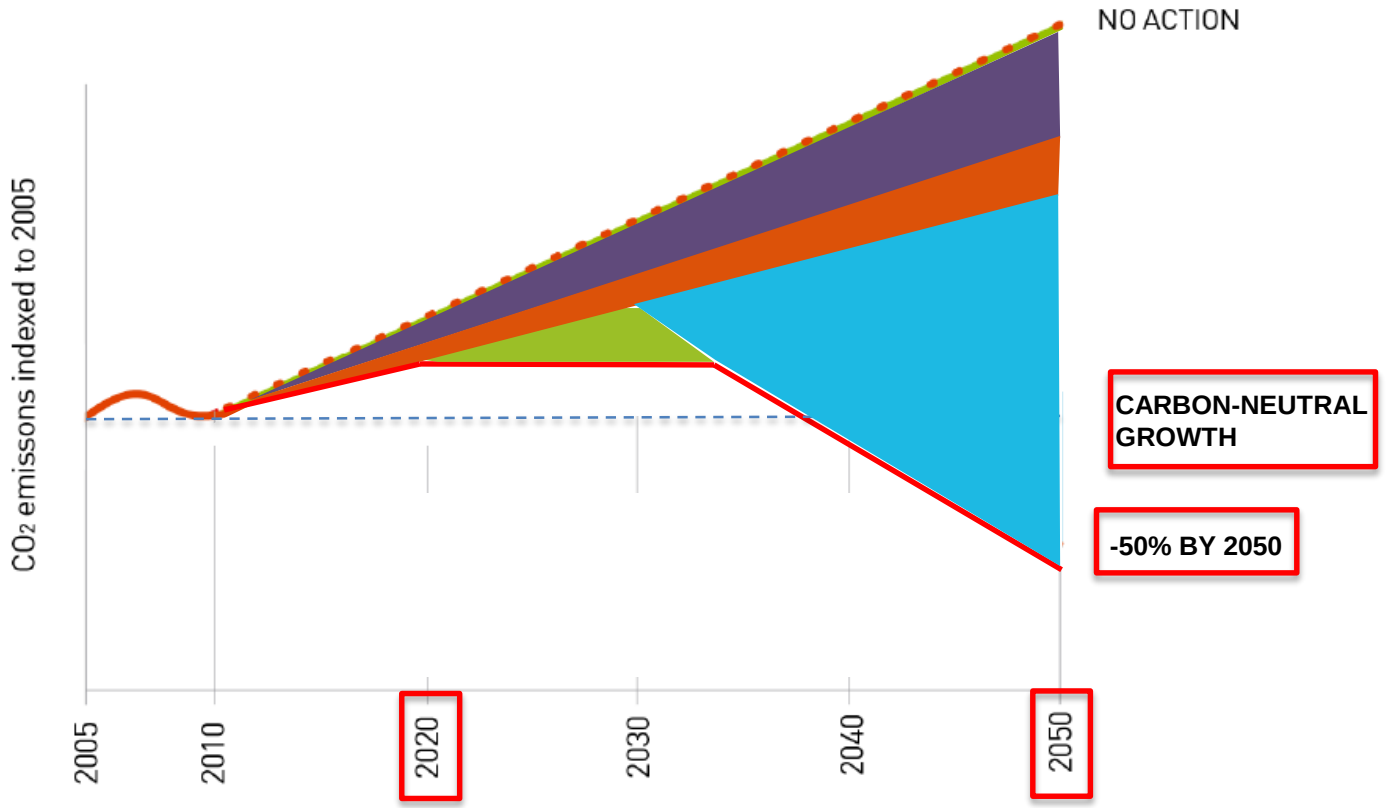
The Case for Sustainable Aviation Fuels

Dr. Alejandro Rios G.

Context: Aviation Industry's Strategy



Fly using more efficient
OPERATIONS

Build and use efficient
INFRASTRUCTURE

Use effective, global,
MARKET-BASED MEASURES

Invest in new
TECHNOLOGY

(including sustainable aviation biofuels)

Source: IATA

Rising demand for biofuel feedstocks

Increasing bio-based feedstock demand

- Sustainable, renewable production
- Insulation from petroleum price increases
- Consumer appeal

Dragging bio-based feedstocks down

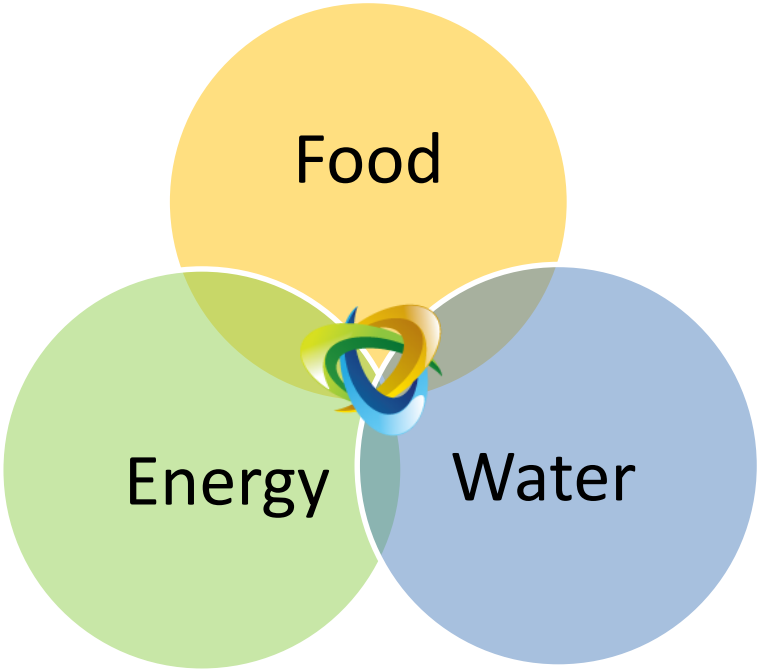
- Indirect land-use change
- Environmental (e.g. drought-related) supply and price volatility
- Food versus fuel
- Fear of genetically modified organisms
- Resistance to corporate agribusiness

Source: Lux Research

Biomass Production

- Biomass supply chain
  - → Cost-effective
  - → Scalable
  - → Sustainable

- **Food – Water – Energy** nexus



- **Research** as a driver for sustainability

The SBRC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ETIHAD
AIRWAYS
BOEING
Masdar
INSTITUTE
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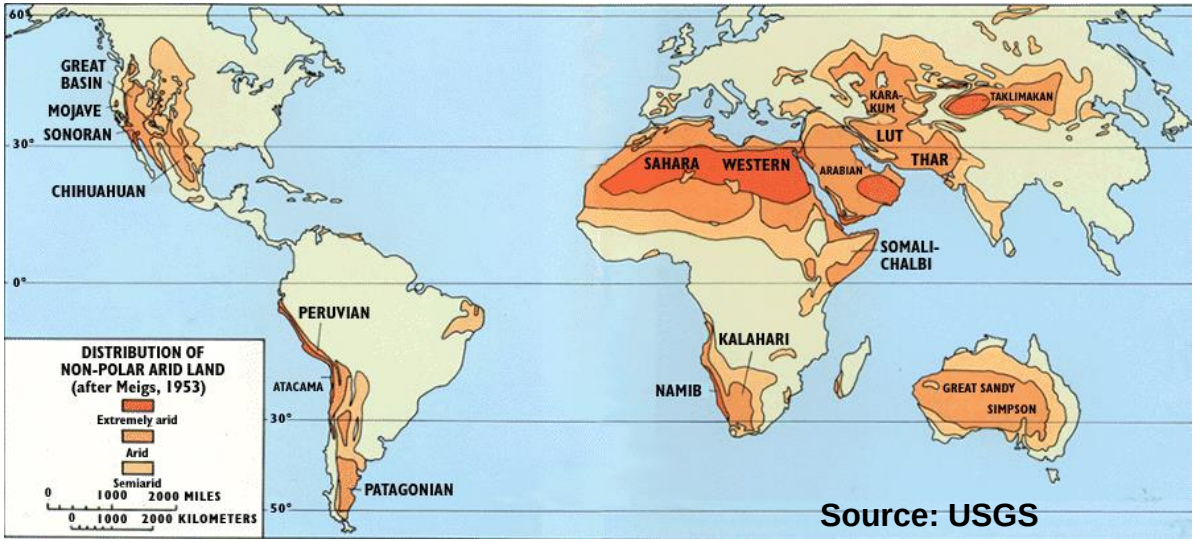
A Honeywell Company

Why is SBRC research important?

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

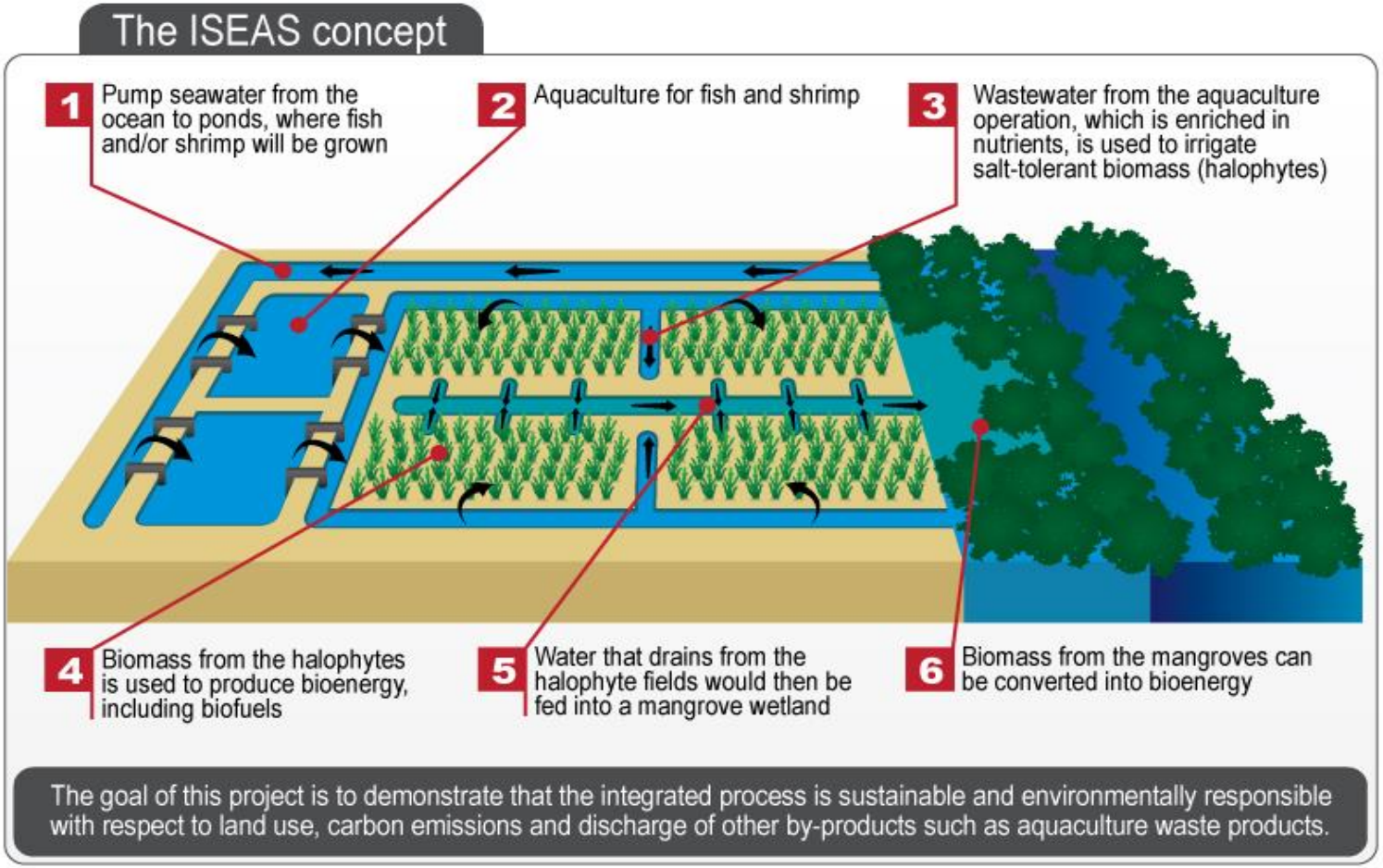
97%
of the Earth's water is in the oceans

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

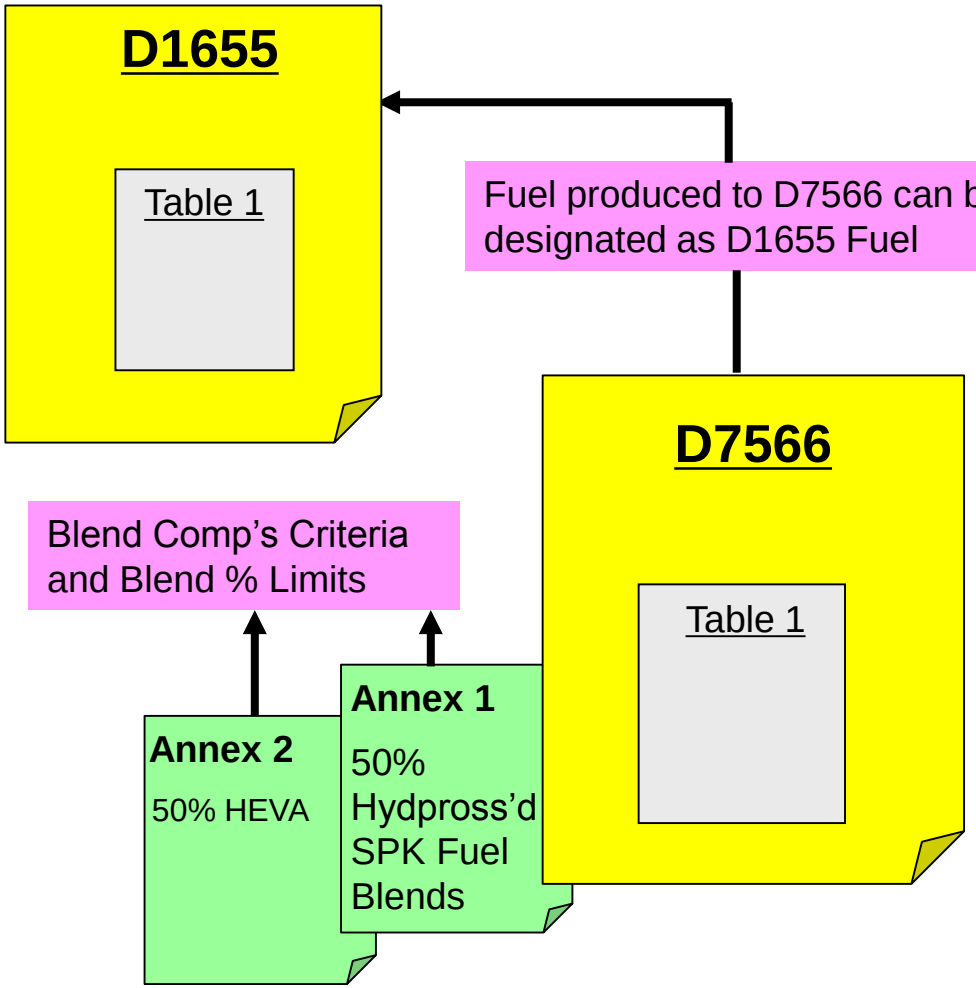


The ISEAS

The flagship project of the SBRC is the Integrated Seawater Energy and Agriculture System – ISEAS



Aviation biofuel specifications



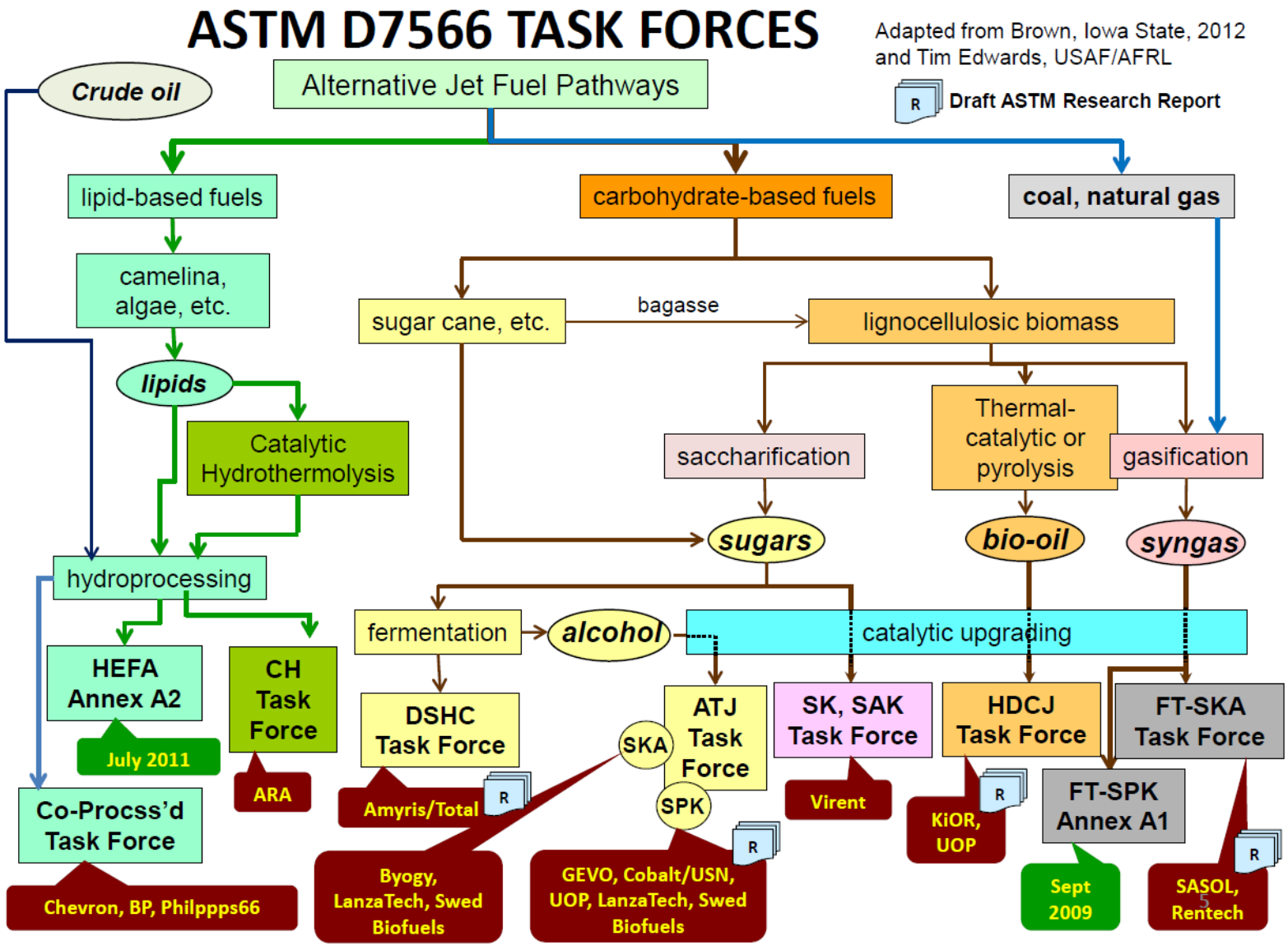
Designation: D1655 – 13a

Standard Specification for Aviation Turbine Fuels[1]

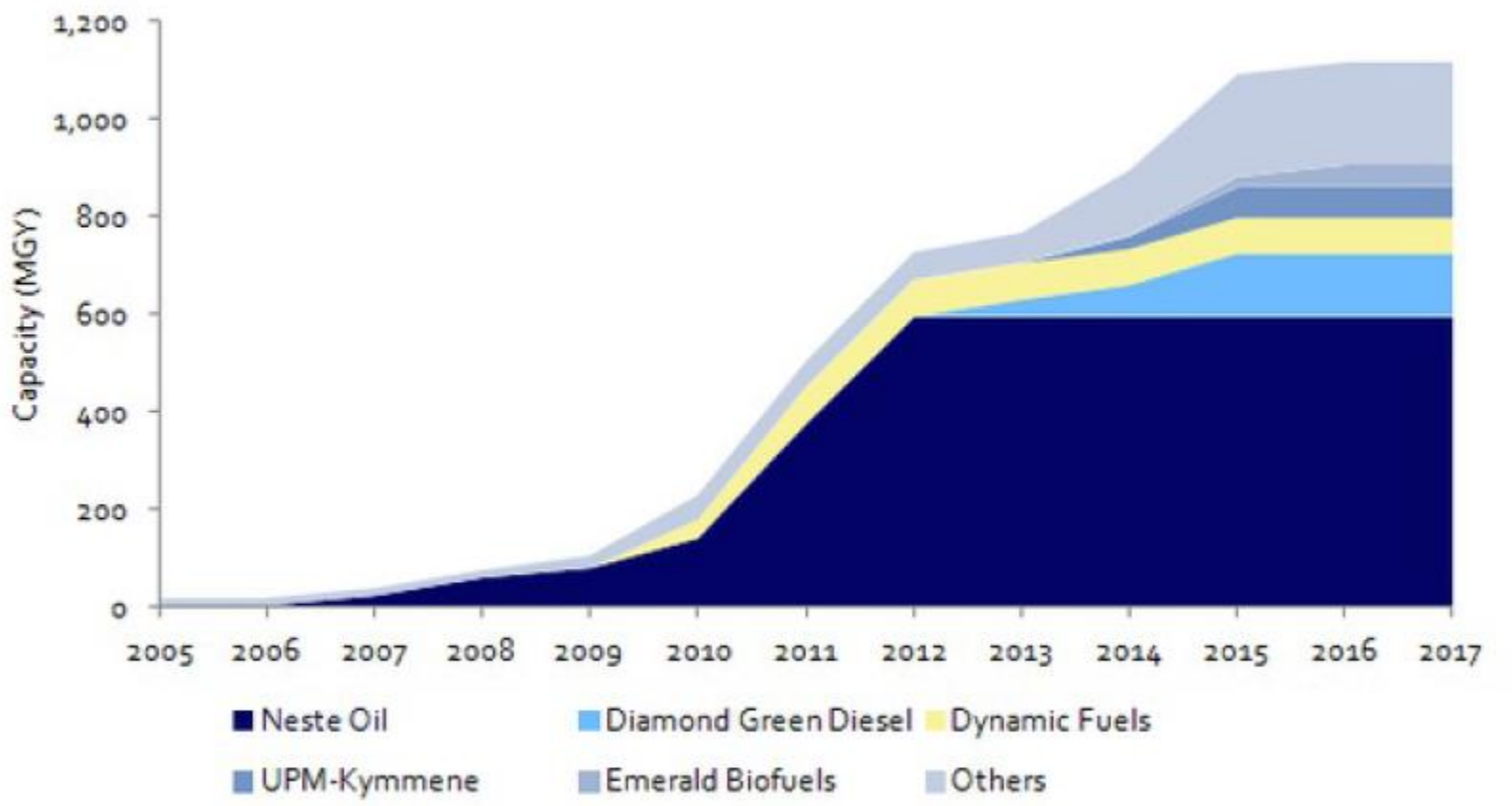
Designation: D7566 – 13

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

Many new fuels coming…



Increasing capacity



Source: Lux Research

Biofuel Supply Chain

Feedstocks

Refining

Transport and distribution

Into-plane operations

It is already happening…

2 LOCAL Saturday May 17 2014 ARUBADAILY www.aruba-daily.com Follow us

KLM COMPLETES LONGEST BIOFUEL FLIGHT TO ARUBA

Aruba and KLM are writing history with used cooking oil

ORANJESTAD – Yesterday afternoon, Aruba's Prime Minister Mike Eman received the KLM Royal Dutch Airlines Airbus that just completed a 10-hour flight from Amsterdam to Aruba using sustainable jet fuel. This marks the longest biofuel flight to date by an Airbus aircraft and another step forward on the journey to more sustainable aviation, by reducing CO2 emissions and fuel consumption.

The Airbus flew with a 20% blend of sustainable fuel made of used cooking oil as the first of a series called "Initiative Towards sustAinable Kerosene for Aviation" (ITAKA), which aims to speed up the commercialization of aviation biofuels in Europe. KLM and the Dutch government chose Aruba and Bonaire as the best destination for these flights because both islands have a high sustainability agenda, aiming to be carbon neutral by 2020. Aruba aims to have a 100 per cent sustainable economy by 2020.

A large delegation was on-board, including Camiel Eurlings, President & CEO KLM, Jos Nijhuis, CEO Schiphol Group, Paul Riemens, CEO LVNL and chair of CANSO, Johan van de Gronden, CEO of WWF-NL, Andrea Debbane, Head of Environmental Affairs Airbus Group, and Paul Verhoef, Head of Unit Renewable Energy Resources of the European Commission. The President of Carbon War Room Jose Maria Figueres was also on the flight with the winners of the Green Aruba Challenge.

The Green Aruba Challenge is an initiative of KLM Innovations, directed at looking for promising sustainable solutions for a better world that can be implemented on Aruba with support from KLM. In April, KLM challenged innovators to send their concepts to the greenaruba.klm.com platform.

The Green Aruba Challenge represents a perfect match between KLM and Aruba, because of Aruba's ambition to become carbon neutral by 2020 and KLM's ambition to reduce CO2 emissions by 20% by 2020.

The submitters of the five best concepts were invited by KLM and Aruba to present their ideas to a panel of judges consisting of Mike Eman, Camiel Eurlings, several CEO's and high-level local experts today May 17th at the Dr. Edward Cheung Aruba Center for Innovation.

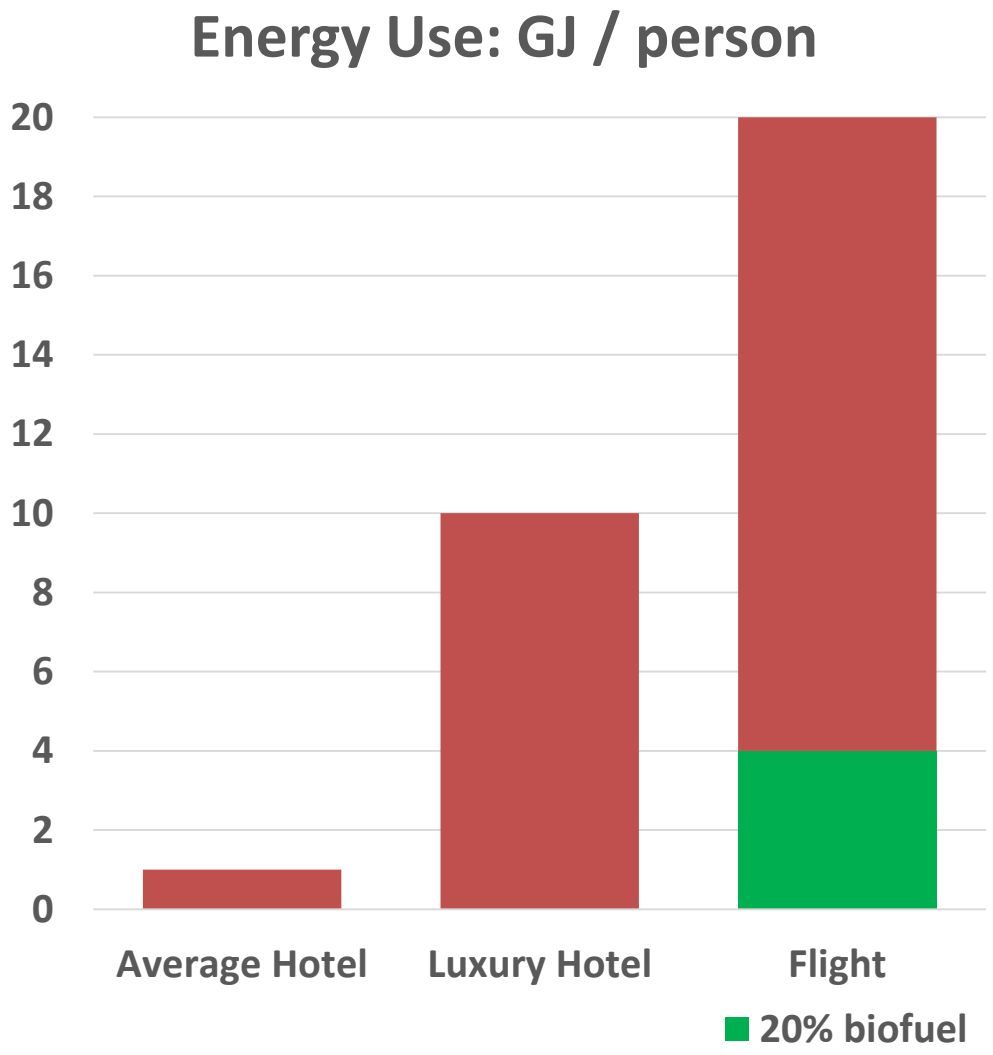
Ideas were submitted from various parts of the world and on May 9th, twelve selected participants were asked to give a presentation at the KLM headquarters in Amstelveen for KLM's top executive Wim de Jong and Aruba Minister Plenipotentiary in The Hague Alfonso Boekhoudt.

The finalists are: Maarten von Wining with "Minipower," Jan Tijs Nijssen and Jurrian Ruys with "Land Life Box," Chintan Shah with "Twilight," Lara van Druten with "Waste Transformers" and Hompe Heijmerink with "Evening Breeze."

The winner of the Green Aruba Challenge will receive financial support from KLM on Aruba for a quick implementation of the business concept.

Aruba to Amsterdam: one week vacation

- Hotel energy use: 1 – 10 GJ
  - 7 night stay
  - Average: 140 MJ/night
  - Luxury: 1400 MJ/night
- Flight energy use: 20 GJ
  - Boeing 747
  - 350 passengers
- Flight renewable energy: 4GJ
  - 2014 KLM flight
  - 20% biofuel from waste oil



Thank you!

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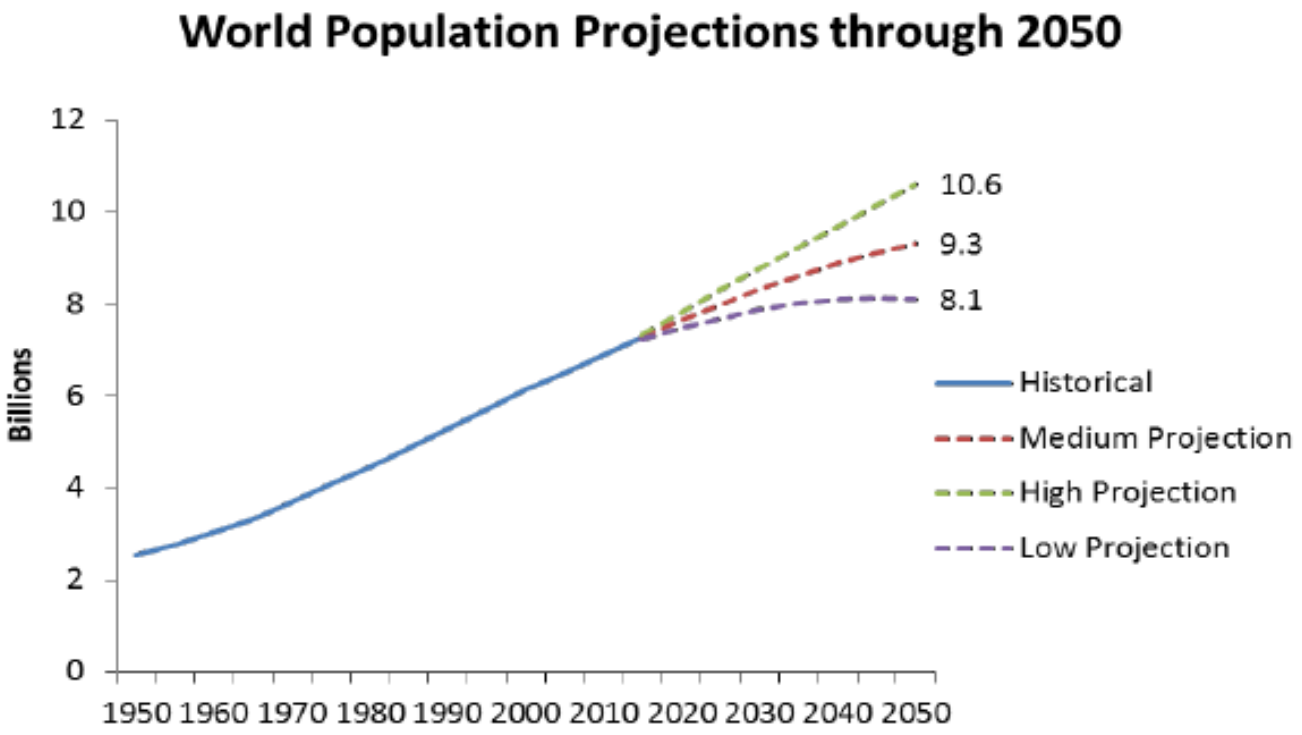
Demographic Trend



Source: UN Population Division

Bennett's Law

As people become wealthier, they switch from simple starchy plant-dominated diets to a more varied food input that includes a range of vegetables, fruit, dairy products, and especially meat.

- The food types consumed by wealthy people tend to require more resources to produce

Source: www.pnas.org/cgi/doi/10.1073/pnas.1118568109

How is Bioenergy Research done?

- The United States is by far the world leader in bioenergy research
  - Over $100 million USD per year is invested
  - The US Department of Energy has been funding three research centers for the last 5 years, and recently renewed this commitment for an additional 5 year period

- The research centers from the Department of Energy are:
  - The Bioenergy Science Center (BESC)
  - The Great Lakes Bioenergy Research Center (GLBRC)
  - Joint Bioenergy Institute (JBEI)

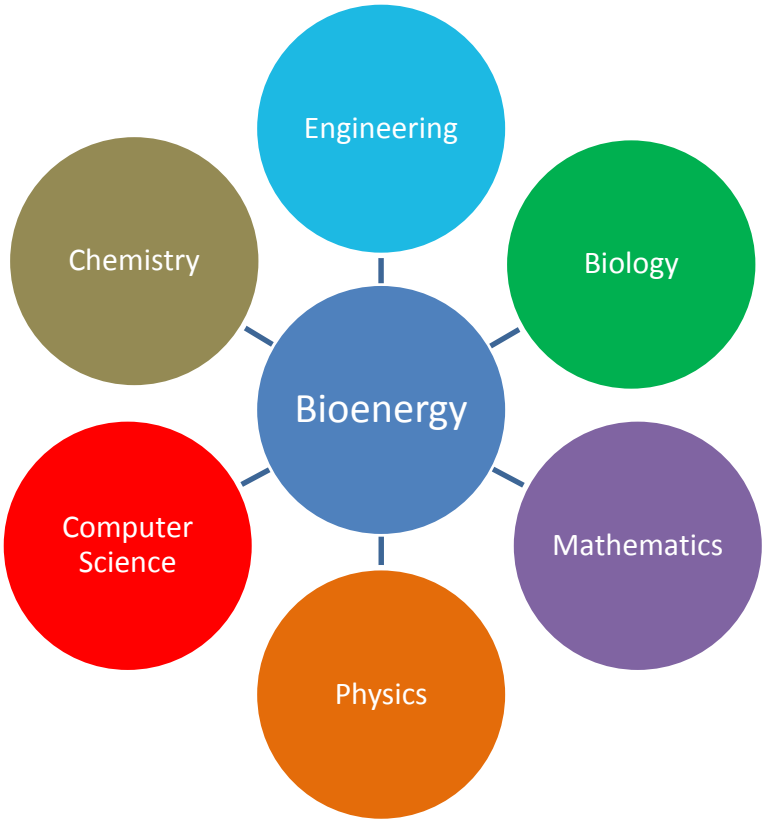
- One additional center in the US is the Energy Biosciences Institute (EBI)
  - The largest public-private partnership of its kind in the world

Common Structure

All Research Centers have a common structure

- **Multi-institutional**
  - They are formed by a diverse group of institutions from academia and industry

- **Multi-disciplinary**
  - They focus on several areas of knowledge that have to do with bioenergy



Research Focus

- Common themes:
  - Plants/Feedstocks/Source of biomass
  - Deconstruction/Depolymerization/Getting to the energy
  - Conversion/Fuels Synthesis/Production of Biofuels

- Then, either:
  - Enabling Technology
  - Sustainability

Industry Engagement

- All centers have a mechanism for engaging in one way or another with industry
- This is how the scientific advances that are being discovered get transferred into viable commercial technologies
- Partnerships with both start-ups and established companies to accelerate innovation and time to market for biofuels, chemicals, and/or feedstocks

Results from Bioenergy Research

- "In five years of operation, the Centers have produced more than 1,100 peer-reviewed publications and over **400 invention disclosures and/or patent applications**. Among the breakthroughs the Centers have achieved are new approaches for engineering non-food crops for biofuel production; reengineering of microbes to produce advanced biofuels such as "green" gasoline, diesel, and jet fuel precursors from biomass; and the development of methods to grow non-food biofuel crops on marginal lands so as not to compete with food production."

  - DOE press release

- "The Bioenergy Centers are six years old now, and a lot of what's coming out of them is making its way into industry"
- "We actually have **startup companies** associated now with the Bioenergy Research Centers, so I think that's a success story."

  - Patricia Dehmer, acting head of DOE's Office of Science, 05/Nov/2013

Motivation

– Sustainable bioenergy

- Water use
- Land use
- Food vs. fuel

– Aquaculture effluent

Background

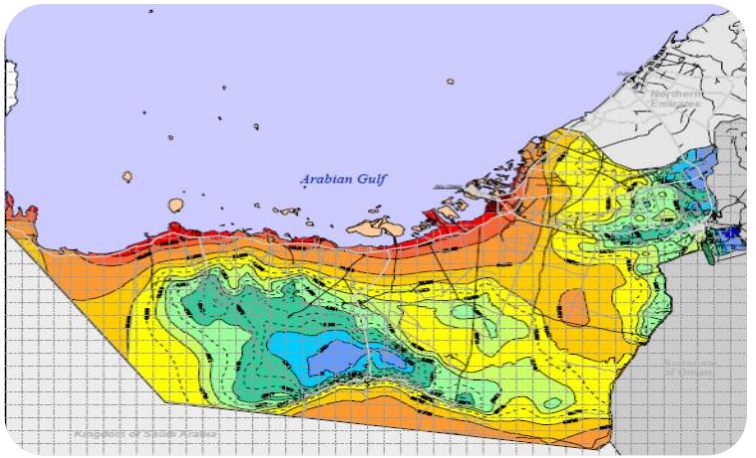
- Previous examples
  - Mexico
  - Eritrea

The SBRC Research Structure

- **Best practices approach**

Research Areas:

1. **Salt-tolerant and arid land biomass**
2. **Releasing and capturing bioenergy**
3. **Synthesizing bioenergy**
4. **Supporting Technology**
5. **Sustainability**

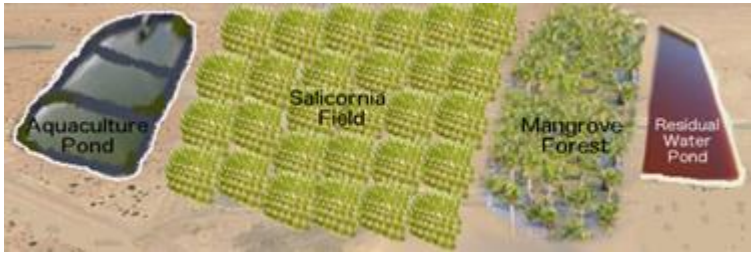


Research Projects

The first five funded research projects are already producing highly promising results

1. Field-Scale Salt and Water Balance during Integrated Seawater Farming in Coastal Regions of Abu Dhabi
2. Screening oilseed halophytes for production under seawater irrigation in the United Arab Emirates
3. Anaerobic digestion as key technology for nutrient and energy recovery in the Integrated Seawater Energy & Agriculture System (ISEAS) project
4. Bioenergy production from high salinity lignocellulosic biomass: *Salicornia bigelovii* and *Avicennia marina*
5. Molecular and Biochemical Screening of Mangrove Sediments in Abu Dhabi for Biomass Degrading Enzymes

Pilot ISEAS Project



1.2.1 Aviation turbine fuel manufactured, certified, and released to all the requirements of Table 1 of this specification (D7566), meets the requirements of Specification D1655 and shall be regarded as Specification D1655 turbine fuel. Duplicate testing is not necessary; the same data may be used for both D7566 and D1655 compliance. Once the fuel is released to this specification (D7566) the unique requirements of this specification are no longer applicable: any recertification shall be done in accordance with Table 1 of Specification D1655.

1.2.2 Field blending of synthesized paraffinic kerosine (SPK) blendstocks, as described in Annex A1 (FT SPK) or Annex A2 (HEFA SPK) with D1655 fuel (which may on the whole or in part have originated as D7566 fuel) shall be considered batch origination in which case all of the requirements of Table 1 of this specification (D7566) apply and shall be evaluated. Short form conformance test programs commonly used to ensure transportation quality are not sufficient. The fuel shall be regarded as D1655 turbine fuel after certification and release as described in 1.2.1.

1.2.3 Once a fuel is redesignated as D1655 aviation turbine fuel, it can be handled in the same fashion as the equivalent refined D1655 aviation turbine fuel.