Project 093(A) Collaborative Research Network for Global SAF Supply Chain Development

Massachusetts Institute of Technology

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University Participants

Massachusetts Institute of Technology (MIT)

- P.I.: Dr. Raymond Speth
- FAA Award Number: 13-C-AJFE-MIT, Amendment Nos. 114, 115, 118, 133, and 143
- Period of Performance: January 1, 2023, to August 31, 2027
- Tasks (for reporting period October 1, 2024, to November 30, 2025):
  1. Assess global biomass availability for sustainable aviation fuel (SAF) production
  2. SAF supply chain design for Africa, with specific focus on sub-Saharan Africa
  3. Facilitate a network for capability building for global SAF supply chain development
  4. Support knowledge sharing and coordination across ASCENT Project 093 universities

Hasselt University (UHasselt, through subaward from MIT)

- P.I.(s): Prof. Robert Malina
- FAA Award Number: MIT Subaward Purchase Order No. 855522
- Period of Performance: September 1, 2016 to September 30, 2026 (based on no cost extension in process)
- Tasks (for reporting period October 1, 2024, to November 30, 2025):
  1. *(omitted, led by MIT)*
  2. SAF supply chain design for Africa, with specific focus on sub-Saharan Africa
  3. Facilitate a network for capability building for global SAF supply chain development
  4. Support knowledge sharing and coordination across ASCENT Project 093 universities

Project Funding Level

The Federal Aviation Administration (FAA) provided $1,150,000 in funding and $1,150,000 matching funds were received. Sources of matching fund are approximately $90,000 from MIT, plus third-party in-kind contributions of $1,060,000 from Earth Force Technologies.

Investigation Team

Dr. Raymond L. Speth, Principal Investigator (MIT), all tasks
Dr. Florian Allroggen, Principal Investigator (MIT), all tasks
Prof. Robert Malina, Principal Investigator (UHasselt), all UHasselt tasks
Dr. Niamh Keogh, Co-Investigator (MIT), Tasks 1 and 3
Dr. Alessandro Martulli. Postdoctoral Associate, Task 3
Dr. Sumit Maharjan, Postdoctoral Associate, Task 2
Francis Mwangi, Graduate Research Assistant (UHasselt). Task 2 and 3
Dr. Teshome Deressa, Graduate Research Assistant (UHasselt), Task 3
Andy Eskenazi, Graduate Research Assistant (MIT), Task 1

Project Overview

Large-scale production of SAF around the globe is needed to meet aviation's ambitious goals to scale up alternative energy sources. Production scale-up will require identification of waste feedstocks and land for energy crop cultivation, sustainable farming and land use practices, and investments in conversion capacity as well as fuel and feedstock logistics. Access to data, expertise, and capital remains a major roadblock towards successfully creating these supply chains around the globe. Under ASCENT Project 093, MIT aims to (1) assess global biomass availability, broken down by region, and the associated potential for SAF production with current and improved conversion technologies, (2) analyze opportunities and roadblocks for supply chain designs, specifically focusing on sub-Saharan Africa, (3) share supply chain designs and feedstock availability assessments with other members of the ASCENT Project 093 team, and (4) facilitate a network of academics around the globe to support capacity building for SAF production.

Task 1 – Assess Global Biomass Availability for SAF Production

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Objective

The objective of this task is to assess biomass availability for producing bio-based aviation fuels in different world regions. The biomass feedstock could originate from two sources: (1) yield growth or land use expansion, as modeled from current and future land use patterns, considering competing demands for land from agriculture and other uses, and (2) waste and residue streams, such as agricultural residues, forestry residues, animal manure, and municipal solid waste (MSW). Initial work under this project focused on the former, while research during the current reporting period focused on the latter.

Research Approach

Residual biomass is an attractive feedstock for SAF production due to its low cost and the lack of competition for additional land. The bioenergy potentials of waste and residue feedstocks can be quantified using a framework of cascading energy potential categories, as shown in Figure 1 (see also report for previous reporting period). The *Theoretical Potential* refers to the maximum amount of residues that are produced; the *Technical Potential* is the quantity of residues (energy equivalent) that could be collected after considering harvesting equipment limitations; the *Sustainable Potential* represents the residual biomass that could be collected ensuring that soil health is maintained (i.e., primarily by keeping the amount of carbon in the soil constant). The combination of the *Technical Potential* and *Sustainable Potential* results in the *Technical Sustainable Potential*, which satisfies both technical and environmental limitations. Finally, the *Available Potential,* represents the amount of residue that is available for fuel conversion after accounting for competing uses, such as for cooking or animal feed. MIT efforts over the past 2 years have sought to (I) create a standard approach for stochastically computing the five energy potentials for 173 residue types, (2) extend the results to a 2,160-by-4,320 map grid for each residue type, and (3) evaluate the logistical challenges of using the residues.

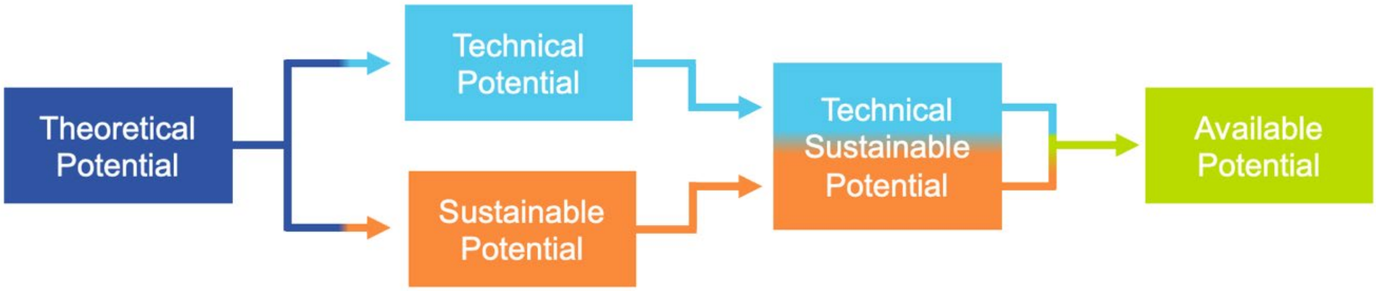

Figure 1. Five categories of energy potentials.

Modeling energy potentials requires a set of parameters. In the case of crop residues, these include (1) the residue-to-product ratio (RPR) (i.e., the amount of residue generated per unit of crop produced), (2) the technical recoverability ratio (TRR) (i.e., the percentage of residues that can be collected with typical harvesting machinery), (3) the sustainable removal ratio (SRR) (i.e., the percentage of residues that can be collected while being able to maintain soil health), (4) the technical sustainable removal ratio (TSRR) (i.e., the minimum between TRR and SRR), and (5) the residue availability ratio (RAR) (i.e., the percentage of residues available after considering competing uses). For this study, these parameters are obtained from a literature review. The literature review revealed substantial variation in some of these parameters. For example, for corn, we find that the RPR ratio (amount of stover per kilogram of grain) varies between 1.4 to 2.55. Given the unknown nature of the "true" value, probability distributions were constructed across the 173 residue types, using the literature estimates. We then obtained distributions of the energy potentials via Monte Carlo simulations.

Preliminary results are shown in Figure 2. The findings are two-fold. First, the imposition of constraints across the potential categories decreases the energy potentials. However, these impacts differ between constraints and feedstocks. For example, in the case of crop residues, enforcing ecological criteria produces the largest drop in potential, due to substantial residue requirements to preserve soil properties. In contrast, in the case of forestry residues and animal manure, the biggest drop is seen with the imposition of the technical constraints, due to the difficulties in waste and residue collection (e.g., manure in pastureland). Second, across each potential category, there is significant uncertainty about the "true" expected potential.

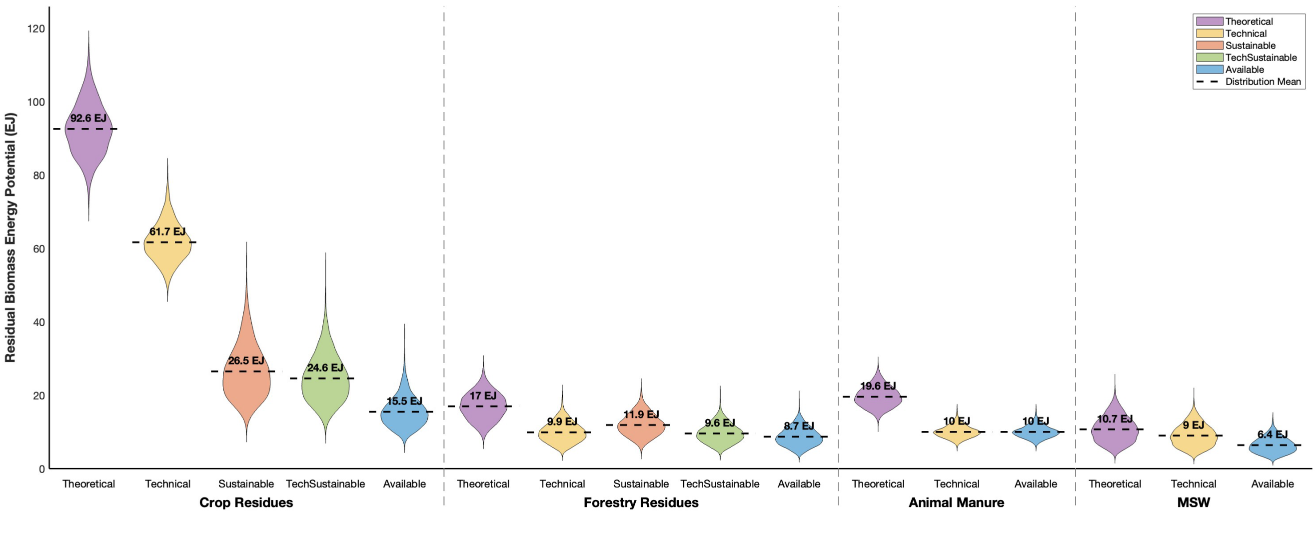

Figure 2. Stochastic evaluation of the energy potentials, considering 173 different residual biomass types.

The mean available potential is mapped in a gridded world map in Figure 3. We find that while some regions have high density of available waste and residue feedstock (including the United States), some regions possess low density in available potentials (e.g., northern Alaska). This raises the question whether such low-density potentials are suitable for advanced energy conversion purposes. The answer to this question depends on whether it is possible to form clusters of sufficient scale (i.e., enough to support the establishment of a biorefinery) within reasonable collection distance (e.g., transporting the residues up to 100 km).

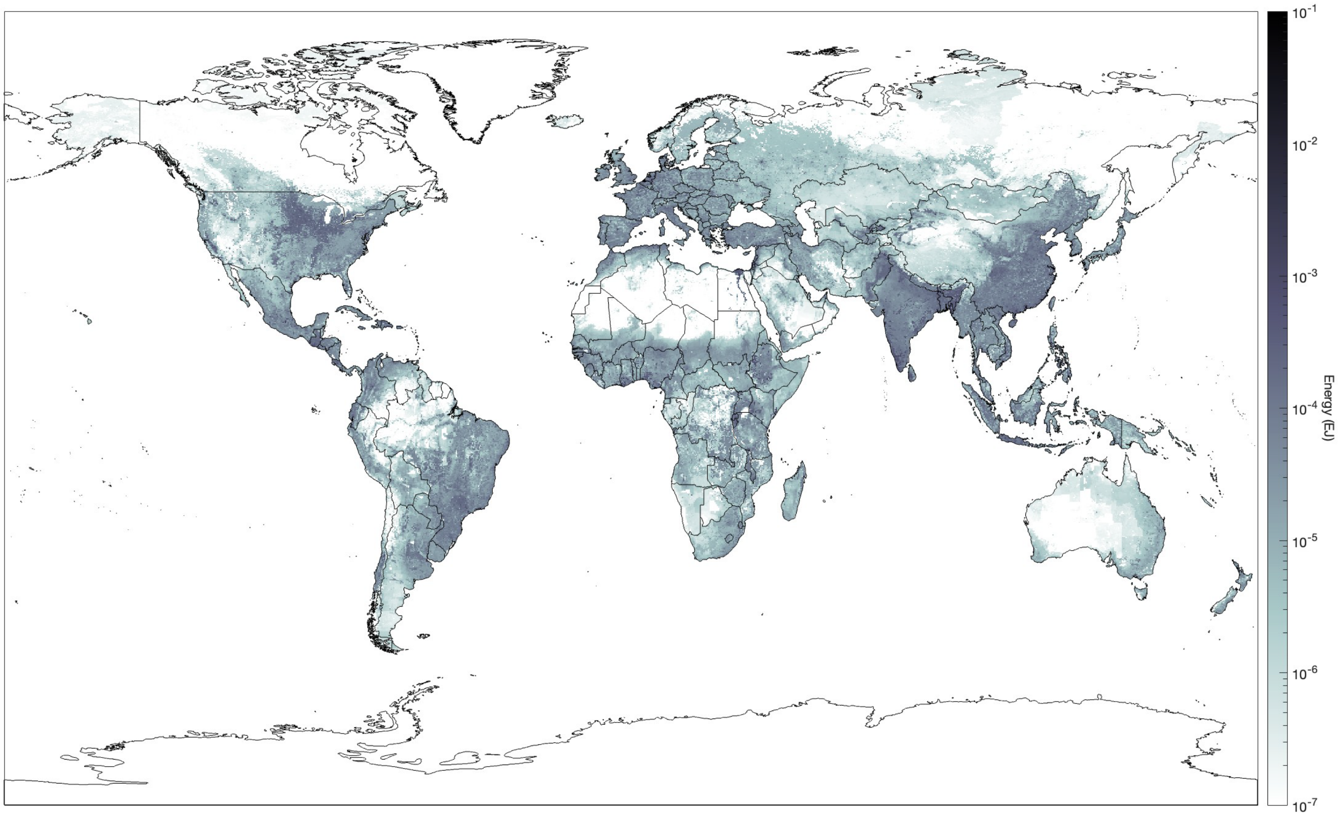

Figure 3. Global distribution of the available energy potential stemming from crop residue production to the 0.1-degree resolution.

To assess such aggregation concerns, we introduce the processable potential. It assesses whether there is sufficient bioenergy potential in surrounding cells with which the available potential in a specific cell can be combined to meet the input requirements of a conversion facility. However, processability also depends on the type of feedstocks, as it is important to ensure that feedstocks can be processed jointly. For this purpose, we collapsed the 173 residue types into three categories, according to their suitability for processing using anaerobic digestion (AD), fermentation, or thermochemical processes. In the initial analysis, we used a 10,000 TJ minimum cluster threshold and a 100 km maximum collection distance. While the stochastic analysis had found a mean available potential of 40.6 EJ across all the residue types (after the imposition of technical, sustainable, and competing use constraints), the processability requirement reduced this potential to 29.7 EJ.

Milestones

- Developed a standardized methodology for evaluating the energy potential from waste streams stochastically via Monte Carlo simulations.
- Pioneered a new metric to evaluate the processability of residues, based on cluster scale and collection distance constraints, as well as residue aggregation.

Major Accomplishments

- Completed the evaluation of the global available and processable energy potential for 173 different residue types.
- Produced a database of 173 maps on a 2,160-by-4,320 resolution, each corresponding to a residue type, across three scenarios (pessimistic, mean, optimistic), containing their available potential.

Publications

A paper summarizing the approach and results is under preparation.

Outreach Efforts

- Presented the results at the ASCENT Spring 2025 Meeting.
- Presented the results at the International Conference on Sustainable Aviation Research (ICSAR) 2025.
- Presentation to the ASCENT Fuels group in October 2025.
- Presentation at the Boeing Cascade conference.

Awards

None.

Student Involvement

Andy Eskenazi (MIT graduate student) conducted the research under the supervision of the PI.

Plans for Next Period

- Submit papers documenting the results.
- Attempt extension to energy cropping.

Task 2 – SAF Supply Chain Design for Africa, with Specific Focus on Sub-Saharan Africa

Massachusetts Institute of Technology
University of Hasselt

Objectives

The objectives of this task are (1) to study the current hurdles for the development of a local SAF industry in Africa, (2) to develop science-driven advice to help overcome these hurdles, and (3) to help kick-start the SAF industry in Africa. For this purpose, our team has developed an understanding of the current economic, social, environmental, technological, logistical, and legal hurdles for SAF development in Africa. We then create quantitative assessments of supply chain designs that leverage the specific opportunity space on the African continent. This entails (techno-) economic assessments and environmental lifecycle assessments of selected supply chain designs, and the inclusion of regulatory and policy considerations.

During the current reporting period, this task focused on working with local partners in Kenya to advance supply chain development.

Research Approach

A set of frameworks were developed and applied for the Kenyan context, which informed the SAF Steering meeting held in Mombasa in October 2024, and the third "High-Level Meeting on SAF Development and Deployment" held in May 2025 in Naivasha, Kenya (see Task 3). The team is also supporting the organization of the next Steering Committee Workshop, to be held in November 2025 in Nairobi, Kenya. The workshop will evaluate the progress made by the SAF Steering Committee. Importantly, the techno-economic study on the Mombasa refinery (International Civil Aviation Organization [ICAO] funding) and the fueling the Africa Flight study (World Bank) will be presented to the delegates. In addition, participants will discuss the next steps in developing a SAF financing mechanism.

Finalization of Green Premium Study for Kenya
During the reporting period, the analysis on the green premium allocation of SAF production in Kenya (see past reporting period) was reviewed and finalized for journal publication.

Socio-economic Contribution of SAF Refinery in Kenya
During the report period, the team supported the development of a draft concept to understand the economic impacts of establishing a SAF refinery in Kenya. More specifically, UHasselt efforts over the past year have sought to create a standard approach for measuring the economic benefits by supporting the study on the assessment of the Kenya petroleum refinery.

Development of SAF Strategy and ROADMAP for Kenya
The team supported the development of the SAF Strategy for Kenya (roadmap). Specifically, the team helped develop the first draft strategy and helped incorporate the comments submitted during the 4th Steering Committee Meeting.

Milestones

- Presented the first set of techno-economic analyses and stakeholder mappings during the Second Meeting of the National SAF Steering Committee on October 3-4, 2024, in Mombasa, Kenya.
- Co-organized, participated in, and contributed to the 3rd SAF Steering Committee Meeting held from 19-21st May 2025.
- Contributed to the African Civil Aviation Commission (AFCAC)/African Union/Common Market for Eastern and Southern Africa SAF Policy guideline workshop held from August 26-28, 2025, in Harare, Zimbabwe.
- Contributed to the development of a SAF strategy and roadmap for Kenya.
- Co-organized, participated in, and contributed to the fourth SAF workshop to be held from November 25-27, 2025, in Nairobi.
- Provided input to and review for the Technical Assessment of the old Kenya Petroleum refinery supported by the ICAO. The study was completed in September 2025.

Major Accomplishments

- Briefed the results from the green premium coverage analysis for Kenya during the second meeting of the National SAF Steering Committee on October 3-4, 2024, in Mombasa, Kenya.
- Supported organization of two workshops to build a SAF strategy and roadmap for Kenya.
- Participated in and contributed to the African SAF initiative under AFCAC.
- Helped secure funding for the SAF Technical Assessment of the Old Kenya Petroleum refinery.
- Contributed to the Energy Policy that has the SAF Policy subsection in the new policy 2025-2034.

Publications

Paper on the green premium study is under preparation.

Outreach Efforts

- Presented the results of initial analyses during the 2nd meeting of the National SAF Steering Committee on October 3-4, 2024, in Mombasa, Kenya.
- Presented the results of initial analyses during the 3rd meeting of the National SAF Steering Committee on May 19-21, 2025, in Naivasha, Kenya.
- Presented a summary of the efforts during the ASCENT Spring 2025 and Fall 2024 meetings.
- Co-organized and helped conduct SAF Steering Committee Meetings in Kenya.

Awards

None.

Student Involvement

Francis Mwangi (UHasselt graduate student) was involved in this task.

Plans for Next Period

- Further refine the analyses for Kenya.

Task 3 – Facilitate a Network for Capability Building for Global SAF Supply Chain Development

Massachusetts Institute of Technology
University of Hasselt

Objective

The objective of this task is to interface with partners to build the skills, expertise, and capacities needed for scaling up SAF development and deployment around the globe. During the current reporting period, the focus of this task was to deepen ties with external partners in support of advancing SAF development in Kenya.

Research Approach

To meet the goals of this task, the MIT/UHasselt team followed three approaches: (1) Capability building in Kenya, (2) developing a structure for capability building within the ASCENT Project 093, and (3) country workshops on SAF development in sub-Saharan Africa. During this reporting period, the first and third approach were emphasized. Specifically, the team continues to support stakeholders in Kenya in building capacity and knowledge to develop a SAF roadmap for Kenya and to build SAF production capacity in Kenya. To achieve this, the team supported the Kenyan Civil Aviation Authority (KCAA) in the running a National Steering Committee. Three MIT and UHasselt team members are members of the National Steering Committee and continue to support organization of meetings.

During the current reporting period, three key meetings were supported: (1) the second Meeting of the National SAF Steering Committee in October 2024, (2) third SAF Steering Committee Meeting in May 2025, and (3) fourth SAF workshop in November 2025. These meetings brought together key governmental and private stakeholders to work on issues such as feedstock sourcing and sustainability certification, plant financing, SAF policy, and fuel blending and certification. In support of these activities, the team fostered a network of supporting international stakeholders, including the KCAA, the Deutsche Gesellschaft für Internationale Zusammenarbeit (giz), the World Bank, the European Union Aviation Safety Agency (EASA), and ICAO.

Major Accomplishments

Co-organized (MIT/UHasselt team) three SAF events in Kenya.

Publications

None.

Outreach Efforts

- Co-organized three SAF workshops.
- Presented a summary of the efforts during the ASCENT Spring 2025 meeting.

Awards

None.

Student Involvement

Francis Mwangi and Teshome Deressa (UHasselt graduate students) supported coordination and implementation of the work.

Plans for Next Period

Continue to support efforts in Kenya as needed.

Task 4 - Support Knowledge Sharing and Coordination Across all ASCENT Project 093 Universities

Massachusetts Institute of Technology
University of Hasselt

Objective

The objective of this task is to share best practices and coordinate efforts with other ASCENT Project 093 universities (Washington State University and University of Hawaii). The sharing of approaches minimizes duplication of ASCENT Project 093 universities' work on similar topics and can help develop transferable approaches for stakeholder engagement across various geographical regions.

Research Approach

The MIT/UHasselt team participated in regular ASCENT Project 093 coordination teleconferences, which served as a venue to discuss progress in the various geographies and to learn about the activities of other ASCENT Project 093 universities.

Milestones

- Shared progress in Kenya.
- Shared global feedstock availability assessment.

Major Accomplishments

Developed and delivered a joint course on the fundamentals of SAF to a first cohort in November 2023.

Publications

None.

Outreach Efforts

Ongoing coordination between ASCENT Project 093 teams.

Awards

None.

Student Involvement

Andy Eskenazi (MIT) and Francis Mwangi (UHasselt) participated in knowledge sharing.

Plans for Next Period

Continue engagement in regular teleconferences and the development and delivery of the SAF lecture series.