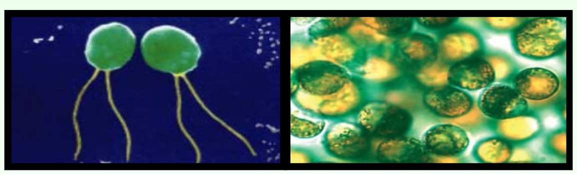
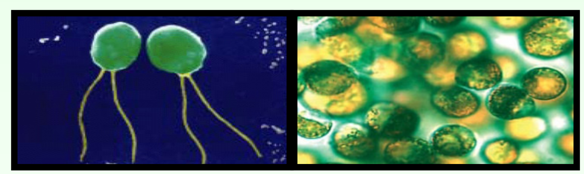
Algae-to-energy systems: The concept, plans, and demonstration of sustainable renewable energy production

MARCH 2011



A. Keith Cowan



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OVERVIEW & CONTENTS

- Why microalgae?
- Algae-to-energy: The Concept
- Algae-to-energy process technologies
- Microalgae bioprocess technology segments
- Technology constraints and net energy yield
- Industry plans and demonstrations
- Demonstrating sustainable renewable energy supply
- Concluding comments
- Q & A

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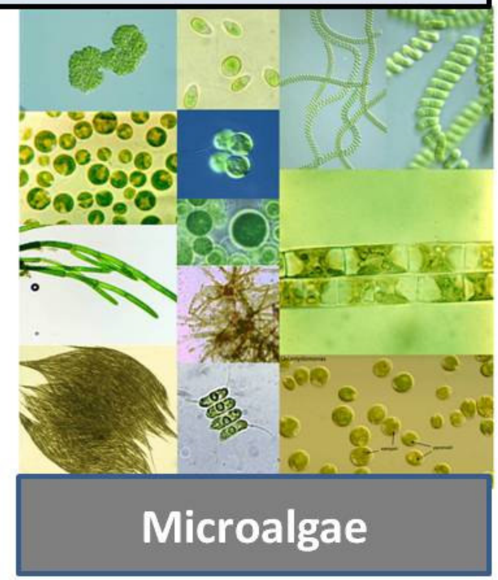
ALGAE-TO-ENERGY: THE OPPORTUNITY

First generation biofuels to……………………………………….Second or Third



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WHY MICROALGAE?

- Can be grown on non-arable land
- Oil yields from algae are much higher than from other biodiesel crops
- Capable of fixing CO_2 to reduce GHG emissions
- Algae biofuel is non-toxic, contains little or no sulphur and is readily biodegradable
- Can be used as general biofuel feedstock (e.g. MeOH, EtOH, CH_4, H_2, other hydrocarbons
- Can be integrated into a biorefinery

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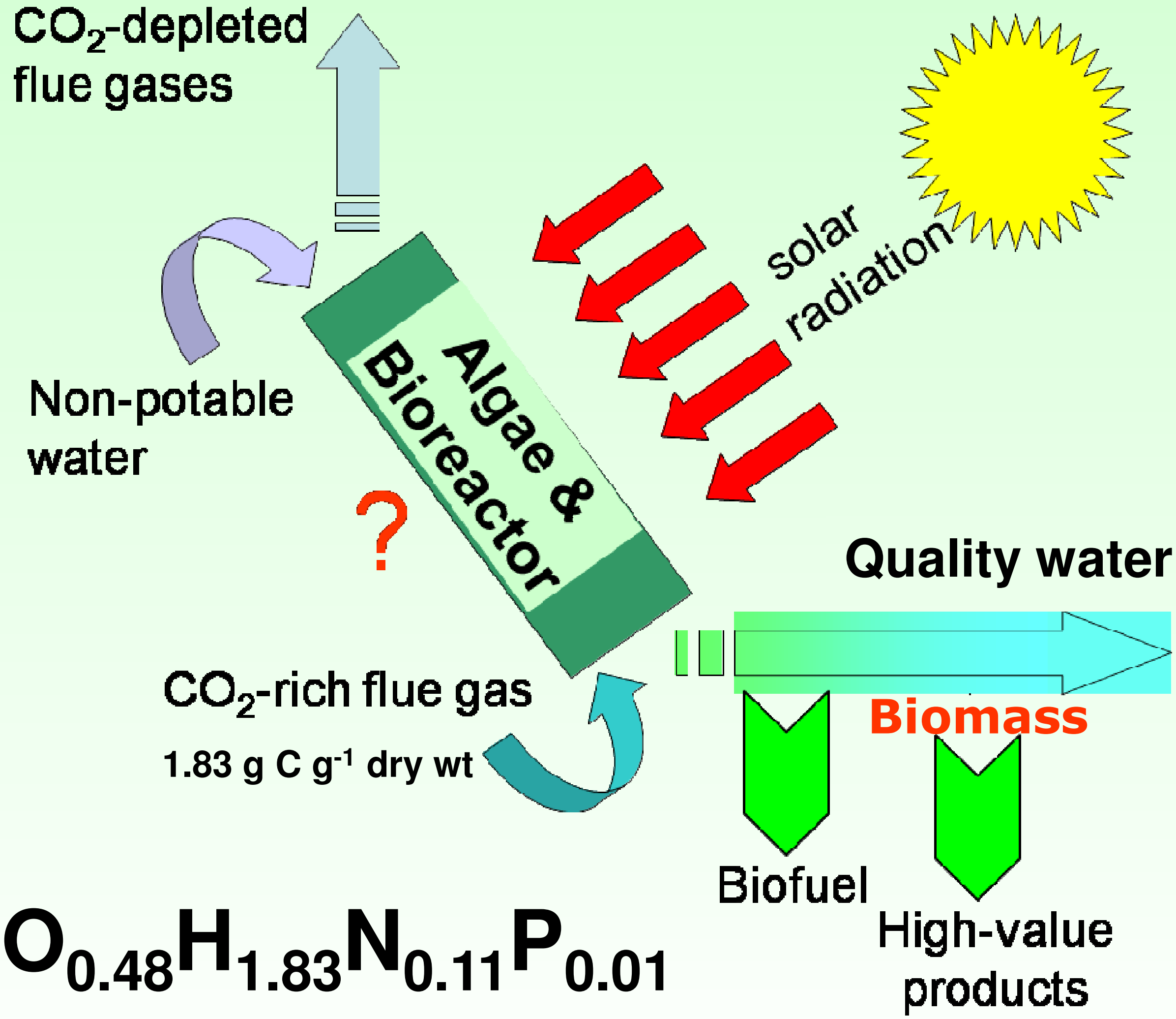
BASIC CONCEPT OF AN ALGAE-TO-ENERGY BIOPROCESS SYSTEM



$$CO_{0.48}H_{1.83}N_{0.11}P_{0.01}$$

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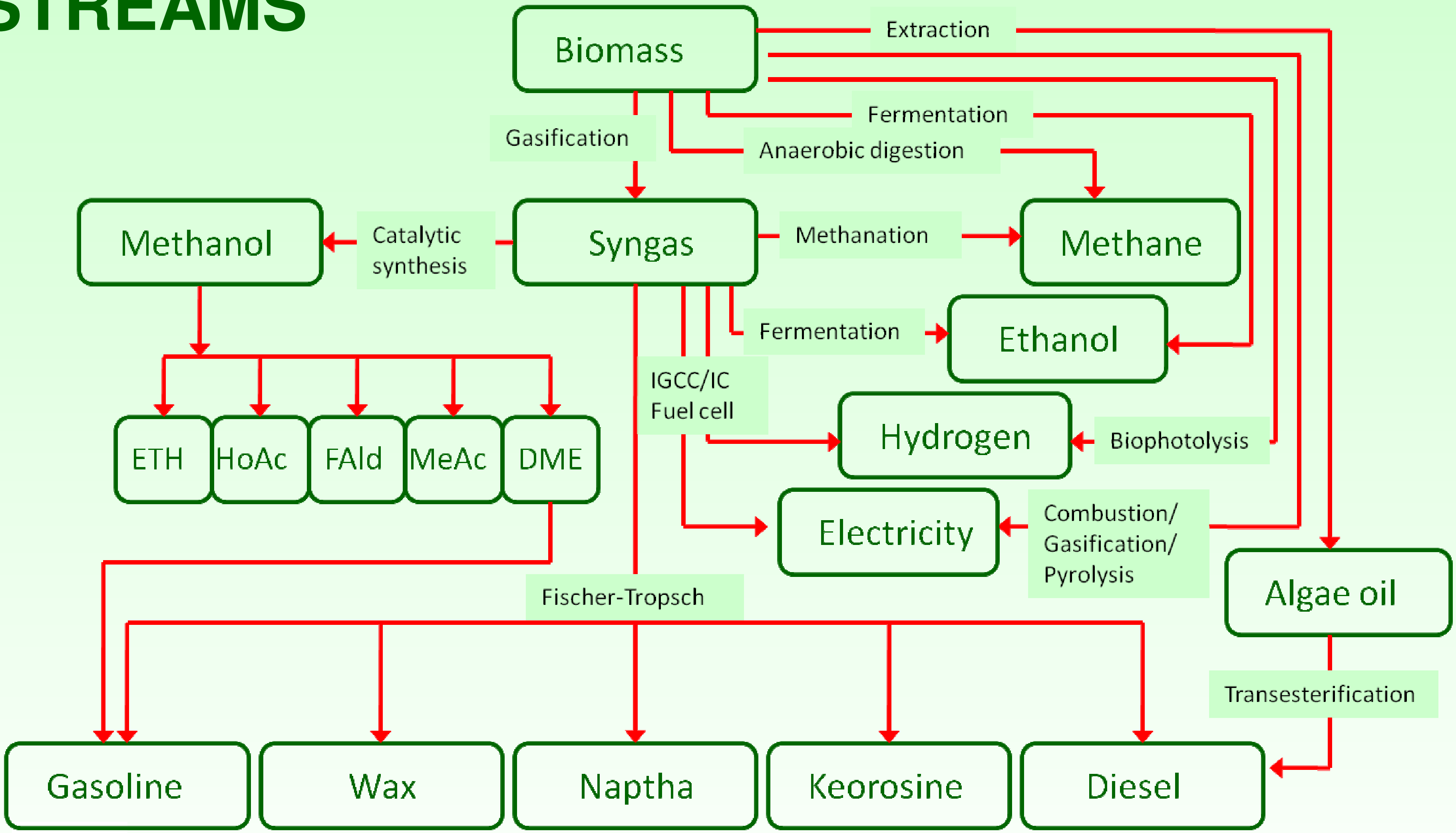
POTENTIAL MICROALGAE ENERGY STREAMS



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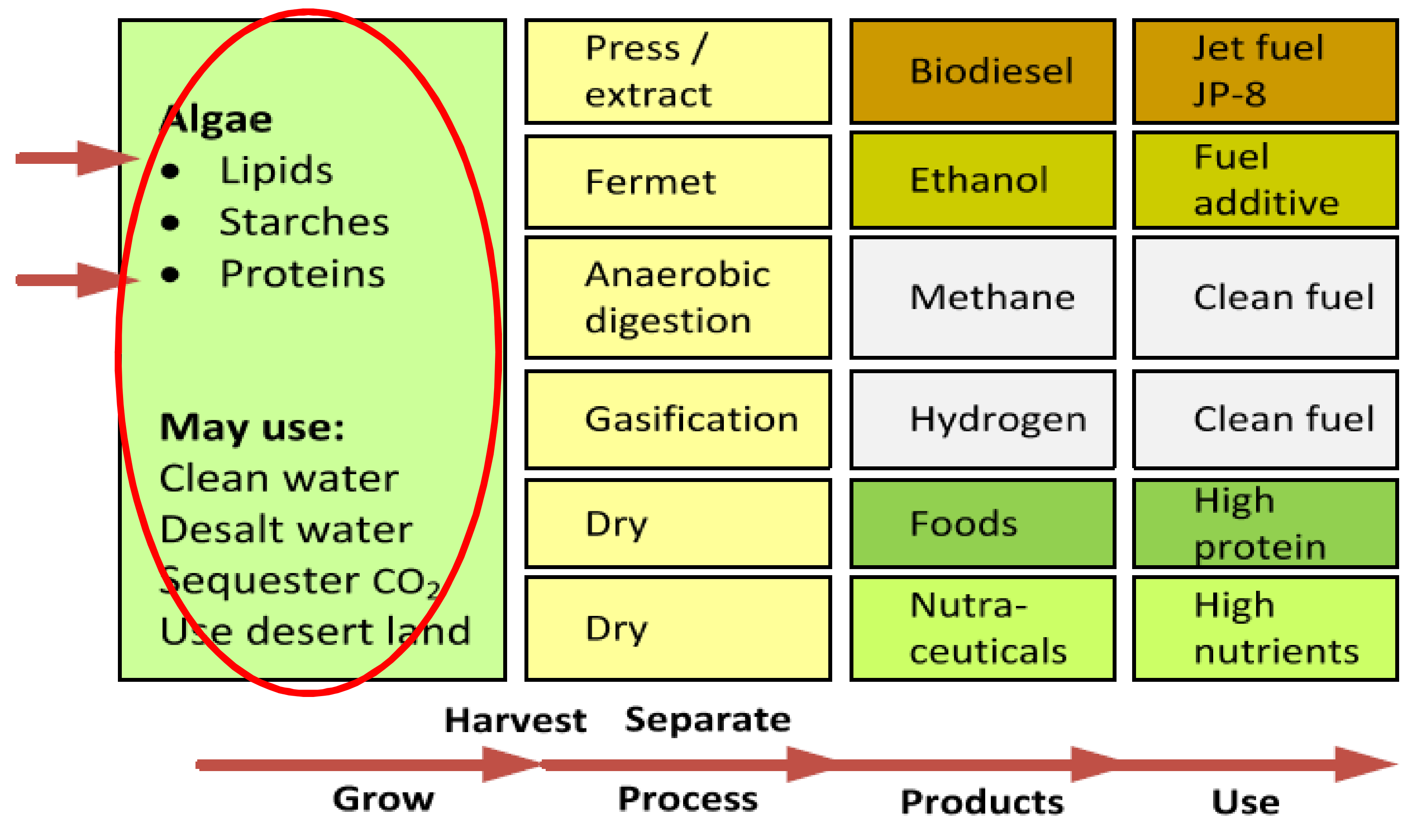
MICROALGAE BIOMASS AND DERIVATION OF CLEAN ENERGY



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MICROALGAE BIOPROCESS TECHNOLOGY SEGMENTS

- Upstream research & development
  - Strain development – product-based
  - Optimization of culture conditions – product based
  - Photobioreactor design and operation – product based
  - Harvesting – product based
- Strain selection
  - Monoculture (marine/fresh water/GMO) – product based
  - Wild strains (specific/mixed) – CO_2 recycling & biomass based
- Growth requirements and culture conditions
  - Strain and product dependent
- Photobioreactor type and maintenance
  - Strain and product dependent
- Downstream harvesting & processing

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MICROALGAE TECHNOLOGY SEGMENTS: SOME CONSTRAINTS

- Which region best to locate algae-to-energy systems?
- Identify most appropriate and best suited high biomass and lipid yielding strains for cultivation at various locations
- Should cultivation be autotrophic or heterotrophic?
- What is the required land/water use intensity?
- What selective pressures required if monoculture?
- Which harvesting and extraction technologies for what strain?
- Which unit processes and sensitivity to variations in biomass yield/lipid content?
- State of current and future technology and potential barriers
- Can significant benefit be obtained from using flue gas CO_2?
- Understand microalgae photosynthesis and productivity!!!

MASS BALANCE ANALYSIS: NET ENERGY YIELD OF ALGAE-TO-ENERGY (MJ/ha/d)

Method	Karoo		Witwatersrand		Average SA	
	Photosynthetic Efficiency (PE)					
	6%	3%	6%	3%	6%	3%
Biodiesel	**-4,543**	**-2,661**	**-1,515**	**-1,000**	**-2,942**	**-1,730**
Biodiesel + CH_4	**-2,091**	**-1,390**	**-876**	**-669**	**-1,397**	**-928**
Methane (CH_4)	**561**	**-125**	**-196**	**-342**	**262**	**-134**
Syngas	**412**	**-199**	**-235**	**-361**	**168**	**-181**

Note: Average daily irradiance data for arid (Karoo) and non-arid (Witwatersrand) used to establish PE

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MASS BALANCE ANALYSIS: NET ENERGY YIELDS WITHOUT 1% CO_2 (MJ/ha/d)

Method	Karoo	Witwatersrand	Average SA
Biodiesel	-914	-544	-628
Biodiesel + CH_4	357	-213	174
Methane (CH_4)	1,938	200	1,170
Syngas	1,549	94	920

Note: Average daily irradiance data for arid (Karoo) and non-arid (Witwatersrand) used. Assumption: No more than 3% Photosynthetic Efficiency achievable without 1% CO_2 infusion

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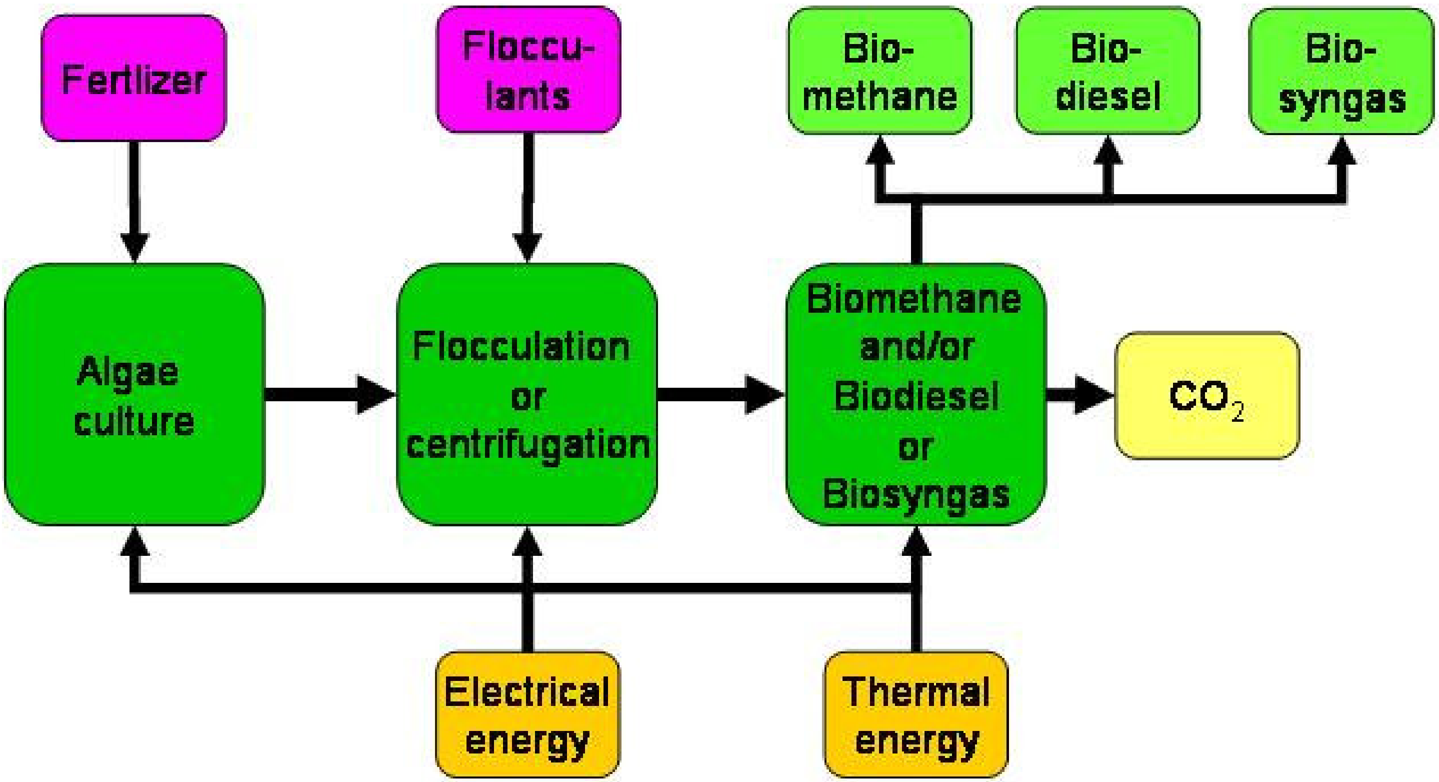
LCA SYSTEM BOUNDARIES: CULTIVATION, HARVESTING AND PROCESSING



System boundaries include the three major market segments viz. culture, harvesting and processing;
Two harvesting methods viz. DAF and centrifugation;
Three processing options: biodiesel, anaerobic digestion and gasification.

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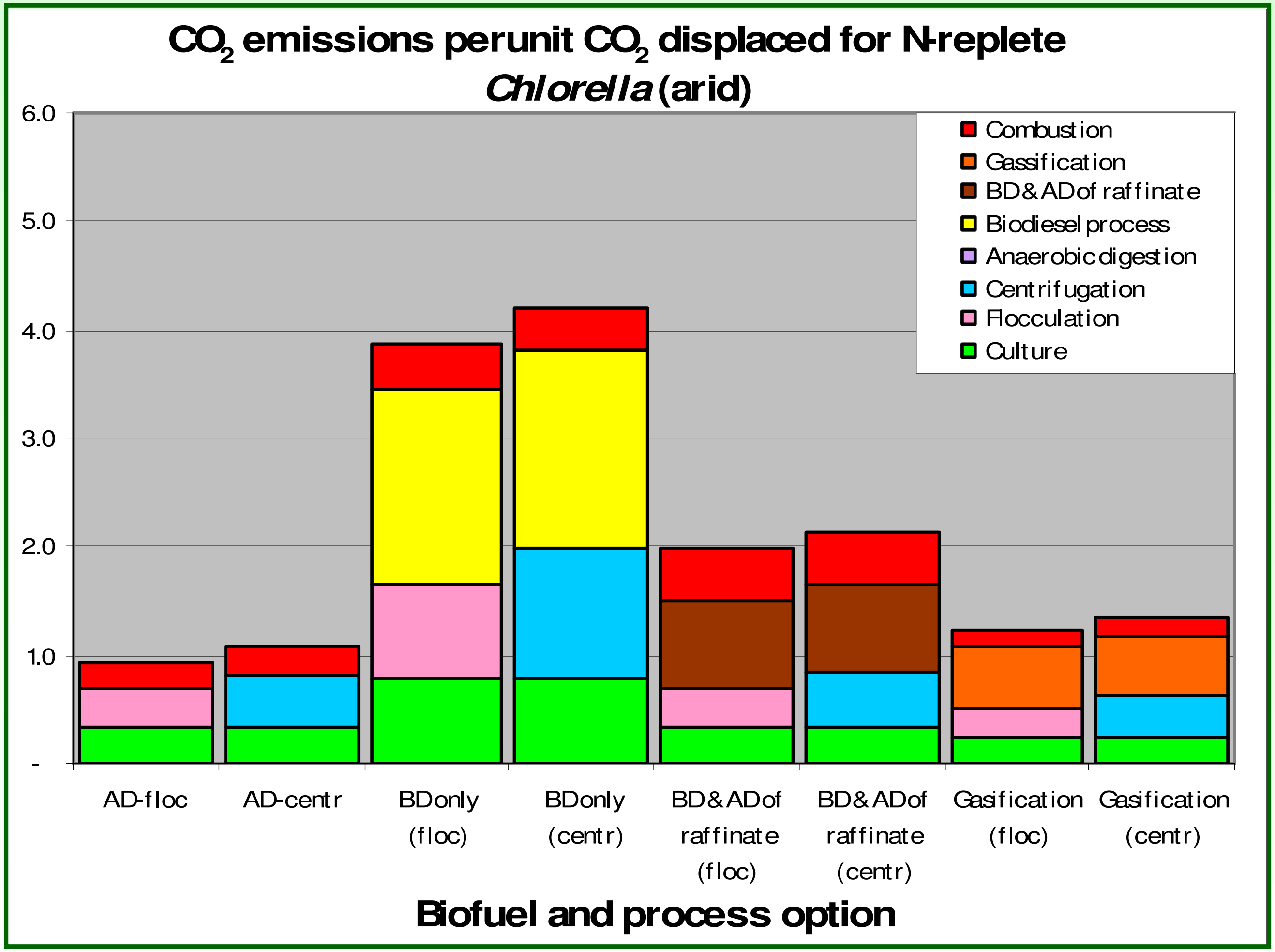
TONNES CO_2 GENERATED PER TONNE FOSSIL FUEL CO_2 DISPLACED IN FINAL ALGAE BIOFUEL PRODUCT



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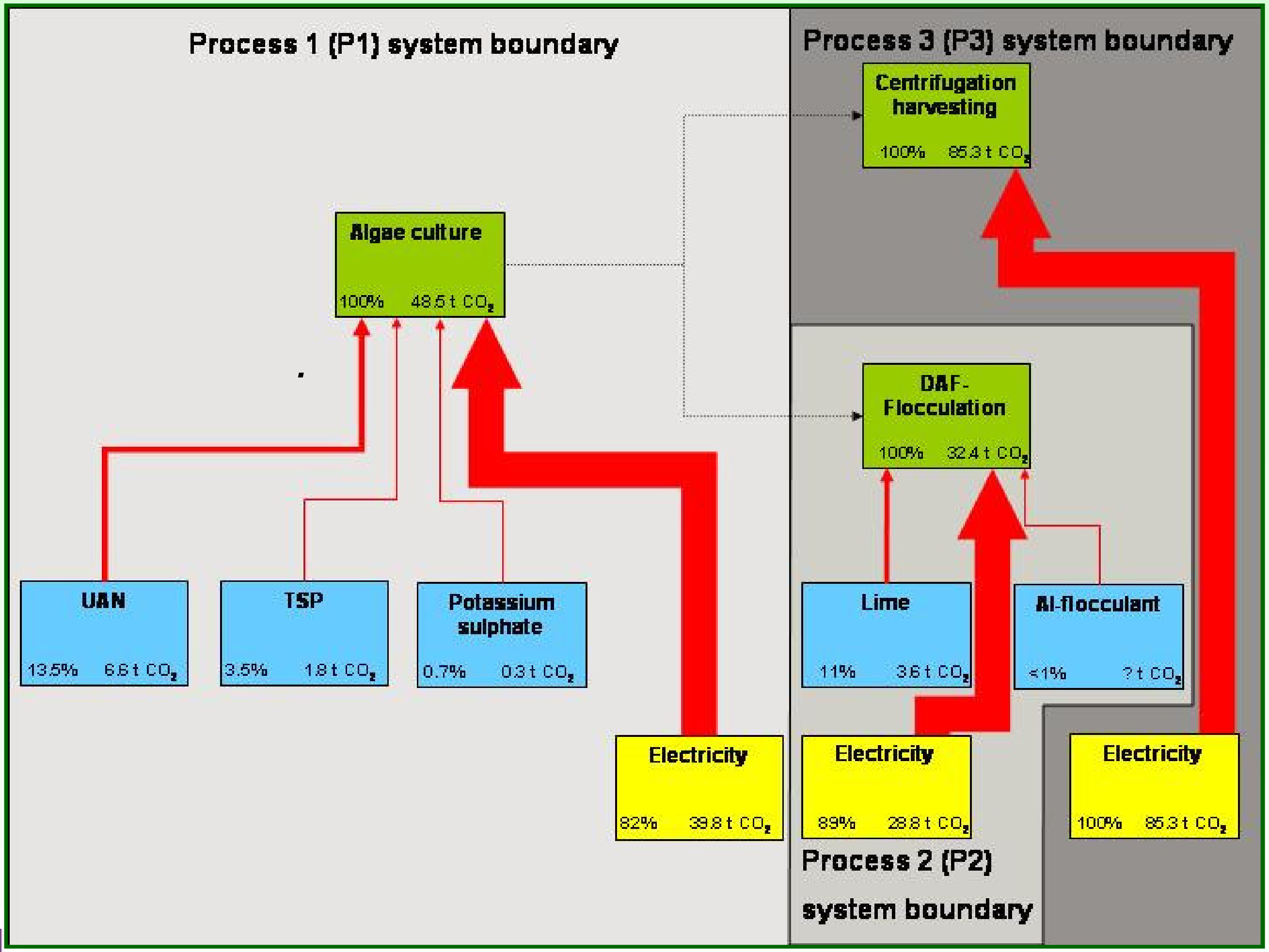
LCA OF PROCESS IMPACTS ON CO_2 FOOT-PRINT FOR ALGAE-TO-ENERGY INPUTS



Arrow thickness represents the proportional contribution of each process input to CO_2 emission for that specific process

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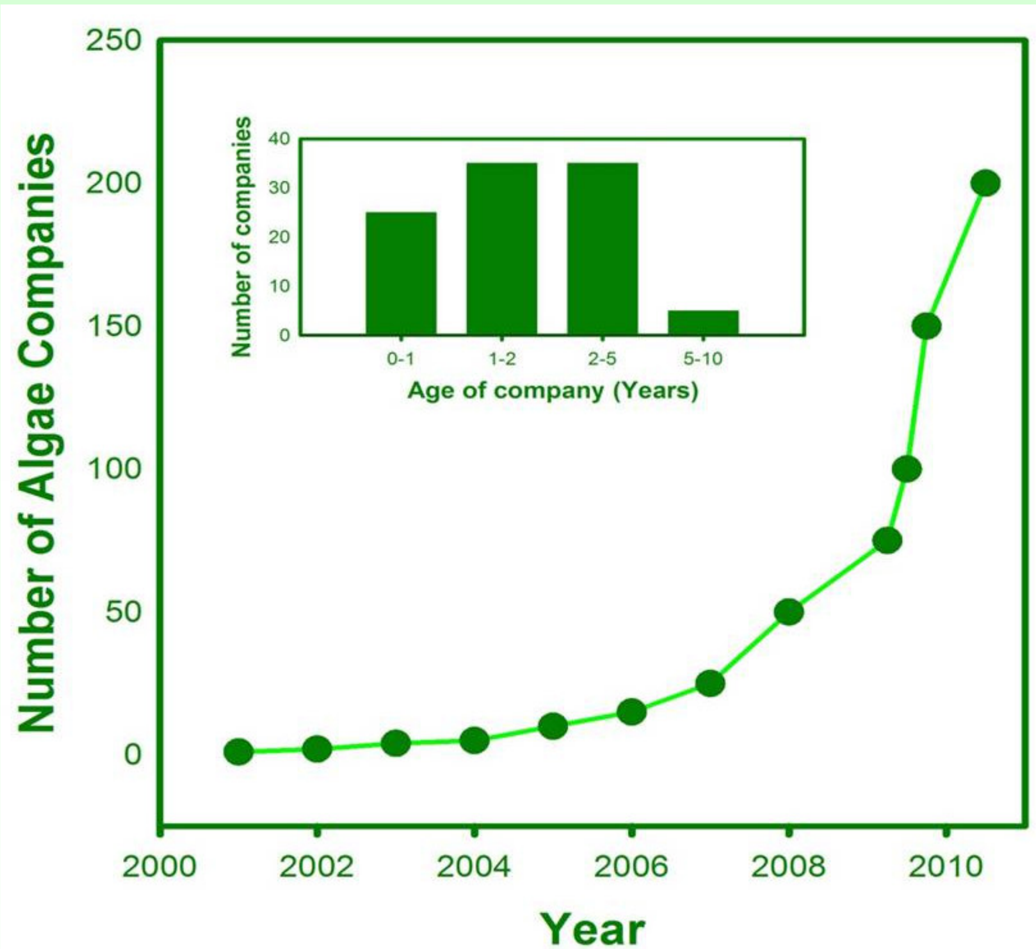
ALGAE-TO-ENERGY COMPANIES: CURRENT STATUS AND PLANS



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ALGAE-TO-ENERGY COMPANIES: SOME CURRENT FRONT RUNNERS

Company	Technology advantage
Sapphire Energy (USA) **No available data on conversion rates.**	Sapphire is leading the new industrial category of Green Crude production with the potential to profoundly change America's energy and petrochemical landscape for the better. With only sunlight and CO_2, Sapphire Energy is turning algae cultivated in open ponds into Green Crude that can be refined into the three most important liquid fuels we use today: gasoline, diesel and jet fuel.
Solazyme (USA) **No available data on conversion rates. Reported to have supplied 1,500 gallons of jet fuel.**	Solazyme uses aerobic fermentation technology to produce oils and biomaterials from algae in standard fermentation facilities quickly, cleanly, cost effectively, and at large scale. Solazyme's indirect photosynthesis bio-production process uses microalgae to convert biomass directly into oil and other biomaterials

ALGAE-TO-ENERGY COMPANIES: SOME CURRENT FRONT RUNNERS

Company	Technology advantage
Aurora (USA) **No available data on conversion rates.**	Aurora Algae have screened a myriad of strains in search of microalgae that outperform others in terms of oil production and yield. Aurora has further bred its select portfolio to maximize production performance and to be cost-effective at scale. Aurora grows its optimized algae in specially engineered open ponds
Origin Oil (USA) **Not in market to produce biomass or biofuel but technology supply.**	Origin Oil develops technology for biomass production and oil. The system is dependent on patented “fracturing technology” in which particles (nutrient and CO_2 to initiate cultures; and produce biomass to extract oil) are rendered to their smallest dimensions by a combination of electromagnetism and pH modification which is also used to break down cells on entry of the biomass into the ultrasonic fracturing tank as part of the harvesting process. It is the ultrasonic stage of the system that permits an easy one-step method of oil extraction

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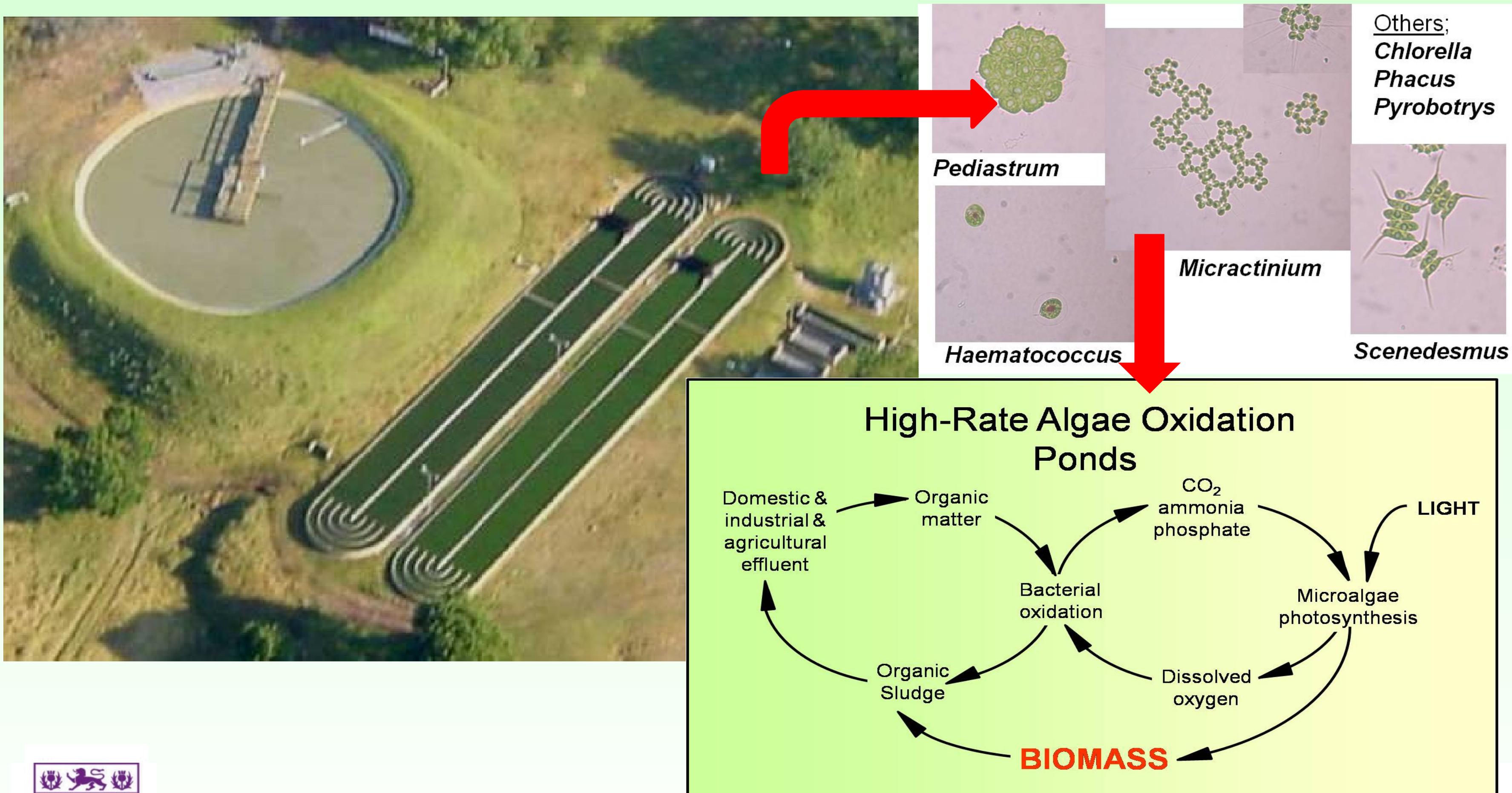
INTEGRATED ALGAE POND SYSTEMS: A SUSTAINABLE SUPPLY OF RENEWABLE ENERGY



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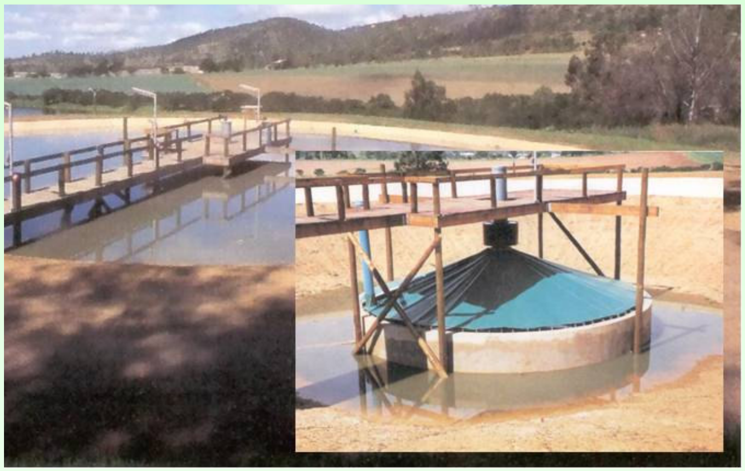
METHANE PRODUCTION FROM THE IN-POND IAPS DIGESTER



Production rate (m^3)	IAPS
CH_4/kg BOD_5	0.15
CH_4/kg BOD_{ULT}	0.24
CH_4/day (400 PE)	7.68
CH_4/day (500 PE)	9.60
CH_4/day (600 PE)	11.52
Biogas at 86% CH_4, then totals are m^3 biogas/day (500 PE)	11.16

160 GJ OR 44 megawatt-hour per year

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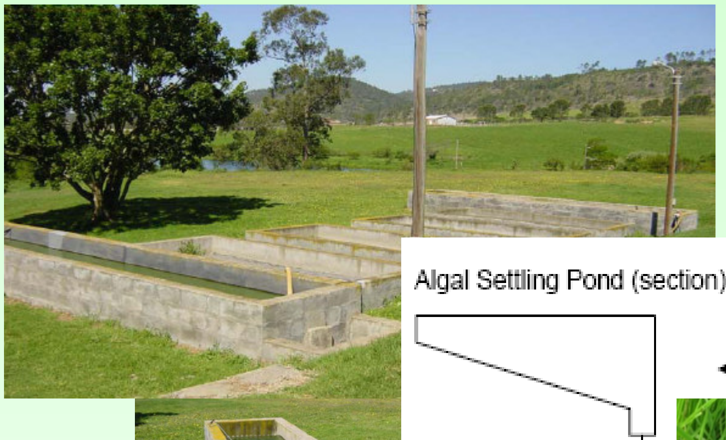
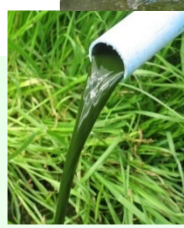
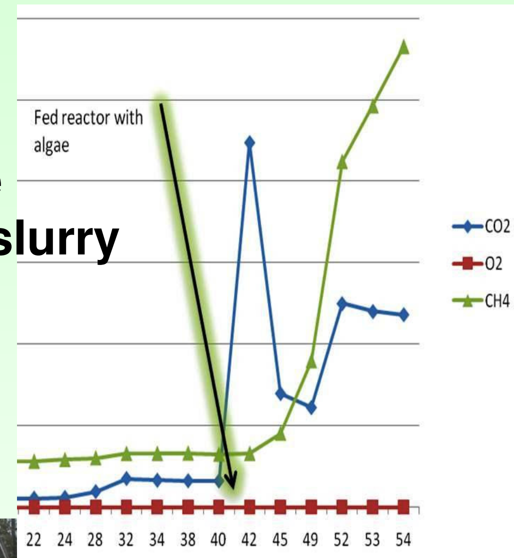
HARVESTING AND DIGESTING THE IAPS MICROALGAE BIOMASS TO METHANE





Wet algae biomass slurry



<u>Biogas</u>

Net energy yield CH_4 = 9.98 $GJ.d^{-1}$ (at steady state)

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CONCLUDING COMMENTS: FUTURE OF ALGAE-TO-ENERGY SYSTEMS

- Algae-to-energy systems provide opportunity and are a reality but progress limited by cost of the industrial scale process,
- Algae-to-energy companies are jockeying for technological advantage but without the requisite scientific know-how,
- Evaluation of available technologies for each technology segment reveals anaerobic digestion and gasification as viable options,
- EBRU (RSA), Aquaflow Bionomic (NZ), and NIWAR (NZ) have demonstrated the success of IAPS as a technology choice,
- Less than 10% of the energy produced by an IAPS algae-to-energy system is needed by the system,
- Can be operated as stand-alone water-treatment and energy producing systems of any size for domestic or industrial waste.

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THANK YOU

Q & A

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