SBRC
Sustainable Bioenergy Research Consortium

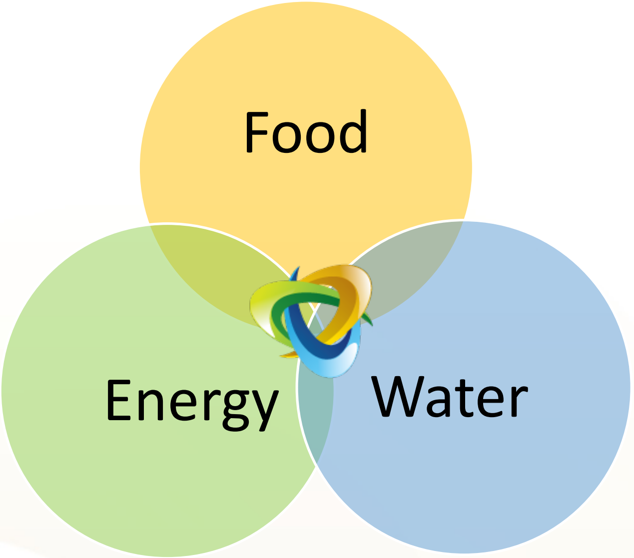
SEAWATER ENERGY AND AGRICULTURE SYSTEM

2018

ESTABLISHED BY: Masdar Institute

Introduction

- The aviation industry is actively working to reduce its carbon footprint



- Food security in the UAE is a top priority

  → Integral part of the Nexus

  → Aquaculture has a role to play

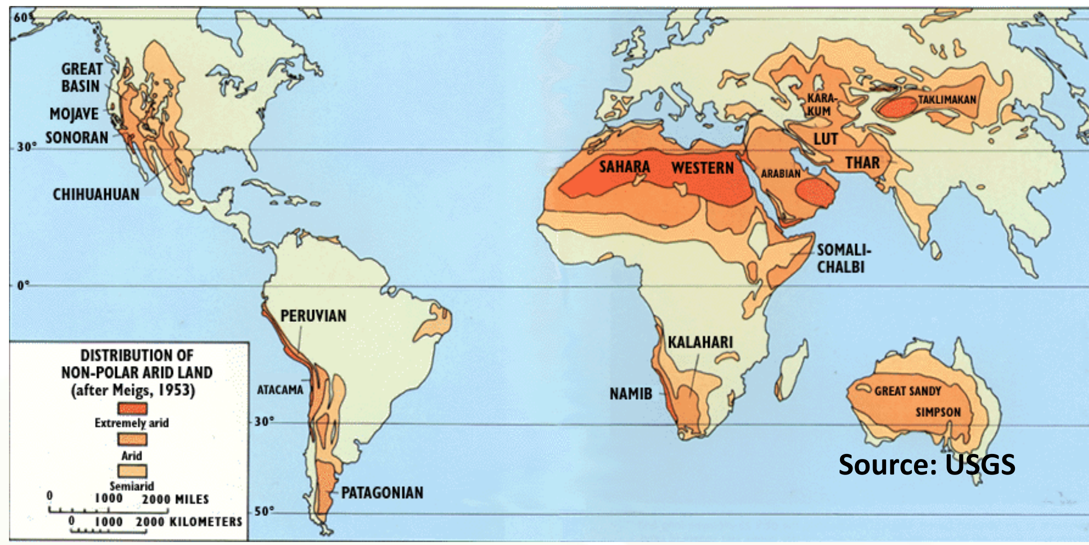
- Sustainable biomass production is a big challenge worldwide, but especially for water and arable land constrained regions

The SBRC

Why is SBRC research important?

97%
of the Earth's water is
in the oceans

About 20%
of the Earth's land mass is desert
~25.5 million km2



Our concept for bioenergy production could be applied to the UAE and many other arid regions of the world

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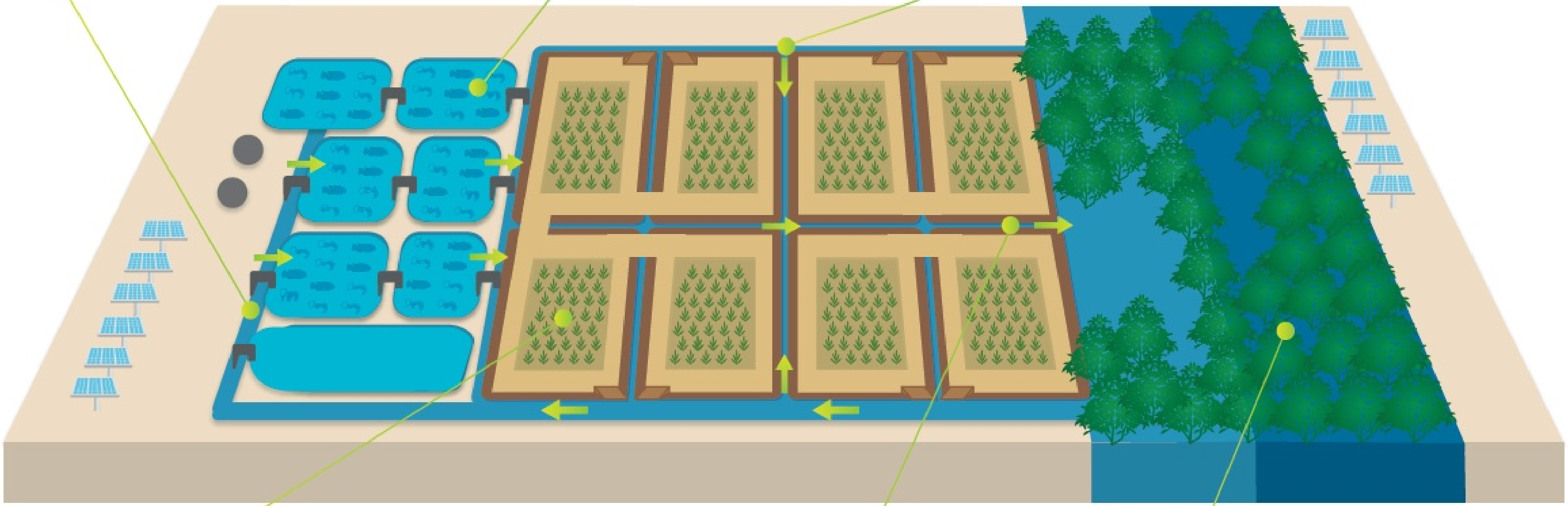
The SEAS

1 Pump seawater from the ocean to ponds, where fish and/or shrimp will be grown

2 Aquaculture for fish and shrimp

3 Wastewater from the aquaculture operation, which is enriched in nutrients, is used to irrigate salt-tolerant biomass (halophytes)



4 Biomass from the halophytes is used to produce bioenergy, including biofuels

5 Water that drains from the halophyte fields would then be fed into the mangrove wetland

6 Biomass from the mangroves can be converted into bioenergy

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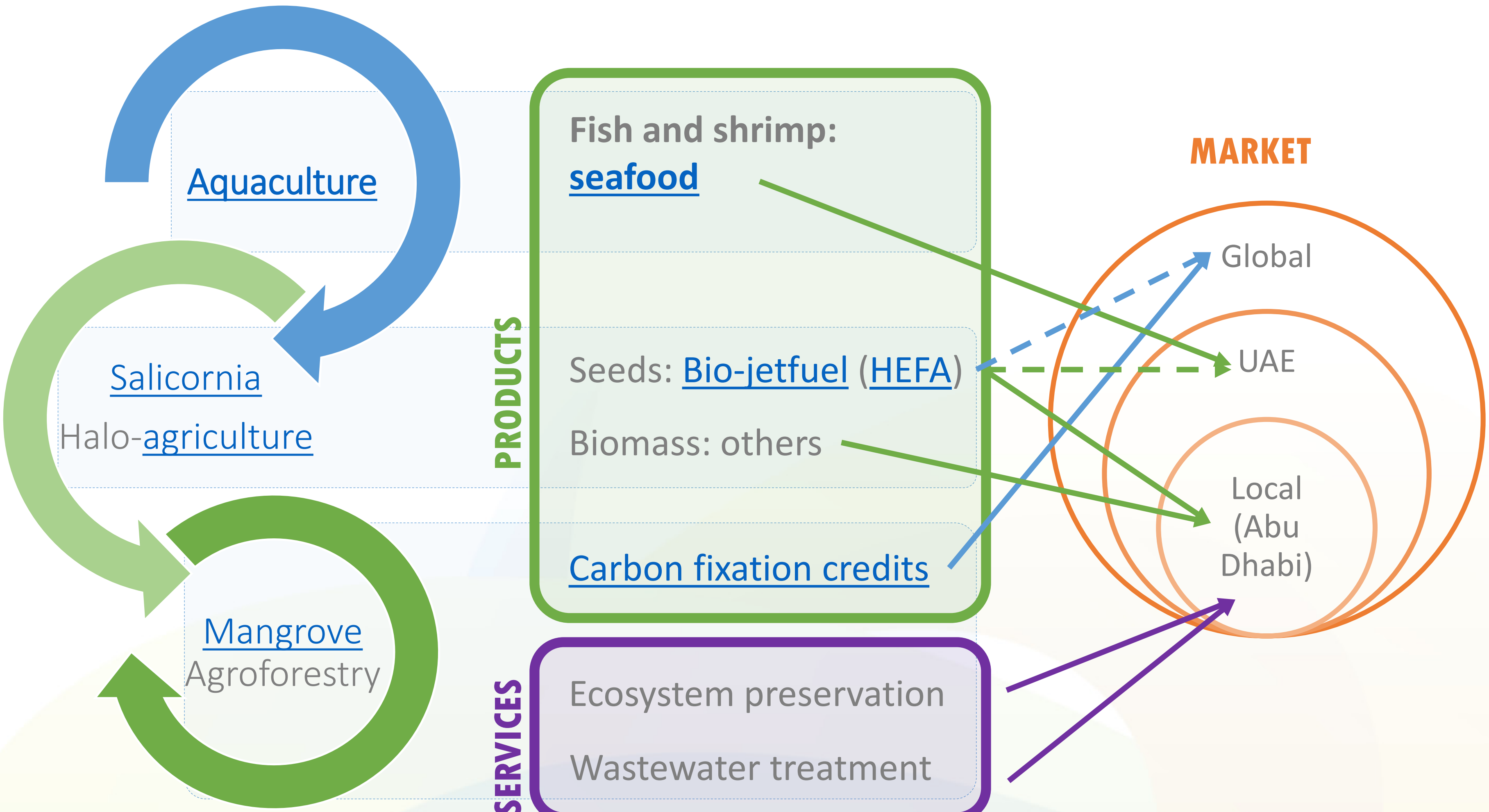
Products and Services



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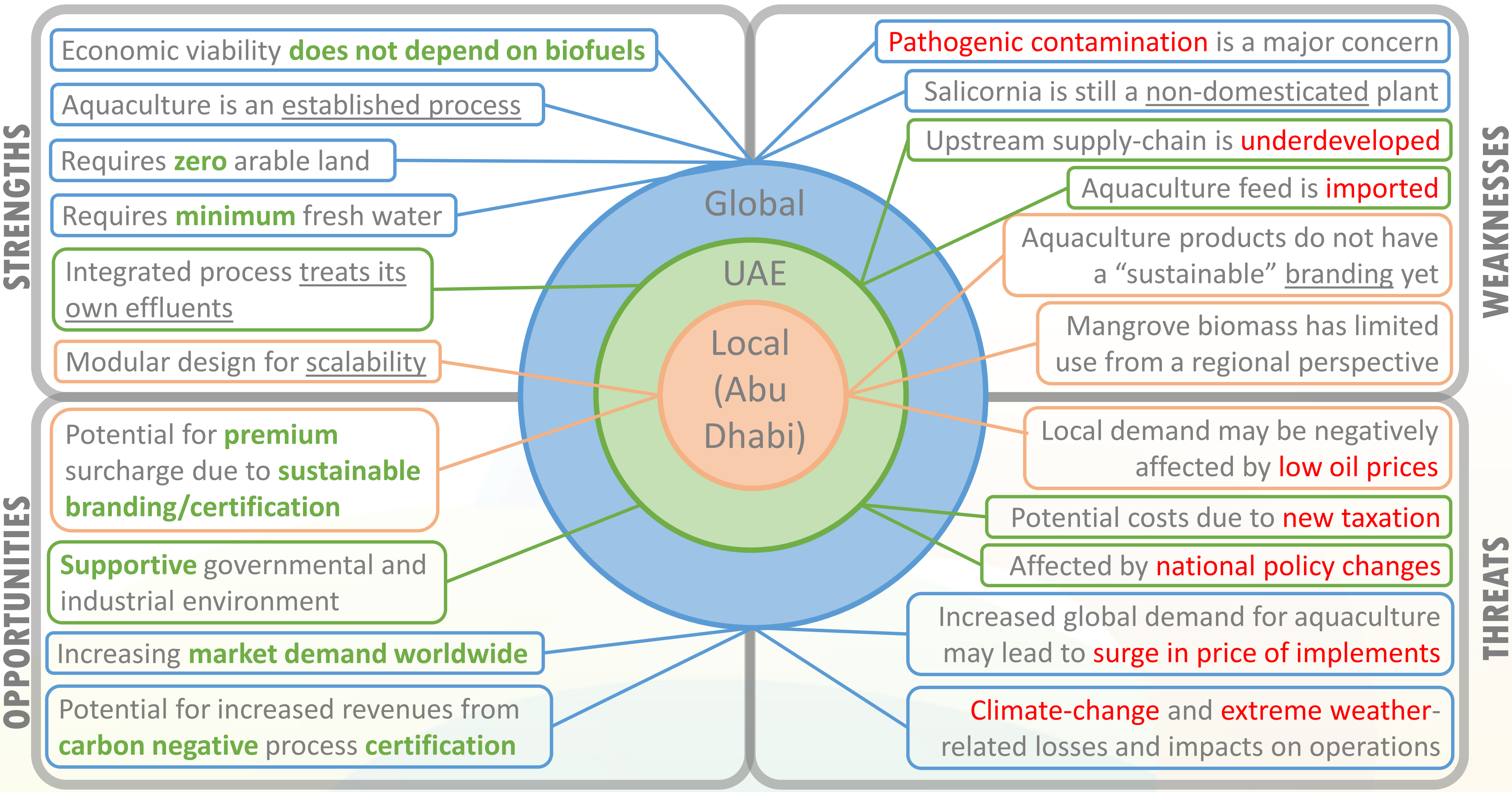
Risk assessment



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The next scale

- For the SEAS to reach commercial reality, the next step is to build a demonstration scale facility

  → 200 hectares

- At this stage, the aquaculture portion would already be a commercial farm

- The objective for the biomass production segment would be to have a proof of concept for further scale-up to 1,000's of hectares

More than biofuel…

+ Resource optimization
+ Food security
+ Industry synergy
+ Knowledge creation

Thank you!

Contact:
Alejandro Ríos G., Ph. D.
Director – Sustainable Bioenergy Research Consortium
Professor of Practice
Masdar Institute, a part of Khalifa University of Science and Technology
Abu Dhabi, United Arab Emirates
Direct +971 2 810 9238
Mobile +971 56 302 6514
Email ariosg@masdar.ac.ae

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Aviation's Goals

THE THREE GLOBAL SHORT-, MEDIUM- AND LONG-TERM GOALS:

GOAL 1

PRE-2020 AMBITION

1.5% AVERAGE ANNUAL FUEL EFFICIENCY IMPROVEMENT FROM 2009 TO 2020.

PROGRESS

Currently tracking well above goal, although figure expected to normalise.

HOW IS INDUSTRY ACHIEVING THIS?

Through actions outlined in this report in the first three pillars: new technology, more efficient operations and better use of infrastructure.

T O I

GOAL 2

IN LINE WITH THE NEXT UNFCCC COMMITMENT PERIOD

STABILISE NET AVIATION CO_2 EMISSIONS AT 2020 LEVELS THROUGH CARBON-NEUTRAL GROWTH.

PROGRESS

Industry is pushing for action at an intergovernmental level.

HOW IS INDUSTRY ACHIEVING THIS?

Through the four-pillar strategy, including a global market-based measure at the International Civil Aviation Organization (ICAO).

T O I + M

GOAL 3

ON THE 2°C PATHWAY

REDUCE AVIATION'S NET CO_2 EMISSIONS TO 50% OF WHAT THEY WERE IN 2005, BY 2050.

PROGRESS

Significant research efforts underway.

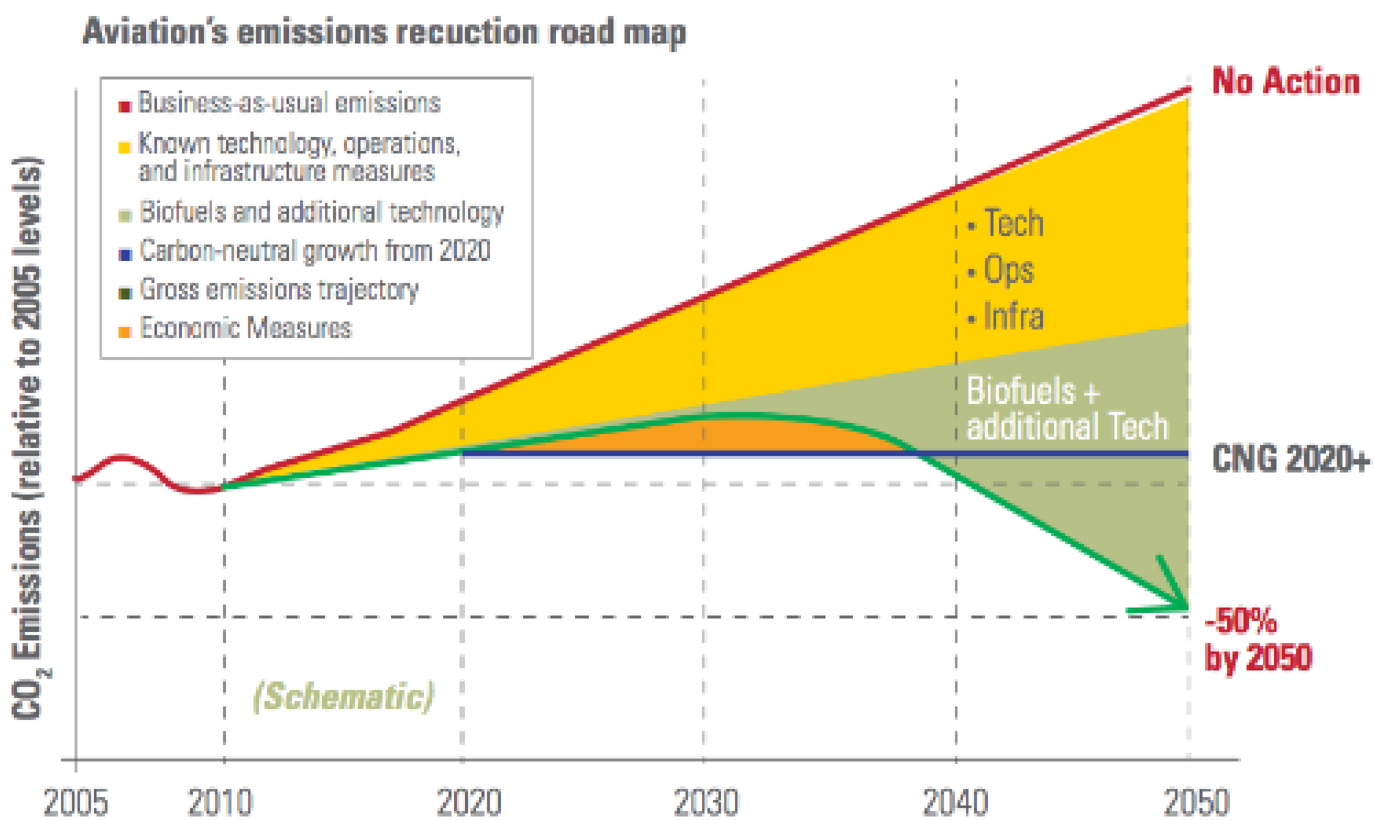
HOW IS INDUSTRY ACHIEVING THIS?

Two main areas of action: development of sustainable alternative aviation fuels; research into future design concepts by aircraft and engine manufacturers.

T O I

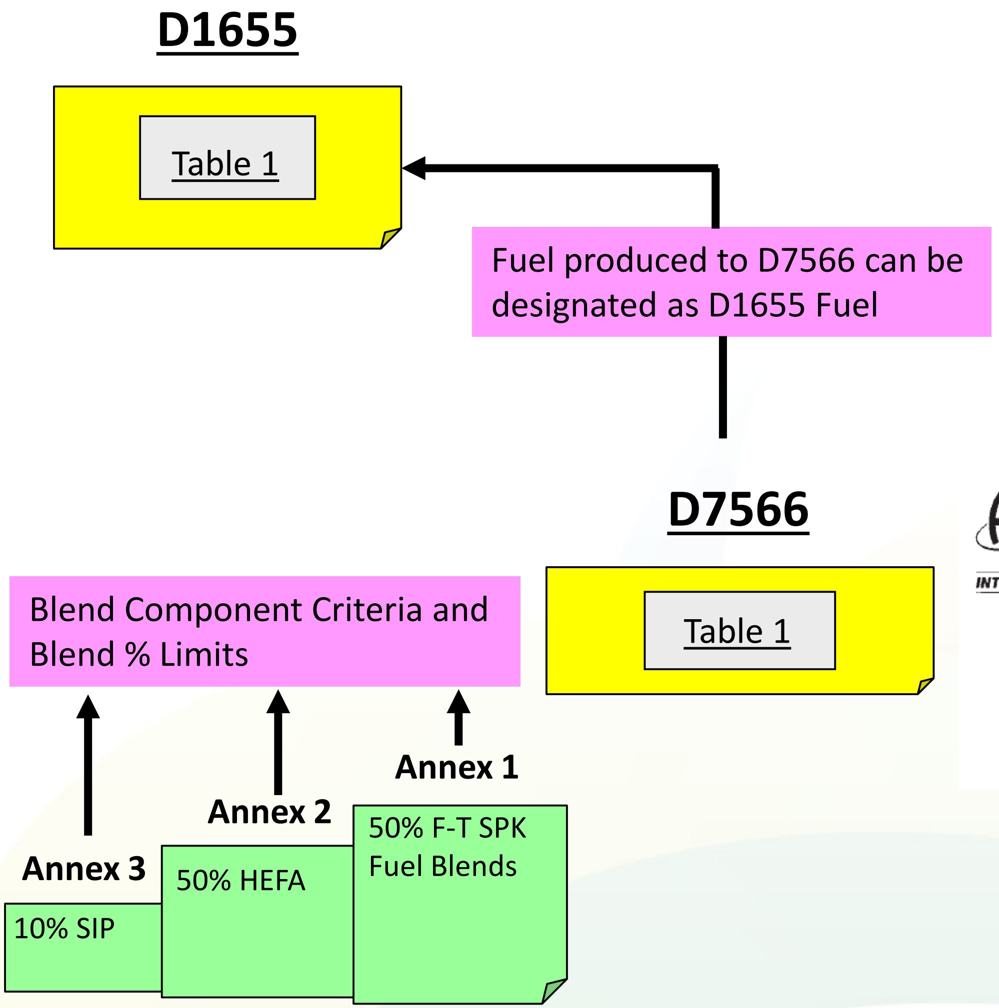
Aviation's Targets

Figure 1. The Aviation Industry's Long-term Targets



Source: Air Transport Action Group (ATAG).

Aviation Biofuel Specifications



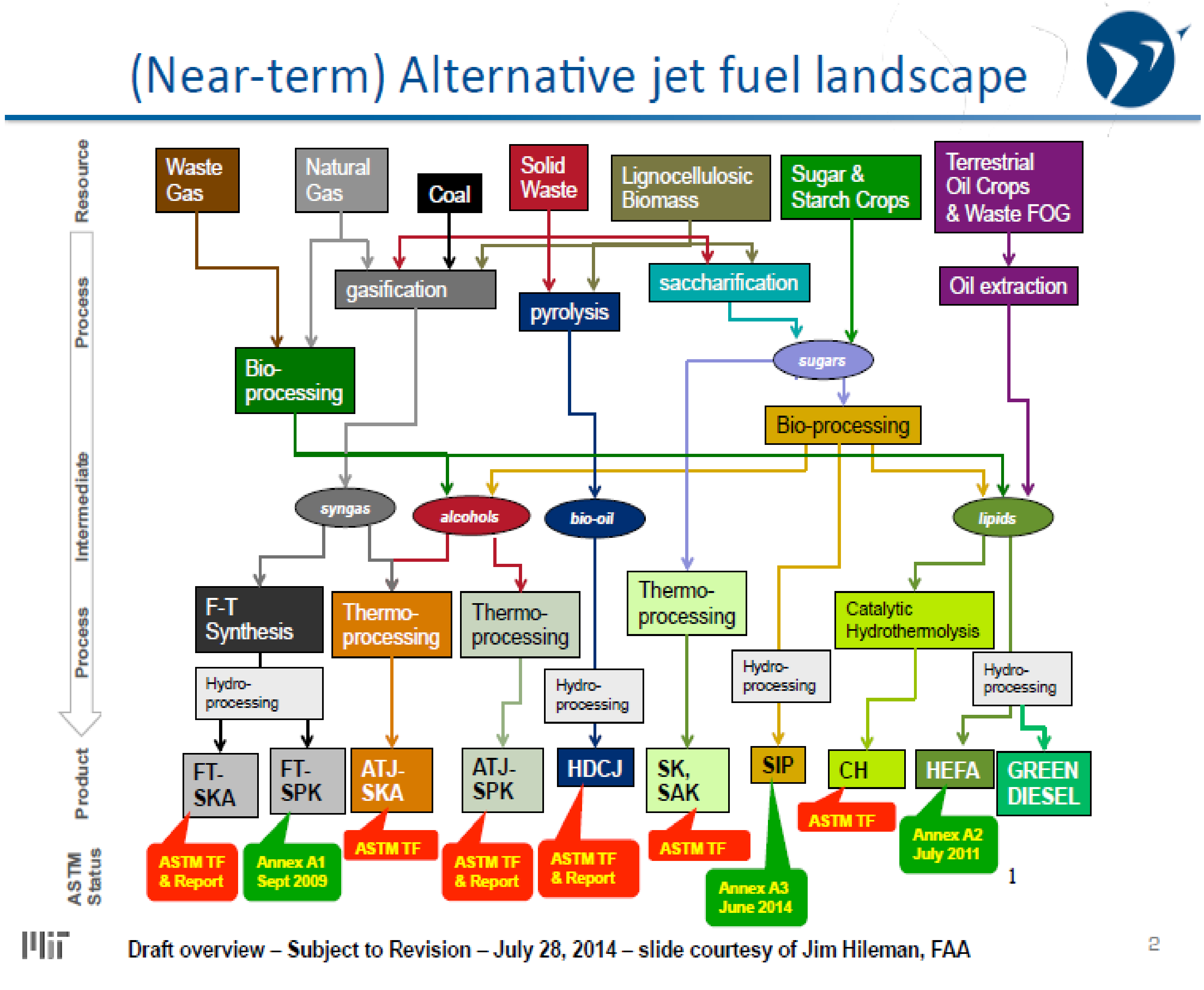
Designation: D1655 – 13a

Standard Specification for Aviation Turbine Fuels[1]

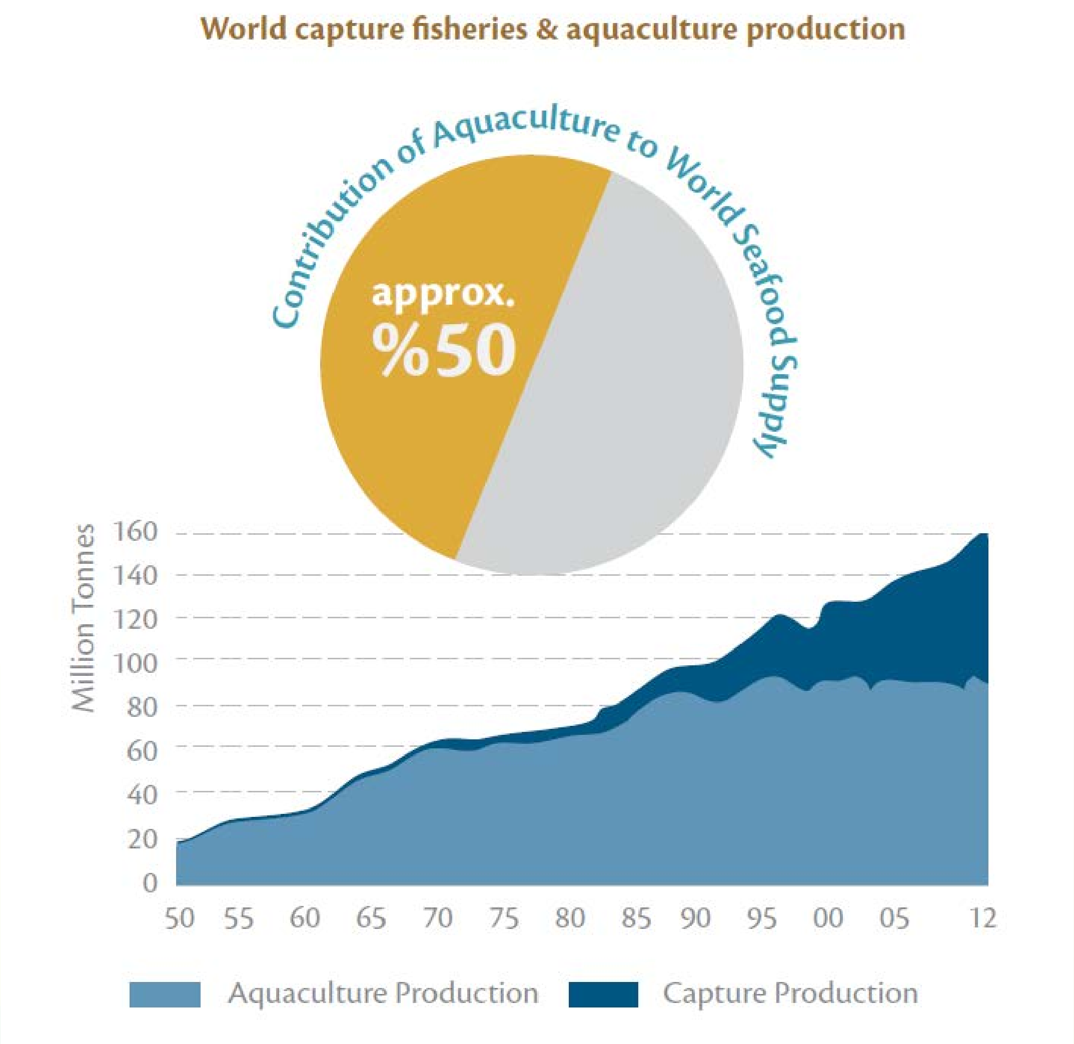
Designation: D7566 – 13

Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons[1]

Many Pathways Under Investigation



World Aquaculture



Current Status of Aquaculture in the UAE

- GDP Contribution of aquaculture & fisheries

<1%

- Number of species cultured

7

- Registered commercial farms

10

- Contribution of aquaculture to total seafood supply

<1%

- Current market valuation of projects (AED)

1.2 b

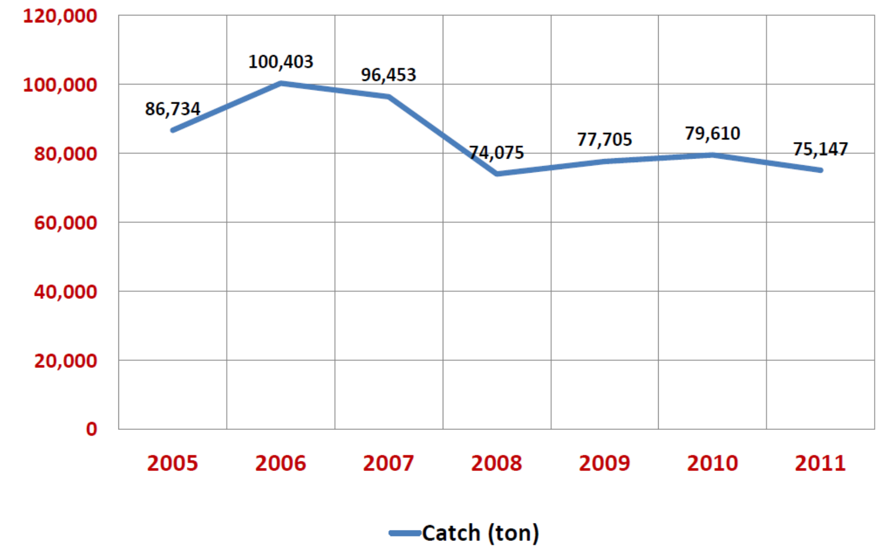
- Total aquaculture production in 2014

788 ton

Aquaculture Statistics

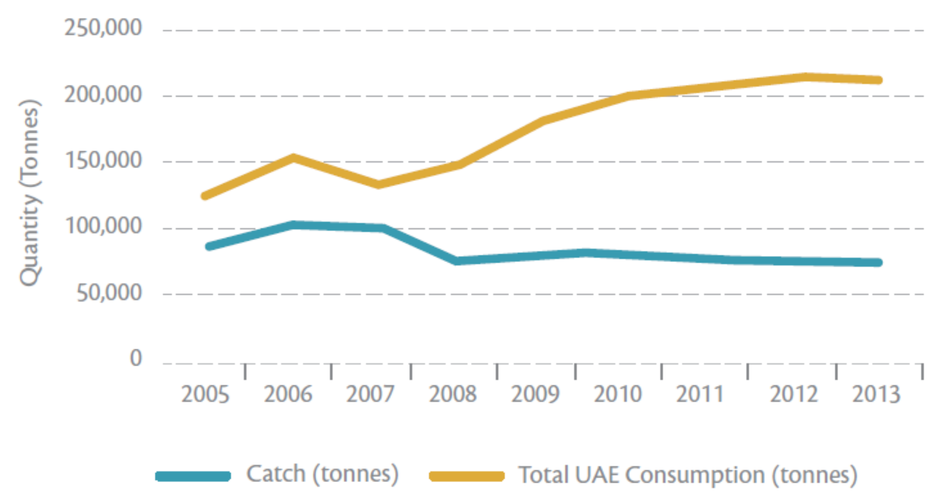
YEAR 2015 **UAE AQUACULTURE PRODUCTION** 790 tonnes

≈ %1 of UAE total capture production



UAE SEAFOOD DEMAND & SUPPLY GAP

136,450 tonnes



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Aquaculture in context

- Global production of aquatic animals from aquaculture reached **73.8 million tonnes in 2014**, with an estimated **first-sale value of US$160.2 billion**;
- **World per capita fish supply reached 20 kg in 2014** (includes wild caught fish; record-high since measurement started)
- Approximately 50% of global supply of fish for human consumption is provided by aquaculture
- FAO worldwide total aquaculture production, 2025 forecast: **102 million tonnes, 39% higher than reference period (average years 2013-2015)**;
- In 2015, total aquaculture production in the UAE was **790 tonnes** of various fin fish and crustacean species;

Seafood in context

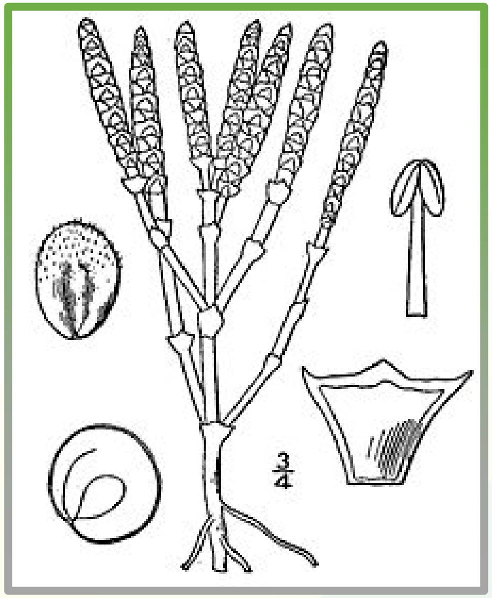
- UAE seafood consumption per capita: >28 kg/person/year (2016);
- In the UAE, the overall demand for seafood has outstripped the current supply from the local sea catches and aquaculture production, and **the gap (136,450 tonnes in 2013) is expected to widen and increase further in the future**
- FAO 2030 UAE seafood demand forecast: 900,000 $t_{seafood}$
- Current commercial aquaculture production in the UAE includes the following species:
  - Sea bream;
  - Black and red tilapia;
  - White shrimp;
  - Sturgeon (for caviar);

Salicornia in context

Salicornia sp. is a promising feedstock due its **oleaginous seeds** and **lignocellulosic straw** that can be used for **biofuel production through various pathways.**

Key data

Family: Amaranthaceae
Carbon fixation via C4 (Hatch-Slack) pathway
>60 species identified
Common names: glasswort, pickleweed
Growth in < 60 gNaCl$_{eq}$/L in irrigation (12 g/L optimum)
Oilseed content: 30% (w/w) lipid fraction in seeds



Composition of *S. bigelovii* biomass (salicornia Meal)

Component, proximate analysis	g/kg	Component, proximate analysis	g/kg
Dry matter	966.0	Calcium	3.65
Crude protein	342.4	Phosphorus	6.57
Ether extract	64.5	Potassium	13.2
Crude fiber	53.0	Magnesium	6.01
Ash	150.0	Iron	0.44
Sugar	227.3	Manganese	0.11
Starch	36.0	Sodium	30.49
		Chlorine	45.80
		Copper	0.01
		Zinc	0.04

Salicornia in context

The productivity of *Salicornia sp.* is competitive with other biofuel feedstocks, even in its current undomesticated state.

Crop	Productivity (t/ha)	Oilseed content (%)	Biofuel yield (m^3/ha)
Salicornia	3.0	30%	1.0
Rapeseed [a,b]	3.3	41%	1.4
Soybean [a,b]	2.6	18%	0.5
Palm oil [a]	18.0	36%	5.1
Camelina [a,c]	2.0	42%	0.9
Jatropha [b,c]	0.4 – 12.0	28%	0.75

[a] de Vries, Sander C., *et al*. "Resource use efficiency and environmental performance of nine major biofuel crops, processed by first-generation conversion techniques." *Biomass and Bioenergy* 34.5 (2010): 588-601.
[b] Mata TM, *et al*. Microalgae for biodiesel production and other applications: A review. *Renew Sustain Energy Rev* (2009)
[c] Achten WMJ, *et al.* Jatropha bio-diesel production and use. B*iomass and Bioenergy* (2008) 32(12), 1063-1084

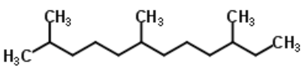
Agriculture in context

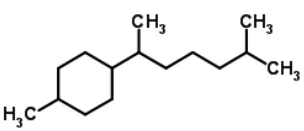
- In the UAE **32% of the water consumption goes to agriculture**, **11% to agroforestry** and 14% to landscaping;
- Global average water footprint* for the cultivation of main biofuel crops:
  - Sugar cane: **2107 liters of water per liter of bioethanol** (91 cubic meters of water per GJ energy as bioethanol)
  - Oil palm: **5166 liters of water per liter of biodiesel** (156 cubic meters of water per GJ energy as biodiesel)
  - Rapeseed: **6429 liters of water per liter of biodiesel** (194 cubic meters of water per GJ energy as biodiesel)
  - Soybean: **11397 liters of water per liter of biodiesel** (343 cubic meters of water per GJ energy as biodiesel)
  - Sunflower: **15841 liters of water per liter of biodiesel** (477 cubic meters of water per GJ energy as biodiesel)

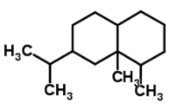
* These numbers are only a reference benchmark, as these crops are not only used for biofuel purposes. The main message is that they all use fresh water and arable land for cultivation.

Advanced aviation biofuels in context

SESQUITERPANES



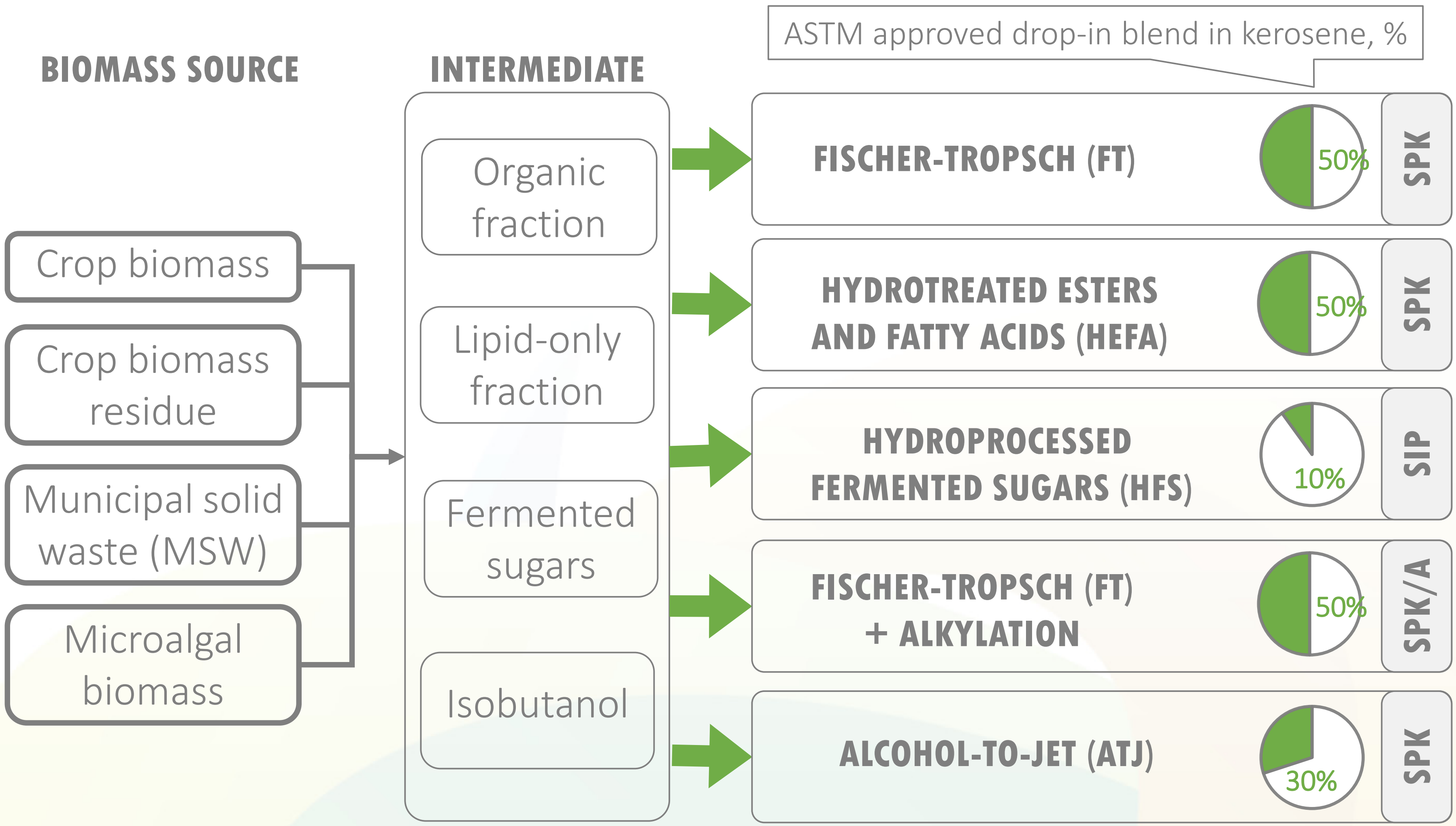




	Density (kg/L)	Freezing point (°C)	Specific energy (MJ/kg)
JET A-1	0.775-0.84	-47	42.80
Farnesane	~0.81	<-70	44.25
Bisabolane	~0.82	-78	
Valencane	0.879		~42.9

- Some studies suggest that the energy content of these fuels is up to 4% better than the fossil-based jet fuels
- This can represent significant savings or increased revenues, especially on long haul flights that are operationally constrained

Hydrotreated Esters and Fatty Acids (HEFA) in context



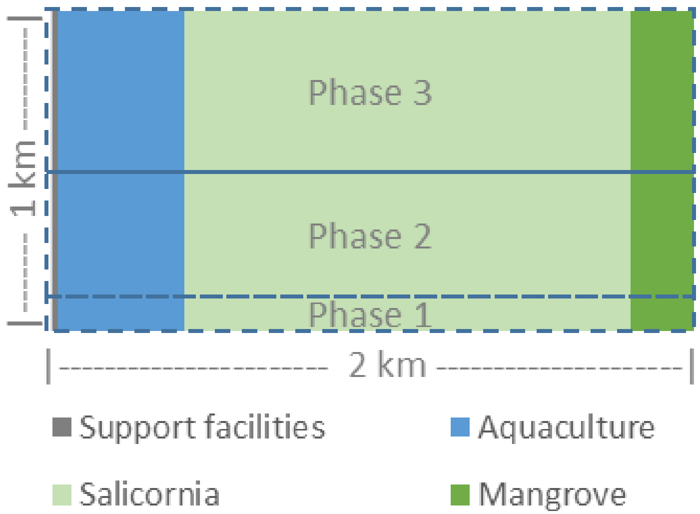
Carbon fixation credits in context

- According to latest figures the UAE emitted **161 million tonnes of CO_2 equivalent** per year in 2005;
- At the 39th ICAO Assembly, emission reductions were agreed in a global **Market-based Measure (MBM)** scheme known as the Carbon Offsetting and Reduction Scheme for International Aviation, or **CORSIA**
  - The **establishment of carbon offsetting mechanisms** is one of the key proposed solutions for emissions reductions to meet the aviation industry's goal of carbon-neutral growth from 2020 onwards
- Carbon credits are validated by two broadly categorized mechanisms: UNFCCC Clean Development Mechanism (CDM) credits and voluntary carbon standards (VCS, GS)
- **Mangrove afforestation projects** have the potential for qualifying for **carbon credits** under these mechanisms

Mangroves in context

- Mangroves in the UAE belong to the *Avicennia marina* species (grey mangrove), the only identified species capable of surviving UAE local weather conditions
- Mangrove coverage in the UAE (both natural and planted) constitutes an area of **13,616** ***ha***
- Forests occupy an area of **317,300** ***ha***
- Date palm plantations occupy an area of **18,530** ***ha***

Project characteristics



INTERMEDIATES	SPECIFIC YIELDS, *mean*	PRODUCTIVITY @ 200*ha*
Fish	23.34 t_{fish}/*ha*/year (*11.67 t_{fish}/ha/cycle, 2 cycles/year*)	734 $t_{seafood}$/year (311 t_{fish} + 423 t_{shrimp} per year)
Shrimp	15.86 t_{shrimp}/*ha*/year (*7.93 t_{shrimp}/ha/cycle, 2 cycles/year*)	
Seeds	3 $t_{oilseed}$/*ha*/year	420 $t_{oilseed}$/year
Biomass	30 $t_{biomass}$/*ha*/year	4200 $t_{biomass}$/year
Carbon (CCS)	799 $t_{CO2,eq}$/ha (cumulative, Year 4)	16 $kt_{CO2,eq}$ (cumulative, Year 4)

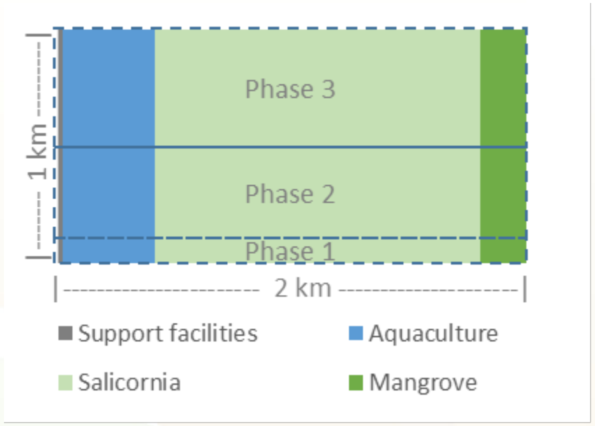
Area per Unit Operation	Phase 1 Area	Phase 2 Area	Phase 3 Area	Total Area
Aquaculture	+4*ha*	+16*ha*	+20*ha*	40*ha*
Salicornia	+14*ha*	+56*ha*	+70*ha*	140*ha*
Mangrove	+2*ha*	+8*ha*	+10*ha*	20*ha*

The demonstration scale will be built using a *proportional scale-up*, characterized by:

- Three-phase construction
- Main unit operations are in a 2:7:1 area ratio (Aquaculture, Salicornia and Mangrove, respectively)
- Demonstration-scale SEAS plant to be built in the Western Region, Abu Dhabi, UAE

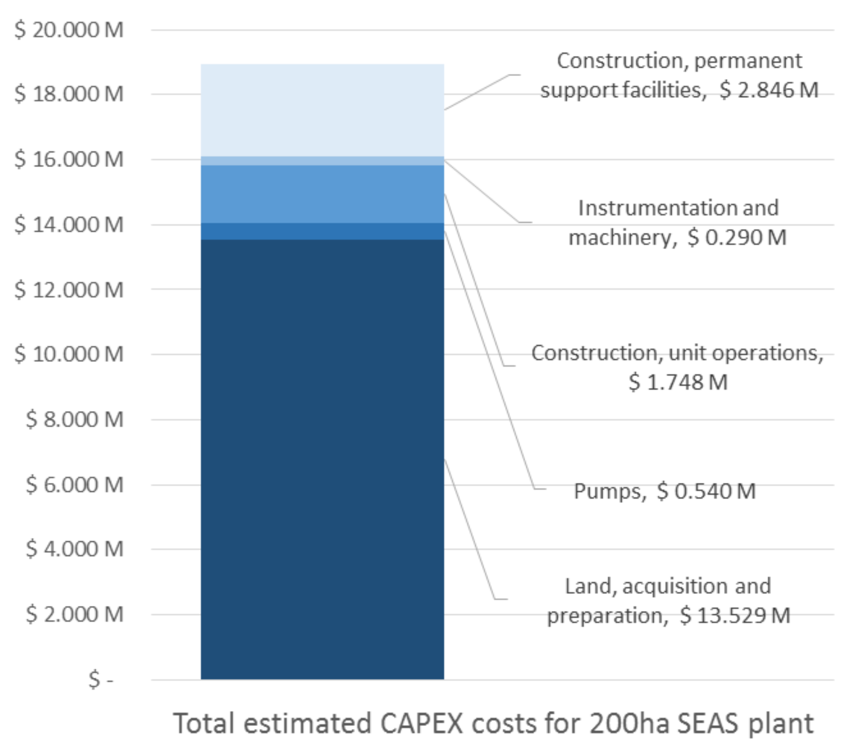
Financial analysis

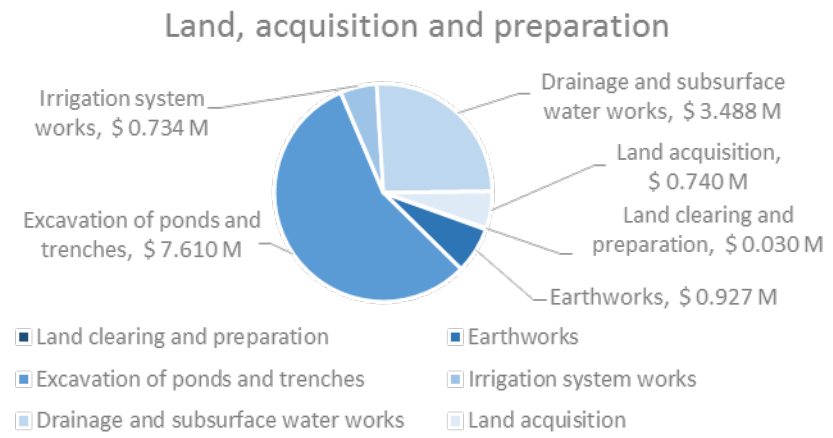
Parameter	Value
Discount rate	14%
IRR	22.45%
Payback time	6.81 years
NPV (Year 10)	$ 5.304 M

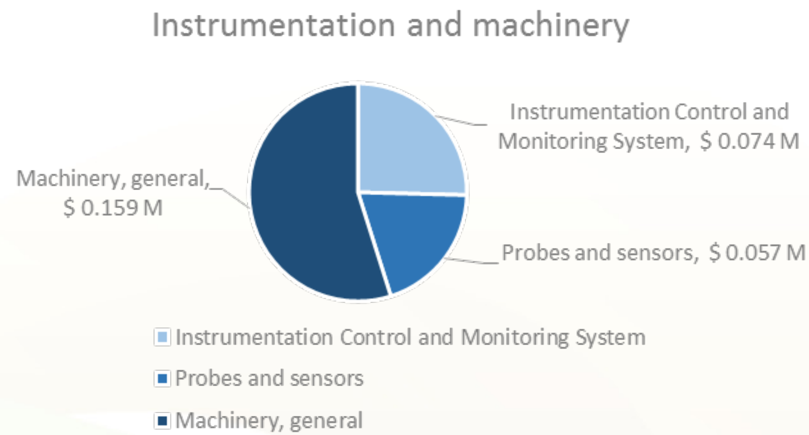


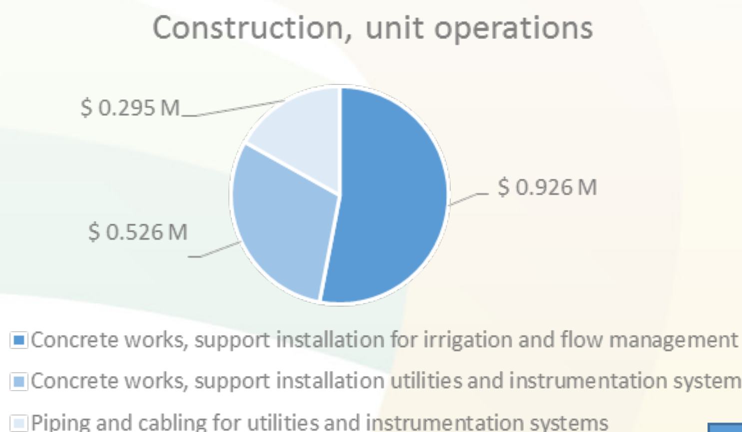
→ Capital allocation: land acquisition, construction and operation of 200*ha* plant
→ Revenue allocation: aquaculture products, salicornia seeds, salicornia biomass, mangrove biomass
→ Sensitivity analysis: revenue volatility

Capital cost inventory









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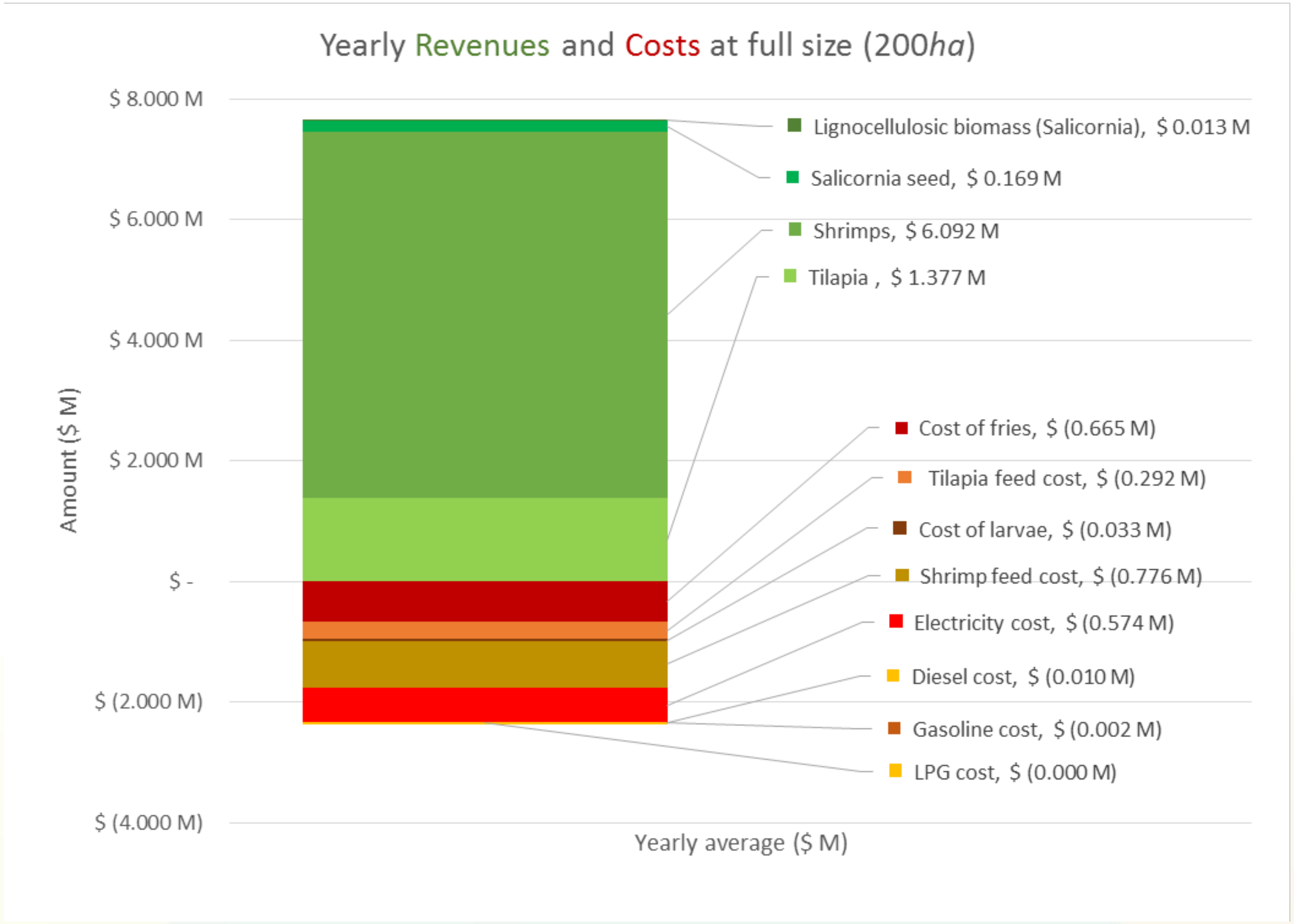
Yearly OPEX and Revenues breakdown



* Carbon credits not included

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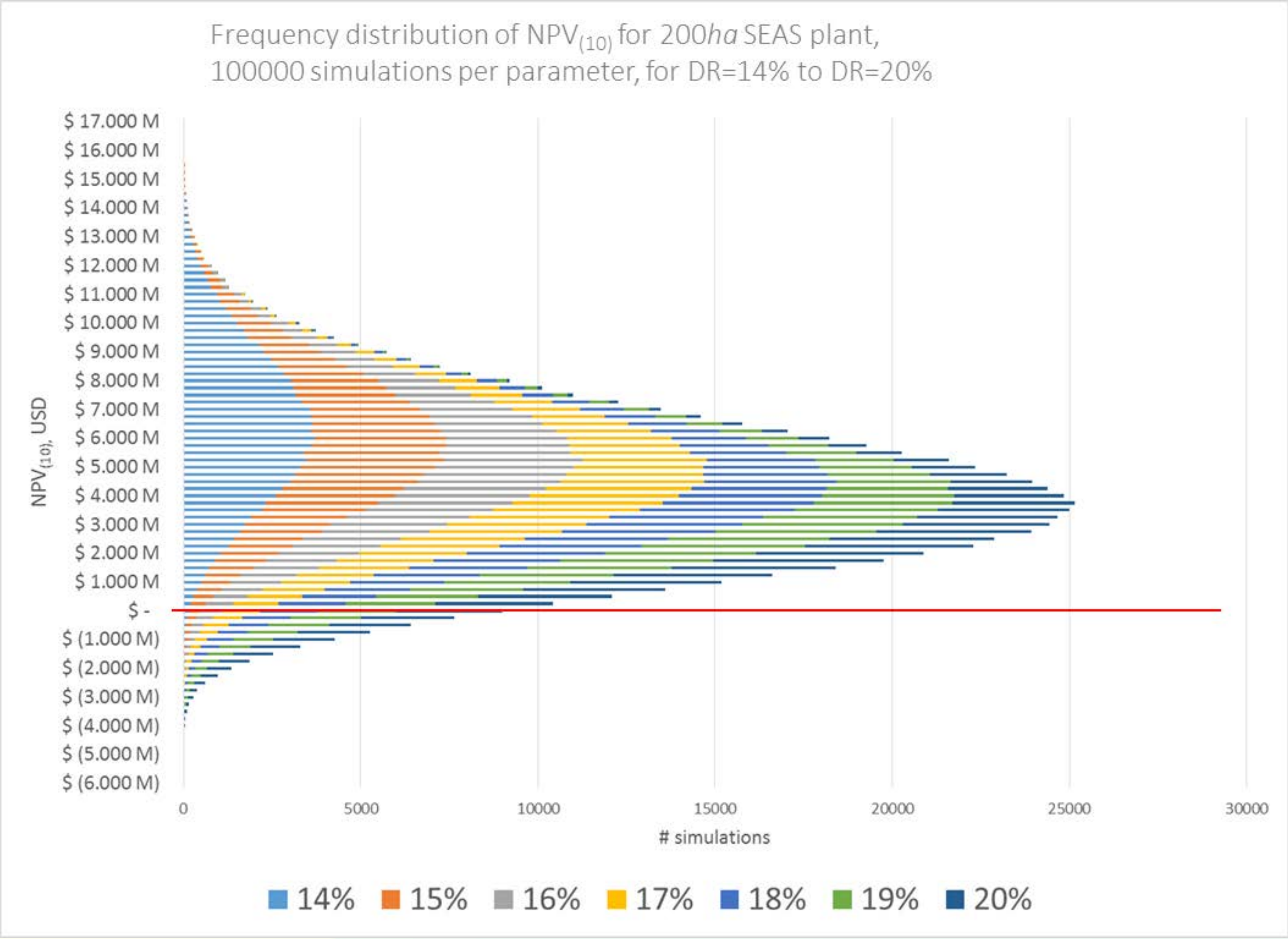
Sensitivity analysis: Monte Carlo-based stochastic TEA



DR	NPV(10), average	Likelihood of NPV+
14%	$ 6.303M	**99.53%**
15%	$ 5.448 M	98.93%
16%	$ 4.654 M	97.71%
17%	$ 3.914 M	95.73%
18%	$ 3.226 M	92.64%
19%	$ 2.585 M	88.39%
20%	$ 1.987 M	82.85%

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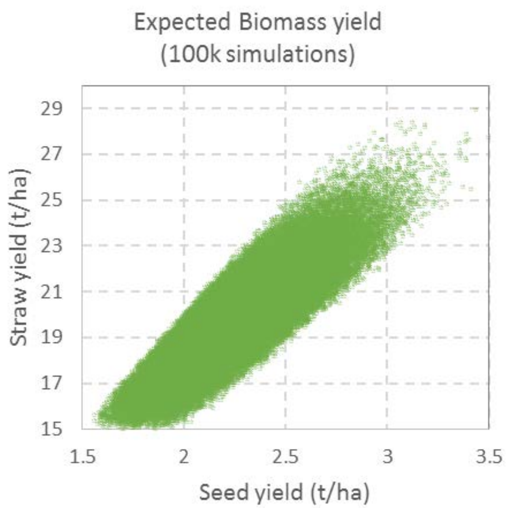
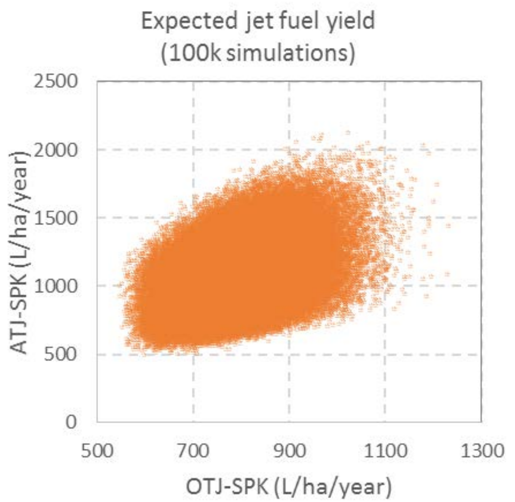
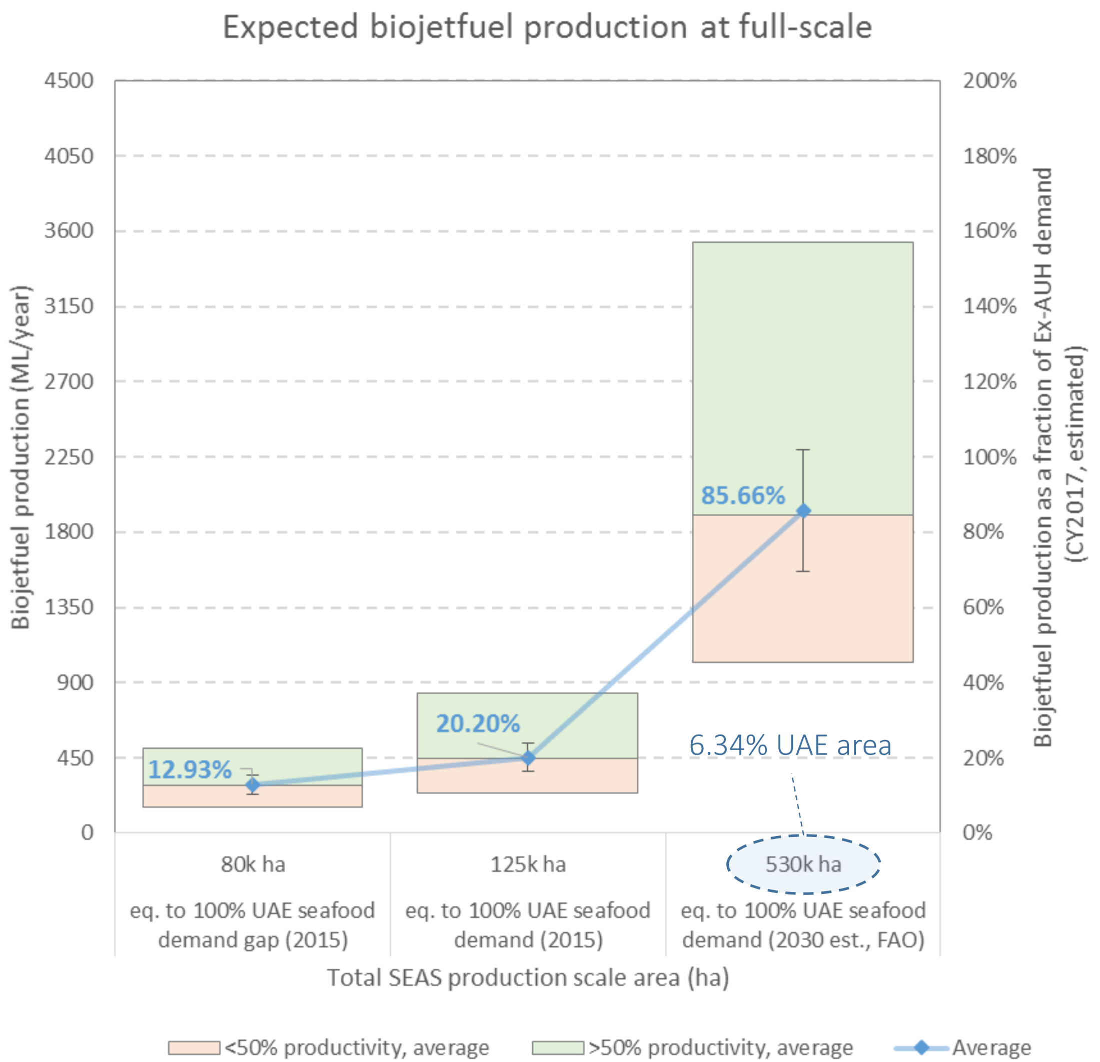
Large-scale production forecast







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