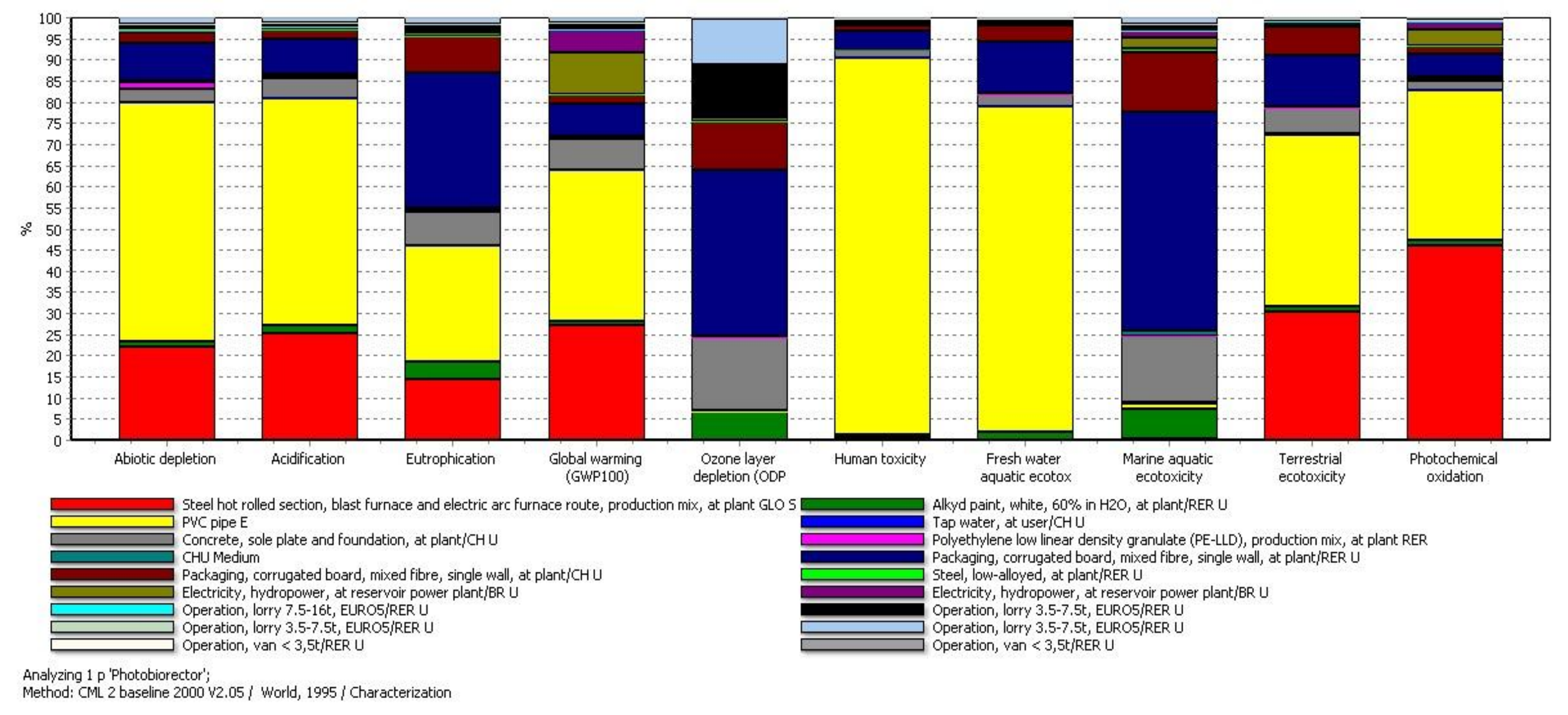
Materials/Assemblies	Amount	Unit	Distribution	SD^2 or 2*SD	Min	Max	Comment
Steel hot rolled section, blast furnace and electric arc furnace route, production mix, at plant GLO S	2594,425	kg	Undefined				Structural Steel
Alkyd paint, white, 60% in H2O, at plant/RER U	36,336	kg	Undefined				Strucural Paint
PVC pipe E	1246,40124	kg	Undefined				Transparent & Brown PVC
Tap water, at user/CH U	9380,4749741	kg	Undefined				Water
Concrete, sole plate and foundation, at plant/CH U	5	m3	Undefined				Structural Concrete
Polyethylene low linear density granulate (PE-LLD), production mix, at plant RER	35	kg	Undefined				Water Tank
CHU Medium	1,3197498846	kg	Undefined				CHU Medium
Packaging, corrugated board, mixed fibre, single wall, at plant/RER U	742,742	kg	Undefined				Transparent PVC Package
Packaging, corrugated board, mixed fibre, single wall, at plant/CH U	192,231	kg	Undefined				Brown PVC Package
Steel, low-alloyed, at plant/RER U	2,36	kg	Undefined				Paint Cans
(Insert line here)							

Processes	Amount	Unit	Distribution	SD^2 or 2*SD	Min	Max	Comment
Electricity, hydropower, at reservoir power plant/BR U	7323,36	kWh	Undefined				Pumps Eletrical Consumption
Electricity, hydropower, at reservoir power plant/BR U	4079	kWh	Undefined				Compressor Eletrical Consumption
Operation, lorry 7.5-16t, EURO5/RER U	7	km	Undefined				Concrete Transport
Operation, lorry 3.5-7.5t, EURO5/RER U	406	km	Undefined				Transparent PVC Transport
Operation, lorry 3.5-7.5t, EURO5/RER U	7	km	Undefined				Brown PVC Transport
Operation, lorry 3.5-7.5t, EURO5/RER U	406	km	Undefined				Steel Transport
Operation, van < 3,5t/RER U	7	km	Undefined				Pumps Transport
Operation, van < 3,5t/RER U	7	km	Undefined				Compressor Transport
(Insert line here)							

Results

International Team 11

Method used: CML 2 baseline 2000 V2.05

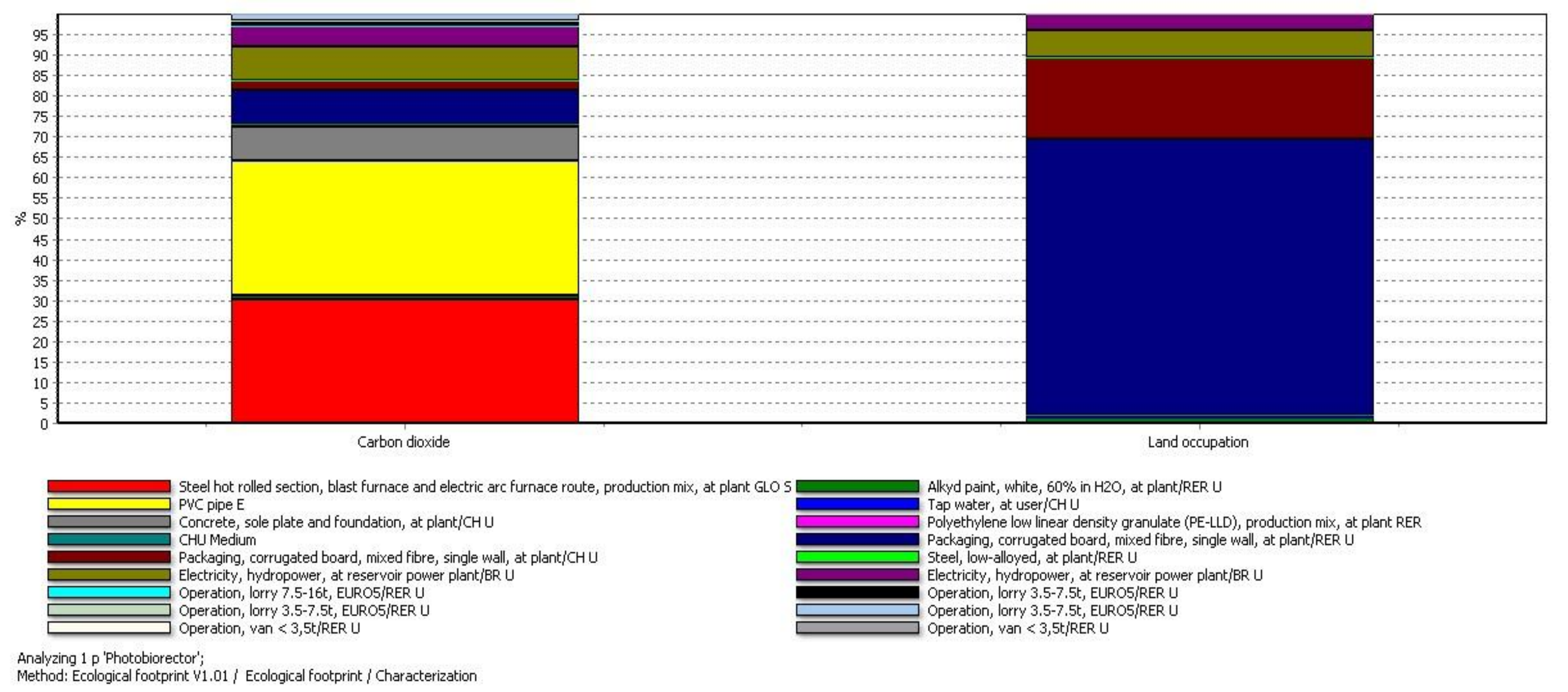


Analyzing 1 p 'Photobiorector';
Method: CML 2 baseline 2000 V2.05 / World, 1995 / Characterization

Results

International Team 11

Method used: Ecological footprint V1.01

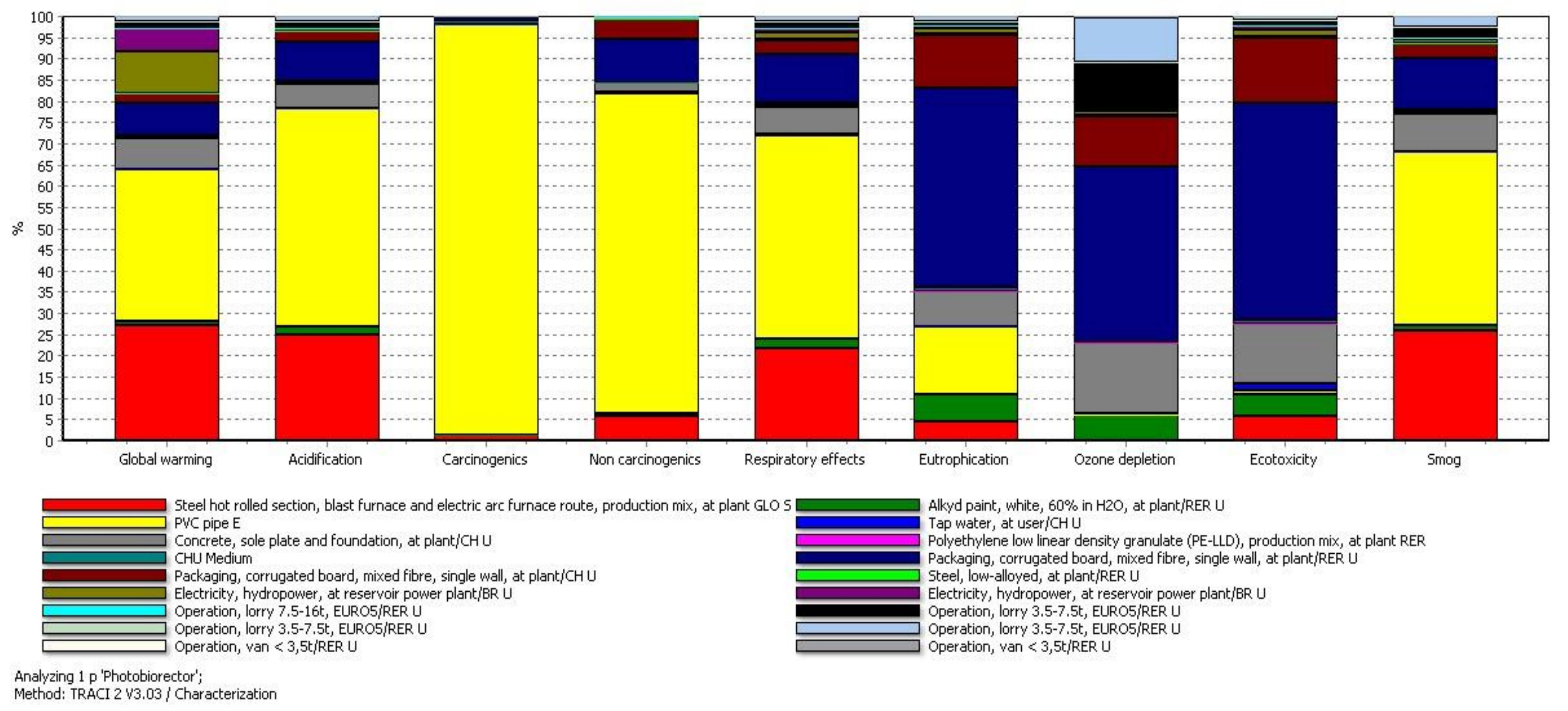


Analyzing 1 p 'Photobiorector';
Method: Ecological footprint V1.01 / Ecological footprint / Characterization

Results

International Team 11

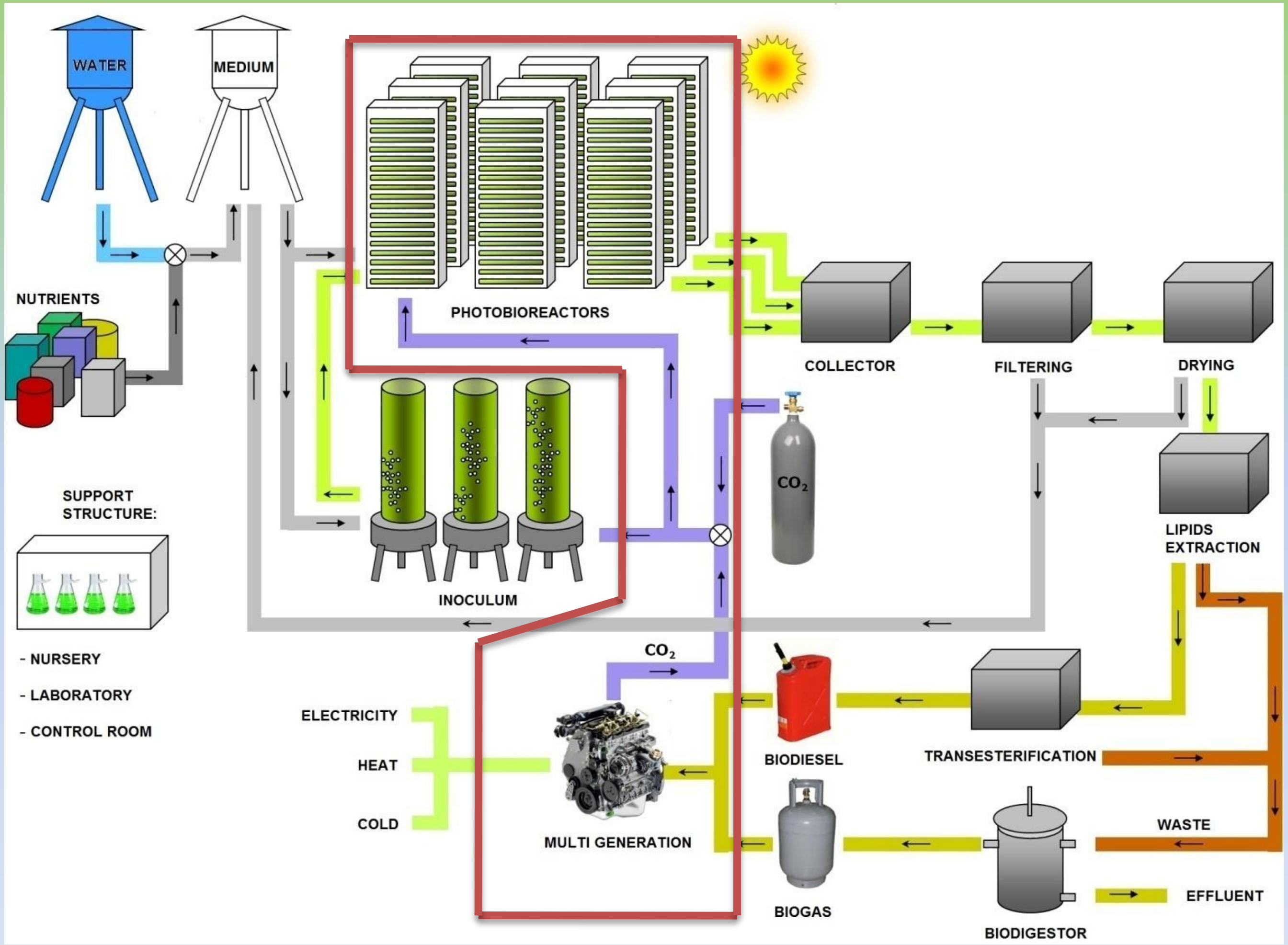
Method used: TRACI V3.03



Analyzing 1 p 'Photobiorector';
Method: TRACI 2 V3.03 / Characterization

US Team Support

International Team 11

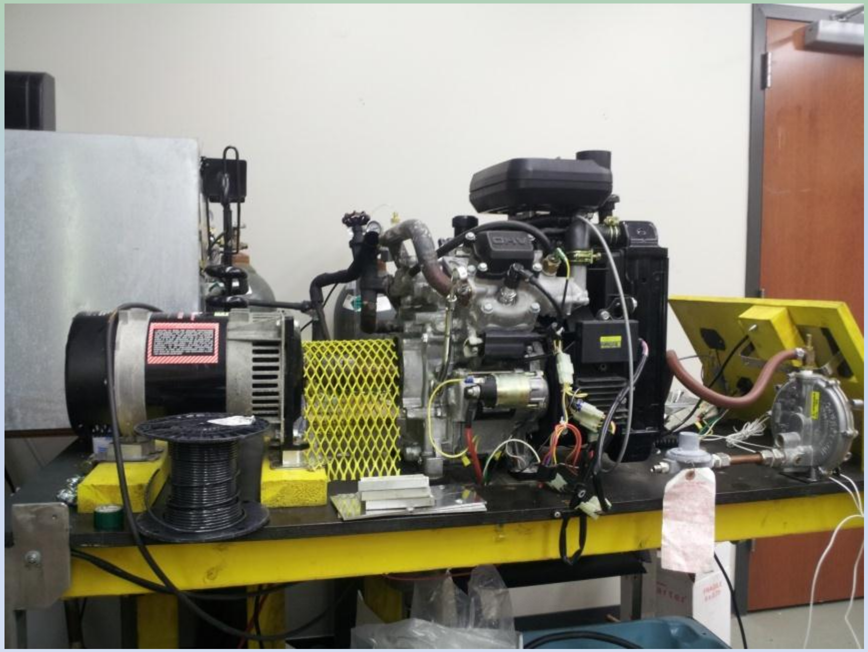


US Team Support

- Information acquired in Brazil:
  - PH Control with CO2 for most efficient algae growth
  - Design Concept Ideas for the Large-Scale Photobioreactor
  - Design Concept Selection (Feasability)
  - Selection of Algae Species
  - Amount of CO2 and Air for most efficient algae growth

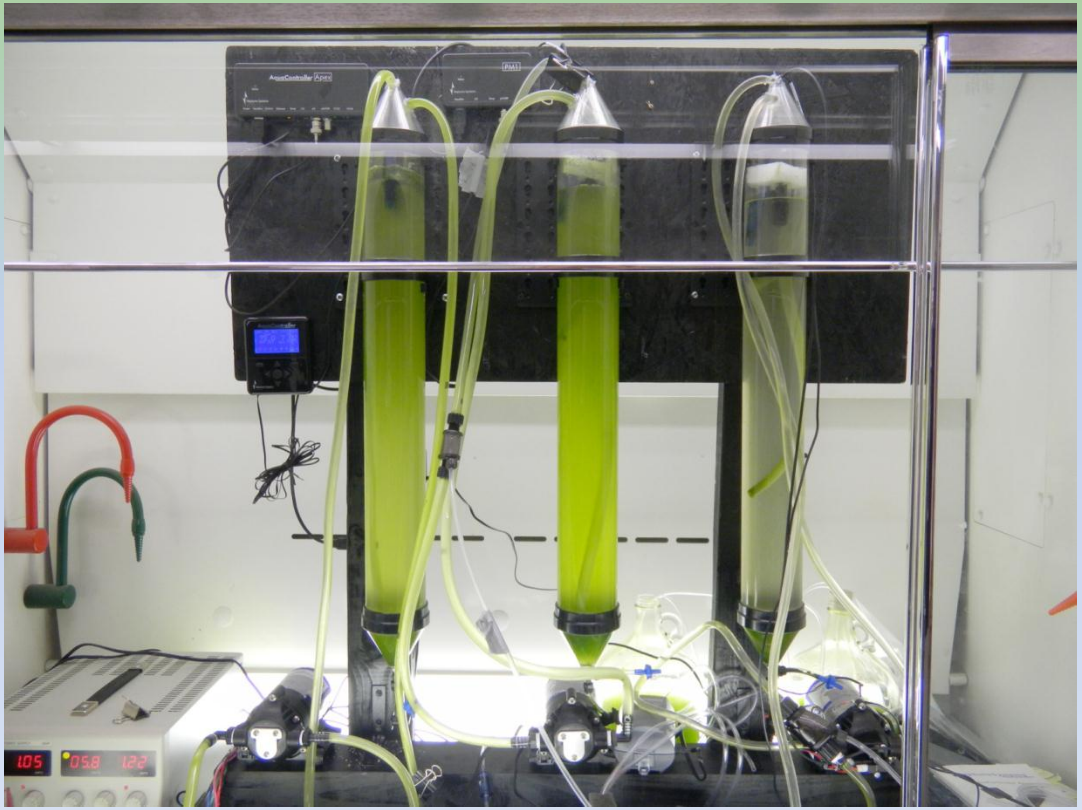
Trigeneration System

- Also known as Combined Cooling Heating and Power
- System design by a previous senior group
- Absorption refrigerator and helical heat exchanger driven by hot exhaust stream
- Produces electricity, refrigeration and hot water



Algae Photobioreactors

- Used to cultivate batches of microalgae
- Aqua-Medic Plankton Light Reactor
- System design by previous senior group
- Was used to test cylinder-stored CO_2 delivery
- Algae is refined into bio-fuels

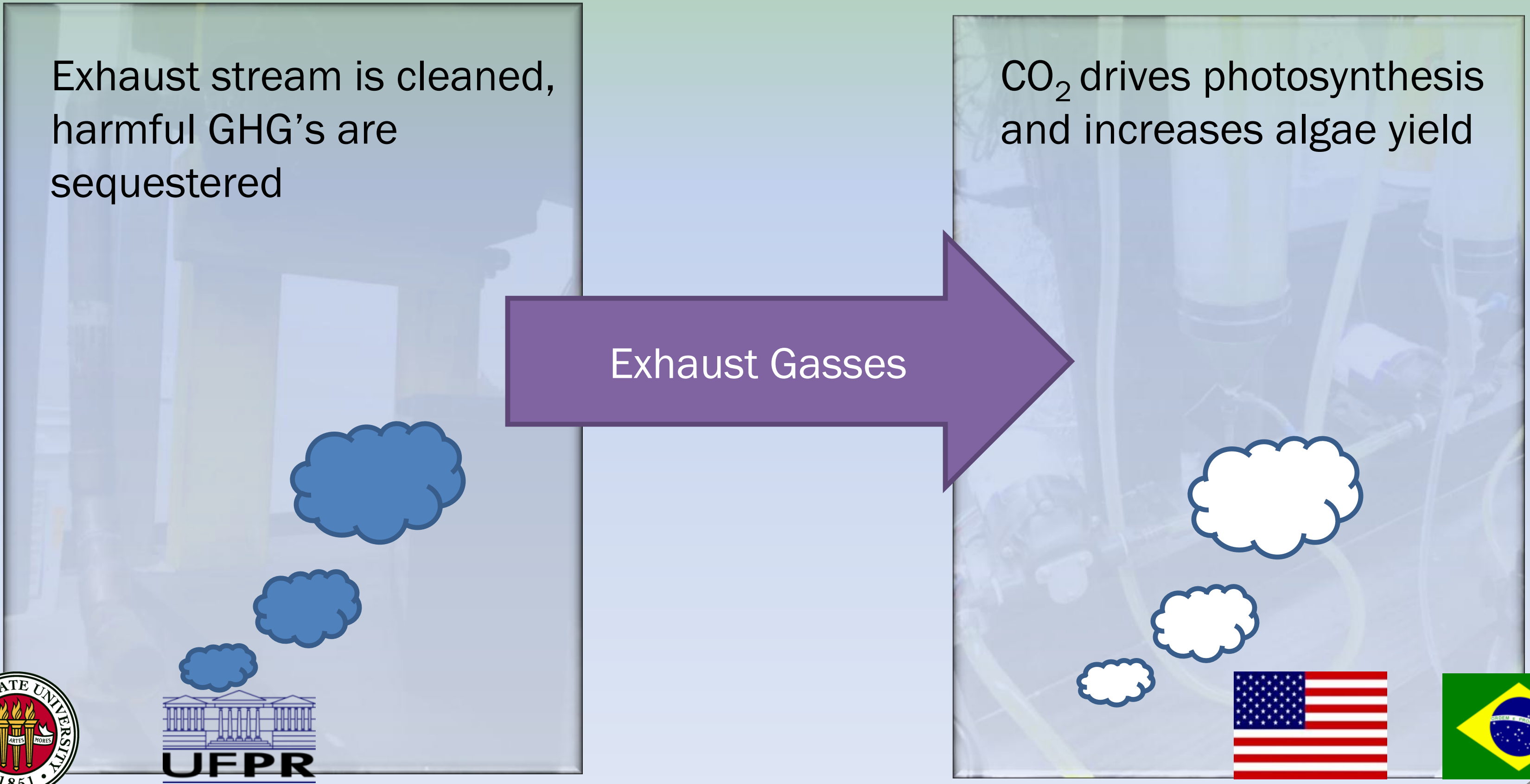


UFPR Photobioreactor

Systems Coupling

Exhaust Gasses

Systems Coupling



Exhaust stream is cleaned, harmful GHG's are sequestered

Exhaust Gasses

CO_2 drives photosynthesis and increases algae yield

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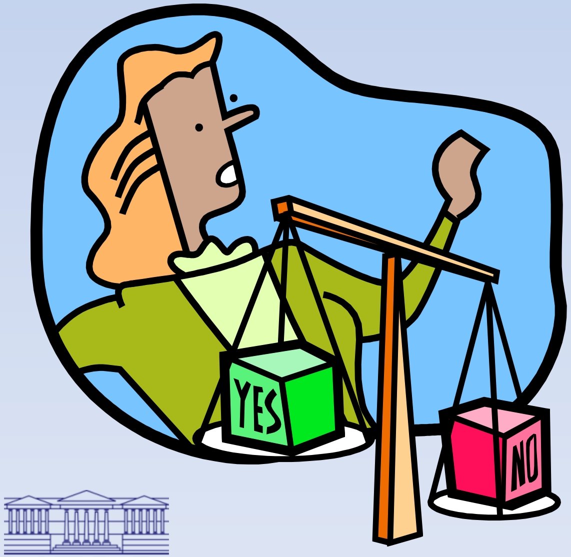
Specifications

- Device must transport the exhaust stream from the trigeneration unit to a photobioreactor
- Stream must be controllable
- Device should be modular and/or scalable
- Budget: $2000

Selection Criteria

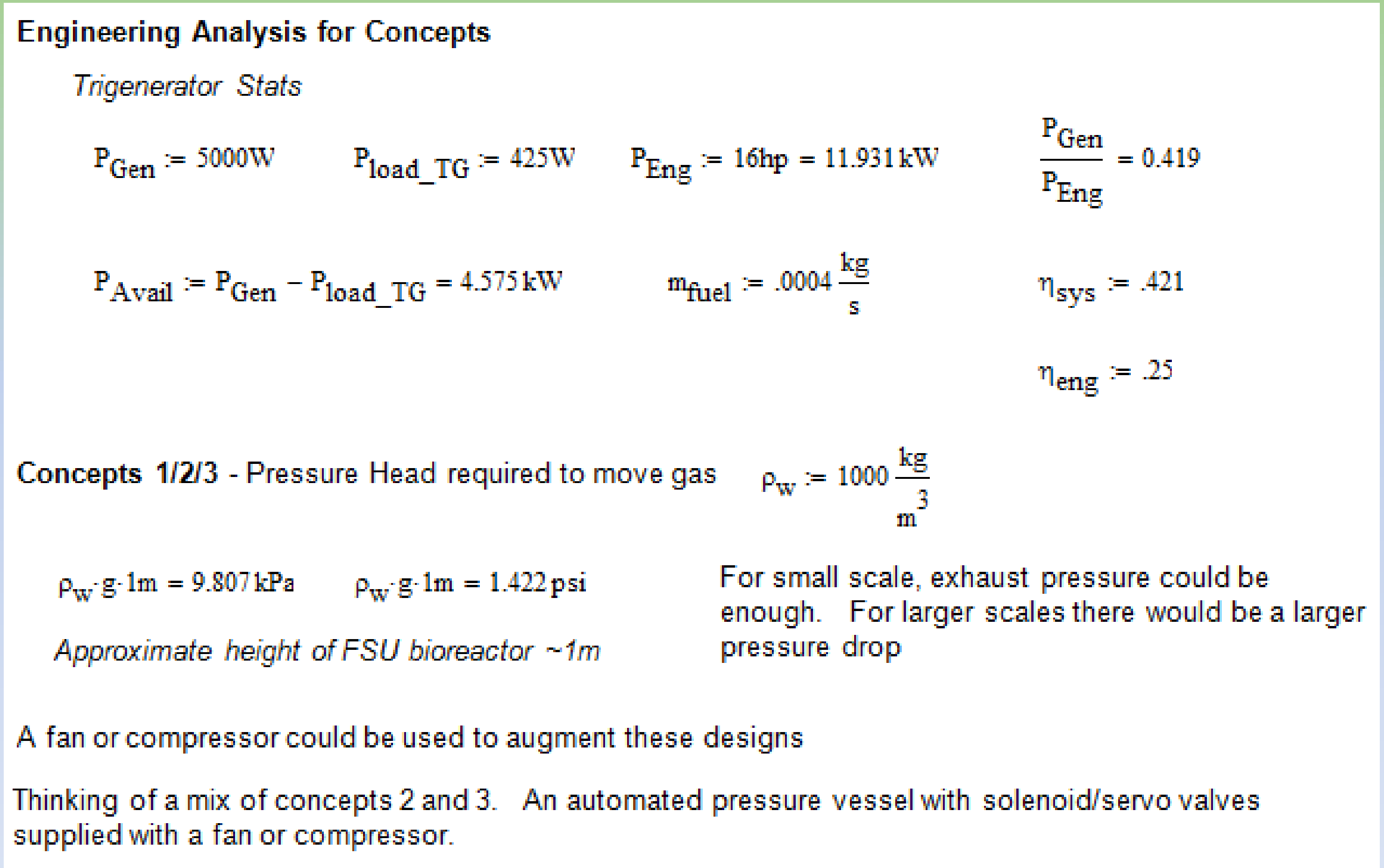
- Each criterion will be weighted, each concept will be scored in each criterion
- Highest weighted score is selected
- Closer evaluation may be needed if more than one concept stands out



- ***Adaptability*** – Can be used with different trigeneration /photobioreactor applications
- ***Scalability*** – Applicable to larger or smaller systems
- ***Power Requirements***– Must not draw too much electrical power from generator
- ***Durability*** – Expected lifespan, resistance to fouling or corrosio
- ***Reliability*** – Consistency of operation and/or steady-state condition
- ***Cost*** – Efficient budget use
- ***Controllability*** – Precision control of nutrient delivery
- ***Capture Effectiveness*** – Portion of exhaust gases sequestered / maximum capacity


Bio-Trigen

Preliminary Calculations



Engineering Analysis for Concepts

Trigenerator Stats

$P_{Gen} := 5000W$ $\quad P_{load\_TG} := 425W$ $\quad P_{Eng} := 16hp = 11.931\,kW$ $\quad \frac{P_{Gen}}{P_{Eng}} = 0.419$

$P_{Avail} := P_{Gen} - P_{load\_TG} = 4.575\,kW$ $\quad m_{fuel} := .0004\,\frac{kg}{s}$ $\quad \eta_{sys} := .421$

$\eta_{eng} := .25$

Concepts 1/2/3 - Pressure Head required to move gas $\quad \rho_w := 1000\,\frac{kg}{m^3}$

$\rho_w \cdot g \cdot 1m = 9.807\,kPa$ $\quad \rho_w \cdot g \cdot 1m = 1.422\,psi$

Approximate height of FSU bioreactor ~1m

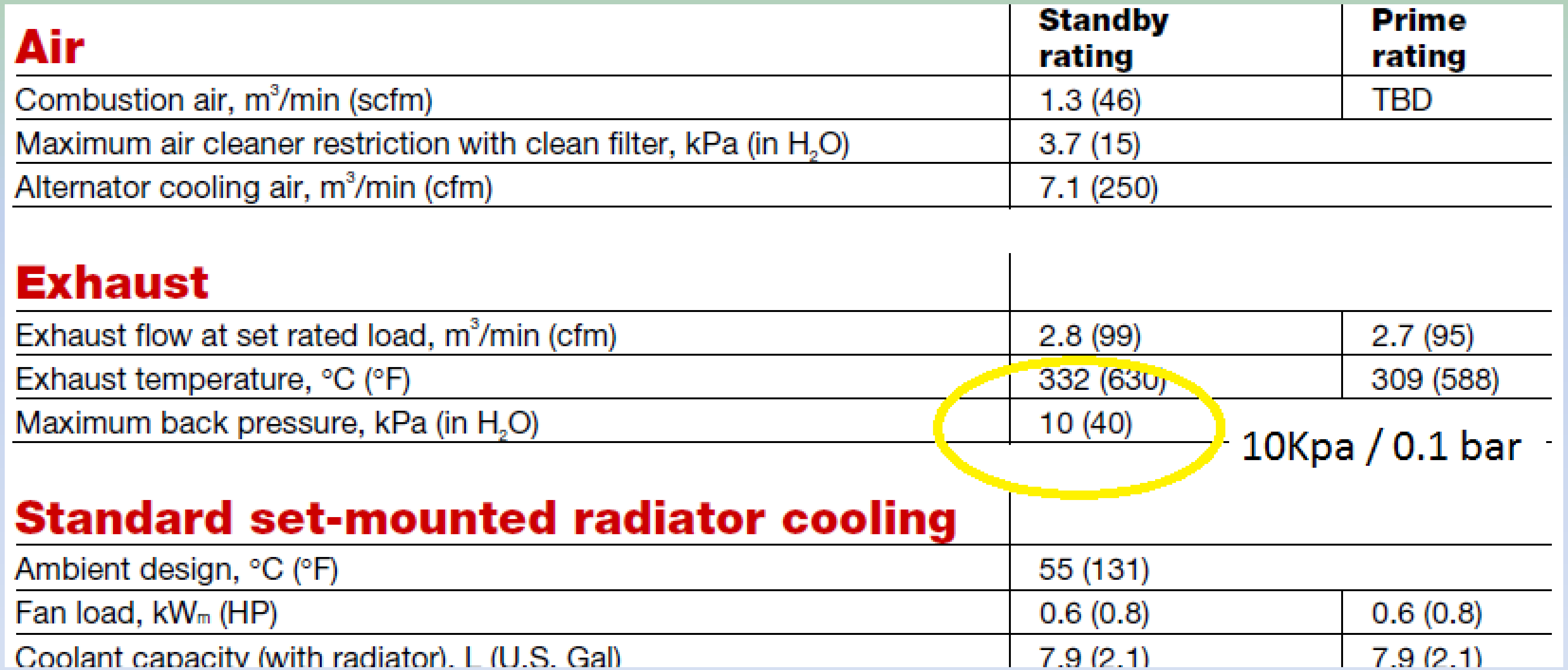
For small scale, exhaust pressure could be enough. For larger scales there would be a larger pressure drop

A fan or compressor could be used to augment these designs

Thinking of a mix of concepts 2 and 3. An automated pressure vessel with solenoid/servo valves supplied with a fan or compressor.

Comparison:

10kW Genset (Cummins Model DSKAA)

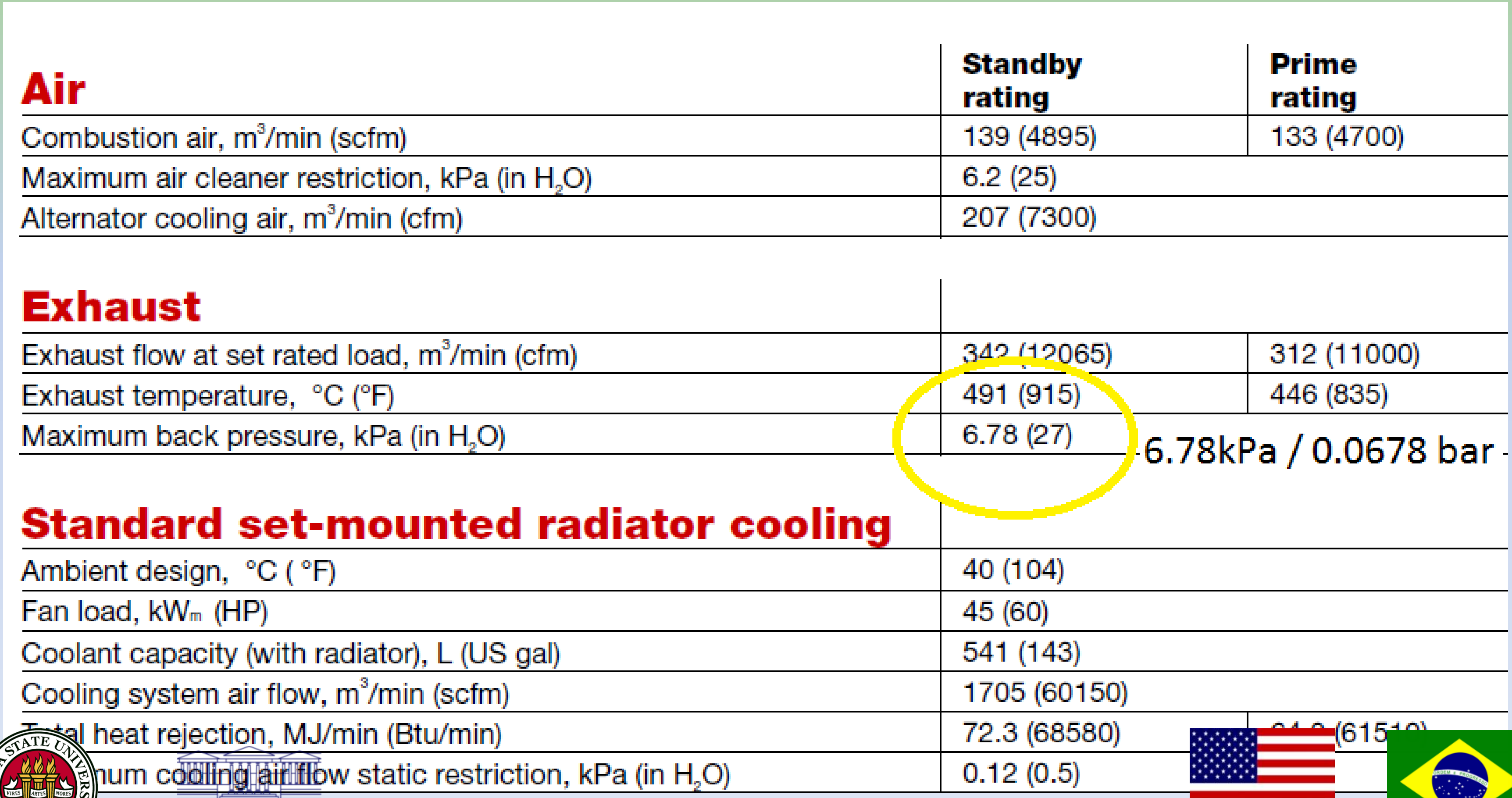


Air	**Standby rating**	**Prime rating**
Combustion air, m³/min (scfm)	1.3 (46)	TBD
Maximum air cleaner restriction with clean filter, kPa (in H_2O)	3.7 (15)	
Alternator cooling air, m³/min (cfm)	7.1 (250)	
Exhaust		
Exhaust flow at set rated load, m³/min (cfm)	2.8 (99)	2.7 (95)
Exhaust temperature, °C (°F)	332 (630)	309 (588)
Maximum back pressure, kPa (in H_2O)	10 (40)	
Standard set-mounted radiator cooling		
Ambient design, °C (°F)	55 (131)	
Fan load, kW_m (HP)	0.6 (0.8)	0.6 (0.8)
Coolant capacity (with radiator), L (U.S. Gal)	7.9 (2.1)	7.9 (2.1)

10Kpa / 0.1 bar

Comparison:

1500kW Genset (Cummins Model DQGAB)



Air	**Standby rating**	**Prime rating**
Combustion air, m^3/min (scfm)	139 (4895)	133 (4700)
Maximum air cleaner restriction, kPa (in H_2O)	6.2 (25)	
Alternator cooling air, m^3/min (cfm)	207 (7300)	
Exhaust		
Exhaust flow at set rated load, m^3/min (cfm)	342 (12065)	312 (11000)
Exhaust temperature, °C (°F)	491 (915)	446 (835)
Maximum back pressure, kPa (in H_2O)	6.78 (27)	
Standard set-mounted radiator cooling		
Ambient design, °C (°F)	40 (104)	
Fan load, kW_m (HP)	45 (60)	
Coolant capacity (with radiator), L (US gal)	541 (143)	
Cooling system air flow, m^3/min (scfm)	1705 (60150)	
Total heat rejection, MJ/min (Btu/min)	72.3 (68580)	(615
mum cooling air flow static restriction, kPa (in H_2O)	0.12 (0.5)	

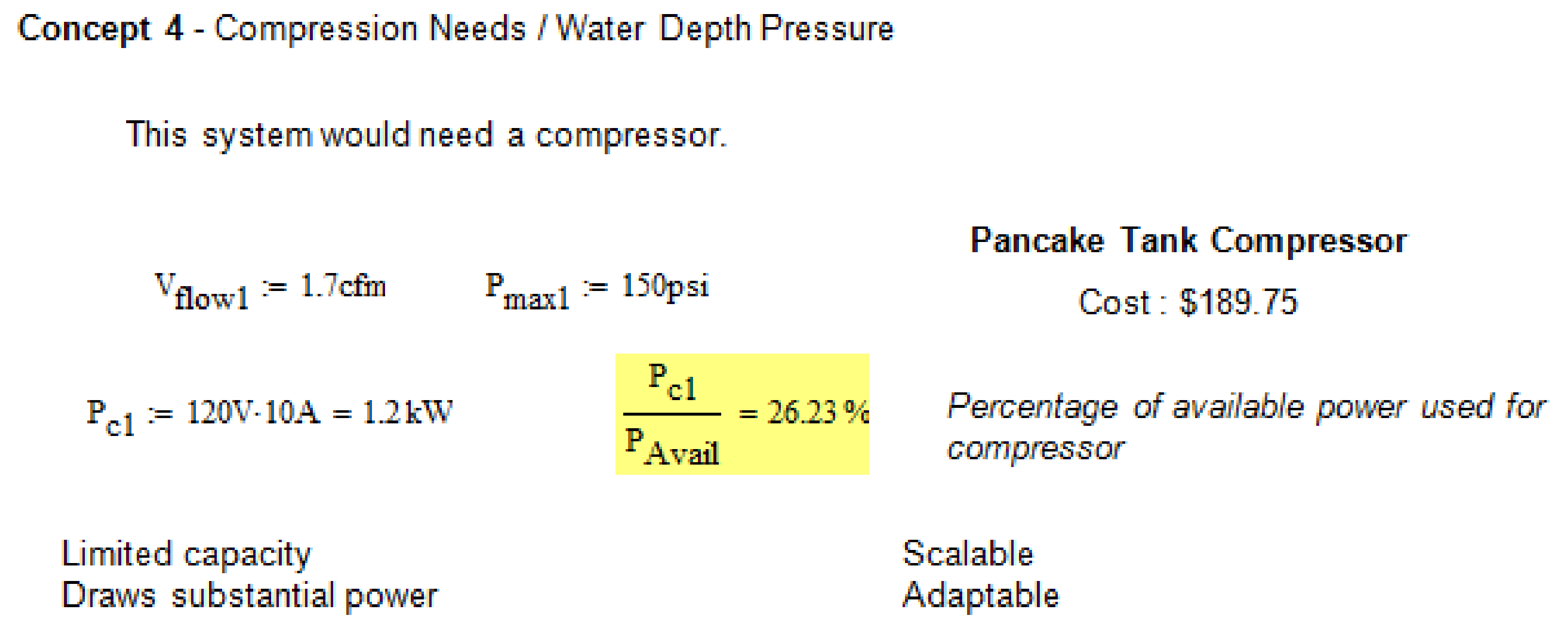
6.78kPa / 0.0678 bar

Concepts 1, 2 & 5

A pump is required to overcome the water pressure and initiate bubbling in the bioreactors

These designs cannot work without modifications

Preliminary Calculations



Concept 4 - Compression Needs / Water Depth Pressure

This system would need a compressor.

$V_{flow1} := 1.7cfm$ $\qquad$ $P_{max1} := 150psi$

$P_{c1} := 120V \cdot 10A = 1.2kW$

$$\frac{P_{c1}}{P_{Avail}} = 26.23\%$$

Pancake Tank Compressor

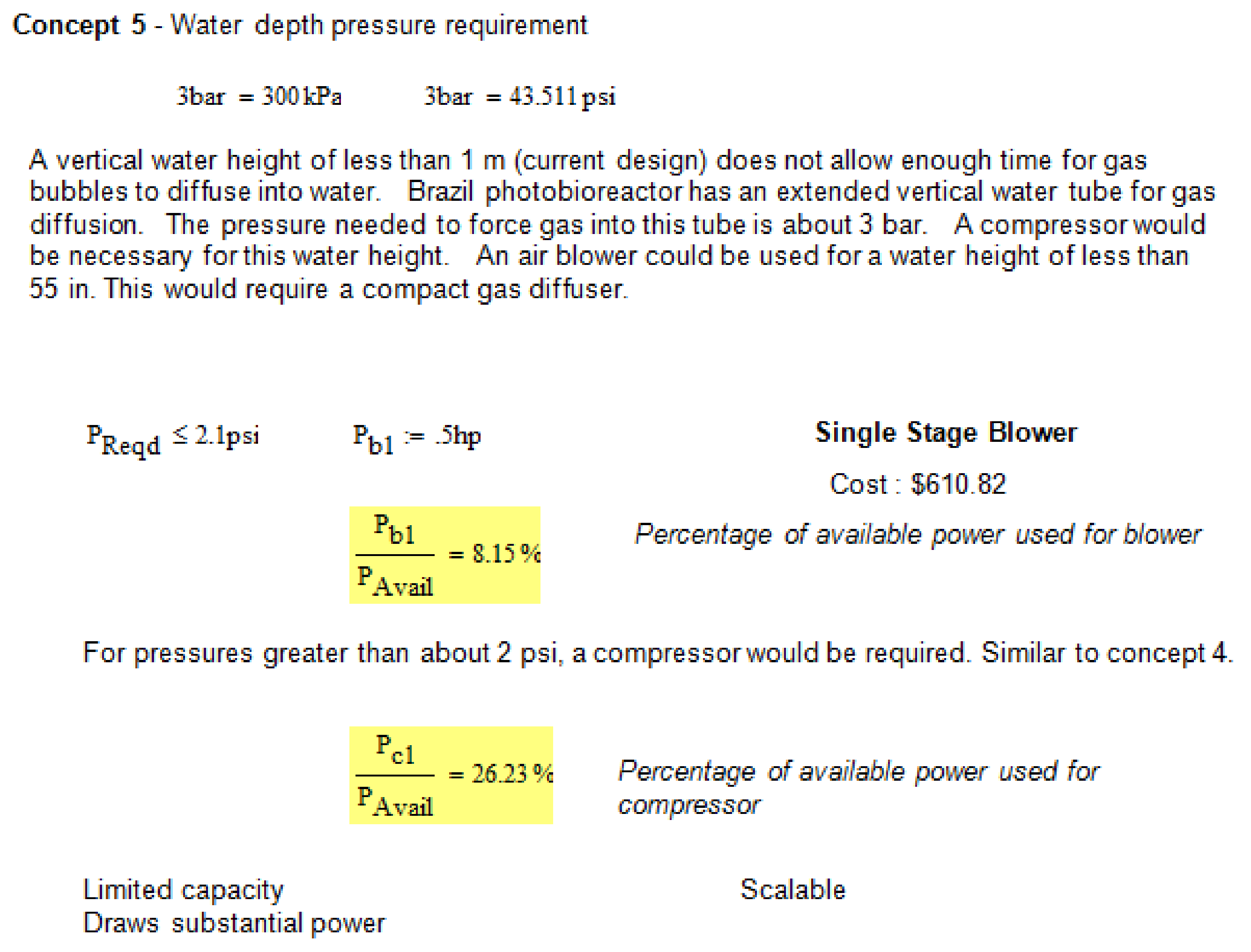
Cost : $189.75

Percentage of available power used for compressor

Limited capacity
Draws substantial power

Scalable
Adaptable

Preliminary Calculations



Concept 5 - Water depth pressure requirement

$$3\text{bar} = 300\,\text{kPa} \qquad 3\text{bar} = 43.511\,\text{psi}$$

A vertical water height of less than 1 m (current design) does not allow enough time for gas bubbles to diffuse into water. Brazil photobioreactor has an extended vertical water tube for gas diffusion. The pressure needed to force gas into this tube is about 3 bar. A compressor would be necessary for this water height. An air blower could be used for a water height of less than 55 in. This would require a compact gas diffuser.

$$P_{Reqd} \le 2.1\,\text{psi} \qquad P_{b1} := .5\,\text{hp}$$

Single Stage Blower

Cost : $610.82

$$\frac{P_{b1}}{P_{Avail}} = 8.15\,\%$$

Percentage of available power used for blower

For pressures greater than about 2 psi, a compressor would be required. Similar to concept 4.

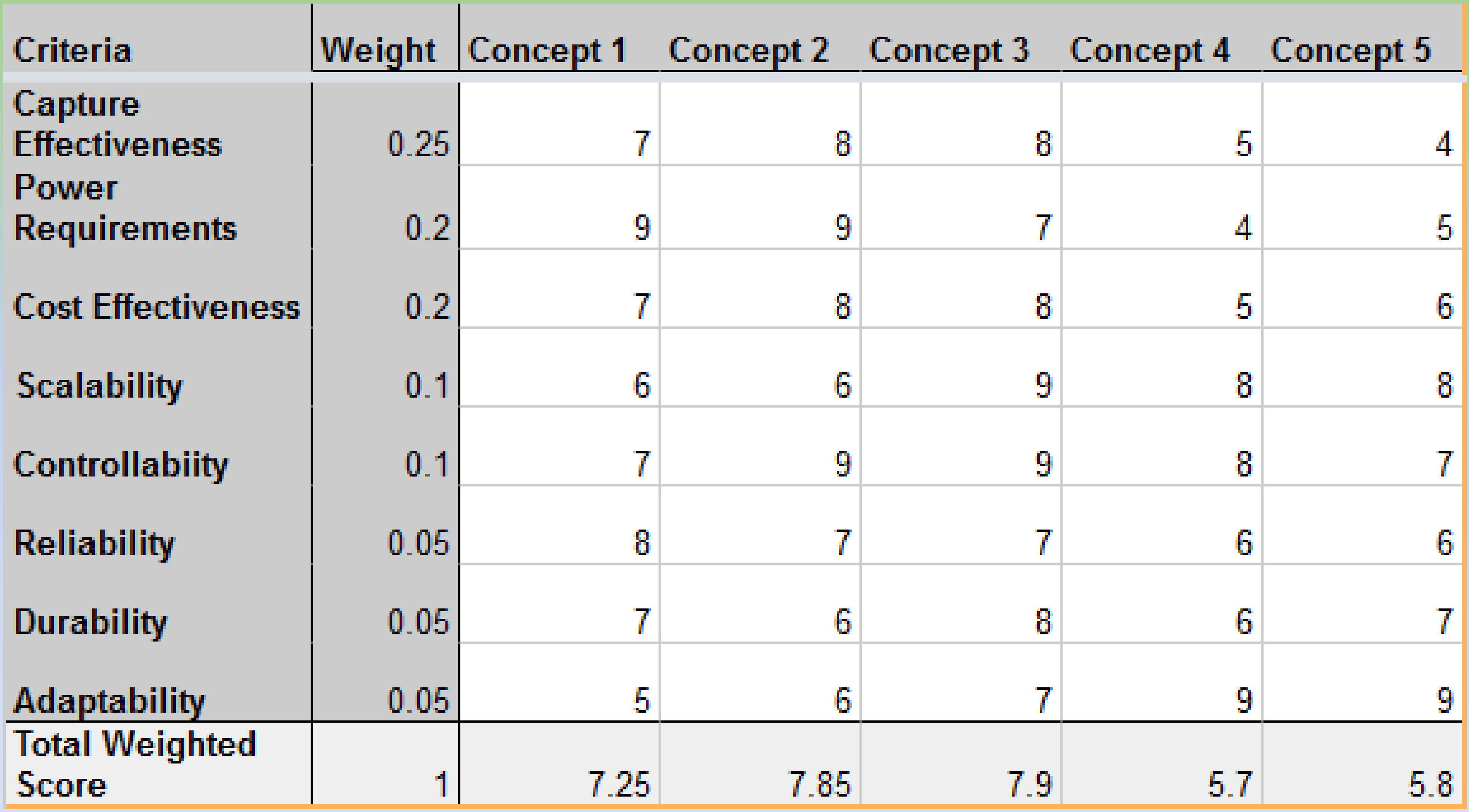
$$\frac{P_{c1}}{P_{Avail}} = 26.23\,\%$$

Percentage of available power used for compressor

Limited capacity
Draws substantial power

Scalable

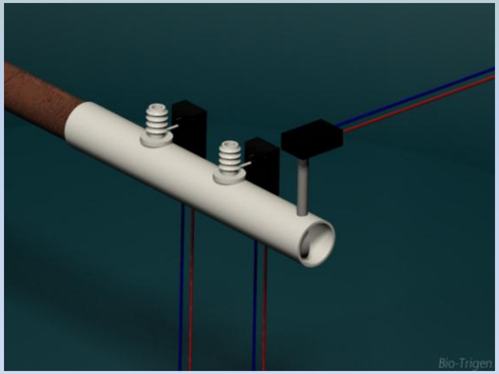
Decision Matrix



Criteria	Weight	Concept 1	Concept 2	Concept 3	Concept 4	Concept 5
Capture Effectiveness	0.25	7	8	8	5	4
Power Requirements	0.2	9	9	7	4	5
Cost Effectiveness	0.2	7	8	8	5	6
Scalability	0.1	6	6	9	8	8
Controllabiity	0.1	7	9	9	8	7
Reliability	0.05	8	7	7	6	6
Durability	0.05	7	6	8	6	7
Adaptability	0.05	5	6	7	9	9
Total Weighted Score	1	7.25	7.85	7.9	5.7	5.8

Conclusions

Concept 3 ranked highest, with concept 2 scoring a close second



However, a lot can be gained from concept 2…

Conclusions

Thus the team has opted for outfitting concept 3 with a control system capable of controlling the gas flow to the bioreactors

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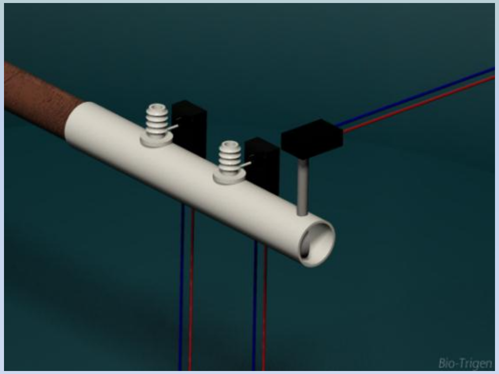
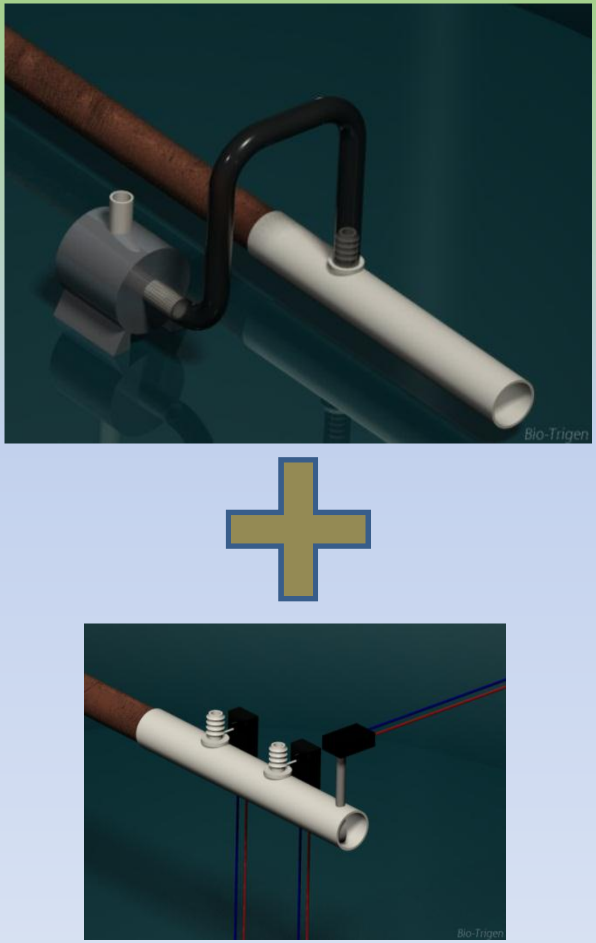


Conclusions

The modified concept has the following advantages:

- Cheap to manufacture
- Relatively easy to maintain
- Easily replaceable parts
- Corrosion resistance
- Low power draw
- High controllability
- Easily scalable
- Robust / adaptable

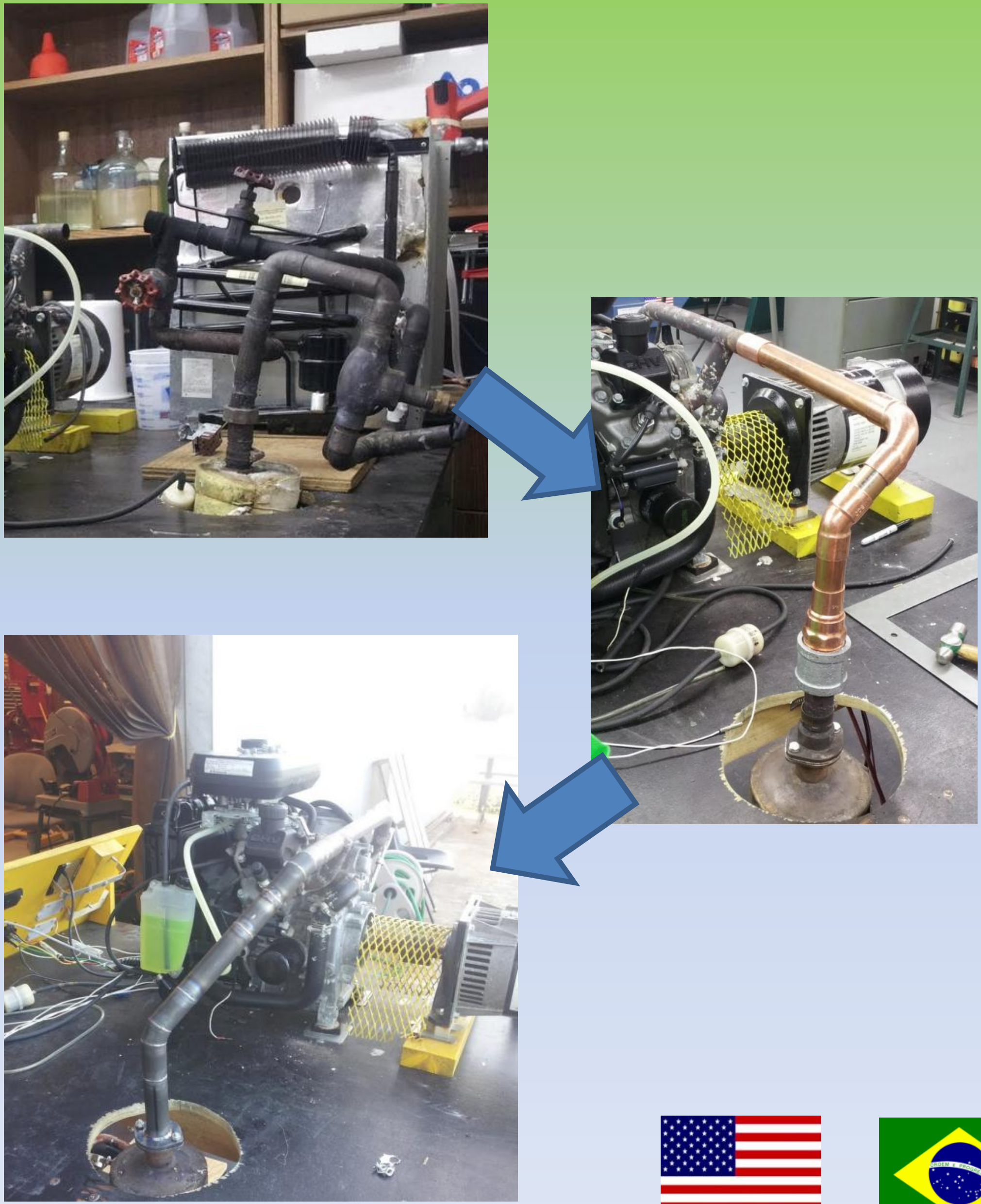


Damage

- Trigeneration system was in disrepair
- Exhaust system corroded and damaged
- Refrigeration heat conduction circuit damaged
- Minor engine problems as a result of neglected maintenance procedures

Repairs

- Engine repaired
- Fluids replaced
- Fuel lines re-primed
- New copper exhaust put in place…
- …but the exhaust temperature was too high; solder melted
- New steel exhaust secured and sealed using Gas Tungsten Arc Welding (GTAW) process
- LP line removed
- General cleaning
- Now in excellent working condition



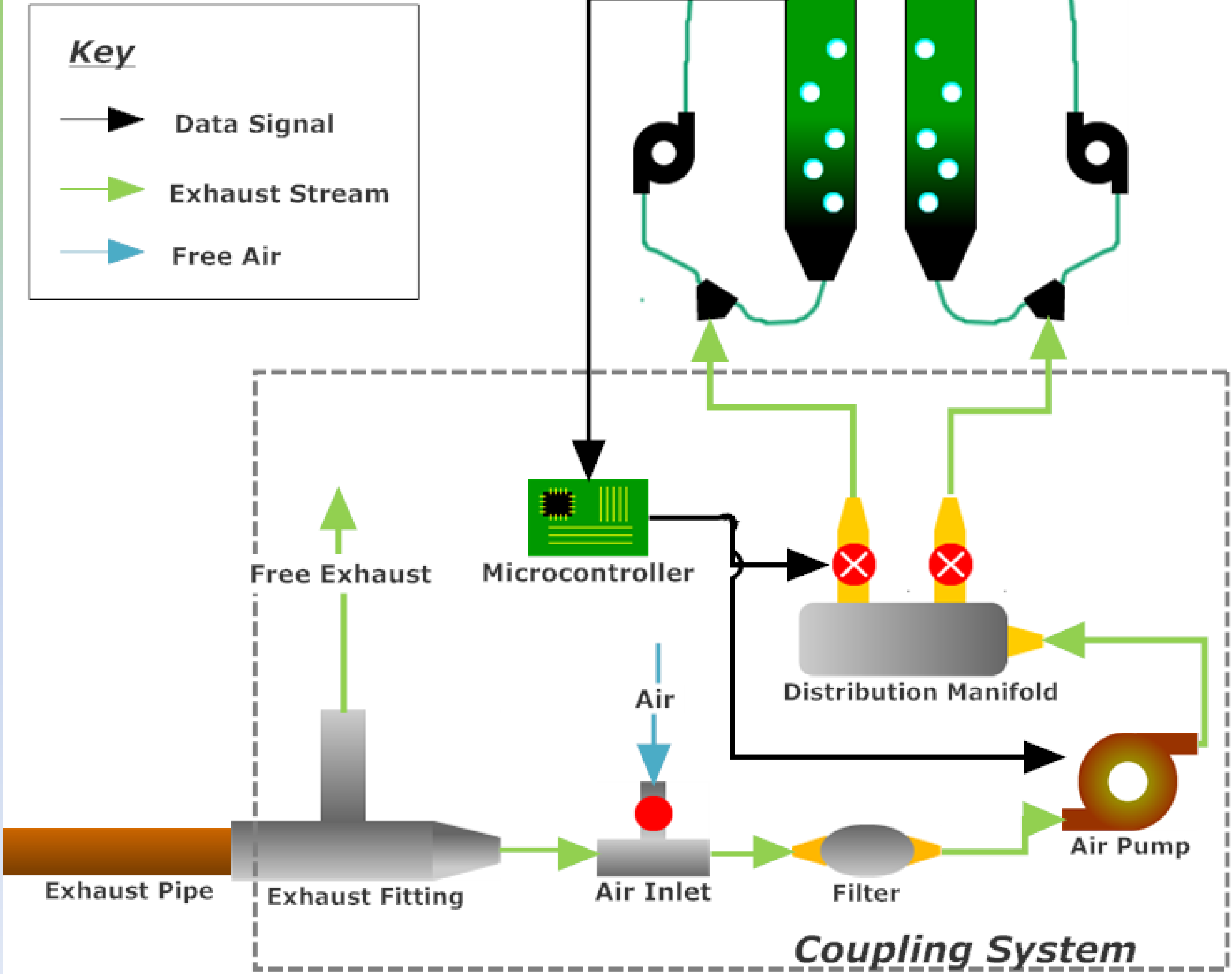
Damage

- Existing photobioreactors were neglected for a long period of time
- Algae had settled to the bottom; clogged tubing
- Bioreactors may need to be used for other experiments; new, clean reactors are required
- Algae in reactors has not been cared for; new cultures are necessary
- pH sensors not maintained

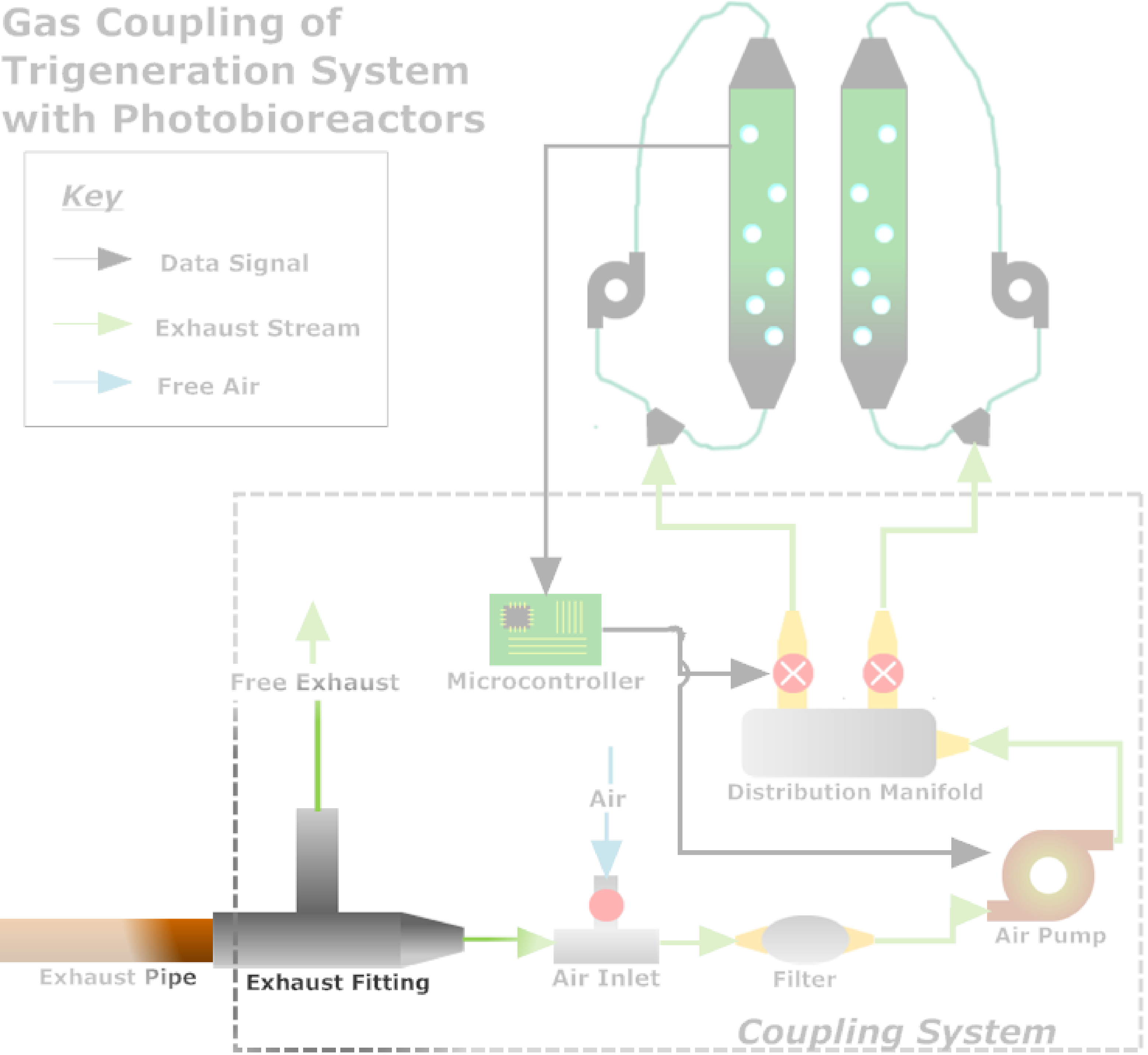
Repairs & Orders

- Two new Aquamedic photobioreactors were ordered; replacement tubing and junctions included
- Two individual algae cultures were ordered for University of Texas: Scenedesmus dimorphus and Chlorella Spirulina
- New pH sensors selected and easily figured into budget

Gas Coupling of Trigeneration System with Photobioreactors

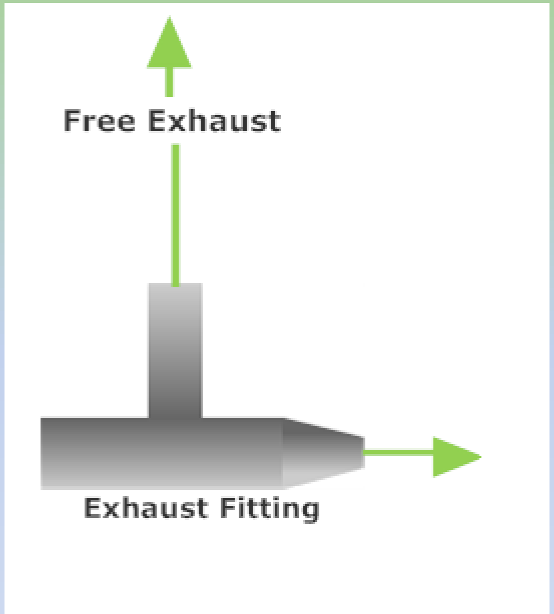


Gas Coupling of Trigeneration System with Photobioreactors

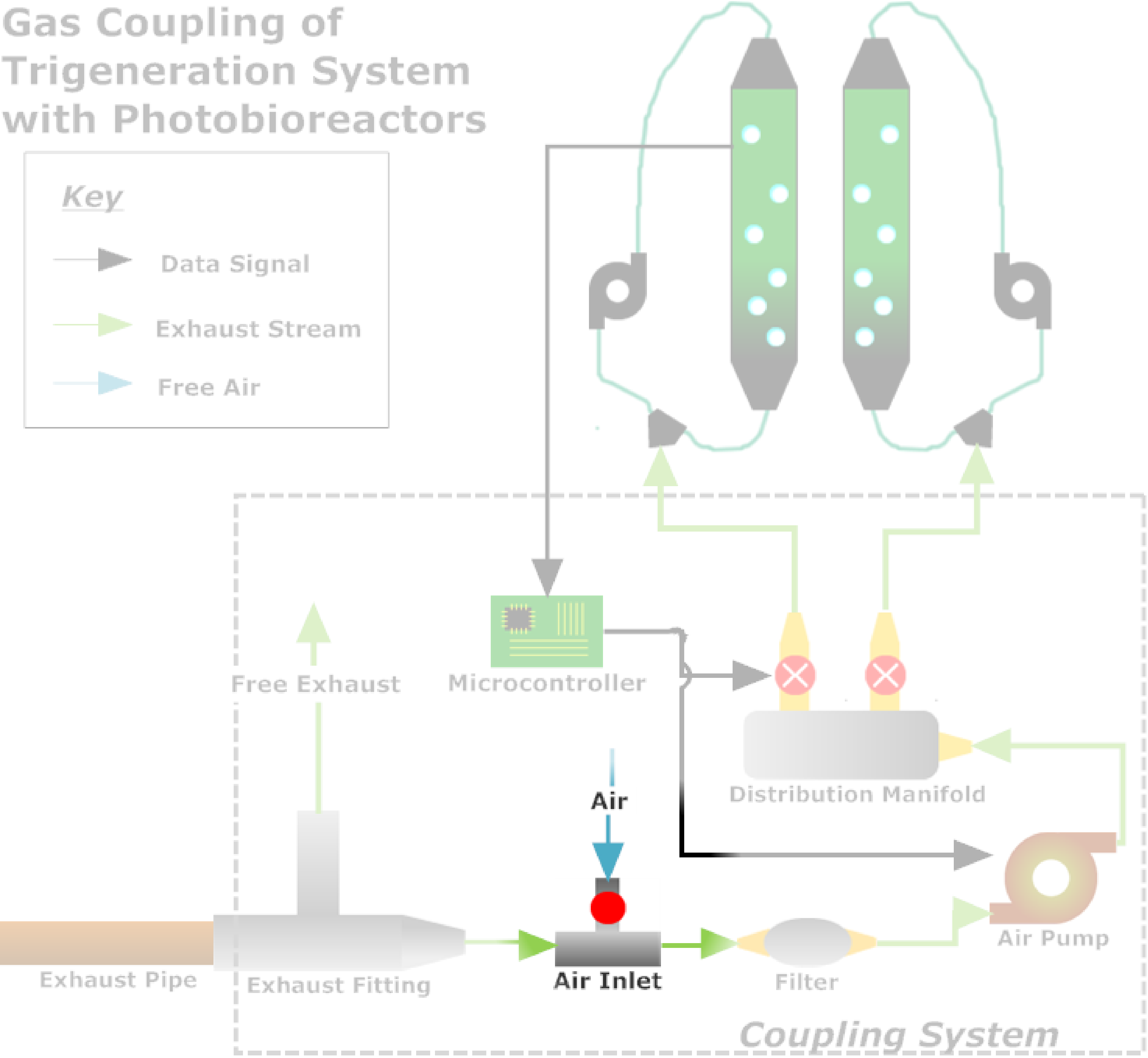


Exhaust Fitting

- 1” ID CPVC fitting directly attached to copper exhaust pipe
- Reducing collar with tube fitting at end of exhaust stream (to make use of dynamic pressure)
- Chlorinated PVC for thermal protection (In the case of trigeneration heat exchange system failure)

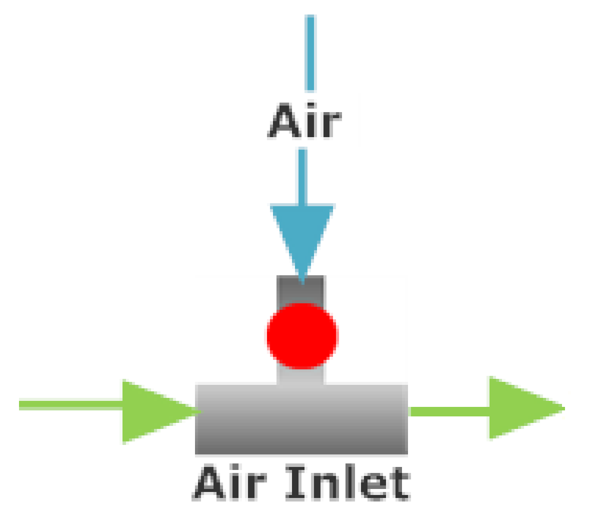


Gas Coupling of Trigeneration System with Photobioreactors

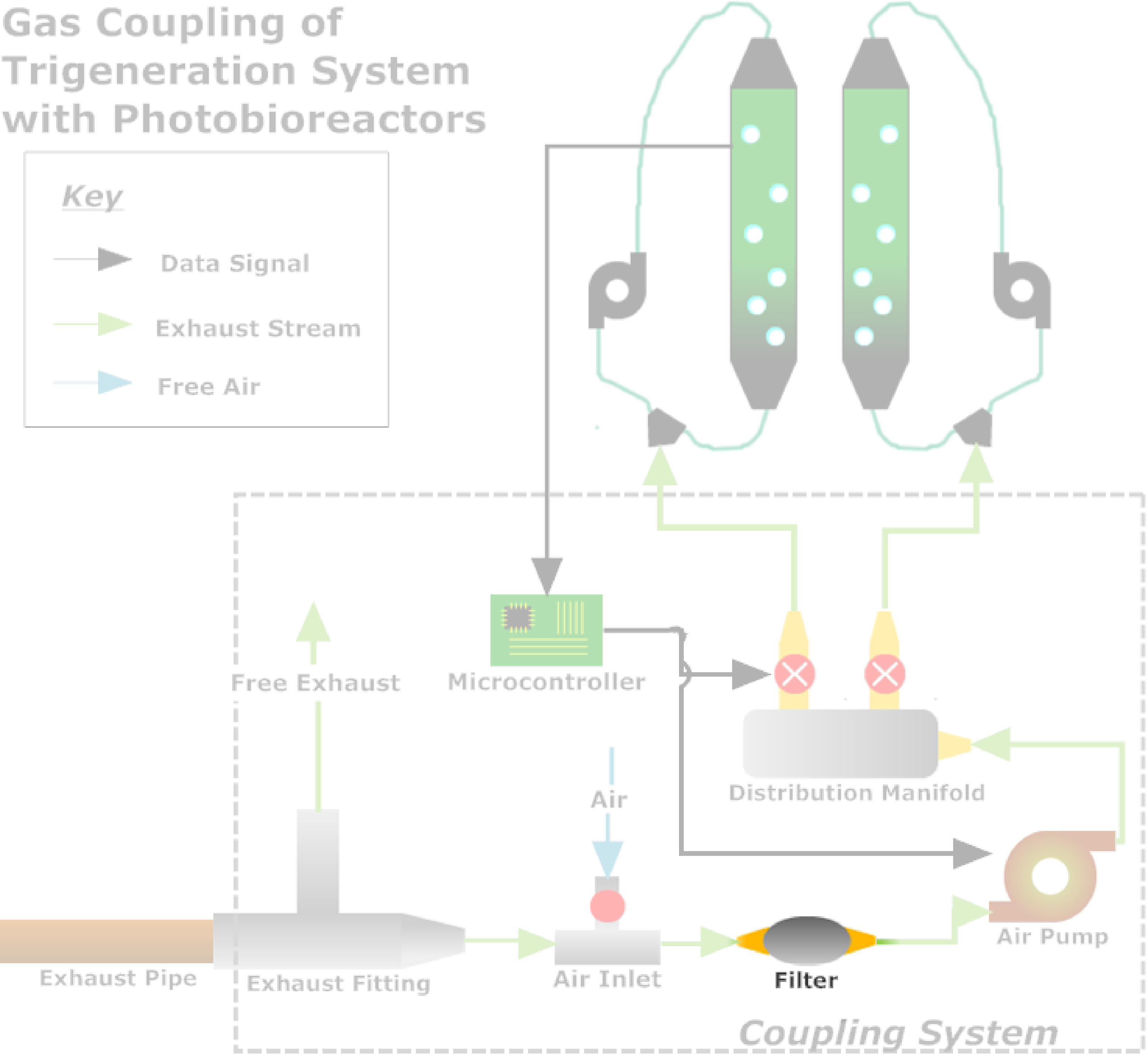


Air Inlet

- Simple PVC T-joint with flow control thumbscrew or ball valve
- Used to control the mixing of exhaust stream with fresh air for optimal growth mixture
- Doubles as an air inlet if engine is not running

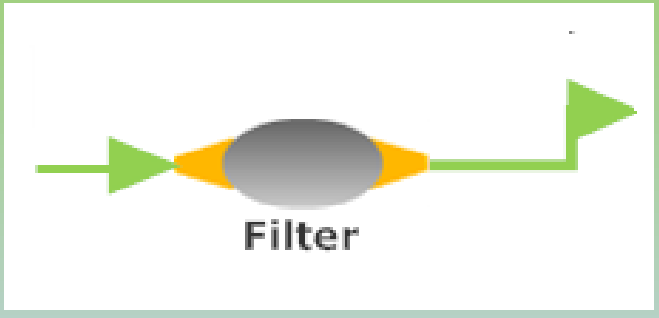


Gas Coupling of Trigeneration System with Photobioreactors

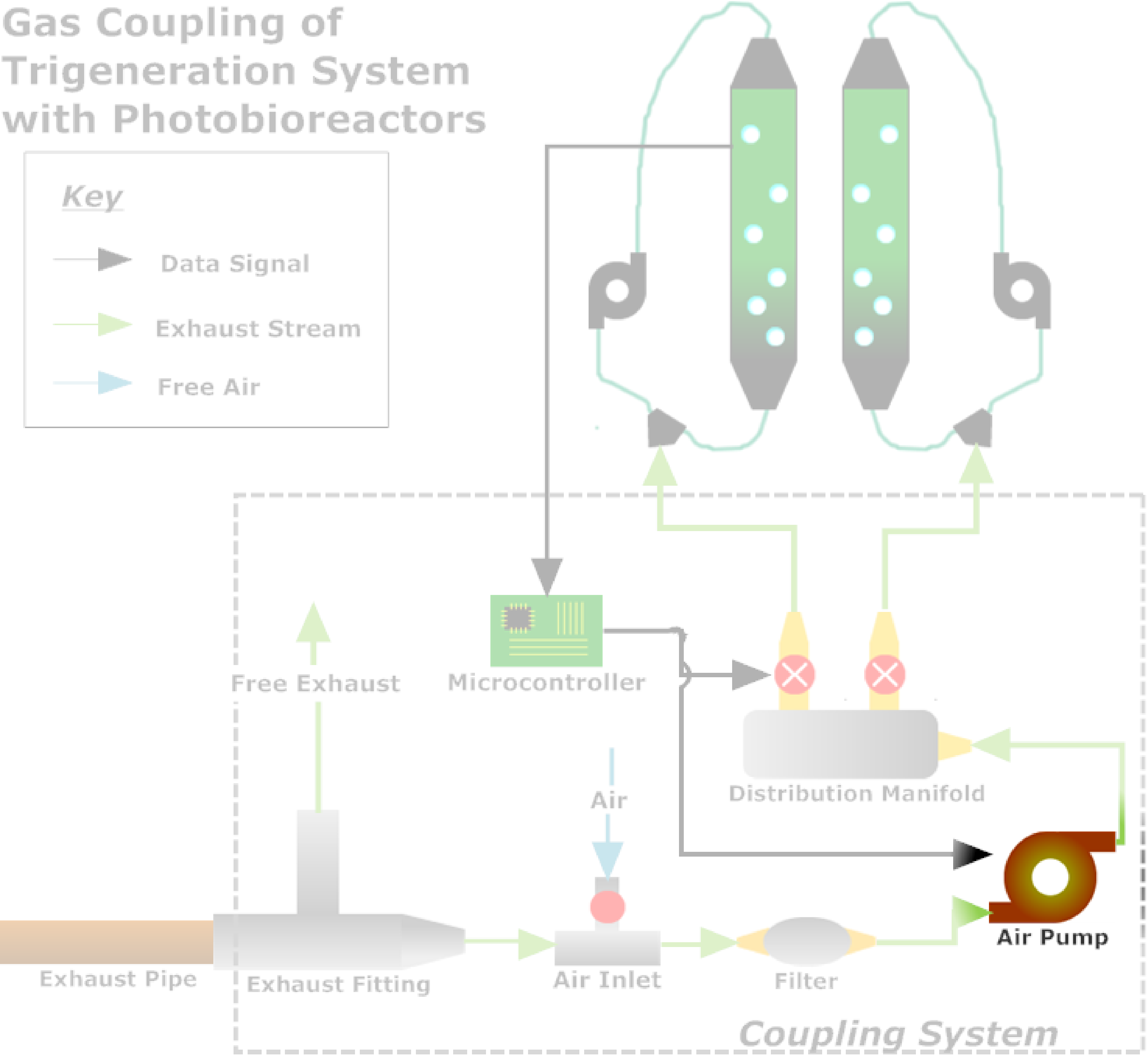


Particle Filter

- Made of threaded PVC piping
- Ends sealed with PVC caps and solvent welded
- Caps are tapped to allow for installation of brass hose barbs
- Filter material can be placed inside piping, and the ends screwed together
- Fiberglass filter medium is inexpensive and very effective



Gas Coupling of Trigeneration System with Photobioreactors



Key

Data Signal

Exhaust Stream

Free Air

Free Exhaust

Microcontroller

Air

Distribution Manifold

Air Pump

Exhaust Pipe

Exhaust Fitting

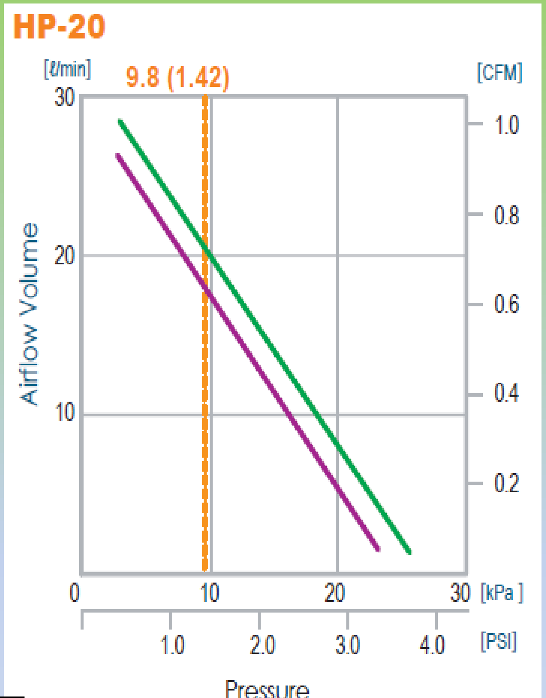
Air Inlet

Filter

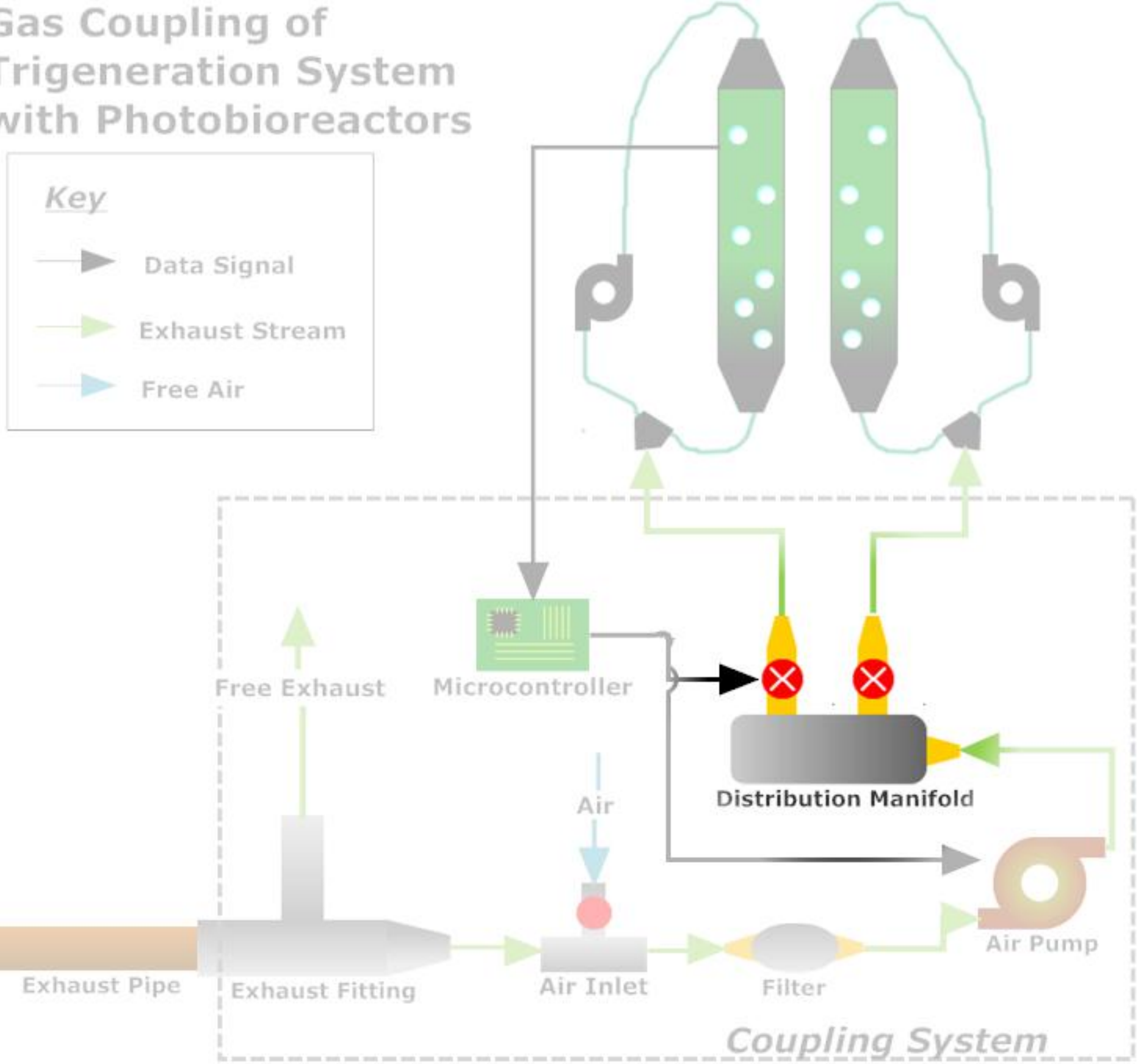
Coupling System

Gas Pump

- Line of high performance air pumps were selected for use
- HIBLOW linear diaphragm blowers capable of great pressure heads and flow rates
- HP-20 model is currently favored; budget will allow for better models if modifications in design ensue
- Continuous operation and low power consumption (17-75 W)
- Runs on 120V AC; can be pulse-width modulated

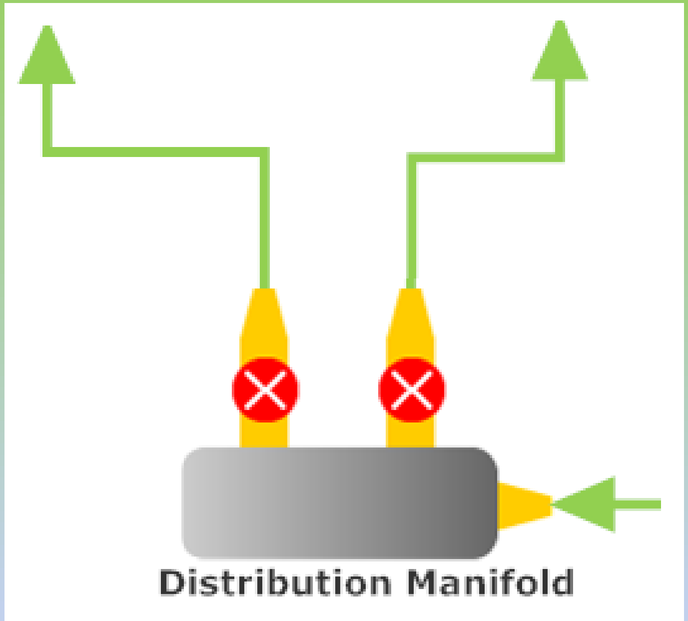


Gas Coupling of Trigeneration System with Photobioreactors

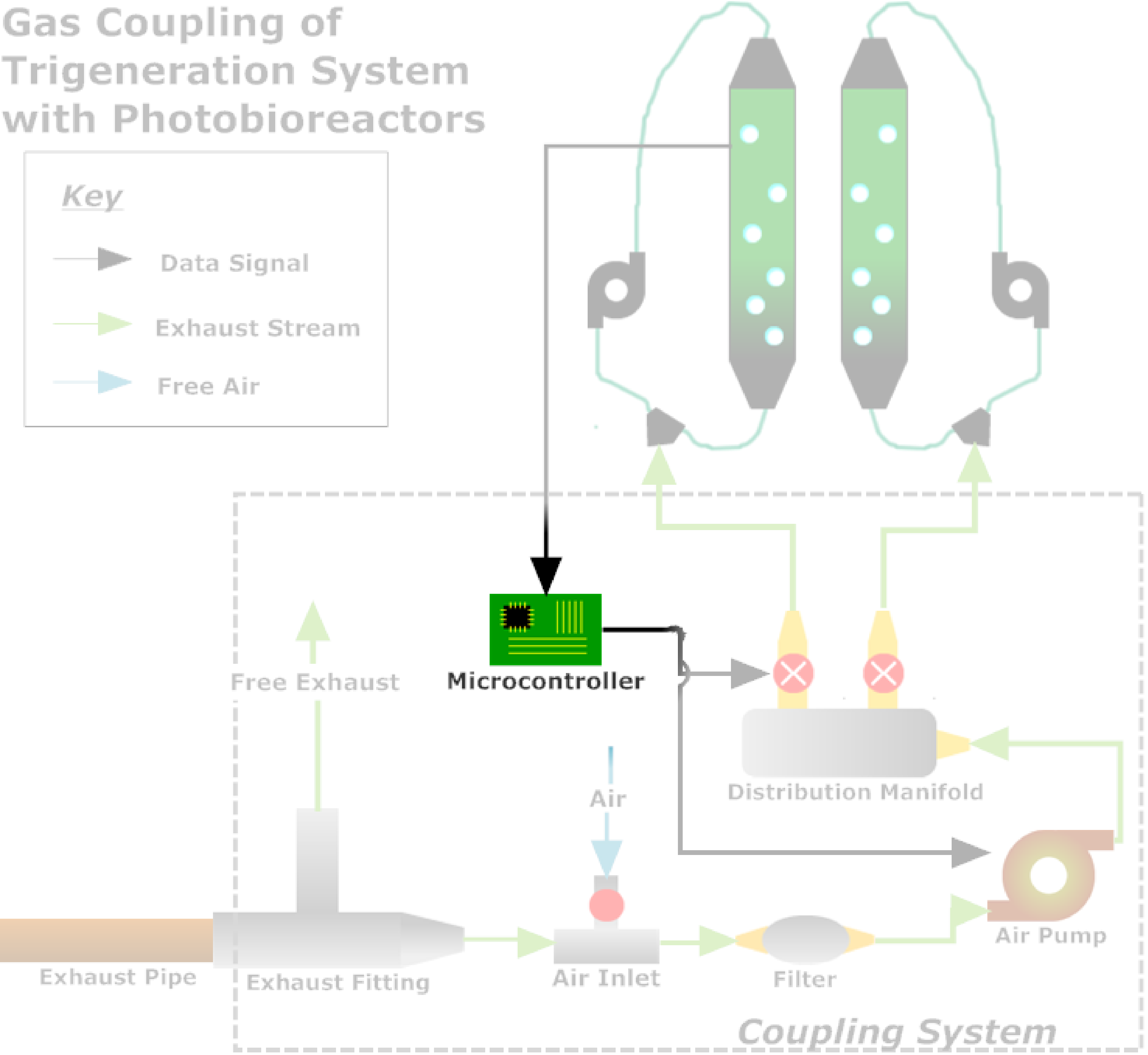


Distribution Manifold

- Distributes exhaust gases between each bioreactor
- Solenoid valves automatically controlled to supply gases to reactors independently
- PVC pipe body
- Ends sealed with prefabricated end caps and solvent welded
- PVC housing will be tapped to fit hose barbs
- Brass hose barbs will allow for easy hose connections



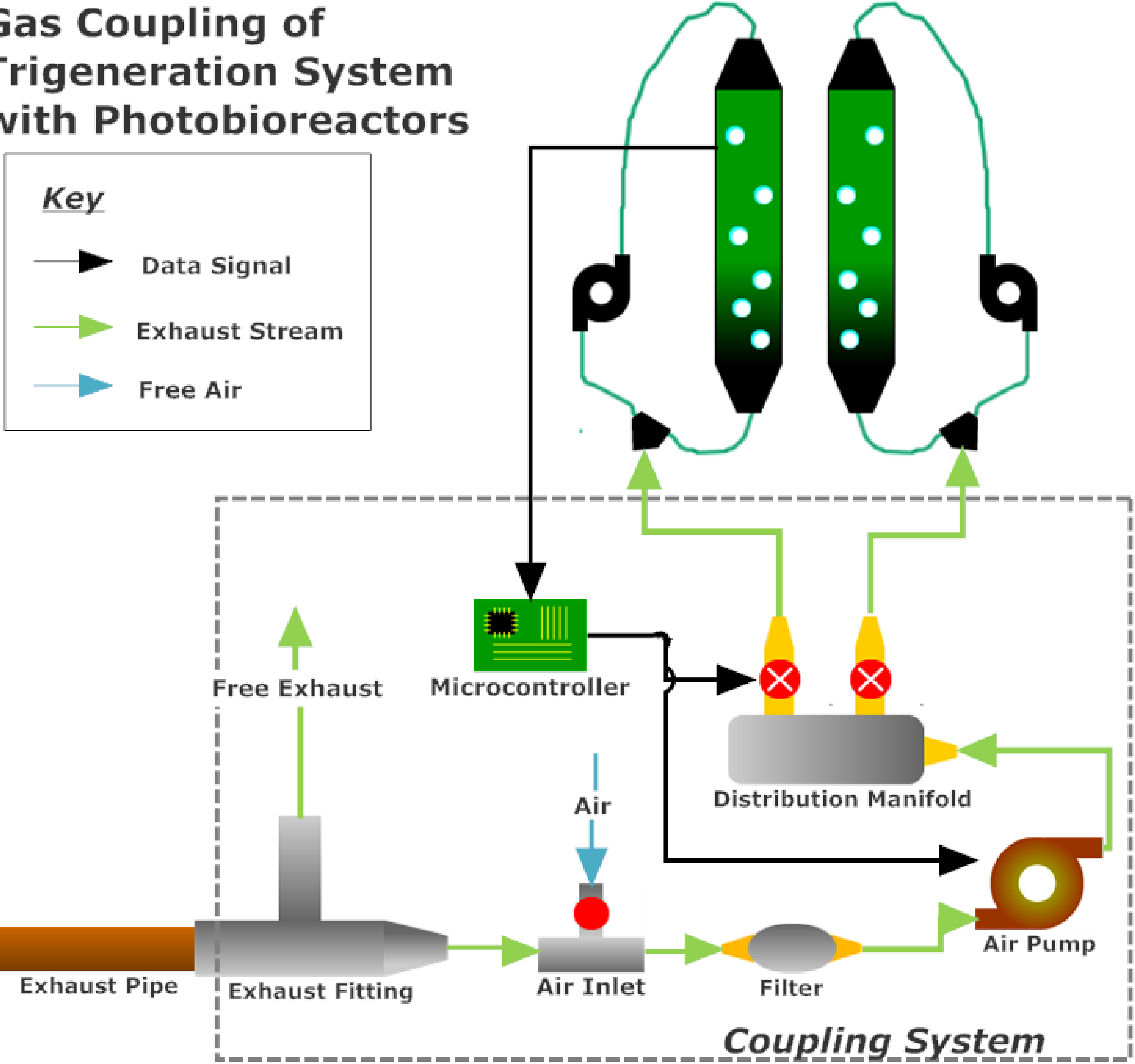
Gas Coupling of Trigeneration System with Photobioreactors



Microcontroller

- Neptune Systems APEX microcontroller; expands up to 240 modules, hundreds of probes, thousands of controlled outlets, detects power failure, 6 digital inputs, plug and play, etc
- Neptune Systems EnergyBar 8; eight independently controlled outlets, soft start to reduce pump wear, built in circuit breaker, solid state switches, current monitoring, etc.
- Other great features
- Plug and play pH probes will be utilized

Gas Coupling of Trigeneration System with Photobioreactors



Potential Issues

Thermal

- The trigeneration system was designed to heat a large quantity of water with a heat exchanger. As a result of the rising temperature of the water, the gas exit temperature will gradually increase with time
- A fresh stream of water may need to be employed to keep the gas exit temperature low enough for use in algae bioreactors
- Any minor thermal effects can be mitigated with the omission of insulation and the addition of finned piping

Biological

- Although it has been experimentally determined that direct feeding of exhaust gases is suitable for algae, it may be found that certain strains have difficulty developing in the presence of NOx, CO, unreacted hydrocarbons, etc.
- A catalytic converter may need to be employed to mitigate such effects

Chemical

- Corrosion may prove to be more of an issue in practice than anticipated
- Although parts have been designed to be corrosion resistant and replaceable, there may still be difficulty with the pump

Environmental & Safety Concerns

Operation

- Always operate the trigenerator in open, well ventilated areas. The exhaust gases and gasoline fumes are toxic
- Never touch exhaust piping, whether the system is running or not. They may still be hot from operation
- Secure the trigenerator table with wheel locks before operating
- Be aware of fuel lines and electrical wires
- Have a fire extinguisher nearby
- Do not wear long hair down or loose clothing, and keep any body part away from the crank shaft

Transport

- Do not attempt to move the trigenerator by yourself
- Use close-toed footwear for transport. The unit is very heavy and could cause foot injury
- Secure electrical wires and fuel lines before transport
- Secure the fuel tank before transfer to avoid spills

Environment

- Avoid gasoline spills. Gasoline is corrosive and harmful to the environment
- Never dispose of algae by simply pouring it down the drain. Use bleach to kill the culture and prevent it from becoming an invasive organism to your local biome
- Correctly dispose of the battery when necessary

FLORIDA STATE UNIVERSITY 1851

UFPR

Current Budget Breakdown

Item	Quantity	Price	Total
Hiblow USA HP 20 Linear Air Pump 20 lpm @ 1.4 psi 2.5 psi max.	1	$224.95	$224.95
Aquamedic Photobioreactors	2	$80.00	$160.00
McMaster-Carr Brass Solenoid Valve, 120VAC	1	$101.66	$203.33
UTEX Algae agar culture	2	$30.00+ $10.00sh	$80.00
Neptune Systems pH probe, standard	2	$44.99	$89.98
Polyester Air Filter Media Pads Package of 6 - 2'' thick pads	1	$10.85	$10.85
PVC Pipe & fittings (estimate)	-	$60.00	$60.00
Brass hose barbs	6	$1.80	$10.80
		TOTAL:	**$839.91**

Calculations Appendix

Engine: Kawasaki FD501D

Power, Engine Speed, Displacement

$P_E := 16hp$ $\omega_E := 3600rpm$

$V_E := 26.7in^3$

Fuel consumption

$mdot_{gas} := .0004\frac{kg}{s}$ $\rho_{gas} := 720\frac{kg}{m^3}$

$$Vdot_{gas} := \frac{mdot_{gas}}{\rho_{gas}} = 0.528\frac{gal}{hr}$$

Air Consumption

$Vdot_{air} := \omega_E \frac{V_E}{2} = 0.082\frac{m^3}{s}$ $v_{air} := \frac{Vdot_{air}}{.25\pi\, 1in^2} = 162.763\frac{m}{s}$ $\rho_{air} := 1.177\frac{kg}{m^3}$

$C_{cd} := 15.5\%$

ExhaustCO.2 concentration for optimal air/fuel ratio (14.7:1)

$\rho_{cd} := 1.797\frac{kg}{m^3}$

Assumed Density of CO2

$Vdot_{cd} := .155Vdot_{air} = 0.013\frac{m^3}{s}$ $mdot_{cd} := Vdot_{cd} \cdot \rho_{cd} = 0.023\frac{kg}{s}$

$Vdot_{air} = 4.948 \times 10^3 \cdot \frac{L}{min}$

$\mu g := 1gm \cdot 10^{-6}$

$mdot_{reqcd} := 13.61\frac{\mu g}{s}$

Optimal CO2 rate for each bioreactor

$Vdot_{reqair} := \frac{mdot_{reqcd}}{\rho_{cd} \cdot .155} = 2.932 \times 10^{-3} \cdot \frac{L}{min}$

Volumetric Flow of Exhaust Needed for Each Bioreactor

$N_{bio} := \frac{mdot_{cd}}{mdot_{reqcd}} = 1.688 \times 10^6$

Number of small bioreactors this engine could support

$2 \cdot Vdot_{reqair} = 5.864 \times 10^{-3} \cdot \frac{L}{min}$

Volumetric flow for 2 bioreactors

Pumping Requirements - Losses

$\mu_{air} := 2.05\cdot 10^{-5}\,\frac{kg}{m\cdot s}$ At approximately 50°C

$\rho_{air} := 1.06\,\frac{kg}{m^3}$ At approximately 50°C, 50% relative humidity

$d_{tube} := 0.5in = 1.27cm$ An estimate of tube inner diameter (hydrolic diameter) based on current bioreactor setup

$V_{dot} := 2\,\frac{L}{min}$ A (very high) estimate of volumetric flow necessary for bioreactors

$A_{tube} := 0.25\pi\cdot d_{tube}^{\,2} = 1.267\times 10^{-4}\,m^2$ This is the cross-sectional area of the inside of the tube

$Vel := \frac{V_{dot}}{A_{tube}} = 0.263\,\frac{m}{s}$ This is the velocity of the flow

$Re_{flow} := \frac{\rho_{air}\cdot Vel\cdot d_{tube}}{\mu_{air}} = 172.797$ Reynolds number for estimated flow parameters

$\varepsilon_{tube} := 0.0025mm$

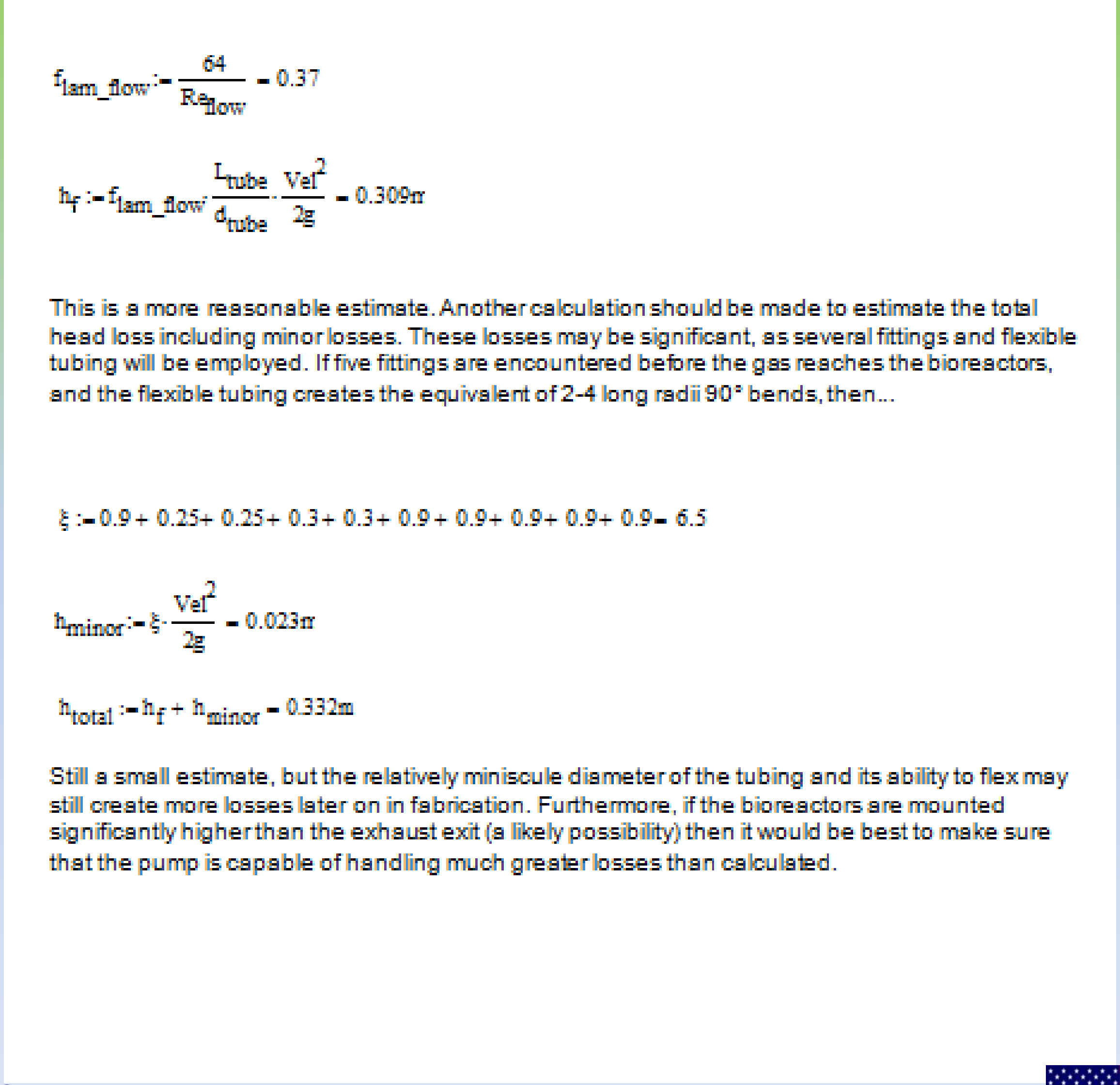
$Roughness_{tube} := \frac{\varepsilon_{tube}}{d_{tube}} = 1.969\times 10^{-4}$

$f := 0.015$ Darcy friction factor found on Moody chart. This is only a rough estimate and assumes turbulent flow!

$L_{tube} := 3m$

$h_f := f\cdot\frac{L_{tube}}{d_{tube}}\cdot\frac{Vel^2}{2g} = 0.013m$ $g = 9.807\,\frac{m}{s^2}$

This is a pretty small estimate. It may be better to assume the pump produces laminar flow



$$f_{lam\_flow} := \frac{64}{Re_{flow}} = 0.37$$

$$h_f := f_{lam\_flow} \cdot \frac{L_{tube}}{d_{tube}} \cdot \frac{Vel^2}{2g} = 0.309\,m$$

This is a more reasonable estimate. Another calculation should be made to estimate the total head loss including minor losses. These losses may be significant, as several fittings and flexible tubing will be employed. If five fittings are encountered before the gas reaches the bioreactors, and the flexible tubing creates the equivalent of 2-4 long radii 90° bends, then...

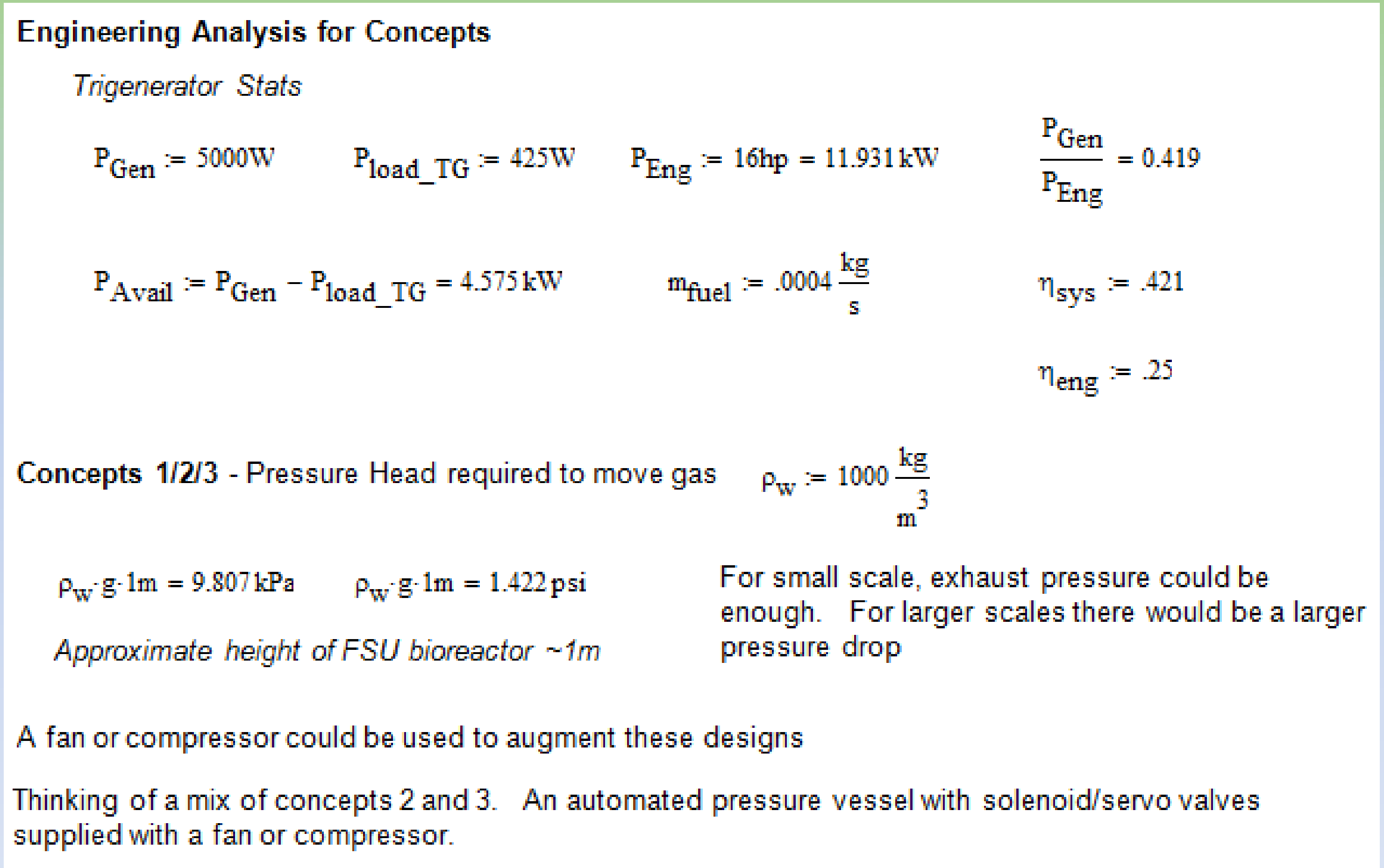
$$\xi := 0.9 + 0.25 + 0.25 + 0.3 + 0.3 + 0.9 + 0.9 + 0.9 + 0.9 + 0.9 = 6.5$$

$$h_{minor} := \xi \cdot \frac{Vel^2}{2g} = 0.023\,m$$

$$h_{total} := h_f + h_{minor} = 0.332\,m$$

Still a small estimate, but the relatively miniscule diameter of the tubing and its ability to flex may still create more losses later on in fabrication. Furthermore, if the bioreactors are mounted significantly higher than the exhaust exit (a likely possibility) then it would be best to make sure that the pump is capable of handling much greater losses than calculated.

Preliminary Calculations



Engineering Analysis for Concepts

Trigenerator Stats

$P_{Gen} := 5000\text{W}$ $\quad P_{load\_TG} := 425\text{W}$ $\quad P_{Eng} := 16\text{hp} = 11.931\text{kW}$ $\quad \dfrac{P_{Gen}}{P_{Eng}} = 0.419$

$P_{Avail} := P_{Gen} - P_{load\_TG} = 4.575\text{kW}$ $\quad m_{fuel} := .0004\dfrac{\text{kg}}{\text{s}}$ $\quad \eta_{sys} := .421$

$\eta_{eng} := .25$

Concepts 1/2/3 - Pressure Head required to move gas $\quad \rho_w := 1000\dfrac{\text{kg}}{\text{m}^3}$

$\rho_w \cdot g \cdot 1\text{m} = 9.807\text{kPa}$ $\quad \rho_w \cdot g \cdot 1\text{m} = 1.422\text{psi}$

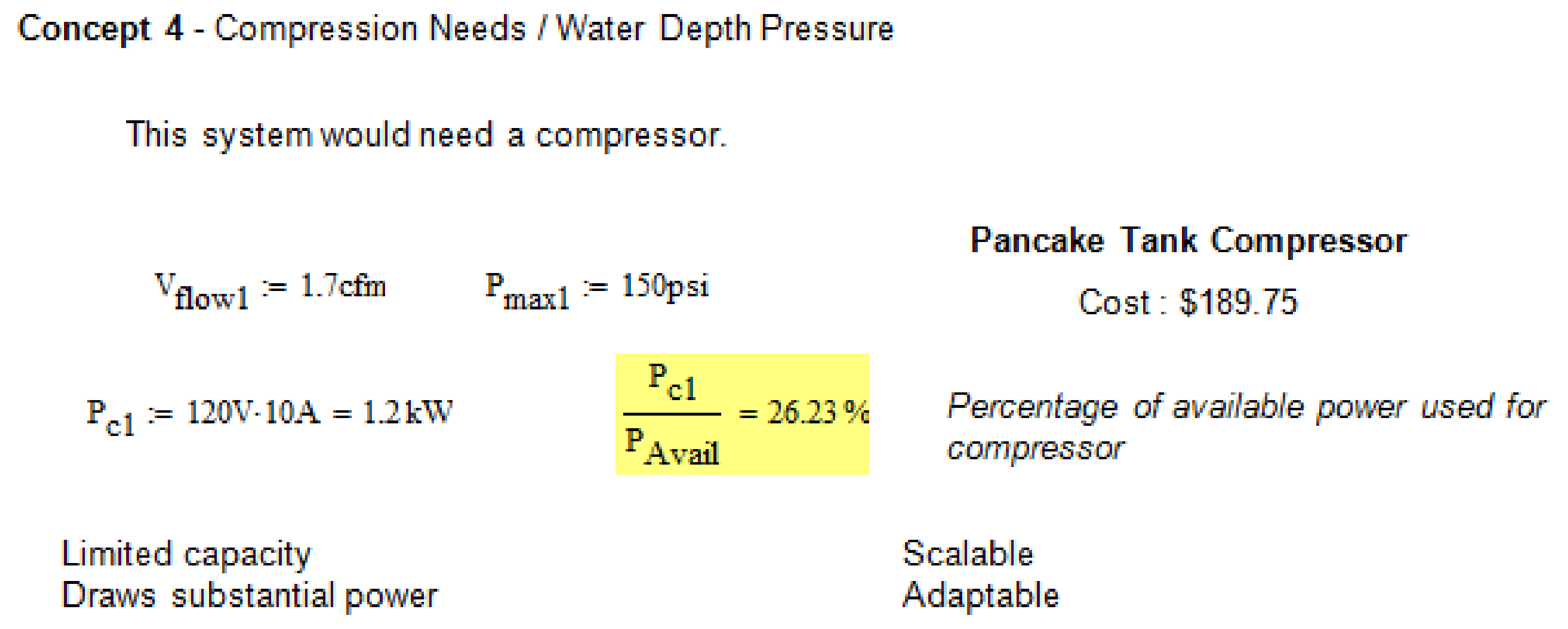
Approximate height of FSU bioreactor ~1m

For small scale, exhaust pressure could be enough. For larger scales there would be a larger pressure drop

A fan or compressor could be used to augment these designs

Thinking of a mix of concepts 2 and 3. An automated pressure vessel with solenoid/servo valves supplied with a fan or compressor.

Preliminary Calculations



Concept 4 - Compression Needs / Water Depth Pressure

This system would need a compressor.

Pancake Tank Compressor

Cost : $189.75

$V_{flow1} := 1.7 cfm$ $P_{max1} := 150 psi$

$P_{c1} := 120V \cdot 10A = 1.2 kW$

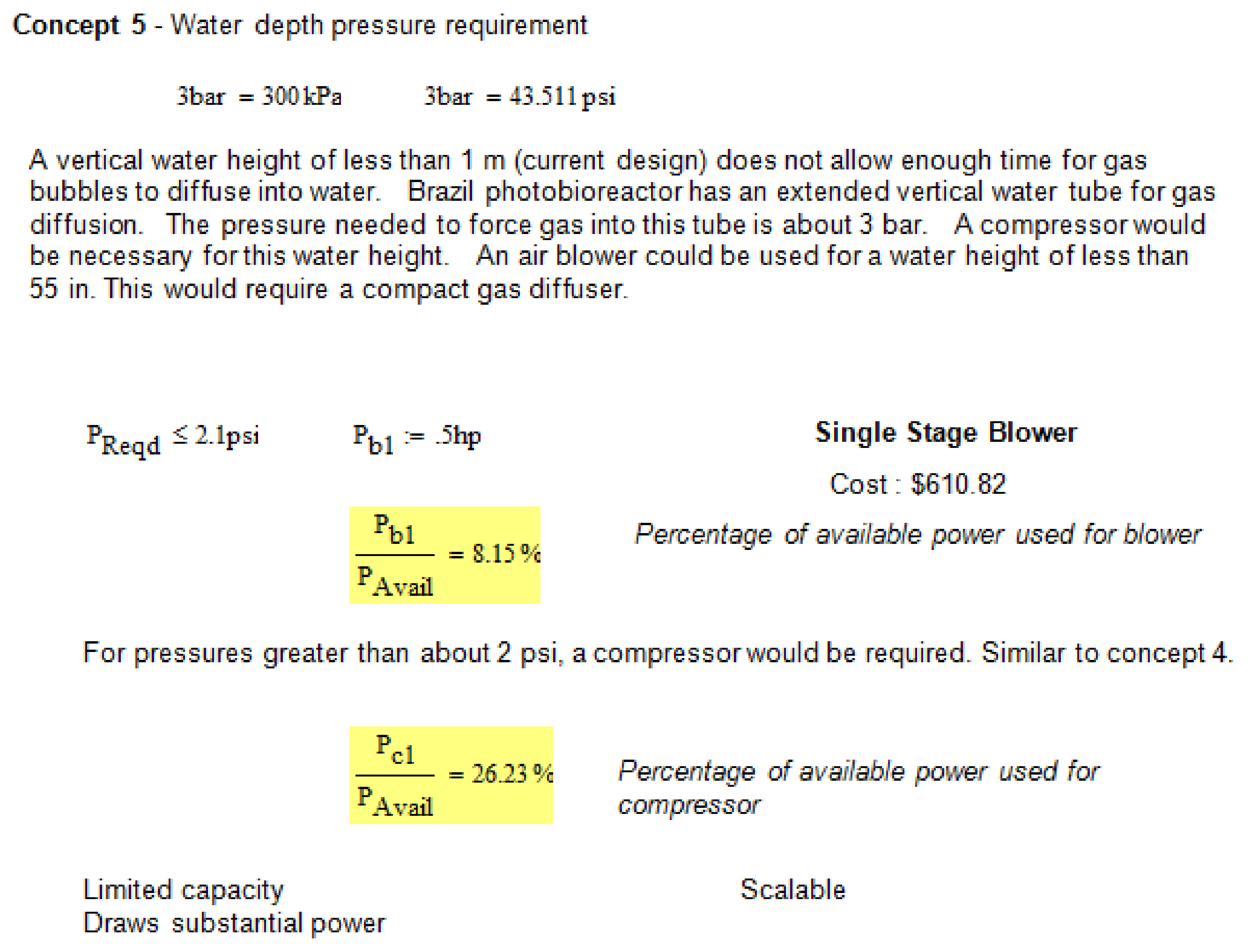
$$\frac{P_{c1}}{P_{Avail}} = 26.23\,\%$$

Percentage of available power used for compressor

Limited capacity
Draws substantial power

Scalable
Adaptable

Preliminary Calculations



Concept 5 - Water depth pressure requirement

$3\text{bar} = 300\,\text{kPa}$ $\qquad$ $3\text{bar} = 43.511\,\text{psi}$

A vertical water height of less than 1 m (current design) does not allow enough time for gas bubbles to diffuse into water. Brazil photobioreactor has an extended vertical water tube for gas diffusion. The pressure needed to force gas into this tube is about 3 bar. A compressor would be necessary for this water height. An air blower could be used for a water height of less than 55 in. This would require a compact gas diffuser.

$P_{Reqd} \le 2.1\text{psi}$ $\qquad$ $P_{b1} := .5\text{hp}$

Single Stage Blower

Cost : $610.82

$$\frac{P_{b1}}{P_{Avail}} = 8.15\,\%$$

Percentage of available power used for blower

For pressures greater than about 2 psi, a compressor would be required. Similar to concept 4.

$$\frac{P_{c1}}{P_{Avail}} = 26.23\,\%$$

Percentage of available power used for compressor

Limited capacity
Draws substantial power

Scalable

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