RENUEL Study Initiative: Accelerating SAF Adoption Through Decentralized Feedstock Solutions

Executive Summary

The global aviation industry faces an urgent imperative to decarbonize, with Sustainable Aviation Fuel (SAF) emerging as the most viable near-term solution. However, the widespread adoption of SAF is currently hampered by significant upstream challenges, particularly concerning feedstock availability, efficient extraction, and cost-effective logistics. The RENUEL Initiative, a collaborative global network of aviation fueling professionals, scientists, oil companies, universities, farmers, regulators, and technologists, has broadened its mission to directly address these critical bottlenecks. Building upon our foundational work in downstream SAF blending systems, RENUEL is now focused on pioneering decentralized, modular, and mobile crop extraction technologies. This comprehensive feasibility study aims to rigorously evaluate these innovative approaches, quantify their impacts on SAF supply chain efficiency and economics, and ultimately unlock a far greater SAF production potential at the source. By streamlining feedstock logistics, protecting agricultural lands, and fostering economic benefits for rural communities, RENUEL seeks to accelerate the global scale-up of SAF, ensuring a sustainable and secure energy future for aviation. This proposal outlines our expanded mission, detailed study objectives, robust organizational structure, and a multi-faceted funding strategy designed to secure the necessary support for this transformative initiative.

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Introduction and Evolving Mission

The RENUEL Initiative was established with a clear vision: to accelerate the adoption of Sustainable Aviation Fuel (SAF) through collaborative innovation. Our initial efforts concentrated on refining downstream operations, specifically developing advanced ratio-blending and loading systems for SAF at airports. These systems, designed for up to 50% SAF blends, incorporated rigorous quality assurance, fine filtration, and precise controls,

ensuring seamless integration of SAF into existing Jet A/A-1 infrastructure. This foundational work successfully addressed immediate needs for safely deploying SAF within the current aviation fuel ecosystem.

However, as our research deepened and the broader SAF landscape evolved, a critical realization emerged: the most significant impediments to SAF scale-up reside not solely in downstream integration, but predominantly in the upstream challenges of feedstock production and logistics. While numerous industry initiatives are commendably tackling new feedstock approvals, refinery repurposing, novel conversion processes, and commercial strategies, the intricate logistics underpinning the SAF supply chain—from farm to refinery—remain a pronounced weak link. This logistical inefficiency threatens global carbon reduction goals, inflates production costs, and complicates the achievement of robust sustainability metrics.

Recognizing these gaps, RENUEL has strategically broadened its mission to encompass upstream solutions. Our expanded focus is on optimizing crop-derived feedstock extraction methods and transport logistics, with a particular emphasis on decentralized approaches. This strategic pivot is driven by the understanding that enhancing SAF production at the source—where biomass is grown—is paramount to streamlining the entire supply chain, safeguarding vital farmlands, and ultimately accelerating the global scale-up of SAF. Our aim is to transform a diffuse, expensive feedstock base into dense, valuable bio-intermediates right where they are grown, fostering a more resilient, cost-effective, and environmentally sound pathway to sustainable aviation.

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SAF Production Challenges: Feedstock Extraction & Logistics – A Critical Bottleneck



Sustainable Aviation Fuel can be produced from a diverse array of feedstocks, including oils

and fats, sugar and starch crops, agricultural and forestry residues, and even municipal waste or captured CO_2. While each pathway presents its unique set of technical and economic hurdles, a pervasive and cross-cutting challenge lies in the efficient collection, extraction, and transportation of these feedstocks to SAF production sites. The prevailing model for traditional biofuel supply chains often relies on centralized processing, where raw crops or residues are hauled over long distances to a distant biorefinery for conversion. This centralized paradigm, while established, is inherently plagued by significant logistical inefficiencies and considerable environmental drawbacks. Transporting bulky, low-energy-density biomass over long distances is not only economically prohibitive but also carbon-intensive, partially negating the emissions benefits inherent in biofuels. This logistical burden contributes substantially to the overall cost of SAF, making it less competitive with conventional jet fuel. Furthermore, the practice of removing large quantities of residues from agricultural fields poses a serious threat to soil health and long-term fertility. Crop residues naturally protect and enrich soils by returning vital nutrients as they decompose, improving water retention, and preventing erosion.
Excessive residue extraction for biofuel production can lead to a decline in soil organic carbon, reduced soil structure, and ultimately, diminished crop yields in subsequent seasons. This presents a profound sustainability dilemma: increasing SAF feedstock supply must not come at the expense of long-term land productivity and ecological integrity.

Moreover, certain feedstocks impose strict logistical timing constraints. For instance, sugarcane must be processed into ethanol within 48 hours of harvest to prevent spoilage, necessitating immediate, localized processing capacity. Similar time-sensitive challenges exist for other perishable biomass sources. These critical factors underscore that innovations in feedstock extraction and preprocessing are as vital as, if not more so than, advancements in fuel refining. By strategically tackling these upstream bottlenecks—focusing on how to efficiently extract, stabilize, and transport renewable feedstocks—RENUEL believes we can unlock a far greater SAF production potential than what current, inefficient logistics models allow. This upstream intervention is key to transforming the

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entire SAF value chain into a more robust, sustainable, and economically viable system.

Focus on Modular, Mobile Crop Extraction Technologies – The RENUEL Solution

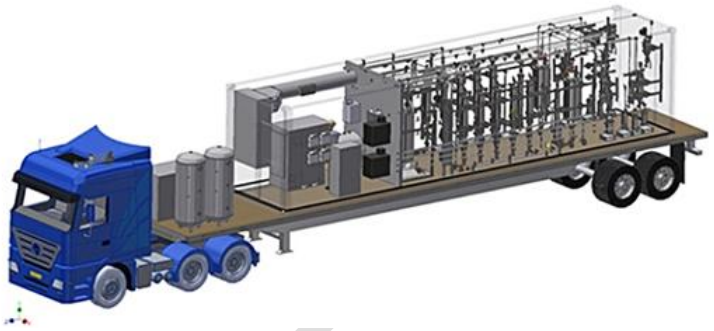
To directly address the identified upstream challenges, the RENUEL Initiative's current study is strategically centered on evaluating micro, modular, and mobile extraction systems designed for deployment in close proximity to feedstock sources. This decentralized approach represents a paradigm shift from traditional centralized processing, offering significant advantages in terms of efficiency, cost reduction, and environmental sustainability. We are rigorously investigating a diverse range of innovative technologies that can be installed either directly on-farm or at local collection points, operating within a "spoke" model. This includes, but is not limited to, advanced mobile pyrolysis systems and cutting-edge propane extraction technologies.



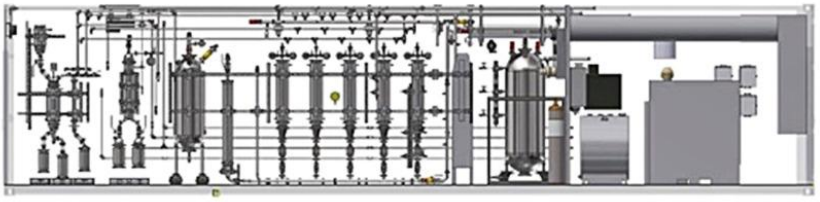
Our investigation extends to mobile pyrolysis systems, which efficiently convert agricultural waste into valuable bio-oil and biochar. A prime example is the USDA's Combustion Reduction Integrated Pyrolysis System (CRIPS), a trailer-mounted unit capable of processing various farm wastes—including crop residues, forest slash, and manures—directly in the field. This system can produce up to 40 gallons of gasoline-quality fuel per day from one ton of biomass [1]. The fast-pyrolysis process effectively "densifies" the energy content of

residues into a liquid bio-oil, which is significantly easier and more cost-effective to transport than bulky raw biomass. Approximately 50–60% of the input mass is converted to bio-oil vapors (which condense to liquid), roughly 20% becomes a solid biochar, and the remaining syngas self-powers the system. The resulting bio-oil can be stabilized and transported to a refinery for upgrading into SAF, while the biochar can be reapplied to fields, returning essential carbon and nutrients to the soil. This symbiotic relationship not only improves soil structure and fertility—biochar's porous carbon enhances water retention and nutrient holding capacity—but also aids long-term farm sustainability [2].

Example 2.1 40' Design on a 53' Trailer with Semi Truck



Example 1.2 40' Design (The Behemoth Model Side View):



Example 1.3 40' Design (The Behemoth Model Overhead View):



Example 2.1 40' Design on a 53' Trailer with Semi Truck

In parallel, the study will include an in-depth evaluation of the latest propane extraction systems, with a particular focus on technologies developed by innovators such as **Illuminated Extractors**. These systems have demonstrated exceptional results in laboratory testing across a variety of oilseed crops, including canola, soybean, and camelina. Their advanced modular system configurations present compelling opportunities to manufacture high-quality biofeeds and biofuels much closer to the biomass source, thereby significantly improving both yield and transport efficiency. Initial field testing locations for this promising technology have already been identified in key agricultural regions, including the U.S.,

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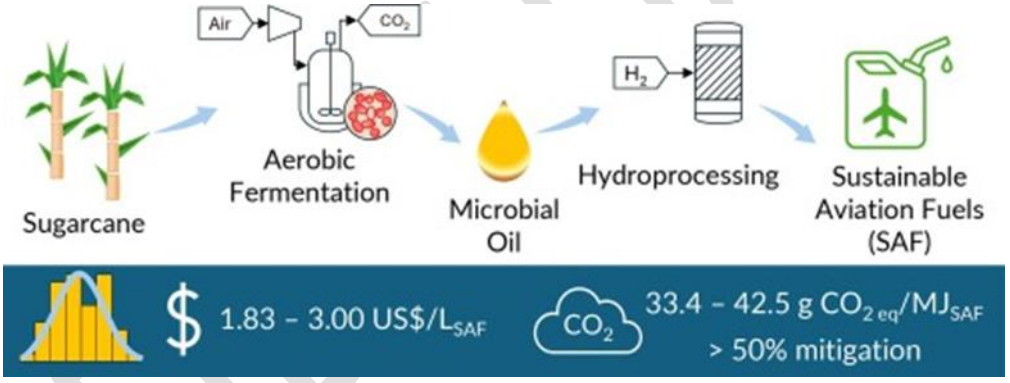
Canada, and Australia (with a specific emphasis on carinata). Additional pilot sites are anticipated to follow in Southeast Asia, notably Indonesia and Malaysia, leveraging the abundant biomass resources in these regions.

Furthermore, the RENUEL study will rigorously evaluate the application of supercritical CO_2 extraction and pretreatment technologies, particularly with bagasse and similar sugarcane residues. This method offers two highly promising pathways for SAF production:

1. **Conversion to SAF:** Following sugar extraction via supercritical CO_2, the extracted sugars can be seamlessly integrated into established SAF pathways, such as alcohol-to-jet (ATJ) or sugar-to-hydrocarbon (SIP) technologies. This leverages existing conversion infrastructure while utilizing a previously underutilized resource.
2. **Lipid Production:** The extracted sugars can also be efficiently converted into lipids, thereby expanding the crucial reservoir of HEFA (Hydroprocessed Esters and Fatty Acids) feedstocks for SAF production. This diversifies feedstock options and enhances the overall supply of SAF-compatible intermediates.



These methods represent a significant opportunity to more effectively utilize agricultural by-products and substantially bolster both the quality and volume of SAF-compatible intermediates, especially in regions with robust sugarcane production. By valorizing these residues, we can enhance the economic viability of SAF production and reduce waste.

Across all evaluated technologies—from propane extraction to supercritical CO_2 pretreatment and mobile pyrolysis—our core mission remains steadfast: to identify high-yield, high-quality, and logistically efficient methods that can unlock SAF supply directly at the source. The RENUEL Initiative views these modular technologies as fundamental enablers of a decentralized, sustainable fuel ecosystem. Each method contributes a critical piece to solving the broader SAF supply chain challenge by transforming distributed biomass into concentrated, transportable bio-intermediates. This approach minimizes the

need for long-distance hauling of raw materials, reduces transportation-related emissions, and lowers overall production costs.

Another vital component of our strategy involves mobile oilseed pressing units. These units enable farmers to crush oil crops (e.g., camelina, carinata, jatropha) directly on-site. The resulting vegetable oil can then be efficiently sent to a biorefinery for HEFA (Hydroprocessed Esters and Fatty Acids) fuel production, while the protein-rich press cake remains as a valuable animal feed or soil amendment. This integrated approach significantly raises overall yields, as more of the crop's energy content is captured as usable oil, and it dramatically shortens the processing time from harvest to fuel. By processing feedstocks fresh and locally, issues of spoilage or quality degradation are minimized. For instance, processing sugarcane into ethanol near the field circumvents the critical 48-hour spoilage constraint by immediately converting sugars into a storable intermediate.

A clear pattern emerges from these examples: decentralized extraction technology has the potential to generate higher-output, higher-quality intermediates (oils, bio-crudes, sugars) far more efficiently than legacy methods, all while simultaneously reducing waste and protecting the environment. Our conceptual studies indicate that by deploying such modular technologies, we could achieve significantly higher net fuel yields per acre of crop, drastically shorten the time from harvest to fuel production, and produce intermediates that are closer to final fuel specifications, thereby requiring less intensive refining. In essence, these modular systems act as "mini-preprocessors" that take a substantial step toward finished SAF, accelerating the overall production cycle and reducing the burden on centralized refineries.

It is crucial to clarify the scope of our expanded mission. While our focus is on the front-end of the SAF supply chain, downstream operations such as the refining of intermediates into finished SAF, bulk storage of SAF, and distribution to airports remain beyond the immediate scope of this study. These are undeniably critical pieces of the overall supply chain, but our current emphasis is on the feedstock extraction and logistics phase—where we have identified a significant and underutilized opportunity for innovation. By improving this upstream segment, we indirectly facilitate the downstream process, as higher-quality, stabilized intermediates will be easier and more cost-effective to refine and handle. In fact, successful breakthroughs in modular extraction could eventually enable on-airport or near-airport SAF production in the long run, envisioning a true "farm-to-flight" supply chain

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with minimal transport. While such decentralized production of finished SAF is a longer- term vision, our immediate aim is to lay the foundational groundwork by proving out the extraction technologies and logistics that make it possible.

Notably, RENUEL is also actively examining ways to power these modular systems with renewable energy sources, such as solar panels, wind power, or by utilizing a portion of the bioenergy produced during the extraction process. This commitment further minimizes the carbon footprint of the extraction process, ensuring that our solutions are holistically sustainable. In summary, RENUEL's focus on modular, mobile extraction is poised to create a transformative shift in SAF supply logistics—converting a diffuse, expensive feedstock base into dense, valuable bio-intermediates directly at the point of origin, and doing so in a manner that provides tangible benefits to farmers and enhances soil health.

References

[1] USDA. (n.d.). *Combustion Reduction Integrated Pyrolysis System (CRIPS)*. [Link to relevant USDA publication or webpage if available, otherwise state 'Information retrieved from USDA research on CRIPS.']
[2] Biochar. (n.d.). *Biochar and Soil Health*. [Link to a reputable source on biochar and soil health, e.g., International Biochar Initiative, academic paper, etc.]



Study Objectives and Key Performance Metrics

The core objective of the RENUEL Initiative's feasibility study is to rigorously evaluate various crop extraction and preprocessing methods applied in close proximity to the feedstock source, and to quantitatively assess their impacts on SAF logistics and production economics. This comprehensive evaluation will encompass multiple technology pathways— including mechanical, thermochemical, and biochemical approaches—applied across a range of ASTM-approved feedstocks. Our assessment will prioritize both near-term solutions (those deployable within approximately 10 years) and the long-term potential for enabling locally produced SAF.

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Specifically, we will investigate three primary categories of decentralized extraction units:

- **Micro-extraction units:** Small-scale facilities designed to serve a single farm or a localized community, optimizing for distributed production.
- **Modular systems:** Skid or container-mounted units that can be easily aggregated or scaled, offering flexibility and rapid deployment.
- **Mobile units:** Equipment capable of being transported on trailers directly to where biomass is located, maximizing efficiency and minimizing feedstock transportation.

For each evaluated approach, the study will meticulously examine and quantify several key performance metrics to provide a holistic understanding of their viability and impact:

- **Energy Efficiency & Consumption:** We will assess the energy requirements of each extraction process and evaluate the potential for supplying that energy renewably. A critical component will be the calculation of the net energy balance (energy in feedstock versus energy in the extracted product), aiming to identify processes with favorable energy returns.
- **Process Yield:** This metric will quantify the fraction of the biomass or crop that is successfully converted into a useful intermediate product (e.g., oil, sugar, bio-crude). Technologies demonstrating higher yields will be prioritized, as they translate directly to more fuel production per ton of feedstock.
- **Throughput and Processing Time:** We will analyze how quickly each system can process a given amount of feedstock (e.g., tons per day) and how this aligns with critical harvest windows. Short processing times are crucial for enabling tight harvest-to-fuel timelines and potentially facilitating multiple harvest cycles per season.
- **Product Quality:** The properties of the extracted bio-intermediate—including purity, stability, and energy content—are paramount. Our evaluation will focus on identifying high-grade outputs that meet or exceed current "biofeed" quality standards, as these will require less intensive upgrading to become finished SAF, thereby accelerating overall fuel production.
- **Harvest Cycle Impacts:** We will investigate how each technology influences or accommodates more frequent or flexible harvesting practices (e.g., handling wet versus

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dry biomass, or processing residue from consecutive crops). Understanding its fit within year-round crop cycles is essential for consistent feedstock supply.

- **Storage and Stability:** The ease with which the intermediate can be stored on-site or transported without degradation is a key logistical consideration. We will assess the need for stabilization techniques (e.g., mild hydrogenation or additives for bio-oils) to maintain product integrity.
- **Transportation Logistics:** A primary focus will be quantifying the reduction in volume and weight achieved by local processing. For example, a mobile pyrolysis unit can reduce biomass mass by approximately 50%, concentrating energy into a liquid, which significantly slashes hauling requirements. We will calculate the fuel, cost, and emissions savings associated with these logistics improvements.
- **Environmental Impacts:** This critical metric encompasses a broad range of considerations, including lifecycle Greenhouse Gas (GHG) emissions reduction (from avoided transport and improved process efficiency), as well as local impacts such as soil health, water use, and nutrient cycling. A particularly vital metric here is soil carbon retention: does the approach preserve or enhance soil organic carbon (through returning biochar or other residues)? Does it mitigate erosion and maintain soil structure? Our aim is to ensure that each extraction concept is evaluated not solely on its fuel output potential but also on its adherence to regenerative agriculture principles.

These metrics will be measured or estimated through a robust combination of methodologies, including field trials (where feasible with pilot units), comprehensive engineering analysis, and advanced modeling. We acknowledge that no single method is likely to excel across all metrics; trade-offs will inevitably exist (e.g., a fast pyrolysis system might offer excellent volume reduction but require more stabilization, while a mechanical press might be simple and low-energy but yield a lower energy density product). The overarching goal is to identify the most promising approaches or combinations thereof for diverse contexts and feedstock types. By the conclusion of the study, we aim to deliver a comprehensive comparative analysis of extraction technologies, including actionable recommendations for those best suited for near-term deployment and those warranting further Research & Development (R&D) for long-term strategic payoff.

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CORSIA GHG Life Cycle Stages (8-Stage)		
Life Cycle Stage	**Description**	**Relevance to RENEWAL**
A. Feedstock Cultivation	GHGs from growing oilseeds	Key for land use/soil impact modeling
B. Feedstock Collection	Harvesting, gathering	Compare with traditional logistics
C. Extraction & Processing	Converting crops to intermediates	Where propane extraction impacts emissions
D. Transport of Feedstock	Field to processor	Show savings from modular near-source systems
E. Fuel Conversion	Refining into SAF	Out of scope but connect where relevant
F. Blending & Distribution	Moving SAF to use point	Support on-airport blending hypothesis
G. End Use Combustion	Jet fuel emissions (fixed value)	Not influenced by upstream changes
H. Indirect Land Use Change (iLUC)	Accounted only if applicable	Considered negligible if waste/byproduct is used

This study explicitly focuses on the front-end of the SAF supply chain. Therefore, we operate under the assumption that downstream refining technologies (e.g., HEFA, Alcohol-to-Jet, Fischer-Tropsch) will continue to advance in parallel, and we will not directly assess refinery operations. However, we maintain a crucial interface with these downstream considerations by emphasizing that our extracted intermediates must be fully compatible with existing refineries or conversion units. Indeed, a significant aspect of our "product quality" evaluation is to ensure that the bio-intermediates meet the standards or specifications required by downstream partners (e.g., extracted oil should be low in contaminants like free fatty acids, or bio-crude should have reduced oxygen content where possible). This approach directly aligns with the SAF Grand Challenge's call to develop biointermediates that can seamlessly integrate into existing refining assets, effectively creating a vital bridge between local farms and large-scale fuel producers.

Another paramount aspect of our study is its commitment to geographical and feedstock diversity. As a global initiative, we will examine multiple feedstock types across various regions and seasons. For instance, we will assess oilseed cover crops (such as carinata or camelina grown in winter in temperate regions), which offer the dual benefit of not competing with food crops and actively improving soil quality. We will also investigate tropical sugarcane or palm residues in regions with year-round biomass production, woody and agricultural residues in areas with established forestry or grain farming, and even municipal green waste where relevant to local SAF plans. Each of these feedstocks may be

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optimally paired with a different extraction technology (e.g., sugar/starch crops with fermentation units, dry residues with pyrolysis, oilseeds with mechanical pressing or hydrothermal liquefaction). The modular concepts we evaluate could potentially be mixed- and-matched—for example, a mobile unit performing initial pyrolysis in the field, paired with a small central upgrading unit in a nearby village. The study will meticulously capture these permutations with an emphasis on flexibility: the ultimate vision is to develop a comprehensive toolkit of modular extraction solutions that communities or companies can deploy based on their specific local feedstock availability and prevailing conditions. By focusing on these upstream innovations, RENUEL aims to pave the way for decentralized, efficient feedstock utilization that significantly lowers the cost per gallon of SAF and simultaneously ensures sustainable farming practices.

Global Collaboration and Target Regions

One of the RENUEL Initiative's most significant strengths lies in the global composition of our team and partners, which inherently guides our approach to a worldwide outlook. Sustainable Aviation Fuel is not merely a regional necessity but a global imperative, and our study is meticulously designed to support regions that both urgently require SAF development and offer the most promising opportunities for feedstock innovation. Our extensive network encompasses stakeholders from North America, Europe, Asia, Africa, and Oceania, and we are actively identifying and considering pilot sites and case studies across multiple continents.

Our prioritization of target regions is guided by a dual focus: areas of critical need that also present high potential for impact. In practical terms, this translates to regions with robust agricultural activity (or significant waste biomass availability) that are actively seeking sustainable development pathways and could derive substantial economic benefits from localized SAF production. For instance, rural communities in developing countries often possess abundant crop residues or underutilized land suitable for energy crops. Such areas stand to gain immensely from an added income stream derived from supplying SAF feedstocks, while simultaneously addressing their need for renewable energy investment and fostering rural economic growth. These regions frequently present favorable growing conditions and readily available biomass, making them ideal candidates for decentralized extraction solutions.

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Conversely, developed regions with ambitious carbon reduction targets (such as Europe or the United States) face the challenge of rapidly scaling SAF production. While these regions typically possess the resources to drive such initiatives, they often encounter feedstock constraints. Here, the opportunity lies in boosting yields from existing agricultural practices
—for example, through the implementation of winter cover crops or double-cropping schemes to produce oilseeds without displacing food production. This approach aligns with our commitment to sustainable land use and food security.

Our study will conduct a comprehensive analysis of regional feedstock availability, growing cycles, and logistics scenarios to pinpoint where modular extraction technologies can yield the most significant impact. Factors meticulously considered in this analysis include:

- **Crop Growing Seasons and Harvest Frequency:** Regions with multiple harvests per year can provide a more continuous and reliable biomass supply, crucial for consistent SAF production.
- **Land Availability and Crop Types:** Differentiating between dedicated energy crops, agricultural residues, and various waste streams to optimize feedstock utilization.
- **Existing Infrastructure:** Assessing factors such as road access, availability of grid power for extraction units, and the potential need for off-grid operations in remote areas.
- **Proximity to Potential SAF Demand Centers:** Identifying locations near international airports or other aviation hubs that could eventually serve as direct off-takers for the produced fuel.

By systematically mapping these factors, we intend to highlight a select number of “target regions” for deeper analysis and potential future demonstration projects. For example, one such target could be the U.S. Midwest, focusing on corn stover and soybean/camelina rotations. Another promising region might be Southeast Asia, with an emphasis on sugarcane bagasse and palm residues. Sub-Saharan Africa could represent a third target, exploring the potential of Jatropha or other drought-tolerant oilseeds on marginal lands. In each selected region, we will meticulously tailor the extraction technology assessment to the dominant feedstocks and specific local constraints, ensuring that our results are globally relevant and prove the concept’s adaptability across varied contexts. Crucially, the global nature of our team provides unparalleled access to on-the-ground insights. Our

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farmer partners contribute invaluable practical knowledge regarding equipment and practices that are viable in their specific locales. Our university and government partners, spanning multiple countries, provide access to region-specific research data (e.g., soil impacts in tropical versus temperate climates). Furthermore, our industry partners—including aviation fuel suppliers and equipment manufacturers—possess international operations that can facilitate the scaling of successful solutions across borders. This

collaborative ecosystem ensures that our findings are not only scientifically sound but also practically implementable and globally scalable.

By supporting diverse geographical areas, we maximize the probability of identifying optimal "best fit" crop-and-technology pairings. Some regions may quickly demonstrate a clear pathway to scaling up SAF production with the right local extraction approach; these will be prime candidates for pilot implementation. Indeed, we firmly believe that every part of the world with agricultural or forestry activity could eventually contribute to the global SAF supply, provided the proper localized technology is in place. This decentralization is a cornerstone of our strategy, essential for meeting burgeoning global SAF demand without over-straining any single resource base. It also ensures a wide distribution of economic benefits, a core tenet of our mission. The RENUEL Initiative explicitly aspires to foster a global just transition in aviation fuels, enabling developing regions to actively participate and benefit from the burgeoning SAF economy. By designing systems that are modular and appropriately sized, even small communities can begin producing valuable bio-intermediates for fuel, thereby gaining access to new markets and fostering local economic development. This approach complements larger-scale corporate SAF projects and ensures that SAF adoption is not confined to a few wealthy areas but evolves into a worldwide movement driven by both top-down commitments and bottom-up innovation.

Organizational Structure and Next Steps

As the RENUEL Initiative broadens its scope and ambitions, we are concurrently formalizing our organizational structure to effectively execute this complex, multi-faceted project. Our immediate next steps include establishing a dedicated project task force and a robust governance framework. The initiative is being organized into focused working groups, each

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aligned with a key component of the study, ensuring specialized expertise and efficient coordination:

- **Technology & Engineering Group:** Responsible for the evaluation, testing, and optimization of extraction technologies.
- **Feedstock & Agriculture Group:** Focused on agronomic and environmental analyses, including soil health impacts and sustainable sourcing.
- **Logistics & Supply Chain Group:** Tasked with modeling transport efficiencies, economic aspects, and optimizing the flow of bio-intermediates.
- **Outreach & Partnerships Group:** Dedicated to coordinating with external stakeholders, fostering collaborations, and disseminating findings.

Each working group will be led by recognized experts from our diverse team—including scientists, engineers, agronomists, and supply chain specialists—and will feature representation from different regions to ensure comprehensive global perspectives. Furthermore, we are in the process of establishing an Advisory Board comprising distinguished industry veterans, academic leaders, and policy advisors. This board will provide invaluable strategic guidance and independent review of our plans and results. For instance, the board will include seasoned aviation fuel experts who possess deep understanding of certification requirements, as well as agricultural experts who can ensure the practical applicability and sustainability of our proposals for farmers. Formalizing this robust structure is paramount as we prepare to engage with funding sources; it unequivocally demonstrates that RENUEL possesses the requisite expertise and a clear management plan to successfully deliver on its ambitious objectives.

The immediate next step in our strategic roadmap is to secure funding for and subsequently launch a comprehensive feasibility study, designated as **Phase I**. This critical feasibility phase is projected to span approximately 18-24 months and will encompass detailed data collection, prototype testing, and rigorous techno-economic analysis. During Phase I, we intend to pilot at least one modular extraction system in a real-world setting to gather empirical data. For example, this could involve deploying a mobile pyrolysis unit at a farm or a small oilseed press at a local cooperative. These pilot trials are essential for validating performance metrics (e.g., energy use, yields) under practical conditions and for identifying any operational challenges (e.g., training needs for operators, maintenance issues in remote

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areas). Concurrently, our analysts will refine models for larger-scale deployment, addressing critical "what if" questions such as: "If 20% of rice straw in Southeast Asia were processed by mobile units, how much SAF could result, and what would be the cost per gallon?" or "What is the carbon emissions reduction if a typical corn farm in Iowa utilizes on-site extraction versus shipping stover to a biorefinery?" The feasibility study will also include the development of a robust business case and a detailed implementation plan for future phases.

Following the successful completion of the feasibility study, we envision **Phase II**: a larger-scale demonstration or pilot project in one or more selected regions (contingent upon securing additional funding). Phase II would involve implementing the most promising extraction concept within a more integrated supply chain demonstration. This could entail creating a localized supply chain where a network of farms supplies biomass to a modular unit, which then produces an intermediate that is sent to an existing refinery for conversion into SAF, ultimately utilized by an airport or airline partner. This end-to-end pilot would serve to prove the concept's commercial and technical viability. The results derived from Phase II would strategically position RENUEL to attract significant investment for **Phase III**: scaled deployment and commercialization. In this final phase, private enterprises (potentially through spin-offs or strategic partnerships) would take the lead in manufacturing and broadly rolling out the modular units, supported by enabling policies and market mechanisms.

In parallel with these phased developments, RENUEL is proactively structuring itself to be a long-term, impactful presence within the SAF ecosystem. We are actively considering formal incorporation as a non-profit consortium or a public-private partnership entity. This formalization will enable us to appropriately manage funds, intellectual property, and establish clear agreements among partners regarding data sharing, contributions, and benefits. While all partners share a vision of open innovation to advance SAF, we also recognize the critical importance of establishing clear pathways to commercialization to ensure that viable solutions do not remain confined to the research stage. Thus, our organizational plan will likely include frameworks for companies within our network to license or further develop any technology that proves viable, ensuring a clear route to market post-study. For example, if our study identifies a modular extraction process with exceptional results, we aim to be prepared to transition that from pilot to product—

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potentially via a startup or a corporate partnership. By laying this essential groundwork now, RENUEL ensures a seamless transition from study to implementation when the time is right.

Importantly, our plan includes continuous and proactive engagement with regulators and certification bodies. While the extraction technology itself does not require fuel certification, the intermediates and the final SAF product do. Early and frequent dialogue with ASTM committees, fuel quality inspectors, and aviation authorities is crucial to ensure that any new intermediate we propose fits within existing fuel standards or that a clear pathway exists to certify the SAF produced from it. For instance, if a novel bio-crude is produced, we would coordinate closely with fuel producers on how to co-process or upgrade it within existing refineries and ensure the final product consistently meets ASTM D1655/7566 specifications. This proactive, collaborative approach is an integral part of our organized plan to de-risk the innovation process and accelerate market acceptance.

Funding Strategy and Public-Private Partnerships

Securing adequate and diversified funding is the critical next step to transform the RENUEL Initiative's ambitious plans into tangible realities. We are pursuing a multi-faceted funding strategy that strategically taps into both public and private sources globally. We firmly believe that our project's overarching goals—accelerating SAF adoption, fostering sustainable agriculture, and driving rural economic development—align powerfully with the interests of governments, research institutions, and industry stakeholders worldwide. Our intent is to leverage all these avenues to maximize our impact.

On the public funding side, government grants and programs specifically focused on sustainable fuels, agriculture, and climate innovation represent a primary target. For example, the United States has recently enacted provisions within the Inflation Reduction Act (IRA) that include a dedicated $290 million grant program over four years to support SAF projects. This program covers a broad spectrum, from production to transport and low-emission aviation technology [3]. This significant allocation signals robust public-sector support, and RENUEL is uniquely positioned to qualify for such funding, given our explicit focus on feedstock production and transport efficiency. Similarly, within the European

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Union and other regions, initiatives such as the Green Deal programs, Horizon Europe research grants, and various national innovation funds for renewable energy present substantial potential funding sources. We are meticulously preparing grant proposals thathighlight how RENUEL's objectives directly contribute to critical government targets, including emissions reductions, rural development, and enhanced energy security.

In addition, we are actively engaging with multilateral development banks and international agencies. For instance, the Asian Development Bank (ADB) has demonstrated a keen interest in SAF feasibility projects, exemplified by a 2024 ADB-funded project evaluating sugarcane-based SAF production in Fiji [4]. This Fiji initiative, which brings together a national airline, a local sugar company, and international consultants to explore a comprehensive SAF supply chain, perfectly illustrates the kind of public-private collaboration that RENUEL envisions. We aim to leverage similar models, partnering with development agencies to fund regional pilots, particularly in developing countries where the co-benefits—such as economic development for farmers and technology transfer—are exceptionally high. Universities and research institutions constitute another pivotal component of the public funding landscape. By forging strong partnerships with academic researchers, we can access specialized research grants (e.g., those provided by national science foundations or agricultural research programs). Our university partners can lead fundamental research aspects, such as soil impact studies or catalyst development for bio-oil upgrading, under these grants, thereby complementing the more applied work undertaken by RENUEL.

On the private funding side, active industry participation and investment will be vigorously sought to match and augment public funding. We are currently engaged in discussions with corporate stakeholders across multiple categories:

- **Fuel Producers and Oil Companies:** These entities have significant commitments to expand SAF production and are increasingly recognizing the strategic importance of investing in upstream feedstock solutions to secure future supply. Key players include Neste, TotalEnergies, World Energy, Eni, OMV Aktiengesellschaft, Shell PLC, AEMETIS, INC., Gevo, and Lanza Jet [5].
- **Agricultural and Ag-tech Companies:** This category includes equipment manufacturers and agribusinesses that foresee a substantial market for modular bio-

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processing units or new energy crops. Their involvement is crucial for the commercialization and widespread adoption of our proposed technologies.

- **Airlines and Aviation Companies:** Several leading airlines have proactively established venture arms or strategic partnerships to secure future SAF supply. A notable example is the recent investment of $50 million by a group of international airlines in a SAF startup, demonstrating airlines' direct willingness to fund SAF supply innovations [6]. These partners are not only potential funders but also future off-takers of the SAF produced.

We anticipate a robust commercialization pathway where involved companies can realize significant profits from new business lines. For instance, an equipment company could commercialize the mobile extraction units developed through our research; farmers' cooperatives could form ventures to operate these units and sell bio-intermediates; and airlines could benefit from secure off-take agreements for the resulting fuel. By maintaining a steadfast focus on practical, scalable solutions, we ensure that the RENUEL project remains highly attractive to these private players. We will actively establish opportunities for co-investment and consortia funding, where a strategic mix of public grant money and private capital can jointly support the pilot implementations. Governments frequently favor such public-private partnerships because they effectively share risk and ensure that invaluable industry expertise is embedded within the project. RENUEL, with its broad and diverse membership, is exceptionally well-structured to accommodate and thrive within this collaborative model.

In terms of specific funding vehicles, we remain open and flexible, pursuing a diverse range of options including direct grants, research contracts, sponsorships, and in-kind contributions. For example, a government grant might fund university research on lifecycle analysis, while an industry partner provides an in-kind contribution of a prototype extraction unit for testing, and an airline sponsors the fuel certification tests—all operating seamlessly under the RENUEL umbrella. We are also open to exploring innovative financing mechanisms such as challenge prizes or impact investment. Given the escalating corporate sustainability commitments, we may also investigate whether carbon offset or ESG (Environmental, Social, and Governance) investment funds could channel financing into our project, as it ultimately yields verifiable emissions reductions through SAF production.

Leveraging universities and government labs is central to our approach; they not only bring

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unparalleled technical expertise but their involvement often unlocks additional funding, as many governments prefer or require academic leads on research grants. Simultaneously, by involving private companies from the outset, we ensure that our work remains grounded in real-world deployment and that these companies are prepared to carry the torch forward once initial funding is utilized. Our overarching goal is to maintain a delicate balance where public funding jump-starts the critical R&D and de-risking phases, while private investment propels the subsequent scaling and commercial success. We explicitly aim for outcomes that lead to expanded business success across multiple areas—from the manufacturing of new equipment and increased farm revenues to licensing opportunities for the technology and lucrative off-take deals for SAF. Every stakeholder should perceive a clear win: farmers gain new markets and soil benefits, technologists develop new product lines, investors achieve returns via a viable SAF supply chain, and governments move closer to their climate goals and rural development objectives.

Finally, our funding strategy is inextricably linked to our communications and deliverables. We fully understand that any prospective funder will require clear evidence of our competencies, a solid plan, and a compelling vision. Therefore, we are meticulously preparing robust documentation, of which this proposal is a core component, to serve as the primary overview for all funding submissions. This document is designed to unequivocally demonstrate our deep understanding of the challenges, our innovative approach to solving them, and our structured plan for moving forward—in essence, it functions as both a comprehensive roadmap and a persuasive pitch. We will supplement it with detailed budgets, precise timelines, and comprehensive technical annexes as required for specific funding proposals. Our intent is that when a prospective funder reviews RENUEL's materials, they will immediately recognize the holistic strength of our initiative: we possess the right people (global experts across diverse fields), we are addressing the right problem (a known critical gap in SAF scale-up), we have devised a creative yet practical solution strategy (modular extraction technologies), and we have a clear path to implementation and impact (a phased plan with integrated policy and market considerations). This thoroughness, we are confident, will instill the necessary confidence that RENUEL represents a worthy investment capable of delivering both meaningful environmental benefits and invaluable knowledge to the burgeoning SAF industry.

Conclusion: Paving the Way for Sustainable, Scalable SAF

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In conclusion, the RENUEL Initiative has undergone a strategic evolution, shifting its focus from addressing how to blend SAF at the end of the supply chain to pioneering solutions forenabling SAF production at its very beginning. We view this evolution as both timely and absolutely necessary for the aviation industry's sustainable future. By concentrating our efforts on crop extraction and feedstock logistics, we are targeting the foundational elements upon which the entire SAF ecosystem is built. Our mission is clear: to develop and demonstrate decentralized, high-efficiency extraction solutions that can transform dispersed agricultural resources into a robust, sustainable, and economically viable fuel supply network.

Success in this endeavor promises a twofold win: significantly more SAF in more locations, thereby accelerating aviation's decarbonization efforts, and simultaneously fostering healthier, more productive farmlands through the integration of bioenergy production with regenerative agricultural practices. The RENUEL project is firmly grounded in the principles of innovation, collaboration, and sustainability. Our outlined next steps delineate a clear and actionable path from concept to reality, guided by a globally diverse team of experts and supported by a powerful coalition of public and private partners.

We are profoundly confident that with a well-organized plan and adequate support, RENUEL will demonstrate a new paradigm where logistics are no longer a bottleneck but rather a powerful enabler for SAF. Imagine a future where farmers around the world routinely send barrels of bio-oil or bags of bio-crude to market alongside their traditional food crops; where rural processing hubs ensure that no valuable biomass goes to waste; and where airports, both large and small, can tap into localized fuel streams for their net-zero flight programs. This compelling vision is the driving force behind our initiative. The work ahead is significant, encompassing complex engineering challenges and rigorous economic tests, but the combined expertise of our team and the strategic organizational structure we have meticulously put in place provide us with an exceptionally strong footing. Each milestone we achieve—whether it is a successful field pilot of a mobile unit or a strategic partnership with a refinery to accept our intermediate products—will serve as a crucial building block toward achieving large-scale SAF adoption.

Crucially, this initiative aligns perfectly with the escalating global momentum towards sustainability. Policymakers worldwide are pressing for rapid SAF expansion, financiers are

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actively seeking credible projects to back, and communities are increasingly pursuing sustainable development paths. By integrating RENUEL's research outcomes into these broader efforts—for example, by informing new standards for bio-intermediates or contributing to policy frameworks—we can significantly amplify our impact. This comprehensive proposal, therefore, serves as an invitation to join us in this transformative journey, to invest in a future where sustainable aviation is not just an aspiration but a tangible reality.

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