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CONFERENCE ON AVIATION AND ALTERNATIVE FUELS

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Agenda Item 1: Developments in research and certification of aviation alternative fuels

INTEGRATED PRODUCTION SYSTEMS FOR SUSTAINABLE AVIATION FUEL (SAF) FEEDSTOCK PRODUCTION IN WATER-STRESSED REGIONS[1]

(Presented by the United Arab Emirates)

SUMMARY

The Sustainable Bioenergy Research Consortium (SBRC) currently conducts research on the development of a feedstock production system that can address volume demands in water-stressed regions, without competing with food crops for irrigation freshwater and arable land. This information paper presents an overview of the current R&D paradigm on the topic and the emerging solutions to overcome hurdles in the bench-to-market process.

1. INTRODUCTION

1.1 One of the main cost drivers for production of aviation alternative fuels (AAF) is feedstock cost, as discussed in CAAF/2-WP/08. The viability of sustainable aviation fuels (SAF) in particular relies on developing feedstock production systems in line with sustainability criteria mentioned in CAAF/2-WP/03 and CAAF/2-WP/04, as well as ICAO Assembly Resolution A39-2 to Member States. Pending ongoing work by the Committee on Aviation Environmental Protection (CAEP), as discussed in CAAF/2-IP/01, will provide recommendations on such criteria in the context of the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA).

1.2 In water-stressed, arid regions, SAF-compliant feedstock sources would ideally have the following characteristics:

a) do not compete with food crops for environmental resources (e.g. irrigation freshwater, arable land);

b) do not require extensive use of petroleum-based fertilizers;

c) can be certified as carbon-neutral or generate carbon offsetting credits;

[1] The content of this paper is based on ongoing research conducted by the Sustainable Bioenergy Research Consortium (SBRC) provided on a preliminary basis. Information presented is subject to change pending final results.

d) can be replicated in similar geographic and climatic conditions globally to achieve necessary scale-up and production volumes at commercial aviation requirement levels;

e) are able to provide environmental services for treatment of waste effluent streams; and

f) can be financially viable while achieving minimum biomass selling prices (MBSP) in line with feedstock costs required by SAF producers.

1.3 This paper provides an overview of and context for the production system envisioned by the Sustainable Bioenergy Research Consortium (SBRC) in the UAE to achieve commercial scale production of a promising set of SAF feedstocks.

2. INTEGRATED PRODUCTION SYSTEMS: ADDRESSING PROCESS ECONOMIC LIMITATIONS AND SOCIO-ENVIRONMENTAL CONSTRAINTS

2.1 The majority of currently researched AAF pathways are still not able to achieve price parity with conventional aviation fuel (CAF)[2]. Notably, cost-effective production of feedstock is challenged by low crude-oil prices and competition for resources with other agronomic activities. Conceptually, feedstock-to-SAF pathway operational expenses (OPEX) can be split into feedstock costs and upgrade costs, with the former being the dominant contributor[3].

2.2 Biofuel research at large is prospecting novel biomass sources, such as biomass waste from other industrial activities[4], to address the economic limitations of single-purpose biofuel crops. The emergence of integrated production systems is an optimal solution that can leverage geographical advantages (i.e. co-location of unit operations) and improve reutilization and valorising opportunities for waste streams. Different industrial activities can coalesce into one interdependent production system in line with the concept of Industrial Ecology[5].

2.3 In water-stressed regions, the negative environmental impact of single-purpose fuel crops is further heightened given the need for either utilising scarce fresh water sources or energy-intensive desalination for irrigation[6]. Furthermore, treatment of desalinated water to meet quality requirements for irrigation leads to additional OPEX and potential GHG emissions[7]. Due to the use of fertilizers, agricultural effluents must be treated prior to release into water bodies to prevent environmental impact (e.g. eutrophication). This treated water re-use can potentially provide an alternative source if social acceptance is improved[8].

2.4 In arid regions, limited access to arable land also hinders utilization of single-purpose fuel crops, to avoid competition with food crops. In the UAE, traditional agriculture practices dominate

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[2] See CAAF/2-WP/08 Figure 1 for minimum fuel selling prices (MFSP) estimates

[3] Pearlson, Matthew, Christoph Wollersheim, and James Hileman. "A techno-economic review of hydroprocessed renewable esters and fatty acids for jet fuel production." *Biofuels, Bioproducts and Biorefining* 7.1 (2013): 89-96.

[4] Tuck, Christopher O., et al. "Valorization of biomass: deriving more value from waste." *Science* 337.6095 (2012): 695-699.

[5] Ehrenfeld, John, and Nicholas Gertler. "Industrial ecology in practice: the evolution of interdependence at Kalundborg." *Journal of industrial Ecology* 1.1 (1997): 67-79.

[6] Dawoud, Mohamed A. "Environmental impacts of seawater desalination: Arabian Gulf case study." *International Journal of Environment and Sustainability* 1.3 (2012).

[7] Elimelech, Menachem, and William A. Phillip. "The future of seawater desalination: energy, technology, and the environment." *Science* 333.6043 (2011): 712-717.

[8] www.moccae.gov.ae/assets/download/40a8d3c1/green-economy-report-2016.aspx

the utilisation of scarce arable land, with date palm as the primary crop planted[9]. Given the limited potential for conventional biomass sources for SAF, the SBRC focused on an integrated production system approach based on seawater irrigation for food and biomass production[10]. The benefits of this systemic integration are discussed in the next section.

3. SEAWATER ENERGY AND AGRICULTURE SYSTEM (SEAS): OPPORTUNITIES AND CHALLENGES TOWARDS SUSTAINABLE AVIATION FUELS

3.1 The Seawater Energy and Agriculture System (SEAS) aims to be an integrated food and energy production system that leverages the local geographic characteristics of the Emirate of Abu Dhabi for seawater-based technologies. The system as currently designed is composed of three main unit operations, namely aquaculture, halo-agriculture and halo-agroforestry. In the SAF feedstock context, the SEAS platform is being developed to address the recommendations listed in paragraph 1.2 of this paper, as expanded below.

3.2 a) *do not compete with food crops for environmental resources (e.g. irrigation freshwater, arable land)*: the current design of the SEAS production plant does not require arable land for cultivation of the main energy crop, the halophyte *Salicornia sp*. Field trials in the SEAS pilot plant irrigated with recirculated salt water effluent from the aquaculture unit operations have been harvested in Q3-2017 and demonstrate the viability of the system with zero direct competition for resources with other agricultural activities.

3.3 b) *do not require extensive use of petroleum-based fertilizers*: by utilising the aquaculture salt water effluent as irrigation water, a two-fold environmental benefit is achieved, as this nutrient-rich stream is simultaneously treated for discharge and the halo-agriculture crops fertilized without need for petroleum-based products. The optimum operational parameters for maximum biomass yield from the unit operations, while still achieving quality requirements for effluent treatment, are the focus of ongoing research.

3.4 c) *can be certified as carbon-neutral or generate carbon offsetting credits*: the SEAS plant can achieve sustainable accreditation for its operation and products under different mechanisms, the extent of which is currently being assessed. The two relevant carbon offsetting opportunities are via the direct production of feedstock for SAF and via the carbon sequestration potential of the mangrove halo-agroforestry unit operation.

3.5 *d) can be replicated in similar geographic and climatic conditions globally to achieve necessary scale-up and production volumes at commercial aviation requirement levels*: the SEAS process is modular by design, allowing for rapid expansion and widespread replication of production facilities wherever favourable environmental and economic conditions are present. Therefore, countries and regions with extensive tracts of arid non-arable land and coastal or brine water sources are potentially suitable. A distributed production capacity enables regional production and consumption of SAF and minimizes costs associated with the transportation of SAF from process plants to airfields.

3.6 e) *are able to provide environmental services for treatment of waste effluent streams*: all effluent streams are treated *in situ* in the SEAS integrated approach. Depending on the availability and characteristics of waste effluent streams from other industries, a provision of ecological services for effluent treatment is possible to complement the deployment of the SEAS plant. The economic viability

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[9] www.moew.gov.ae/assets/download/c73a4ab6/state-of-environment-report-2015.aspx
[10] https://www.icao.int/environmental-protection/GFAAF/Pages/Project.aspx?ProjectID=21

of such modified implementation strategies is currently being investigated to expand the portfolio of process design variations that are possible under the SEAS framework.

3.7 *f) can be financially viable while achieving minimum biomass selling prices (MBSP) in line with feedstock costs required by SAF producers*: the current configuration of the SEAS depends primarily on revenue generated by the aquaculture unit operation, according to the current techno-economic assessment (TEA) results. By decoupling the financial viability of the process from the revenue stream generated by the feedstock sale, the financial risk of deploying a SEAS plant is reduced and the SAF pathway OPEX cost discussed in paragraph 2.1 can be minimized.

3.8 The successful establishment of the SEAS process still depends on validating process design assumptions and optimizing unit operations. Given that the primary economic driver of the system is the aquaculture food production, expansion and scale-up of the system might be gated by market demand forces for seafood, which might limit readiness of SAF production capacity along the short- and medium-term forecasts discussed in CAAF/2-WP/06. However, aquaculture production is set to grow at a rate of 39% in a ten-year period, from reference period (average 2013-2015) until 2025, which creates the necessary conditions for the expansion of this industry worldwide[11].

4. **SBRC & UAE**

4.1 Since its inception, the SBRC has been a test-bed for an innovation strategy that promotes the vision of the UAE to transition from a finite resource-based economy to a knowledge-based one. As it pursues its goal of sustainable development based on bioenergy generating technologies, the following best practices have emerged from the experience: 1) research being promoted by a consortium of private and public enterprises, 2) stakeholder engagement, 3) governmental (UAE) commitment

4.2 The Sustainable Bioenergy Research Consortium (SBRC) was established in Abu Dhabi in 2011 as a not-for-profit research consortium to advance the aviation industry's commitment to sustainable business practices by developing technology with the promise of producing a clean, alternative fuel supply. The SBRC was founded by the Masdar Institute, a part Khalifa University of Science and Technology, Etihad Airways, The Boeing Company, and Honeywell-UOP. Since then Safran, GE, and the Abu Dhabi Oil Refining Company (Takreer) have joined.

4.3 By being at the forefront of SAF research and development in the UAE, the SBRC partners were able to engage with numerous stakeholders (locally and globally, given its diverse member roster) from industry, academia and government, to help shape a broadly shared and agreed upon innovation strategy. Thus the research agenda set forth by the SBRC directly benefits from the diverse set of stakeholder input and can lead to holistic initiatives, such as BIOjet Abu Dhabi: Flight Path to Sustainability. This initiative aims to develop a comprehensive roadmap for a full Abu Dhabi-based SAF supply chain that can boost the local economy, using the aviation industry as a main driver.

4.4 Furthermore, in order to achieve the sustainable development goals set forth by the country[12], the SBRC can provide answers to challenges such as water, energy and food security, carbon-neutral growth and ecosystem preservation. Governmental bodies such as the UAE Ministry of Climate Change and Environment (MoCCaE), and others such as Advanced National Aquaculture and Fisheries (ANAF), are crucial partners whose support and two-way interaction greatly benefit all involved parties.

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[11] FAO (2016) "The State of World Fisheries and Aquaculture 2016" Rome: Food and Agriculture Organization of the United Nations.

[12] https://www.vision2021.ae/en/national-priority-areas/sustainable-environment-and-infrastructure

The engagement of relevant governmental authorities at all levels is crucial for fomenting any nascent industry that can be achieved with this research and for the establishment of policies necessary to promote and regulate such economic activities.

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