DESIGN AND DEVELOPMENT OF AN AUTOMATED CONTINUOUS HARVESTING SYSTEM FOR MICROALGAE PHOTOBIOREACTORS

SPRING PROJECT UPDATE

GROUP 9: UFPR - FSU FIPSE TEAM
PRESENTATION DATE: January 19, 2015

PRESENTERS:

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Ben Bazyler

Courtnie Garko

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SPONSOR:

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TEAM 9 – TEAM MEMBER NAMES AND ROLES

- Kaelyn Badura[1] - UFPR Team Lead
- Yuri Lopes[1] - FSU Team Lead
- Ben Bazyler[1] - Finance and Inventory Manager
- Courtnie Garko[1] - Scale and Process Engineer
- Benalle Lemos[2] - Hydraulics Specialist
- Tomas Solano[1] - Lead Mechanical Engineer

[1]Florida State University, Tallahassee, Florida, USA; [2]Federal University of Paraná, Centro - Curitiba, Paraná, Brazil

BACKGROUND

- Currently, there are no viable or scalable methods for automated harvesting of the microalgae.
  - Low efficiency production
  - Low autonomy
- Need for automated and continuous harvesting process.
  - Increased biomass production
  - Reduction in production time

Fig 1. Industry scale microalgae photobioreactor at NPDEAS (UFPR), Curitiba, Brazil.

Presenter: Kaelyn Badura

KEY TECHNICAL CONSIDERATIONS

- This is a fundamentally interdisciplinary project.
- There are five main technical considerations which will direct the evolution of this project, including:
  - Standardization of cultivation.
  - Scalability of design.
  - Logistics of harvesting 1 gram of algal biomass per liter of culture.
  - Optimization of space efficiency.
  - Creation of a minimal to no loss system.

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PROJECT SCOPE

Problem Statement:

Microalgae photobioreactors are very dependent on human interaction and currently there are no viable methods for automated and continuous harvesting of the microalgae. This is unsatisfactory because it limits biomass yield and the potential of microalgae as a large scale biofuel source.

Goal Statement:

“Design of an automated and continuous harvesting system for microalgae for increased biomass production.”

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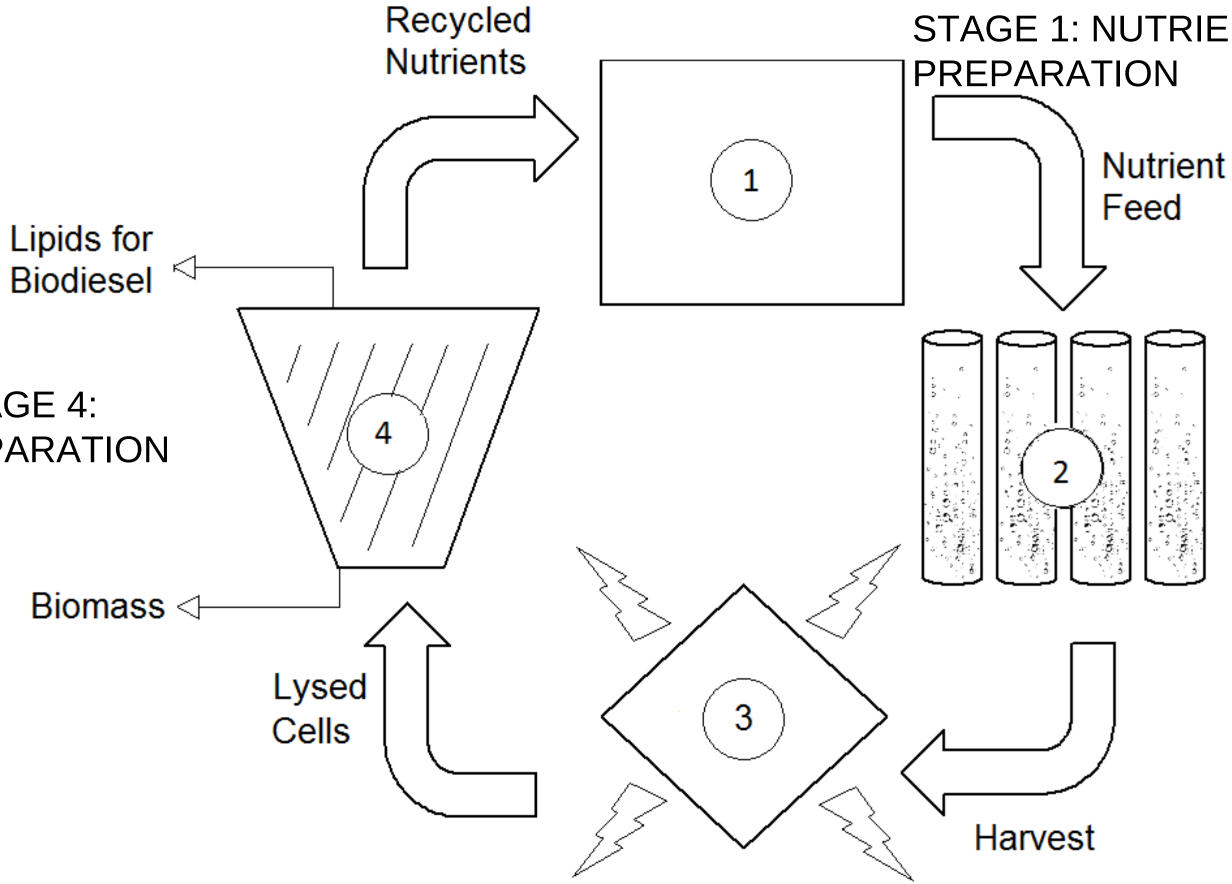
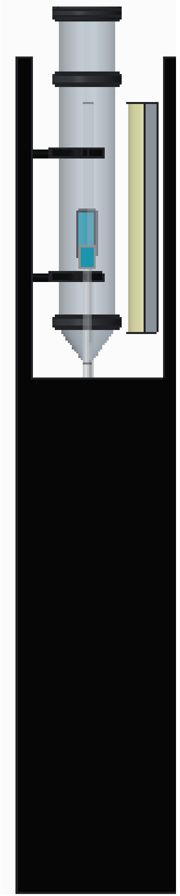
STAGE 1: NUTRIENT PREPARATION

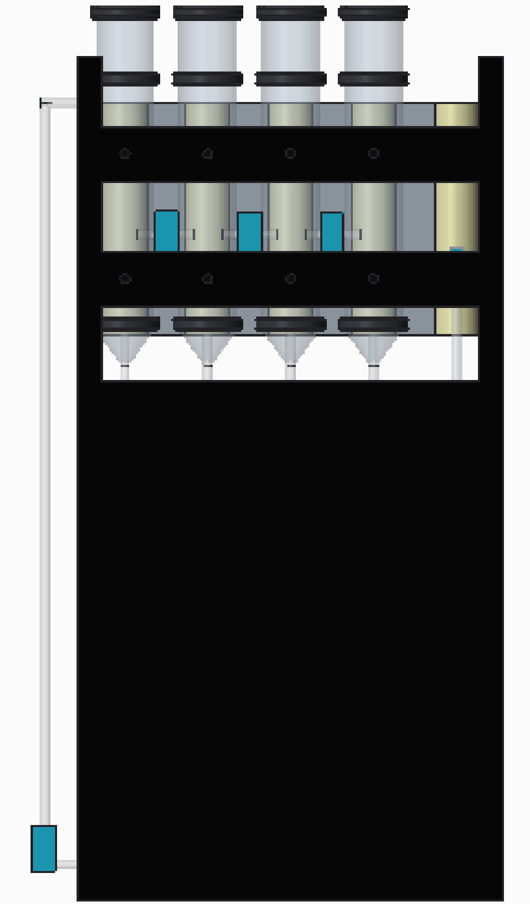
STAGE 2: CULTIVATION

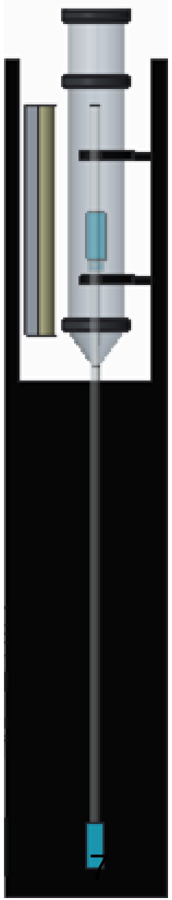
STAGE 4: SEPARATION



STAGE 3: PEF TREATMENT







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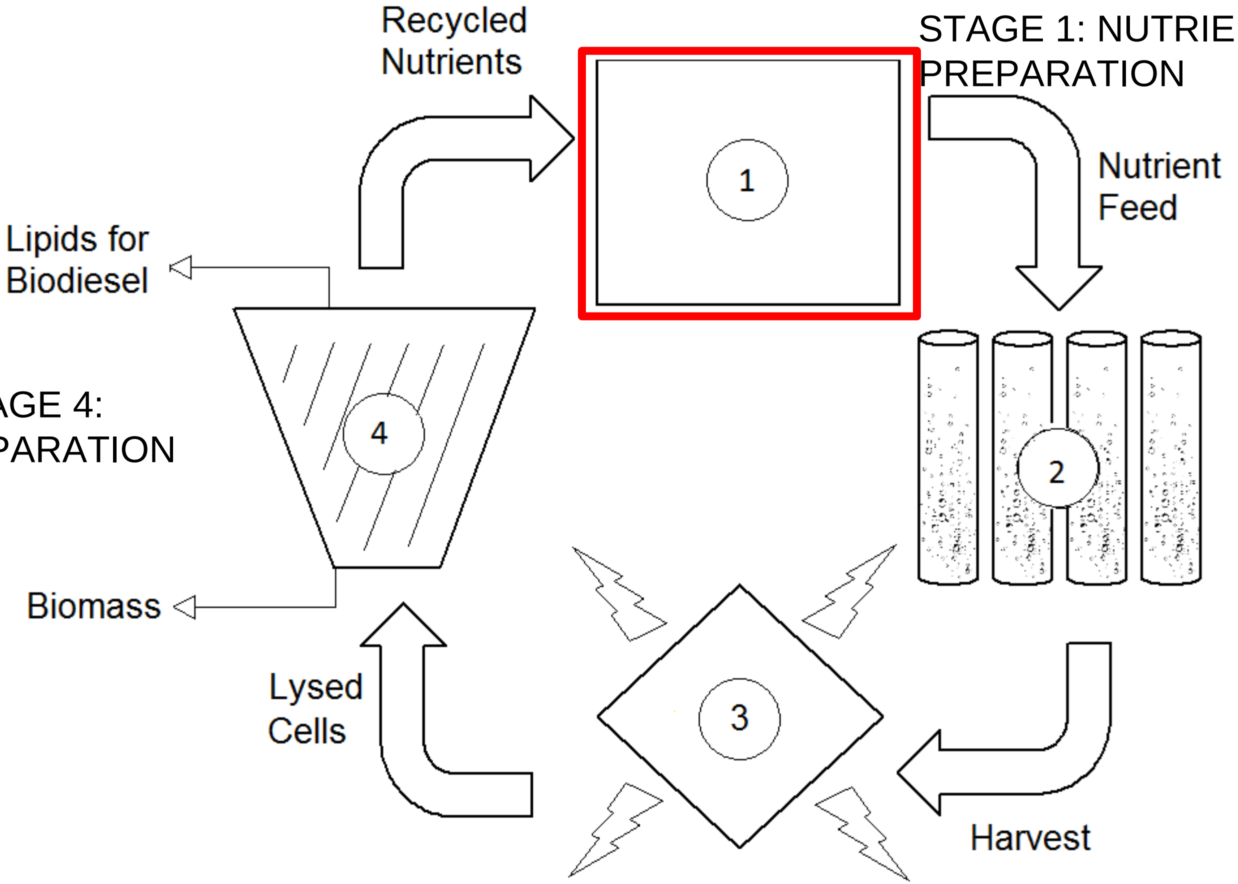

STAGE 3: PEF TREATMENT

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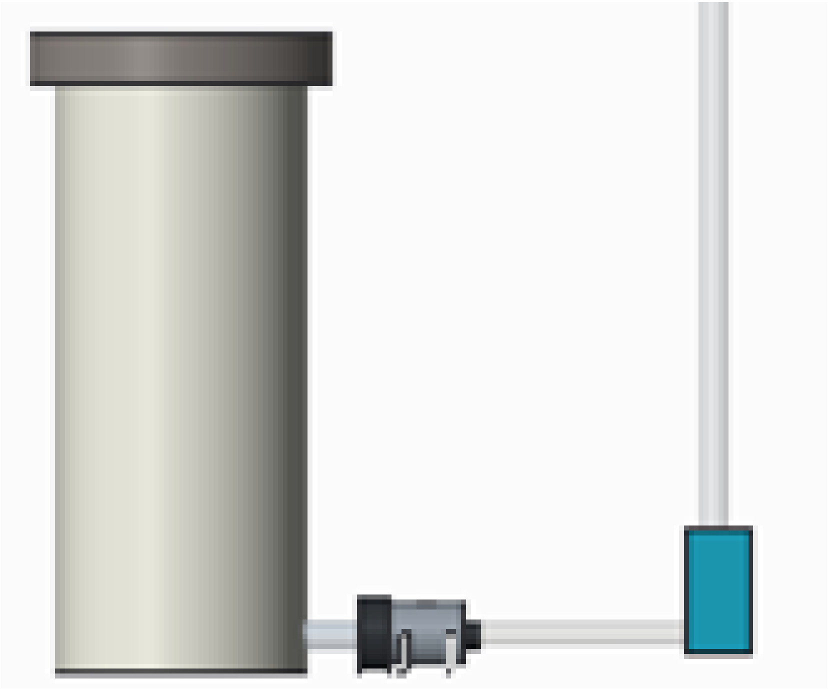

Fig 2. Nutrient preparation stage,

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NUTRIENT PREPARATION UPDATES

- Nutrients needs vary.
- Pre-prepared nutrient is held in a container.
- Exact volume removed from the cultivation unit is replaced by nutrients

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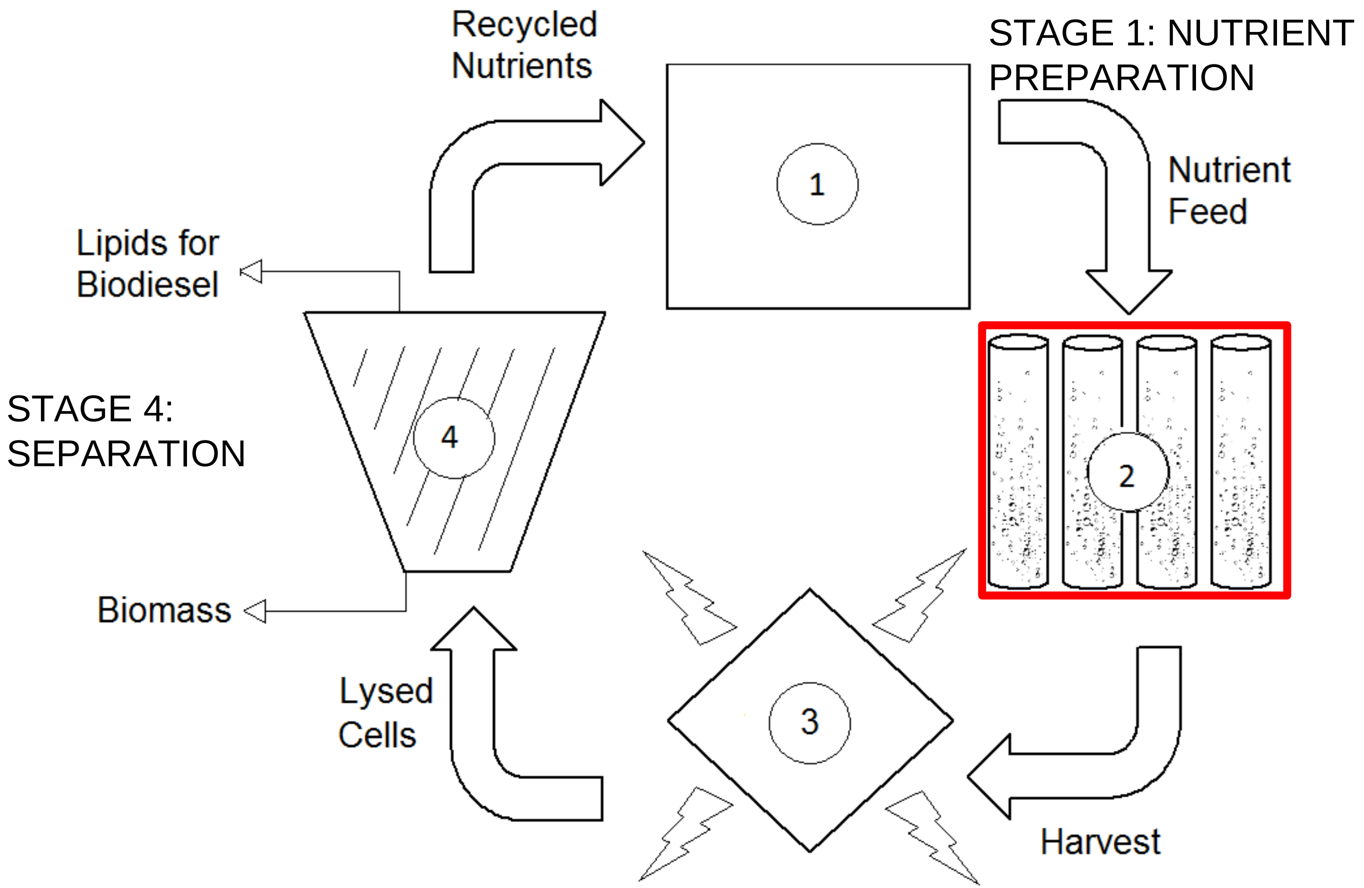

STAGE 3: PEF

Presenter: Courtnie Garko

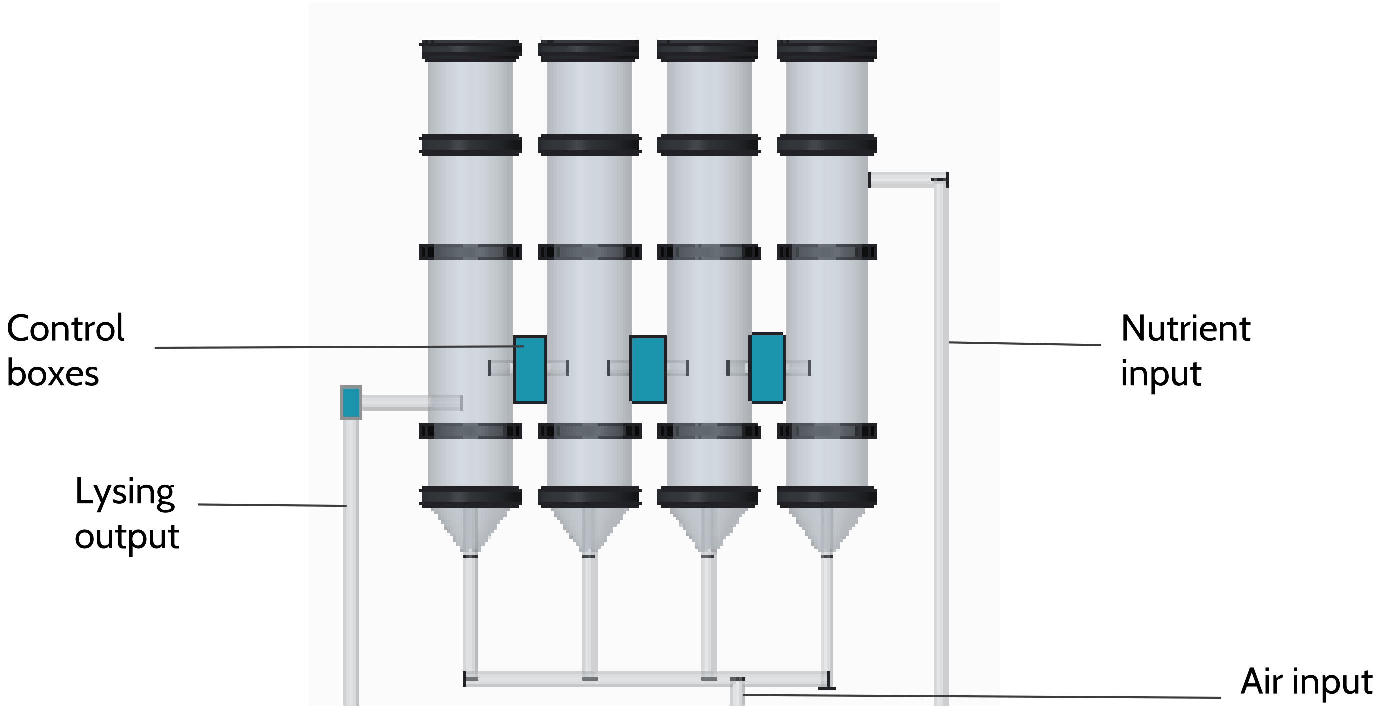

Fig 3. Cultivation stage,

Presenter: Courtnie Garko

CULTIVATION STAGE UPDATES AND PROGRESS-CONTAINERS

- Closed cultivation system; Airlift
  - More reliable culture condition control
  - More compact and portable
  - Carbon source (air) continuously pumped through the bottom
  - Varying growth stages developing simultaneously
- Lab scale system
  - Under 2 m^3 and volume of 8 L
- Large Scale System
  - ~100 L photobioreactor

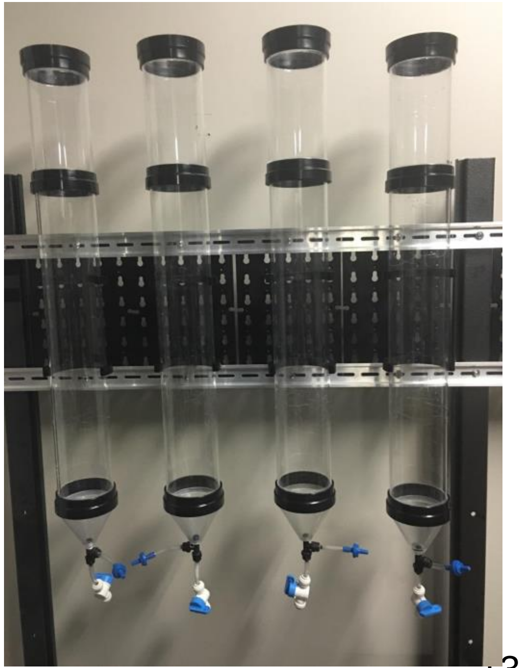

Fig 4. Lab scale airlift being developed at FSU

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CULTIVATION STAGE UPDATES AND PROGRESS-CONTAINERS

- Lab scale system: Airlift
  - Remaining components are scheduled for purchase on 1/19/16.
  - Building is scheduled to finish by 1/27/16.

- Pilot scale system: Mini-Photobioreactor
  - Leaks have been identified.
  - Pump is being replaced.

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CULTIVATION STAGE UPDATES AND PROGRESS-AUTOMATION

Two main automation types:

- LED light sensor will be used to determine if algae has reached appropriate cellular density for extraction.
- Pump and solenoid valve synchronization through micro-controller to maintain system's constant volume.

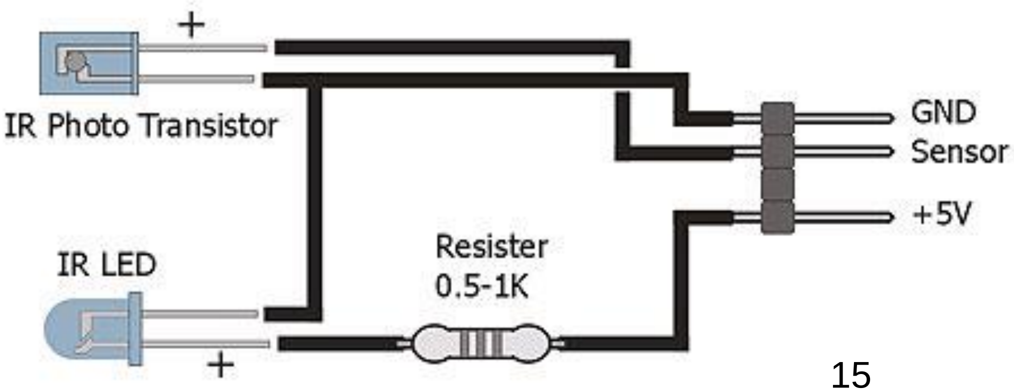

Fig 5. IR/LED Pairing

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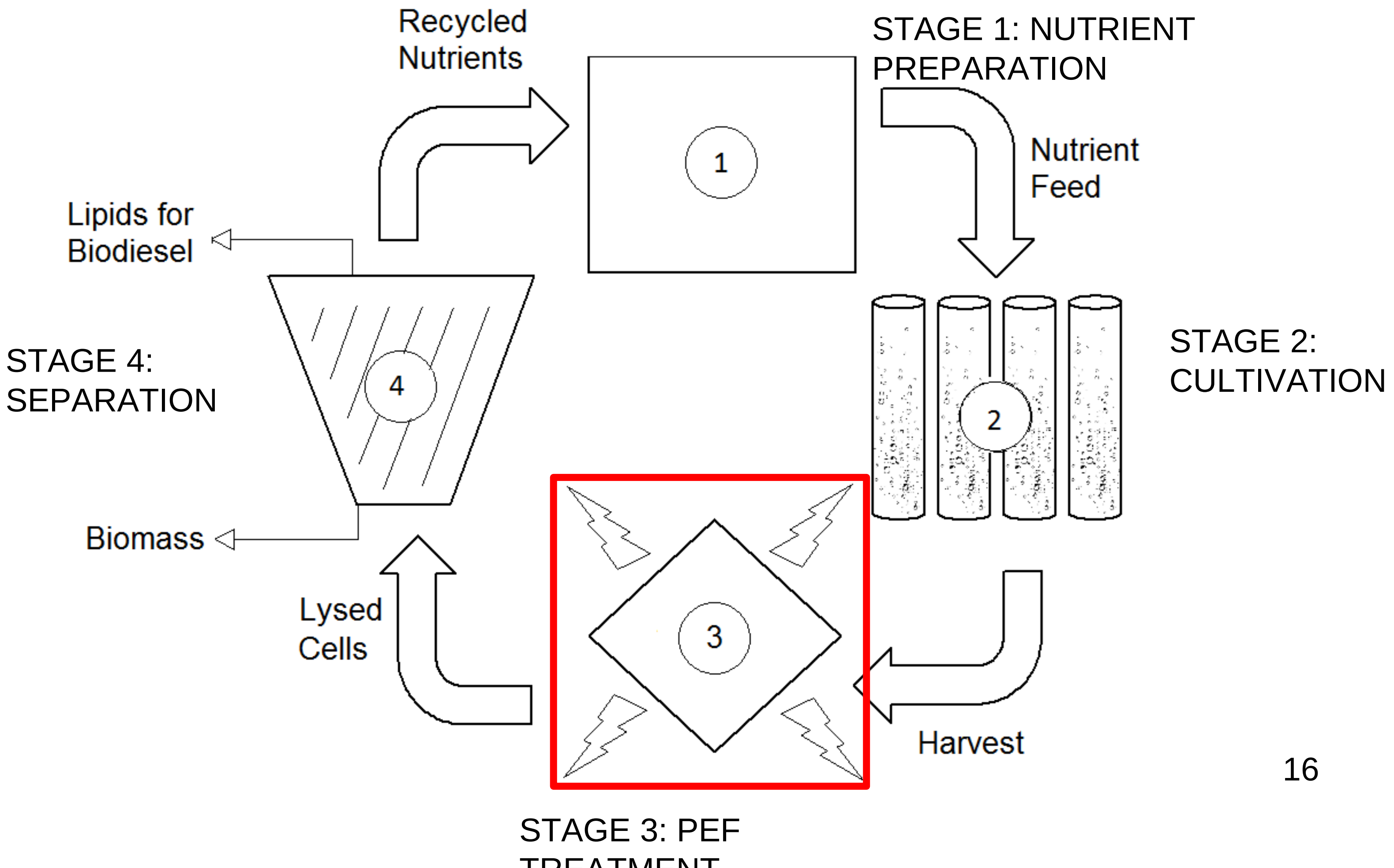
Recycled
Nutrients
STAGE 1: NUTRIENT
PREPARATION
1
Nutrient
Feed
Lipids for
Biodiesel
STAGE 4:
SEPARATION
4
STAGE 2:
CULTIVATION
2
Biomass
Lysed
Cells
3
Harvest
STAGE 3: PEF
TREATMENT

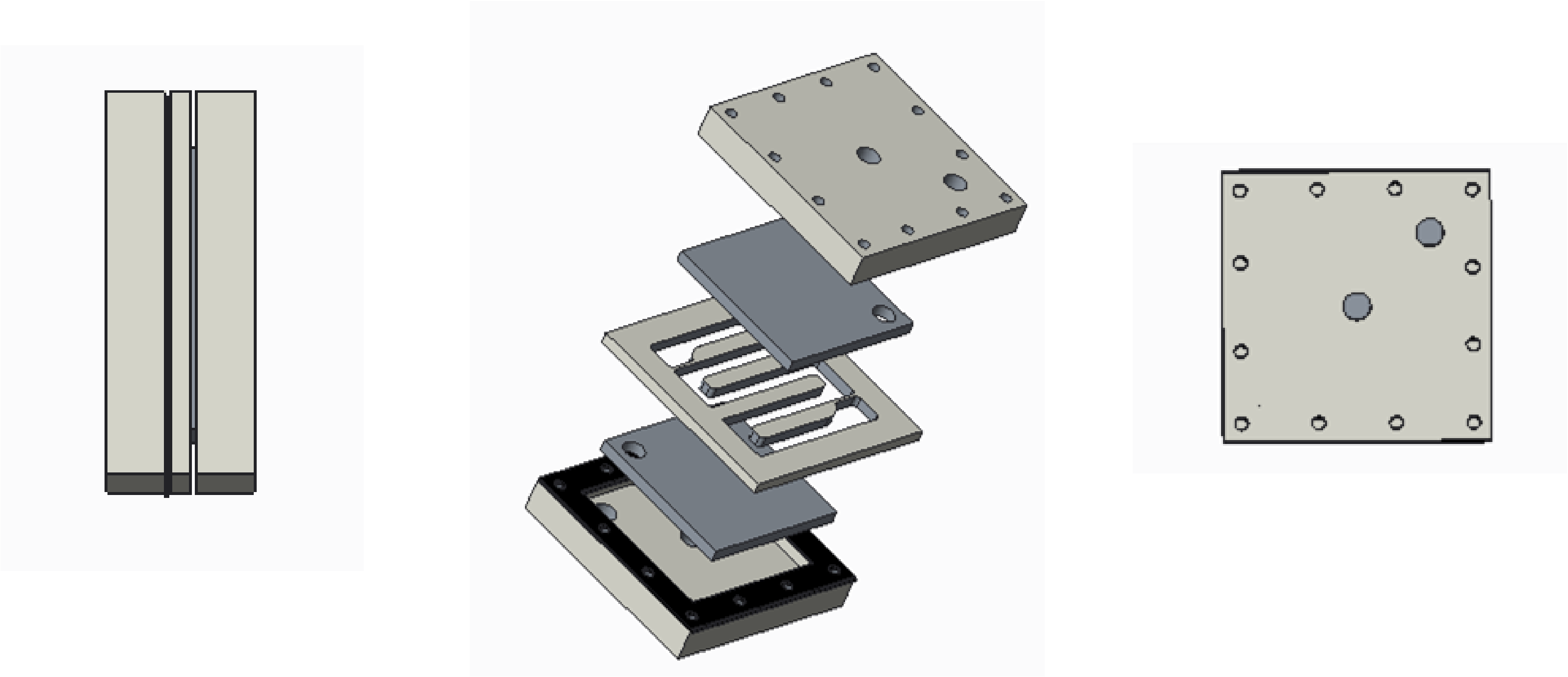

Fig 6. PEF lysis apparatus

BACKGROUND INFORMATION - ELECTRIC SEPARATION

- Pulsed Electric Field Lysis (PEF Lysis)
  - Algae cell lysis; oil extraction and biomass flocculation
  - Pulsed electric fields cause irreversible cell poration, eventually cell wall degradation
  - Reduce post-processing of biomass

Fig 7. Pulsed Electric Field Process.

Presenter: Benjamin Bazyler

PULSED ELECTRIC FIELD LYSING

- Requires low energy expenditure.
- Frequency and voltage determine total energy supplied for cell rupture.
- Low voltage source is stepped up to high voltage needed.

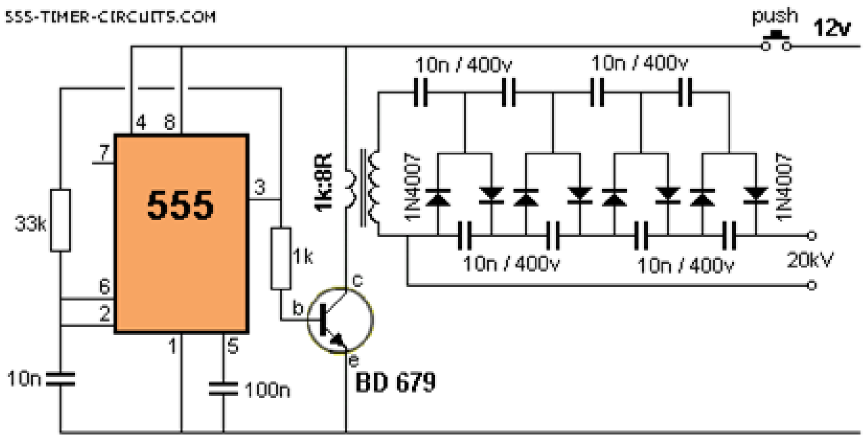

Fig 8. System schematic of pulsed electric field lysis.

Presenter: Benjamin Bazyler

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PULSED ELECTRIC FIELD LYSING

- Lysing the algae cells will cause the oil and organelles to leak out.
- Oil extraction and biomass sedimentation become one process.
- Removes the additional need for centrifugation and manual or chemical oil extraction process after flocculation.

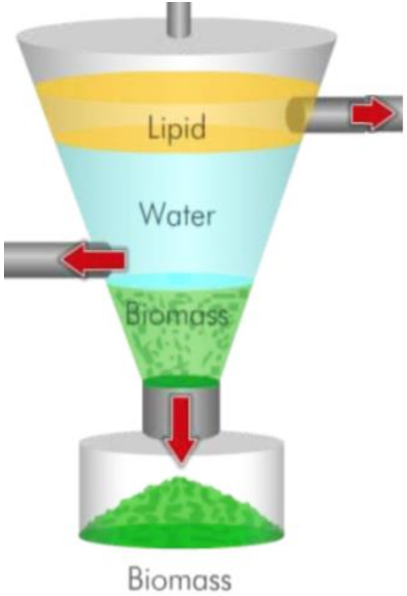

Fig 9. Visual representation of intended results of pulsed electric field lysis.

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Presenter: Benjamin Bazyler

AUTOMATION OF PEF LYSIS

- Frequency and voltage depend on algae species.
- A mathematical model will be used to predict the behavior of the PEF lysing component in order to control its output.
- A micro-controller will control the output pump.

Presenter: Benjamin Bazyler

SEPARATION UPDATES AND PROGRESS

- Prototype circuit has been built and is functional.
  - Currently working to accurately measure output voltage.
  - 555 timing chip → arduino
- Lysis chamber has been constructed.
  - Modify single channel → serpentine channel.

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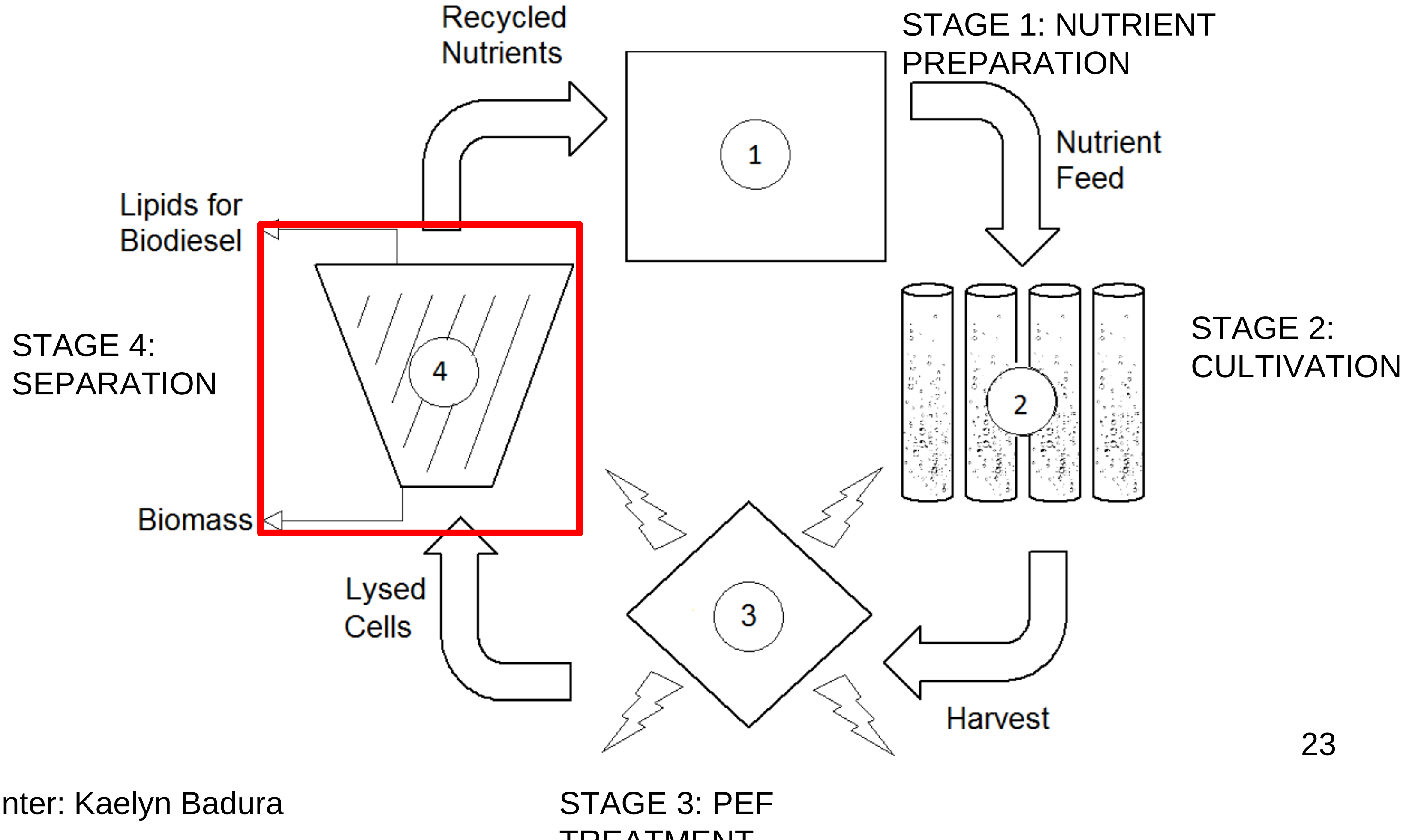
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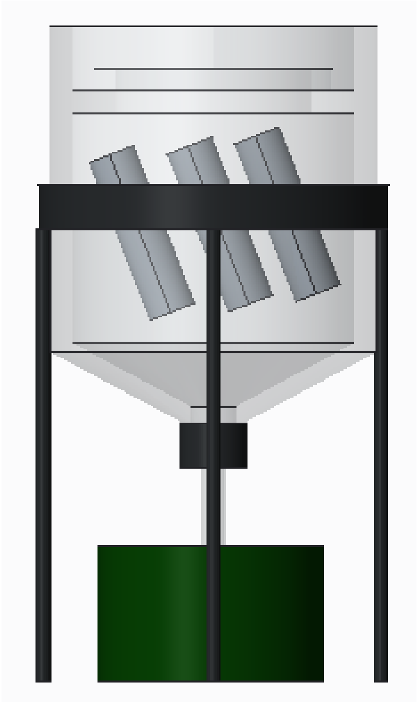
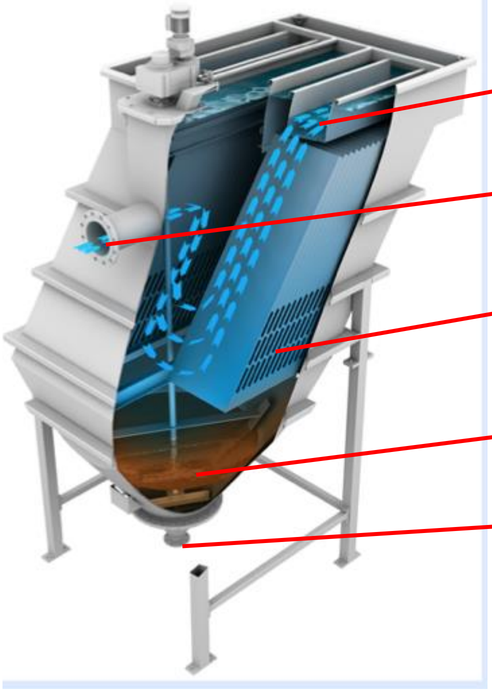


Fig 10. Modified lamella clarifier.



Dam - discharge outlet of the clarified medium

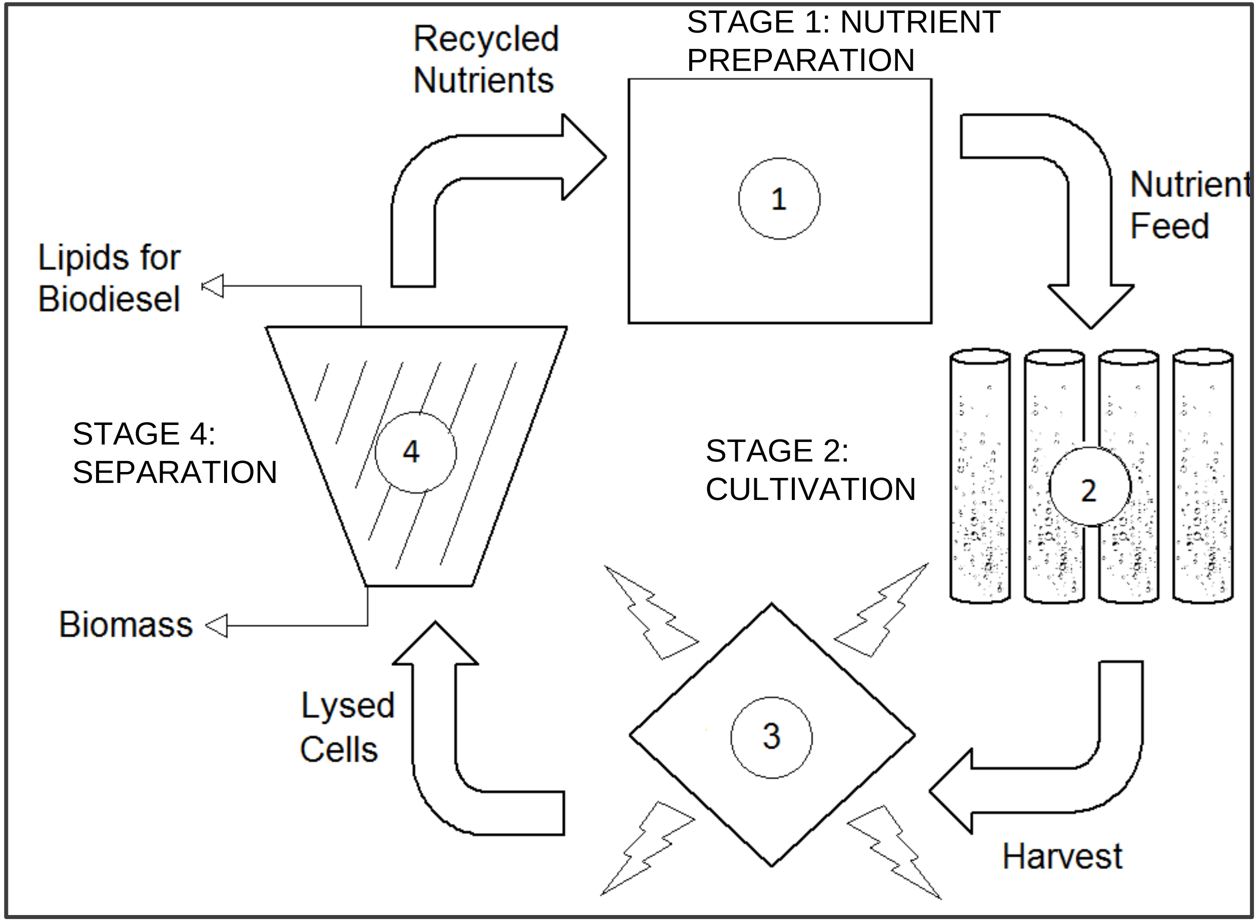
Entry - From flocculation stage

Lamellas - corrugated to increase surface area

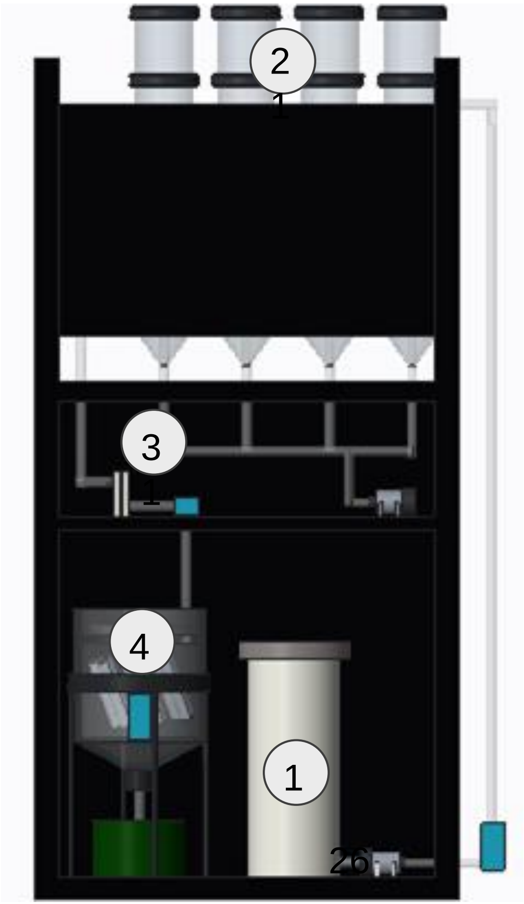
Sludge Blanket

Extraction / dehydration - modified peristaltic pump

Fig 11. Representation of a basic lamella separator.



STAGE 3: PEF TREATMENT



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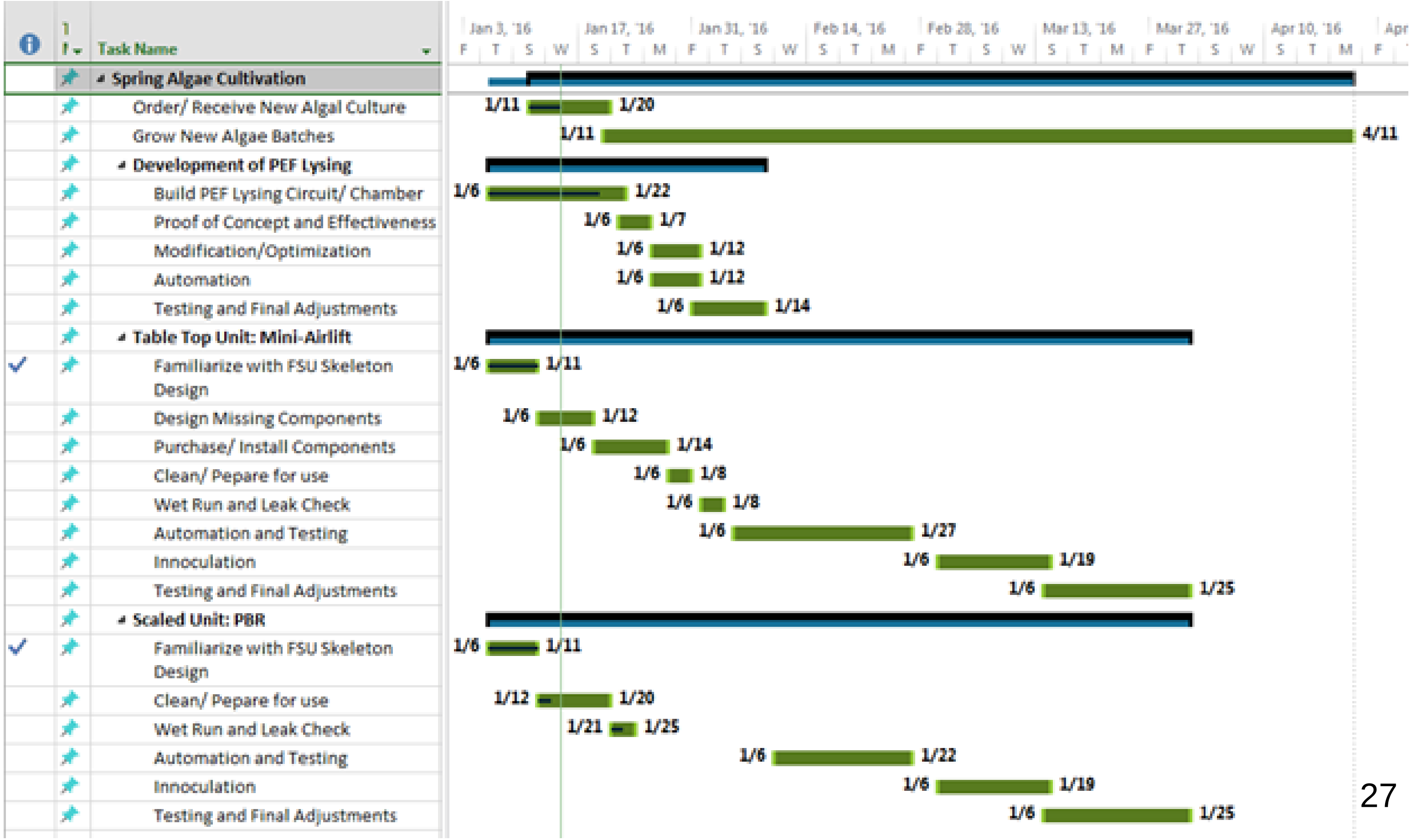

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Fig 12. Updated Spring 2016 gantt chart.

Task	Start	Duration	End
Problem Defintion Through Concept Design	**8/3**	***150***	**1/1**
Spring Algae Cultivation	**1/11**	***100***	**4/20**
Order/Receive New Algal Culture	1/11	*9*	1/20
Grow Algae Batches	1/20	*91*	4/20
Development of PEF Lysing	**1/6**	***33***	**2/8**
Build PEF Lysing Circuit/ Chamber	1/6	*16*	1/22
Proof of Concept and Effectiveness	1/22	*3*	1/25
Modification/Optimization	1/26	*5*	1/31
Automation	1/26	*5*	1/31
Testing and Final Adjustments	1/31	*8*	2/8
Table Top Unit: Mini-Airlift	**1/6**	***85***	**3/31**
Familiarize with FSU Skeleton Design	1/6	*5*	1/11
Design Missing Components	1/12	*6*	1/18
Purchase/ Install Components	1/19	*8*	1/27
Clean/ Pepare for use	1/28	*2*	1/30
Wet Run and Leak Check	2/1	*2*	2/3
Automation and Testing	2/5	*21*	2/26
Innoculation	3/1	*13*	3/14
Testing and Final Adjustments	3/14	*17*	3/31
Scaled Unit: PBR	**1/6**	***85***	**3/31**
Familiarize with FSU Skeleton Design	1/6	*5*	1/11
Clean/ Pepare for use	1/12	*8*	1/20
Wet Run and Leak Check	1/21	*2*	1/23
Automation and Testing	2/10	*16*	2/26
Innoculation	3/1	*13*	3/14
Testing and Final Adjustments	3/14	*17*	3/31

Fig 13. Updated Spring 2016 schedule.

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CONCLUDING REMARKS

Cultivation: 75% Complete

- New cultivation component has been designed and is being constructed

Separation: 60% Complete

- PEF Lysis circuit is being modified for usage with an Arduino microcontroller.
- Lysis chamber is being optimized to allow for longer PEF treatment time.

System Automation: 10% complete

- Sensors have been designed and components ordered.
- Sensors are undergoing calibration.

Extraction: 10%

- Proposed design component has not been revised.

Presenter: Kaelyn Badura

APPENDIX

MATHEMATICAL MODEL AND EXPERIMENTS FOR PEF LYSIS DESIGN

- In order to design a continuous PEF lysing system a model must be created which simulates the lysis behavior based on mass flow rate, and energy consumption.

- Lysis efficiency should be equal to that of chemical flocculation, around 92-96%.

EXPERIMENTAL VALIDATION

- Several experiments will be conducted to validate the model.
  - Efficiency, feasibility etc.
- Equivalent jar test for settling velocity to ensure proper clarifier dimensionalizing.
- The frequency, mass flow rate and electric field strength predict lysing efficiency and response time

ASSUMPTIONS

Mathematical Model Assumptions

- A lysed cell by definition is half of a whole original cell.
  - 2 lysed cells = 1 whole original cell
- Uniform properties in the medium and homogenous reaction.