ALGAL FEEDSTOCK PRODUCTION POTENTIAL OF TWO TAMPA BAY CITIES USING WASTEWATER

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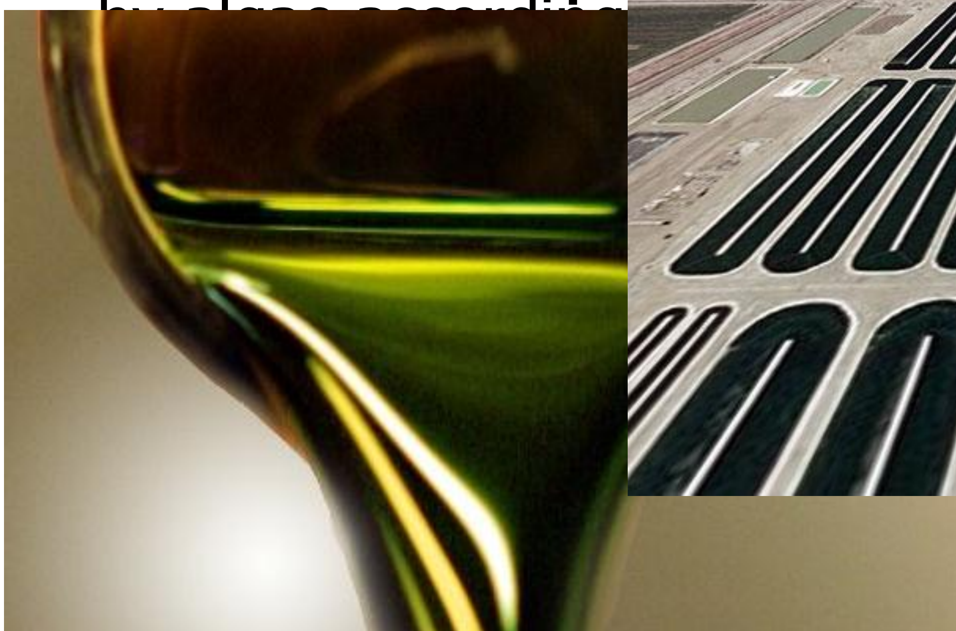
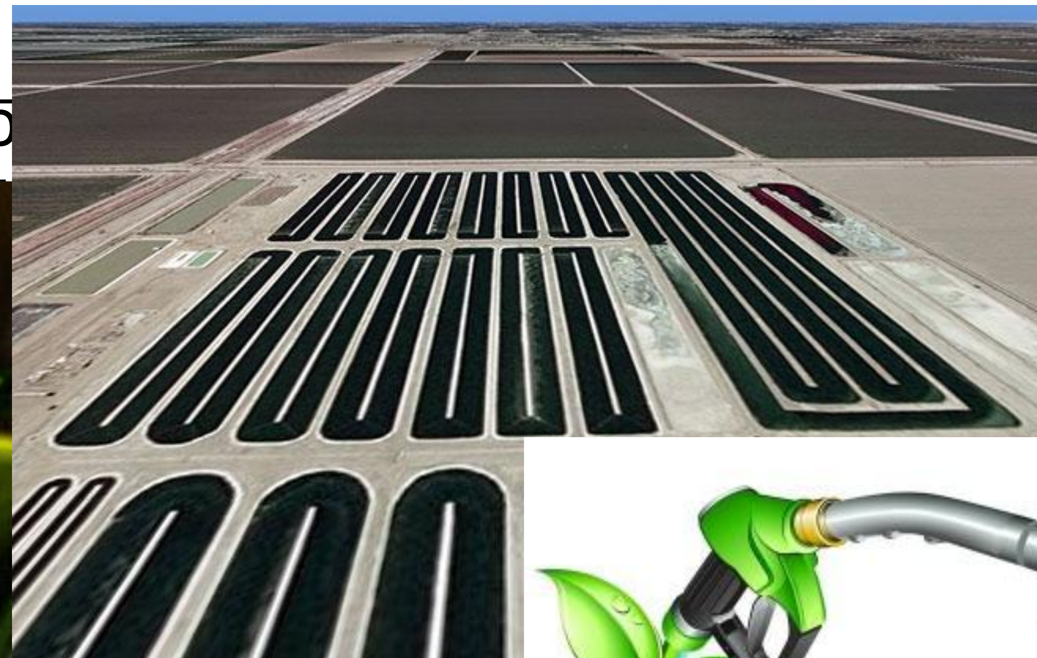
INTRODUCTION

- Algae have huge potential for biofuel production

- 17% of US transpo

Crop





th was

1,57

of nut

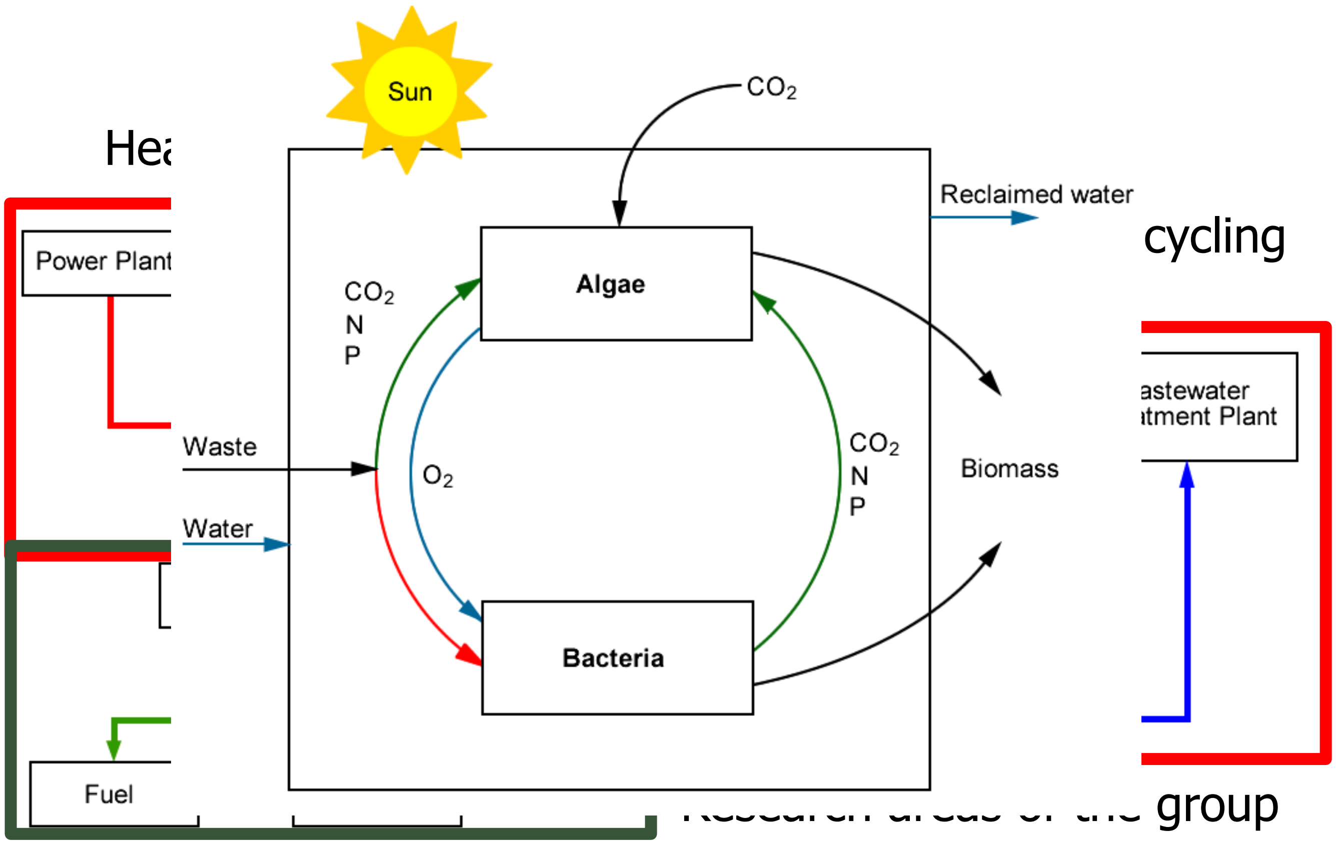
15,50

respectively may reduce the overall c

Microalgae (70% oil by wt) 36,16

Source: Christi (2007), Biotechnology Advances 25:294-306

ALGAE WITH WASTEWATER AND POWER PLANT



Source: National Algal Biofuels Technology Roadmap

Background

- Florida, particularly Tampa Bay, has been identified as an ideal location for developing algal feedstock
- The Howard F. Curren Advanced Wastewater Treatment Plant (HFC AWTP) treats ~56 MGD, produces ~1 MGD centrate with 450 mg/L N
- Lakeland uses a 1,400-acre wetland system for nutrient removal with a flow of 5.2 MGD, achieved largely by algae

Overall goal

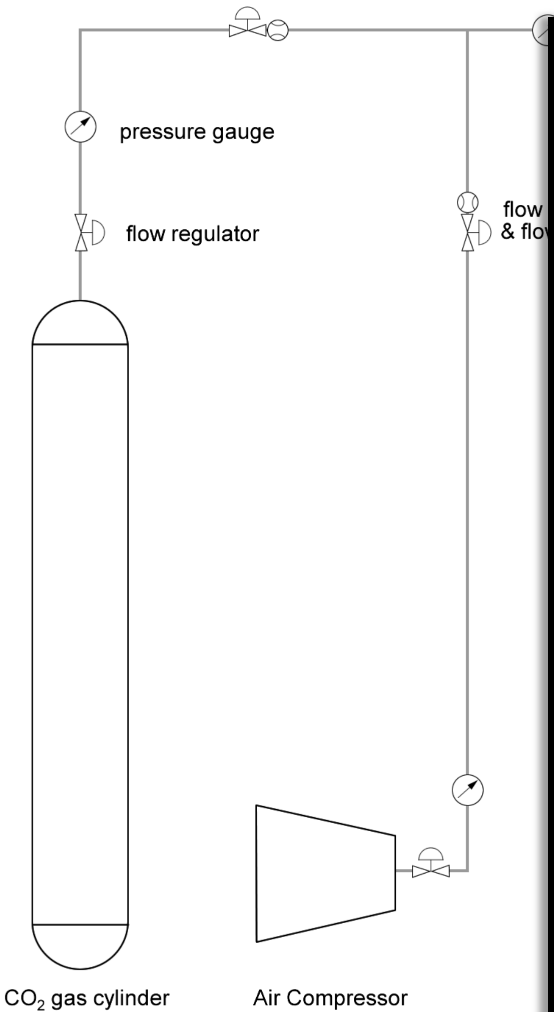
- Explore the **potential synergy** for the production of algal feedstock from **wastewater and power plants**

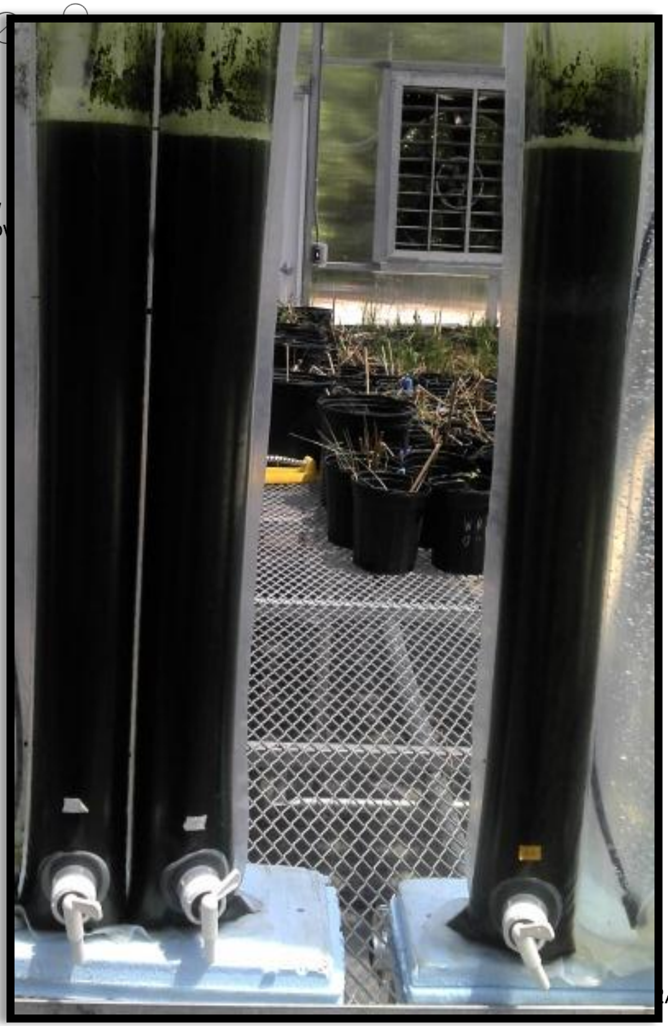
Specific objectives

- Assess the **growth, nutrient removal, and lipid production** for algae grown on wastewater centrate from HFC AWTP and the algae growing in the Lakeland WTS

- Perform a preliminary analysis to determine the **quantity of algal feedstock** that can be obtained

Photobioreactor Setup



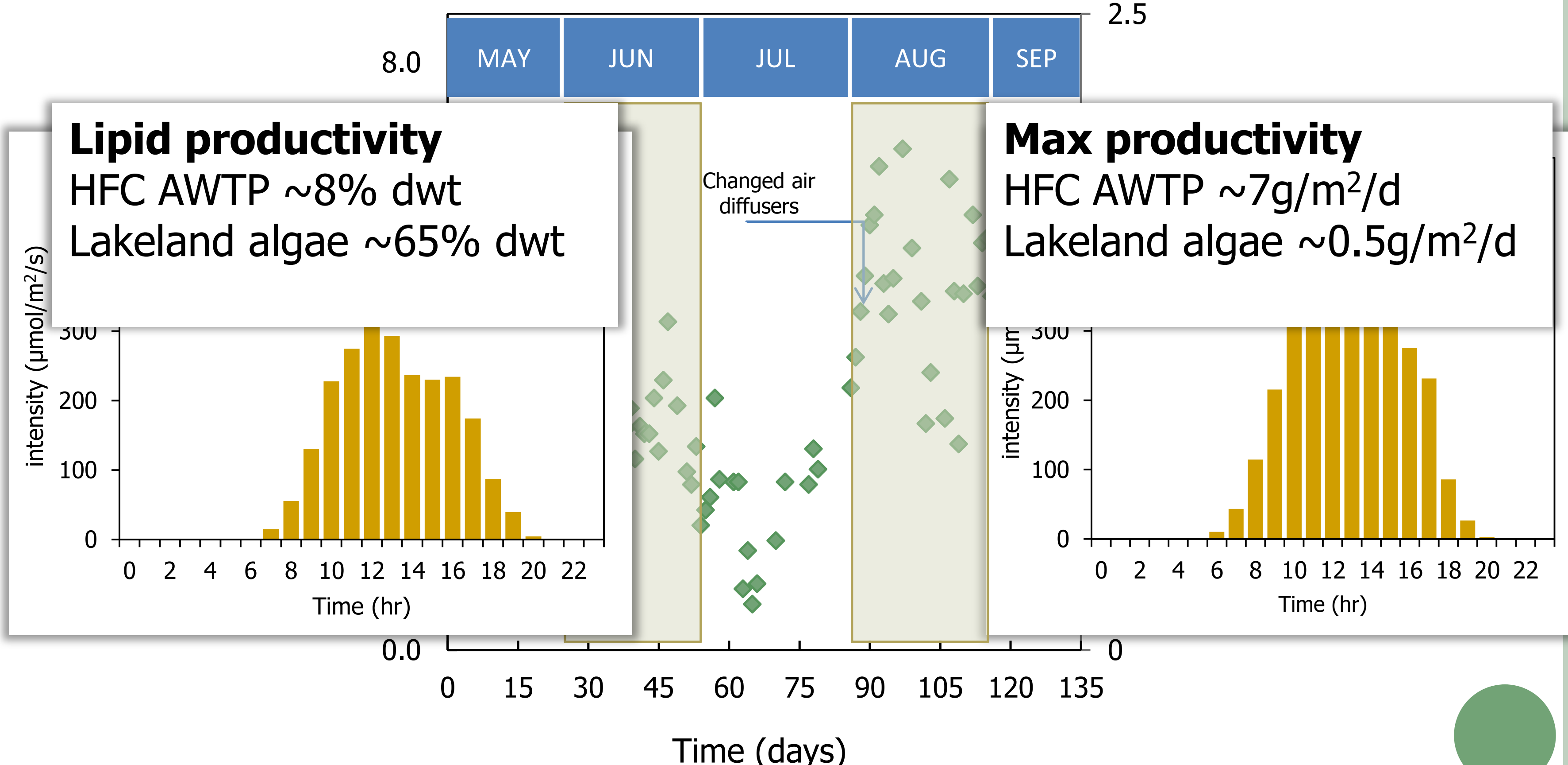


Measured Parameters

- Ammonia
- Light intensity
- Lipid content
- Nitrate
- pH
- Total phosphorous
- Temperature
- Total nitrogen
- Total suspended solids

Results

- Growth and production rates in PBR

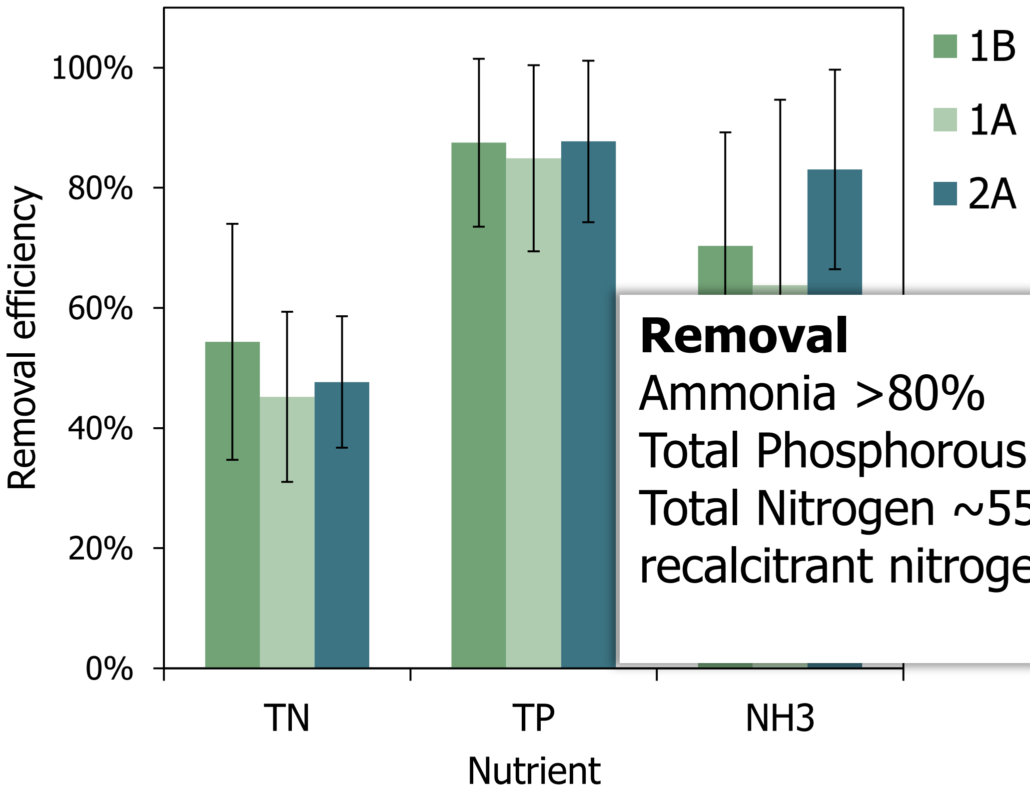


Lipid productivity
HFC AWTP ~8% dwt
Lakeland algae ~65% dwt

Max productivity
HFC AWTP ~7g/m^2/d
Lakeland algae ~0.5g/m^2/d

RESULTS

- Nutrient removal efficiencies



Removal
Ammonia >80%
Total Phosphorous >85%
Total Nitrogen ~55% (lots of recalcitrant nitrogen material)

Engineering analysis

- Feedstock and biomass estimation

Algae

Ammonia as nitrogen source

$$16NH_4^+ + 92CO_2 + 92H_2O + 14HCO_3^- + HPO_4^{2-} \xrightarrow{h\upsilon} C_{106}H_{263}O_{110}N_{16}P + 106O_2$$

1 g NH_4^+ as N gives 15.8 g algae and consumes 18.1 g CO_2

Nitrate as nitrogen source

$$16NO_3^- + 124CO_2 + 140H_2O + HPO_4^{2-} \xrightarrow{h\upsilon} C_{106}H_{263}O_{110}N_{16}P + 138O_2 + 18HCO_3^-$$

1 g NO_3^- as N gives 15.8 g algae and consumes 24.3 g CO_2

Theoretical maximum production

$$P_{max} = \frac{\tau_p C_{PAR} \varepsilon_a E_s}{E_a}$$

P_{max} = maximum productivity

C_{PAR} = %photosynthetically active radiation

ε_a = photon conversion efficiency

E_s = total solar intensity

τ_p = transmission efficiency

E_a = energy content of algae

Month	Average greenhouse solar radiation (μmol/m²/s)	Greenhouse P_{max} (g/m²/day)	Outdoor P_{max} (g/m²/day)
February	237	3.59	21.18
March	321	4.85	15.85
April	456	6.90	18.83
May	416	6.29	18.56
June	357	5.41	16.29
July	307	4.65	13.12
August	236	3.58	10.54

Biomass production based on nutrients

- Productivity for algae:
  - High strength – 7-16 $g/m^2/day$
  - Moderate strength - 3 $g/m^2/day$
  - Low strength - 0.5 $g/m^2/day$

Description	Source	Flow rate (MGD)	Nitrogen (mg/L)	Algae biomass (tons/yr)	CO_2 consumed (tons/yr)	Indoor Area (hectares)	Outdoor Area (hectares)
Wastewater	HFC AWTP	3.0	30	1,965	3,026	179	179
Wastewater	WTS	5.0	10	1,091	1,681	598	598
Centrate	HFC AWTP	0.5	427	4,660	7,179	182	80
Total				**7,716**	**11,889**	**959**	**857**

LIQUID BIOFUELS

- 80% conversion efficiency to biofuel (same for vegetable oil)
- Lipid content algae:
  - High strength – <10% not appropriate for liquid fuel
  - Moderate strength – 20% usable lipids
  - Low strength – 50% usable lipids

Description	**Source**	**Biofuel (gal/yr)**
Wastewater	HFC AWTP	112,833
Wastewater	Lakeland WTS	156,712
Total		**269,545**

BIOGAS PRODUCTION

$$C_{106}H_{263}O_{110}N_{16} + 6.672H_2O$$
$$\longrightarrow 13.668NH_4^+ + 33.502CO_2 + 47.170CH_4 + 2.332C_5O_2H_7N + 13.668HCO_3^- + HPO_4^{2-} + 2H^+$$

- 1 g algae = 62.7 mg methane
- Energy content of methane 55 MJ/kg

Description	Source	Algae Biomass (tons/yr)	Biogas Production (kg/yr)	Total Energy (MJ/yr)	Households powered
Wastewater	HFC AWTP	1,965	123,215	6,776,838	240
Centrate	HFC AWTP	4,660	292,294	16,076,165	570
Total		**6,625**	**415,509**	**22,853,003**	**810**

Conclusions

- Algal production can be integrated with wastewater to both produce feedstock and remove nutrients
- Feedstock potential for HFC AWTP and Lakeland WTS together
  - ~71 tons/ha/yr of biomass
  - ~270,000 gal/yr of liquid biofuel
  - ~415,000 kg/yr of biogas
- Simplified analysis, but illustrates good potential for feedstock development
- Many important factors still to be considered to determine overall cost competitiveness

Acknowledgements

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