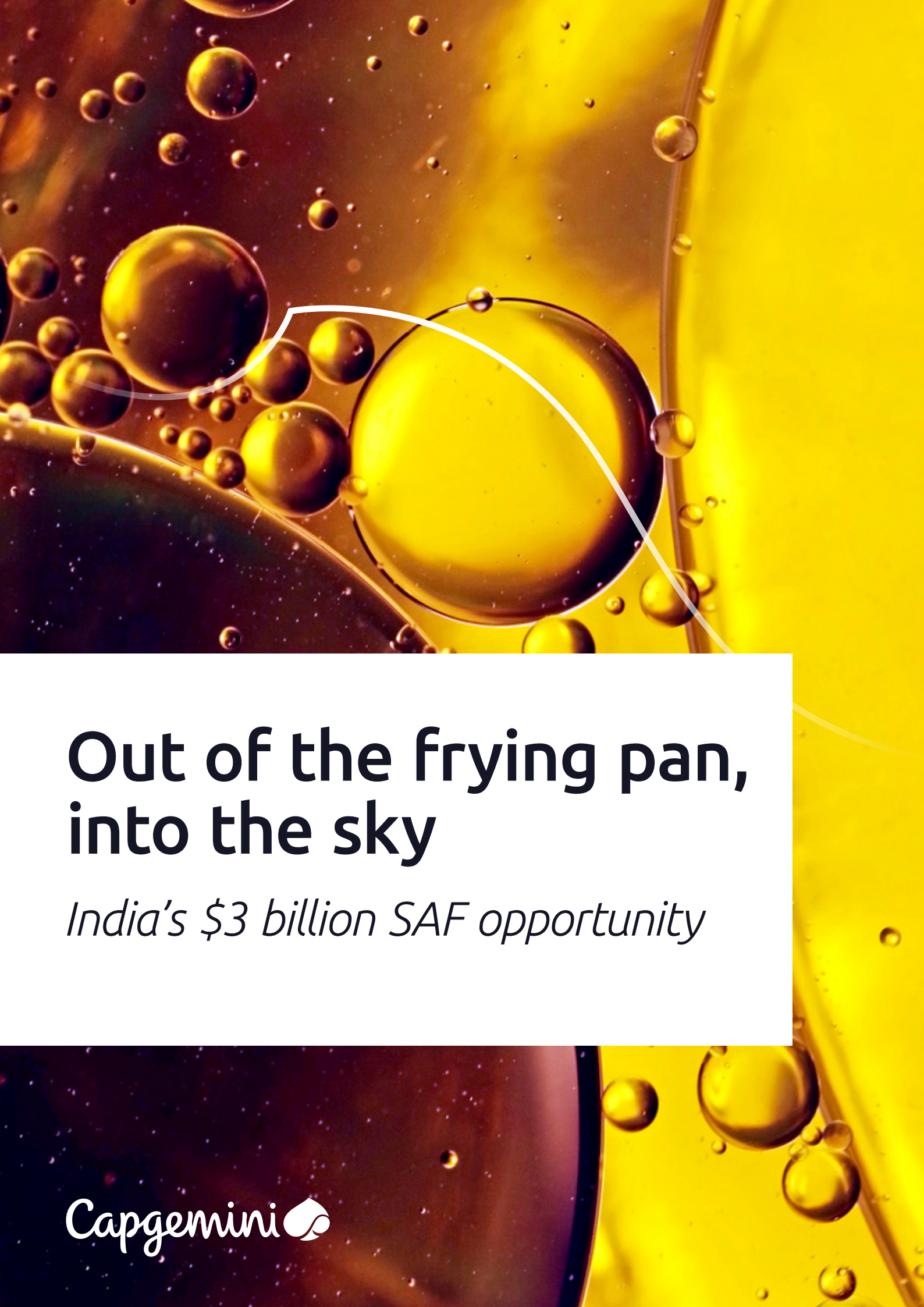

Out of the frying pan, into the sky

India's $3 billion SAF opportunity

Capgemini

A global opportunity in India

SAF is emerging as a crucial innovation in the aviation industry, offering a viable alternative to conventional fossil fuels that reduces greenhouse gas emissions. Worldwide, the sustainable aviation fuel (SAF) market is projected to reach $16.8 billion by 2030, representing a CAGR of 47.7%.

The primary driver is the growing necessity to cut GHG emissions, while the main obstacle is the cost disparity between SAF and traditional fuel. There are opportunities due to the increasing global demand for SAF by airlines, but significant challenges persist in producing large volumes of SAF.

A notable advancement in this field is the production of SAF from used cooking oil (UCO) and other waste materials. India's substantial UCO market, and the Indian government's dedication to SAF, make it an ideal location for SAF development. The Indian government has set a goal to blend 1% SAF with jet fuel by 2027, and 2% by 2028. By 2030, they aim to have enough feedstock to produce 19 to 24 million tons of SAF per year, far more than the 8 – 10 million tons that India will require (even considering a blend of 50%). Very soon then, India could become a significant exporter of SAF.

Aerospace leaders have a central role to play in this transformation. They are the ones most familiar with the requirements of jet fuel production. As natural innovators, they are used to complex challenges. But most of all, the aerospace industry brings a spirit of possibility that is unmatched in the world today.

As we will see, capitalizing on India's used cooking oil will require ingenuity, collaboration and engineering at its best. This is a project for aerospace.

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Part I

India's used cooking oil

India's demand for cooking oil is impressive. In 2022, India consumed over 22 million metric tons – out of 204 metric tons worldwide – encompassing coconut, cottonseed, olive, palm, peanut, rapeseed, soybean, and sunflower oils. They produced 3.2 million metric tons of used cooking oil.

India's role in the global UCO market is becoming increasingly important. As the world's second-largest consumer of cooking oil, India has a substantial supply of UCO that can be harvested for SAF production. This is good news, as other major UCO producers – including the largest, China – struggle to meet the growing global demand. Going forward, that demand will only rise.

The global UCO-to-SAF market today stands at $38.8 million. It's projected to rise by an astounding 63% CAGR up to $734 million by 2030. India's ability to scale up UCO-to-SAF production could help bridge the gap between supply and demand, making it a central player in the global SAF market.

India's UCO supply chain involves multiple players, including cooking oil manufacturing companies, food business operators, private households, and UCO aggregators. The dining-out culture in India has seen significant growth, driven by urbanization and higher disposable incomes. This trend has made quick service restaurants major consumers of cooking oil, catering to the fast-paced lifestyle of city dwellers. The result is an increase in UCO of 3.3% per year, from 3.2 million metric tons in 2022, up to a projected 4.1 million metric tons by 2028. However, only 10% of this used cooking oil is currently being repurposed for biodiesel production, representing an enormous missed opportunity.

Current disposal practices and environmental impact

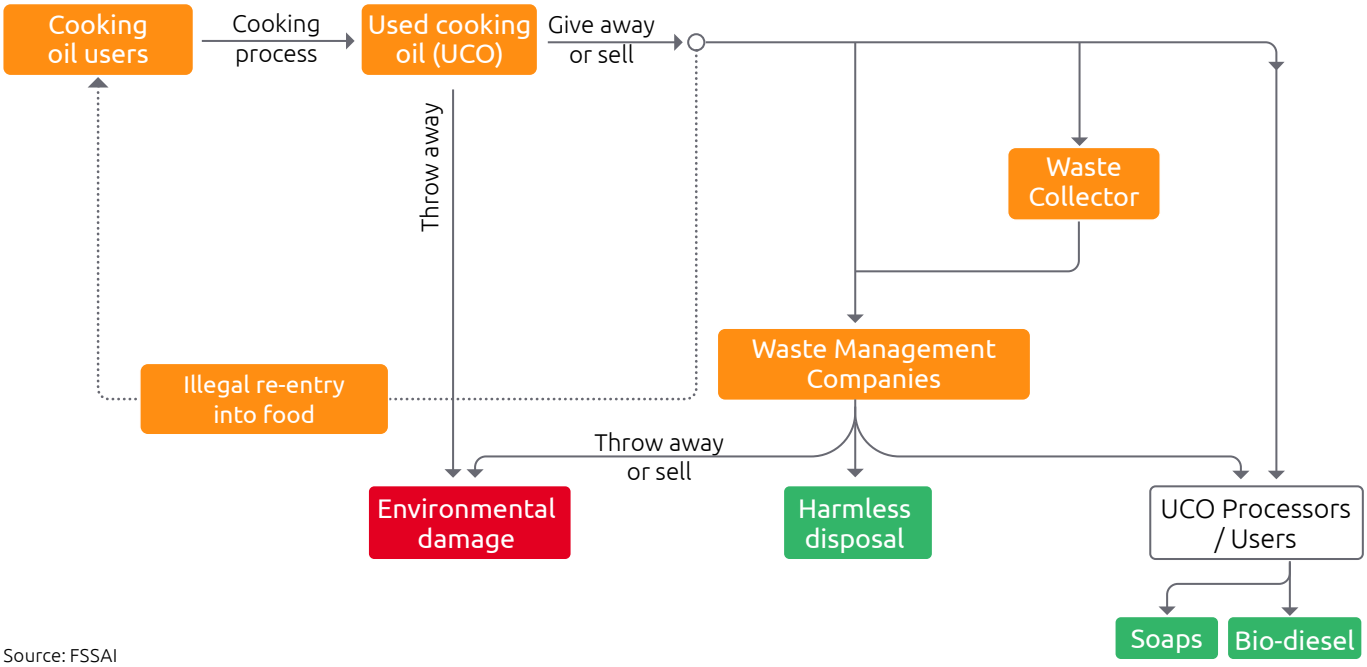
People dispose of used cooking oil in different ways, each with varying degrees of impact on the environment and society. There's also evidence of used cooking oil finding its way back into the food chain, which poses potential health risks.

What it is	What it does
Throwing away	
This "method" means simply discarding the used cooking oil, typically in household waste or pouring it down the drain.	This can lead to environmental pollution and clogging of drainage systems.
Waste collector	
Users may choose to give away or sell their used cooking oil to waste collectors or aggregators who specialize in collecting and managing such waste.	The waste collector will deliver the used oil to a waste management firm or UCO processor.
Waste management firms	
Waste management firms or agents often provide services for collecting and processing used cooking oil directly.	Either disposes of, or recycles the oil, often with the help of a specialized UCO processor.
UCO processors	
Some users may opt to sell or give away their used cooking oil directly to UCO processors or other users.	UCO will be used for various purposes such as biodiesel production or industrial processes.

To address these issues, the Food Safety and Standards Authority of India (FSSAI) has introduced guidelines for the safe disposal of UCO. These guidelines recommend that UCO should be sold to authorized aggregators who convert it into biodiesel or use it for other industrial purposes. The Repurpose Used Cooking Oil (RUCO) initiative by FSSAI aims to streamline this process, ensuring that UCO is collected and repurposed efficiently.

Despite these efforts, the reuse of cooking oil remains common, especially among small eateries and roadside vendors, posing serious health risks due to the formation of harmful compounds in repeatedly heated oil.

Ecosystem for production, disposal and usage of used cooking oil



Source: FSSAI

Success story

Neste, a Finnish renewable fuels company, has established itself as a global leader in UCO to SAF conversion. Neste collects UCO from various sources, including households, restaurants, and food processing facilities, and processes it into sustainable aviation fuel at its refineries.

Neste employs innovative refining processes, such as hydrotreating and isomerization, to convert UCO into high-quality SAF. These processes ensure the removal of impurities and contaminants, resulting in a clean and sustainable aviation fuel product.

Between 2019 and 2022, Neste reported a steady rise in SAF production, with annual output reaching over 200,000 tons by 2022.

Part II

Sustainable Aviation Fuel (SAF)

Sustainable Aviation Fuels offer comparable performance, while reducing GHG emissions by as much as 80%. We'll be looking specifically at bio-SAF derived from the Hydroprocessed Esters and Fatty Acids (HEFA) process.

Bio-SAF is derived from renewable and sustainable feedstocks, such as used cooking oil, agricultural residues, algae, or waste materials. (Throughout this document, we will refer to bio-SAF simply as SAF.) It is designed to reduce the carbon footprint of the aviation sector by producing fuel with lower lifecycle greenhouse gas emissions than conventional jet fuel. In other words, the total amount of greenhouse gases emitted during the production, use, and disposal of SAF is less than that of traditional jet fuel. 80% of aviation CO2 emissions result from flights covering distances of over 1,500 km (mid- and long-range flights), for which hydrogen and electric are not options. SAF is thus vital to reducing the industry's emissions.

Diverse feedstocks and conversion technologies

Cooking oil is just one of the feedstocks capable of being converted into SAF. Biomass feedstocks are another, encompassing a wide range of organic materials, including agricultural residues, forestry by-products, and dedicated energy crops. These feedstocks offer renewable and abundant sources for SAF production, contributing to waste reduction and carbon sequestration. Algae-based feedstocks present another intriguing avenue for SAF production due to their high lipid content and ability to grow in non-arable land and wastewater. Municipal Solid Waste (everyday garbage) presents a dual benefit – waste management and biofuel production. Finally, waste oils and fats from food processing, restaurants, and other sources can be transformed into biodiesel, a component of SAF. Utilizing waste streams for fuel production promotes circular economy principles and reduces reliance on virgin feedstocks.

Conversion technologies

The methods used to convert feedstocks into fuel are just as varied as the resources themselves. They include:

1. **Fischer Tropsch (FT) Technology:** This method turns various feedstocks like coal, natural gas, biomass, and even municipal waste into synthetic fuels. The raw materials are converted into synthetic gas (syngas), which is then transformed into long-chain hydrocarbons and refined into sustainable aviation fuel.
2. **Alcohol-to-Jet (ATJ) Process:** This process converts alcohol-based feedstocks, such as ethanol or butanol, into jet fuel. It stands out for using renewable feedstocks, being compatible with existing aviation infrastructure, and potentially reducing greenhouse gas emissions. ATJ is notable for its integration with existing ethanol production facilities and its potential for large-scale use.
3. **Synthetic Iso-Paraffinic (SIP) Production:** SIP fuels are created by synthesizing branched-chain hydrocarbons that mimic conventional jet fuel properties. This involves using light olefins from various feedstocks like biomass, natural gas, or industrial waste. SIP fuels are known for their excellent cold flow properties and high energy density, making them ideal for aviation.
4. **Hydroprocessed Esters and Fatty Acids (HEFA) Pathway:** This method converts triglycerides from vegetable oils or animal fats into aviation fuel through hydroprocessing. HEFA fuels have been used in commercial aircraft for over a decade, relying on renewable feedstocks and existing refining infrastructure. For converting UCO, it's the method of choice.

Following production, the resulting SAF is blended with conventional jet fuel at varying ratios to meet industry specifications, facilitating its use without any modifications to aircraft.

Why HEFA is ideal for used cooking oil

First, on the technical side, used cooking oil contains high levels of free fatty acids and impurities, which HEFA technology removes in its pre-treatment steps. Pairing HEFA with cooking oil also offers significant environmental and regulatory benefits. It helps in diverting waste from landfills or improper disposal methods, thereby reducing environmental pollution and associated negative impacts. HEFA-derived SAF also meets the stringent aviation fuel specifications and regulatory standards. On the minus side, only about 15% of the output of a traditional HEFA refinery is kerosene, compared to 85% road fuel (though this ratio can be raised significantly – up to 50% – with the right technology).

Overall, the HEFA pathway provides an effective way to convert used cooking oil into SAF, making it an excellent choice.

How converting oil into fuel reduces carbon emissions in the aviation sector

The significance of this conversion process lies in its potential to significantly reduce carbon emissions within the aviation sector. SAF derived from UCO and other renewable feedstocks boasts a lower lifecycle carbon footprint compared to traditional jet fuel, thanks primarily to its production method, which is far less energy-intensive than traditional fuel production.

Using organic waste has another benefit as well. Jet fuel releases the same amount of CO2, no matter what the source. But UCO was going to release that CO2 anyway, slowly degrading in a landfill or drain. By using it as jet fuel, we're essentially just putting that inevitable CO2 production to good use. In contrast, conventional fuel draws additional carbon from underground oil, and releases it into the air. This additional use of UCO is right in line with the concept of circular economy, mentioned earlier.

Airlines and aerospace stakeholders face challenging emission reduction targets. SAF provides a practical pathway to achieving these goals, and one that's incentivized by government support and policy frameworks. There are, however, formidable challenges ahead, beginning with collection.

Part III

Challenges in UCO collection

Collecting used cooking oil is no small task. The challenges include:

- **Lack of structured collection mechanisms:** Unlike other recyclable materials, such as paper or plastic, there is often no designated infrastructure for UCO collection. This lack of organization makes it challenging for both consumers and businesses to dispose of UCO properly and for collection entities to efficiently gather it.
- **Limited awareness among consumers and businesses:** Many individuals are unaware of the environmental impact of improperly discarding UCO and the opportunities for its conversion.
- **Inefficiencies in existing collection infrastructure:** Even in areas where UCO collection programs exist, issues such as suboptimal collection routes, inconsistent schedules, and inadequate capacity to handle UCO volume can lead to missed collection opportunities and inefficient resource utilization.

Implementing structured collection systems, raising awareness about UCO recycling, and optimizing collection infrastructure are crucial steps toward overcoming these obstacles and promoting sustainable UCO management. And the best news is, recent innovations are making this a lot easier.

Success story

Qantas Airways, Australia's flagship carrier, has embraced UCO to SAF conversion as part of its sustainability strategy. Qantas has conducted successful flights using SAF derived from UCO, demonstrating its commitment to reducing carbon emissions in the aviation sector.

Qantas collaborates with biofuel producers and technology developers to deploy cutting-edge conversion technologies for UCO to SAF production. These technologies include esterification, hydro processing, and Fischer-Tropsch synthesis, which enable efficient and sustainable conversion of UCO into aviation fuel.

Technological interventions

We suggest three solutions to make UCO collection more efficient:

- **IoT-enabled UCO collection bins:** Internet of Things (IoT) technology can monitor UCO levels in real-time, alerting collection teams when they need emptying. Additionally, IoT-enabled bins can optimize collection routes based on fill levels, reducing unnecessary trips and minimizing fuel consumption and emissions[1].
- **Mobile applications for transparent tracking and reporting:** By using GPS and digital reporting features, mobile apps help collection teams record collection locations, quantities, and timestamps in real-time. This data can be easily accessed and shared with consumers, businesses, and regulatory authorities, enhancing accountability and compliance with UCO recycling regulations.[2]
- **Automation and robotics in collection and transportation:** Automated collection vehicles can efficiently empty UCO bins and transport collected oil to processing facilities. Autonomous drones or robots can also be employed to inspect collection routes, identifying bin locations, and detecting anomalies, further improving operational efficiency and reducing labor costs.

Up to now, the major players involved in UCO collection have included government agencies, waste management companies, restaurants and consumers. Together they've managed to get the ball rolling, but they have not taken advantage of these technological innovations, nor laid down the foundation necessary to industrialize the process. This is a market looking for a leader.

1 Koutsopoulos, I., & Karakostas, B. (2019). Internet of Things (IoT) for Environmental Monitoring of Used Cooking Oil. In Proceedings of the 9th International Conference on Information, Intelligence, Systems and Applications (IISA) (pp. 1-6). IEEE.

2 Qian, J., Cai, H., Yang, F., & Zhang, B. (2020). Mobile Application Based Recycling System of Waste Cooking Oil. In Proceedings of the 12th International Conference on Measuring Technology and Mechatronics Automation (ICMTMA) (pp. 1-5). IEEE.

Part IV

Fueling a revolution

The challenges to collecting, transforming and commercializing UCO are considerable. That's what makes aerospace companies the right partners for the job.

As the final link in the value chain, aerospace companies can play a pivotal role in structuring the market by driving demand. They can invest in production capacity and ensure the collection and availability of feedstock, thereby securing the resources needed to meet both current and future requirements. By doing so, they will help create a sustainable and efficient market for this innovative fuel source.

Aerospace companies are also familiar with navigating regulatory environments, which is essential for ensuring that SAF production meets international standards and certifications.

The need for collaboration across the supply chain

To realize the potential of SAF from India's used cooking oil, collaboration across the entire supply chain is essential. From feedstock collection and processing to distribution and certification, every stage requires coordinated efforts among suppliers, refiners, regulatory bodies, and end-users, including airlines and aerospace companies. Across India, valuable cooking oil is going down the drain (often literally). Saving this resource is possible, but it requires close collaboration with people on the ground who know the terrain.

A key element will be transparent supply chain technology. By offering greater visibility and traceability across each step, a transparent supply chain ensures that the entire supply chain is efficient, clear, and compliant with regulatory requirements. This is one opportunity for aerospace companies and their partners to stake out a substantial role is

Success story

World Energy, a leading biofuel producer based in the United States, has successfully implemented UCO to SAF conversion at its biorefineries. By partnering with restaurants, food service providers, and waste collectors, World Energy collects UCO and converts it into 250 million gallons of high-quality SAF yearly.

SATORP, a joint venture between Saudi Aramco and TotalEnergies, has achieved success in UCO to SAF conversion in the Middle East region. SATORP's innovative approach involves coprocessing UCO to produce International Sustainability and Carbon Certification (ISCC+) certified SAF.

SAF production. By working together, aerospace companies can help build a resilient SAF ecosystem that not only meets immediate environmental goals but also strengthens the long-term sustainability of the aerospace industry.

Potential for collaboration in India

The Indian government is on board for biofuel. They have already implemented the National Policy on Biofuels 2018, which "seeks to mainstream biofuels within the energy and transportation sectors," and the Sustainable Alternative towards Affordable Transportation (SATAT), with the goal of increasing compressed biogas production.

The Indian government has also begun implementing digital tools for traceability, such as the "Repurpose Used Cooking Oil" web portal, managed by the Food Safety and Standards Authority of India (FSSAI) and the Biodiesel Association of India (BDAI). The portal helps public-sector oil marketing companies trace and collect UCO-based biodiesel under a national program. This type of initiative offers a prime opportunity for public-private collaboration, in which the government's inside knowledge, and aerospace companies' ability to innovate and scale, could rapidly expand a program's success.

Given the decentralized nature of UCO producers, participation by national, local, public, and private partners will be essential. Collaboration between local authorities, especially local Food & Drug Administrations in metropolitan areas, and major private collectors of HEFA feedstock can facilitate the establishment of a collection and production scheme. Education and strategic alignment will help bring the many disparate players into a single system with shared goals. Initiatives like the FSSAI's "Triple E" strategy are a good start.

So, with effective technologies, strong partnerships and a clear commitment, just how large an opportunity are we looking at? Here's our back-of-the-napkin estimate: Earlier we used IMARC Group's estimate of 4.1 million metric tons of UCO on the Indian market by 2028 – a reasonable assumption. Let's imagine that all of that UCO is collected, and put through a HEFA process optimized for kerosene (15% to 50%). At a price of $1.5/L, the potential market value might range from $922M to $3.1B. How that estimate will compare with the reality 3 years out is anyone's guess. What's clear though, is that the potential is there. And the world is starting to take notice.

An industry accelerating

Across the board, from UCO collection to SAF production; from engine re-engineering to real-world testing, industry leaders are laying the groundwork for a massive expansion in SAF use. Some recent examples include:

SAF production

Industry leaders like Honeywell, Rolls-Royce, and GE Aerospace, are making significant strides in preparing for the SAF era. Honeywell's SAF, produced using the UOP Renewable Jet Fuel Process™, meets or exceeds the most rigorous jet fuel standards and can reduce greenhouse gas emissions by 60-80% compared with conventional jet fuels. This super-efficient fuel also offers higher energy density, allowing aircraft to fly farther on less fuel, and serves as a drop-in replacement requiring no changes to aircraft technology or fuel infrastructure.

Flight testing

Rolls-Royce has successfully completed compatibility testing of 100% SAF on all its in-production civil aero engine types. This extensive testing, which included a variety of ground and flight tests, confirmed that 100% SAF does not affect engine performance.

In late 2023, GE Aerospace reached a new milestone by testing 100% SAF on ten different engine models. Notable achievements include powering the first commercial airliner flight with 100% SAF on the Boeing ecoDemonstrator in partnership with FedEx Express, and conducting emissions testing with NASA. Most recently, Emirates operated an Airbus A380 using 100% SAF in one of its four GP7200 engines.

In India

Several Indian companies are also driving SAF initiatives. Bharat Petroleum Corporation Limited (BPCL) plans to invest Rs 1,400 crore to establish SAF units at its refineries, aligning with the government's goal of achieving 1% SAF blending by 2027 and 5% by 2030. GPS Renewables is collaborating with Dubai-based SAF One to develop a SAF facility capable of producing 20-30 million liters per year by converting lignocellulosic waste feedstock. Airbus and the CSIR-Indian Institute of Petroleum (CSIR-IIP) have signed a Memorandum of Understanding (MoU) to develop new technology pathways and test and qualify indigenous SAF in India.

Government support and incentives

Governments and regulatory bodies are implementing policies and providing incentives to support SAF production and adoption. The United States introduced the Renewable Fuel Standard (RFS) program, which includes incentives for SAF derived from UCO and other renewable feedstocks. Additionally, the European Union's Renewable Energy Directive (RED) promotes the use of biofuels like UCO-based SAF.

The Government of India has been actively promoting the use of SAF to reduce carbon emissions and support sustainable development. They actively encourage public-private partnerships and have proposed several measures, including lower taxes and even lower passenger fees for SAF-powered flights.

Growing adoption by airlines

Air France-KLM, Lufthansa, Delta Air Lines, and American Airlines have all committed to reducing their carbon footprint by incorporating SAF into their operations.

Additionally, cargo carriers such as DHL Group, Amazon Prime Air, and UPS also rely on SAF to effectively reduce aviation-related emissions. Similarly, British Airways and Lufthansa have also completed flights utilizing UCO-based SAF, demonstrating its viability as a drop-in solution for commercial aviation.

International collaboration and standards development

International organizations like the International Civil Aviation Organization and the Roundtable on Sustainable Biomaterials are developing certification standards for SAF production, helping to ensure that UCO-based SAF meets high environmental standards.

Public awareness and consumer demand

Increasing public awareness of climate change and environmental issues is driving consumer demand for sustainable aviation fuels, including those derived from UCO. Airlines and fuel suppliers are responding by offering SAF as a premium option for environmentally conscious travelers, further incentivizing investment and innovation.

Additionally, SATORP, a platform owned by Aramco and TotalEnergies, has successfully converted used cooking oil through coprocessing into International Sustainability and Carbon Certification (ISCC+) certified SAF – a first for the MENA region.

Expansion of production facilities

The construction and expansion of SAF production facilities is increasing the availability of UCO-based SAF in the market. Total Energies for example, is converting an old refinery (Grandpuits, France) into a zero-crude refinery. This new production site will convert municipal solid waste and residues, including UCO, into SAF. Total Energies has announced a partnership with an agrifood company (SARIA) to secure the feedstock supply.

Neste, a leading producer of sustainable fuels and renewable feedstock solutions, has also announced plans to invest in additional production capacity for UCO-based SAF in Europe.

Industry collaboration and investment

Collaboration between industry stakeholders is driving innovation and investment in UCO-to-SAF conversion technologies. For example, Alaska Airlines partnered with biofuel producer Neste to incorporate UCO-based SAF into its operations. World Energy, a leading biofuel producer, has expanded its production capacity for UCO-based SAF to meet growing demand.

Innovation in conversion technologies

Ongoing research and development efforts are focused on improving conversion technologies for UCO-to-SAF production. Catalytic hydrothermal liquefaction and microbial fermentation are emerging as promising methods for increasing the yield and quality of SAF from UCO and other waste feedstocks.

These trends and success stories underscore the growing momentum behind UCO-to-SAF conversion globally, indicating a shift towards more sustainable and environmentally friendly aviation fuel solutions.

A market ready to rise

The conversion of used cooking oil into sustainable aviation fuel presents a dual opportunity: for India to foster sustainable development in the aviation sector, and for aerospace leaders to promote sustainable flight.

While biodiesel has seen moderate growth, the bio-SAF market is still emerging. Feedstock is not yet available in reliable quantities, and the multiple players and regulators are not aligned. However, the market has a clear direction, driven by consumer demand and incentivizing policies.

Converting UCO into SAF offers significant environmental benefits by reducing carbon emissions and promoting circular economy principles. It holds immense potential to address pressing environmental challenges, such as air pollution and carbon emissions – growing concerns given India's large population and growing aviation sector.

For aerospace leaders looking to get involved, the key will be collaboration. Government agencies, industry players, technology providers, waste management companies, and civil society organizations have a chance to implement technological solutions, establish a sustainable UCO-to-SAF supply chain, and create an enabling policy environment. The aerospace companies that do so will establish a clear competitive advantage in the field of sustainably fuel production.

For India, SAF will unlock new economic, environmental, and social benefits. For aerospace leaders, it's an opportunity to get in on the ground floor, and take advantage of an immense resource that's currently significantly undervalued.

Capgemini's commitment to sustainable aviation

Capgemini has long been a leader in sustainability, making significant progress towards a greener and carbon net-zero future. Our dedication is demonstrated through various initiatives and achievements, such as transitioning all our offices in India to 100% renewable energy, a milestone we reached two and a half years ahead of schedule. We are also committed to helping our clients reduce their carbon emissions by 10 million tons by 2030.

Capgemini is well-positioned to support the transition to SAF. As a recognized leader in sustainability technology with strong global partnerships and three decades of experience in aeronautics – as well as related industries like automotive and energy – we bring valuable insights to aviation. Our expertise covers all aspects necessary for aerospace decarbonization.

For more on the strides organizations are making in environmental and social sustainability, read our report from the Capgemini Research Institute, A world in balance 2024: Accelerating sustainability amidst geopolitical challenges.

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About Capgemini

Capgemini is a global business and technology transformation partner, helping organizations to accelerate their dual transition to a digital and sustainable world, while creating tangible impact for enterprises and society. It is a responsible and diverse group of 340,000 team members in more than 50 countries. With its strong over 55-year heritage, Capgemini is trusted by its clients to unlock the value of technology to address the entire breadth of their business needs. It delivers end-to-end services and solutions leveraging strengths from strategy and design to engineering, all fueled by its market leading capabilities in AI, cloud and data, combined with its deep industry expertise and partner ecosystem. The Group reported 2023 global revenues of €22.5 billion.

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