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Transitioning the Chemical Industry:

Used Cooking Oil as a Renewable Feedstock for Enabling India’s Material Transition

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FOREWORD

Chair RECEIC

India's chemicals and materials industry stands at a critical inflection point. Having developed strong capabilities in scale, efficiency, and increasingly in specialty and performance chemistry, the sector is now navigating a global shift shaped by sustainability expectations, evolving policy frameworks, and changing market dynamics.

This report positions Used Cooking Oil as a practical and underutilised opportunity within this transition. While availability is significant, fragmented aggregation systems present a clear opportunity for industry-led action to unlock both environmental and commercial value. The pathways outlined demonstrate that such alternative feedstocks can be integrated using existing capabilities, offering a pragmatic route forward.

Importantly, the report takes a balanced view of economic readiness-highlighting where opportunities are immediately viable and where enabling mechanisms can accelerate adoption. This supports informed, strategic engagement rather than prescriptive action.

I commend the RECEIC Working Group for this timely and thoughtful report, which provides a valuable basis for forward-looking decision-making.

Manish Sharma
Chair RECEIC

FOREWORD

Partner, EY

India's pathway to net zero has, for much of the past decade, been framed around renewable energy and power, electrification, low-carbon fuels, and mobility. That framing is not wrong; it is incomplete. What this report confronts directly is the dimension that has remained largely unaddressed: the fossil carbon embedded not in what we burn, but in what we make. Here was a resource generated every day, in every city and town across India, in every home kitchen and roadside stall that was being systematically squandered. Not through negligence, exactly, but through a failure of design. A failure to ask the right questions about where this material should go, and why.

It is against this backdrop that Used Cooking Oil emerges not as a niche circular-economy curiosity, but as a strategically significant near- to medium-term bridge feedstock. UCO is renewable, waste-derived, domestically generated at scale, and chemically versatile. It can be upgraded into oleochemical intermediates; used to substitute fossil hydrophobes in surfactants through established industrial pathways; and processed through refinery-integrated routes for broader material applications. Crucially, unlike virgin vegetable oils, it carries no incremental land-use burden, no water demand trade-off, and no food-security tension. These are not incidental attributes. In a resource-constrained transition, they are precisely what make UCO a credible and responsible feedstock choice.

India's decarbonisation conversation has, understandably, been dominated by energy. Renewable power, electric vehicles and green hydrogen have rightly captured attention and investment, but materials have quietly remained the blind spot. The carbon embedded in the surfactant in you dish soap, the detergent in your laundry, the cleaning agent on the factory floor that carbon is fossil-derived, and it eventually returns to the atmosphere. Decarbonising the grid does not fix this. Only a deliberate shift in feedstocks can.

The numbers in this report deserve careful attention. The report Cleary demonstrate that the constraints India faces are not technical or geological. We are not short of UCO. We are not short of industrial chemistry. What we have lacked is a systems-level perspective that looks at this waste stream not as a nuisance to be managed, but as a strategic circular-carbon resource to be governed. That is a policy choice. And it is one that is fully within reach.

The analysis presented here covers a lot of ground: supply estimates, quality grading, economic screening, regulatory architecture, and international comparisons. The readers must not lose the thread that ties it all together. Used Cooking Oil sits at an unusually productive intersection public health, climate mitigation, energy transition, and industrial competitiveness. Very few policy interventions offer that kind of simultaneous leverage. That is worth pausing on.

One dimension of this work that I hope does not get lost in the policy analysis is its public health significance. The diversion of degraded cooking oil back into informal food channels is not an abstract regulatory problem. It is a chronic, daily exposure risk for millions of urban consumers, street food workers, and children. FSSAI's RUCO initiative laid important groundwork, but enforcement through inspection alone has its limits. The most durable enforcement mechanism, as international experience consistently shows, is the creation of strong industrial sinks that pull UCO decisively and permanently out of the informal market. This report is, among other things, a case for building those sinks.

The international evidence reviewed in this report spanning the United States, the European Union, Germany, Japan, China, and the United Kingdom offers a consistent and important lesson: UCO outcomes are determined by system design, not by feedstock availability or technical feasibility. Every jurisdiction that has achieved meaningful UCO recovery has done so through mandatory collection, credible traceability, and differentiated end-use incentives. Every jurisdiction that has relied on voluntary frameworks or low enforcement has underperformed. The lesson for India is not that the challenge is unique it is that the solutions are known, and the barriers are entirely design related.

I am also conscious that this report speaks to priorities well beyond climate. This report lands at a moment of real geopolitical turbulence in energy markets. India's dependence on imported fossil feedstocks is not merely a climate vulnerability it is a strategic one. Building out domestic, waste-derived carbon supply chains is entirely consistent with the Atmanirbhar Bharat agenda. These are not competing priorities.

This Lighthouse Project represents the beginning of a strategic conversation, not its conclusion. The foundational analysis it provides on supply, quality grading, economics, regulatory architecture, and international precedent is designed to give policymakers, industry, and investors a common analytical baseline from which more detailed assessments and coordinated action can proceed. I commend the authors for the precision, intellectual honesty, and cross-disciplinary scope they have brought to this work. And I hope that those who engage with it carry forward its central argument: that treating Used Cooking Oil as a strategic circular-carbon resource, and that is one of the most consequential and tractable choices available to India on its path to net zero. I hope this report serves as a useful contribution to a conversation that India cannot afford to defer.

Amit Kumar
Partner

PREFACE

Chair, Materials Transition Working Group

Transitioning from fossil-based carbon to renewable carbon is critical for India's Chemical Industry to achieve Net Zero while progressing towards self-reliance. Recent geopolitical disruptions have further underscored India's vulnerability to fossil based supply chains, reinforcing the strategic importance of material resilience.

The Material Transition Working Group under the aegis of RECEIC was formed with the conviction that fossil carbon dependence in chemicals must be addressed with the same urgency and rigour as energy transition.

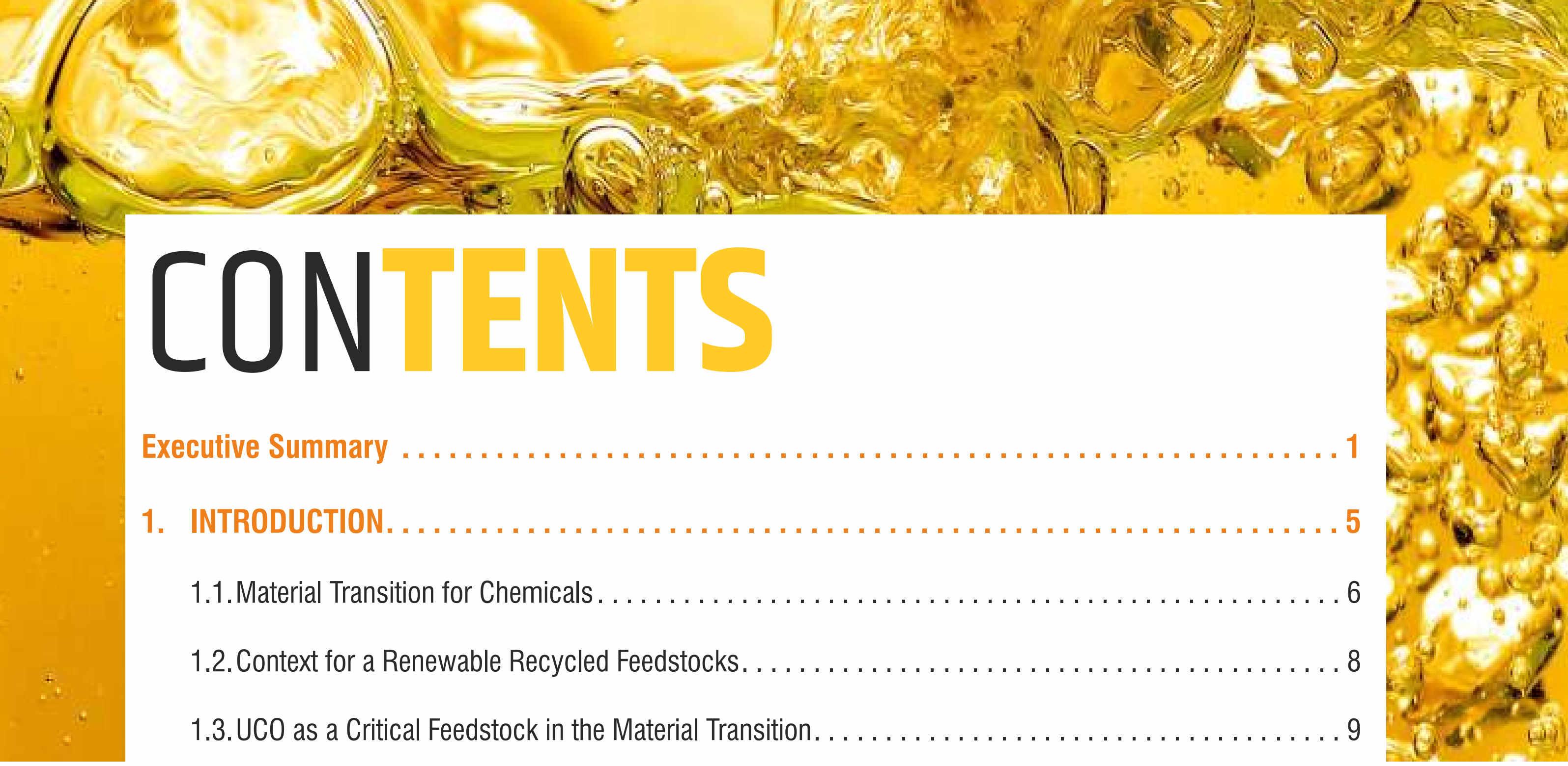
This paper moves the conversation from intent to implementation, demonstrating how Used Cooking Oil (UCO) can enable a near-term material transition for the chemical sector if supported by the right policies.

As a biogenic and recycled feedstock, UCO offers significant potential for greenhouse-gas reduction while mitigating public-health risks associated with food-chain diversion. However, weak collection systems and limited traceability constrain UCO availability in India.

Fixing how UCO is mobilised and diverted into high value materials by bringing together science, policy insights and system design, can provide the highest returns to climate mitigation and public health. This paper highlights where India can act, pragmatically and at scale.

I hope this work will be able to contribute meaningfully and help shaping informed decisions across policy, industry, and the broader ecosystem, as we work together to enable a resilient and sustainable chemical industry in India.

Mr. Rajat Arora
Chair, Materials Transition Working Group
Head R&D, Home Care, India



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Material Transition in the Context of India's Net Zero Ambition

India's pathway to net-zero emissions cannot be realised through energy transition alone. While substantial progress is being made in decarbonising fuels, power, and mobility, materials—particularly chemicals—remain structurally dependent on fossil-derived carbon. For the chemical sector, greenhouse-gas emissions arise not only from energy use during production, but from fossil carbon embedded in feedstocks that is ultimately released at end-of-life. Consequently, decarbonisation of energy inputs, while essential, is insufficient unless accompanied by a material transition that replaces fossil carbon with renewable and circular alternatives.

The Material Transition Working Group under RECEIC has previously articulated that energy and material transitions must be pursued **simultaneously and in a coordinated manner.** Importantly, the energy transition itself will accelerate demand for materials—intensifying the urgency of sustainable chemical feedstocks rather than reducing it. Addressing fossil-carbon dependence in chemicals is therefore not a peripheral issue, but a foundational requirement for achieving India's net-zero ambition in a durable and economy-wide manner.

Role of Biogenic Carbon in Sustainable Chemicals

A central pathway for material transition in chemicals is the substitution of fossil carbon with **biogenic carbon.** This avoids releasing geologically sequestered carbon, supports circular carbon flows, and delivers meaningful life-cycle greenhouse-gas reduction when appropriate environmental guardrails are applied. Among biogenic feedstocks, waste-derived resources are of strategic importance, as they minimise land-use change, water demand, and food-security trade-offs associated with virgin biomass. Products that biodegrade within short time-scales, with carbon emissions typically treated as biogenic under standard lifecycle accounting frameworks.

Used Cooking Oil (UCO) represents one of the most mature and scalable waste-derived biogenic carbon sources currently available in the Indian context. Generated at scale through everyday consumption, already regulated to prevent unsafe reuse, and chemically compatible with existing industrial pathways, UCO offers a pragmatic near-term opportunity to enable material transition without introducing new sustainability tensions.

Strategic Importance of Used Cooking Oil (UCO)

Used Cooking Oil possesses several attributes that make it especially relevant for India's material transition. It is a regulated waste stream with public-health significance, offers high life-cycle greenhouse-gas reduction potential when displacing fossil-derived feedstocks, and exhibits strong chemical versatility. UCO can be upgraded into oleochemical intermediates such as fatty acids, fatty alcohols, and glycerine; used to substitute fossil hydrophobes in surfactants and functional chemical intermediates; and, through refinery-integrated pathways, converted into hydrocarbon streams suitable for material applications.

These characteristics position UCO as a **near- to medium-term bridge feedstock** capable of accelerating material transition in the chemical industry, while remaining aligned with broader circular-economy and energy-transition objectives.

Structural Competition Between Energy and Material Uses of UCO

At present, dominant demand for UCO in India arises from biodiesel and Sustainable Aviation Fuel (SAF), both of which are central to energy transition strategies and benefit from policy mandates, blending targets, and offtake certainty. As a result, most formally collected UCO is channelled toward fuel applications.

From a material-transition perspective, this creates a structural challenge: access to UCO for chemical and material applications remains limited despite the opportunity for high-impact fossil-carbon substitution in the chemical sector. This is not a question of choosing between energy and material transitions, but of recognising that **UCO is a shared strategic resource,** whose allocation will materially influence decarbonisation outcomes across both domains. How UCO is managed, prioritised, and routed therefore matters as much as how much is collected.

Why Chemicals Offer High Climate Leverage

The climate value of UCO depends fundamentally on what it replaces. Use of UCO to displace fossil-derived chemical feedstocks—particularly in surfactants—offers high absolute greenhouse-gas reduction due to direct fossil-carbon substitution and the biodegradation of products at end-of-life. In contrast, polymer pathways, while technically feasible under mass-balance frameworks, embed biogenic carbon in long-lived materials and deliver limited near-term circular or emissions benefit. Polymer decarbonisation is **generally** more robustly addressed through recycling-led strategies, reducing the strategic case for allocating limited UCO volumes to polymer feedstocks.

Substitution of virgin vegetable oils with UCO also delivers emissions benefits, but these are typically lower than those achieved through direct fossil displacement. In this context, **fossil-dependent surfactants represent priority material-transition opportunities,** where relatively modest volumes of UCO can deliver disproportionately large climate benefit.

Need for a System-Level Supply-Chain Perspective

India's current UCO ecosystem is characterised by partial and uneven collection, aggregation networks optimised primarily for fuel applications, limited differentiation of UCO quality for chemical use, and absence of a coordinated framework to manage allocation across competing end uses. Incremental or siloed interventions are unlikely to resolve these structural issues.

A system-level perspective is therefore required—one that examines how UCO collection can be expanded, how differentiated supply chains for fuels and chemicals can coexist, and how policy, infrastructure, and market mechanisms can be aligned to support both energy and material transitions without undermining either.

Positioning of the UCO-to-Chemicals Lighthouse Project

This Lighthouse Project has been undertaken to provide a **foundational, evidence-based assessment** of the potential for Used Cooking Oil to support material transition in India's chemical sector, while remaining aligned with ongoing energy-transition priorities. The intent is to establish a common analytical baseline, identify high-impact material-transition opportunities for UCO, and inform future policy, industry, and investment discussions on sustainable feedstock management.

Closing Perspective

The Material Transition Working Group Views Used Cooking Oil not merely as a waste stream or an energy feedstock, but as a **strategic circular-carbon resource.** How this resource is collected, governed, and allocated will play an important role in shaping India's decarbonisation pathway across both energy and materials. This Lighthouse Project, and the paper presented here, represents an initial step toward developing that strategic understanding and laying the foundation for more coordinated and outcome-oriented action going forward.

CHAPTER 1

INTRODUCTION

CHAPTER 1

Introduction

1.1. Material Transition for Chemicals

Over the last decade, substantial progress has been made in decarbonising key energy end-use sectors such as transport, power generation, and mobility. Policy momentum, technology deployment, and investment flows have increasingly focused on renewable electricity, low-carbon fuels, and efficiency improvements. While these efforts are essential, they address only one dimension of the broader decarbonisation challenge. India's pathway to Net Zero emissions cannot be realised through energy transition alone. Materials—particularly chemicals—remain overwhelmingly dependent on fossil-derived carbon, and this dependency represents a structurally significant source of emissions that energy transition alone cannot eliminate.

In the chemical sector, greenhouse gas emissions arise from two distinct but interconnected sources. The first is energy use during production, which includes process energy, utilities, and upstream energy inputs. These emissions can be progressively reduced through electrification, renewable energy integration, efficiency improvements, and low-carbon fuels. The second, and often less visible source, is embedded fossil carbon in chemical feedstocks. This carbon is chemically bound into products and materials that circulate through the economy and are ultimately released to the atmosphere at end-of-life through degradation, incineration, or disposal. As long as chemicals continue to be derived from fossil feedstocks, a significant portion of emissions remains locked into the material system[1] and released at the end of life, independent of how clean the energy used in production becomes.

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[1] Collett, K. A. et al., 2023. Cleaning up Cleaning: policy and stakeholder interventions to put household formulations on a pathway to net zero., s.l.: Oxford, Smith School Working Paper 23-07.

As a result, decarbonisation of energy inputs, while necessary, is insufficient to achieve deep and durable emissions reductions in the chemical sector unless it is accompanied by a material transition. Material transition refers to the systematic replacement of fossil-derived carbon in materials with renewable, biogenic, circular, or otherwise non-fossil alternatives. For chemicals, this implies rethinking feedstock choices, supply chains, and value-creation pathways, rather than focusing solely on process efficiency or energy substitution. Without such a transition, the chemical industry risks becoming a residual source of emissions even in a largely decarbonised energy system.

The Material Transition Working Group under RECEIC has articulated[2] that energy and material transitions must be pursued together, recognising that they are deeply interlinked. The energy transition—through renewable power, electrification, storage, and new infrastructure—drives rising demand for chemically intensive materials such as polymers, resins, surfactants, coatings, and specialty chemicals. This positions the chemical industry uniquely: it is both a critical enabler of the energy transition and a significant source of material-related emissions. Consequently, decarbonisation cannot be achieved by focusing on energy alone. As highlighted in the Working Group's earlier analysis on transitioning the chemical industry to a net-zero pathway, a deliberate material transition—addressing fossil-carbon dependence at the feedstock level—is essential to avoid emissions shifting within the system and to deliver meaningful, long-term decarbonisation.

Within India's industrial ecosystem, chemicals are foundational, supplying critical inputs across almost all sectors of the economy. Among them, surfactants and polymers stand out due to their scale, functional indispensability, and pervasive presence across consumer and industrial value chains. Their high volumes, broad end-use spread, and embedded fossil carbon make them priority leverage points for material transition.

Surfactants are integral to hygiene, health, and essential industrial processes, underpinning home and personal care products, industrial and institutional cleaning, textiles, food processing, pharmaceuticals, agrochemicals, and formulation chemistry. Their ability to enable emulsification, dispersion, wetting, and solubilisation makes them indispensable to both basic and advanced manufacturing. Polymers similarly form the material backbone of India's growth and industrialisation, supporting packaging, infrastructure, automotive, electronics, healthcare, textiles, and consumer goods through affordability, durability, lightweighting, and design flexibility.

Together, surfactants and polymers account for a significant share of the chemical industry's economic contribution and downstream value creation, with demand closely tied to population growth, urbanisation, and industrial development. Economically, they represent a substantial and growing portion of the sector: the Indian surfactants market is estimated at USD 2–3 billion, growing at around 6–7% CAGR, while the polymers and plastics market exceed USD 40 billion and is projected to grow at approximately 5–6% annually. Their scale and growth trajectories mean that continued reliance on fossil-derived feedstocks has system-level implications for India's material emissions profile, while their transition offers disproportionately high decarbonisation leverage.

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[2] Transitioning the Chemical Industry to a Net Zero Pathway: The Critical Need for a Material Transition, https://receic.com/wp-content/uploads/2025/04/Material-Transition-in-Chemical.pdf

Both classes remain structurally dependent on fossil-derived feedstocks, reflecting the chemical industry's historical co-development with the oil and gas sector. As a result, even where production processes are decarbonised, the fossil origin of feedstock carbon continues to embed emissions across product life cycles, posing a structural challenge to India's Net Zero ambitions.

Recent geopolitical tensions in the Middle East have further highlighted India's vulnerability to disruptions in crude oil supply and price volatility, underscoring the extent of its reliance on imported fossil feedstocks. For the chemical sector, this exposure extends beyond energy to material inputs, particularly for high-volume products such as surfactants and polymers. In this context, increasing the use of domestic, biogenic feedstocks offers a pathway to strengthen supply-chain resilience while reducing dependence on imported crude-derived carbon. Advancing such alternatives can simultaneously support India's Net Zero objectives and reinforce the Atmanirbhar Bharat agenda by anchoring critical material value chains more firmly within the domestic economy.

At the same time, this scale creates opportunity. Transitioning even a fraction of these high-volume product streams towards non-fossil or renewable feedstocks can deliver significant climate benefits, complementing energy transition by addressing emissions embedded in materials rather than energy use alone. Importantly, this is also a strategic industrial consideration: as global markets increasingly factor carbon intensity, circularity, and sustainability into competitiveness, the ability to supply low-carbon or renewable-based materials will influence long-term market access and value creation.

In this context, material transition for high-volume chemicals emerges as a critical pillar of India's Net Zero pathway—one that could enable climate progress while supporting continued industrial development and economic growth.

1.2. Context for a Renewable Recycled Feedstocks

For both surfactants and polymers, biobased feedstock pathways are not new, nor are they technically unproven. Oleochemical value chains based on vegetable oils have long supplied fatty acids and fatty alcohols to the surfactant industry, forming the backbone of several established formulations. Similarly, biopolymers and bio-based polymer intermediates are widely recognised as potential substitutes for fossil-derived polymers across a range of applications. Despite this technical maturity, however, these pathways have not been adopted at scale. One of the principal constraints lies in the reliance on virgin biobased feedstocks, which introduces trade-offs related to land use, water consumption, and, in some cases, competition with the food ecosystem. As demand scales, these pressures become increasingly material, limiting the sustainability and social acceptability of large-scale deployment.

In this context, renewable recycled (waste-derived) feedstocks assume further strategic importance for material transition. Such feedstocks retain the benefits of embedded biogenic carbon while avoiding the structural limitations associated with virgin biomass. Used Cooking Oil (UCO), also referred to as Waste Cooking Oil (WCO), represents one of the most mature and scalable examples of this category in the Indian context. Generated as a by-product of widespread food consumption, UCO is already regulated to prevent unsafe reuse and diversion back into the food chain, positioning it as a controlled and traceable waste stream.

1.3. UCO as a Critical Feedstock in the Material Transition

UCO possesses several attributes that make it particularly relevant for India's material transition. As a recycled renewable feedstock, it delivers high life-cycle greenhouse gas reduction potential, especially when displacing fossil-derived chemical feedstocks. At the same time, it avoids incremental land-use demand and mitigates pressure on agricultural systems. Chemically, UCO is highly versatile. It can be converted into oleochemicals such as fatty acids, fatty alcohols, and glycerine, directly supporting surfactant value chains. Through established thermochemical and refinery-integrated pathways, it can also yield hydrocarbon streams suitable for polymer and material applications.

By combining embedded biogenic carbon with circularity, UCO offers a practical pathway to advance renewable feedstocks for chemicals without the sustainability constraints associated with virgin oils or dedicated biomass. As such, it represents a near- to medium-term bridge feedstock capable of accelerating material transition in surfactants and polymers, while simultaneously addressing waste management, public health, and resource-efficiency Used Cooking Oil (UCO) has emerged globally as a strategically important feedstock at the intersection of carbon reduction, waste valorisation, and material transition. Its significance arises not from a single attribute, but from a unique combination of advantages that collectively make UCO a high-value enabler for defossilising materials and chemicals.

(i) Dual biogenic and recycled carbon enabling high GHG reduction:

UCO is derived entirely from renewable, biogenic carbon and classified as a waste-derived, recycled carbon stream. This dual characteristic enables some of the highest life-cycle GHG reductions when substituting fossil carbon in fuels, chemicals, and materials. By displacing fossil-derived hydrocarbons with recycled biogenic carbon, UCO directly supports material transition while valorising an otherwise under-utilised waste stream and reducing reliance on fossil resources.

(ii) Mitigation of public-health risks from food-chain leakage:

UCO is generated after repeated frying of edible oils, leading to chemical degradation and the formation of compounds beyond accepted food-safety thresholds. Informal diversion of UCO back into the food chain[3] poses significant public-health risks. Establishing regulated, high-value non-food end uses creates a structural mechanism to prevent such leakage while incentivising collection, traceability, and compliance.

(iii) Chemical compatibility with existing hydrocarbon value chains:

UCO exhibits molecular structures closely aligned with fossil-derived intermediates used in fuels and chemicals. Its triglyceride and fatty acid components can be processed through established routes such as transesterification, hydrotreatment, and cracking, enabling integration into existing infrastructure with limited technological risk. This compatibility lowers barriers for substituting fossil feedstocks across multiple value chains.

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[3] Diversion of Used Cooking Oil into the Food Stream: A Study of Four Indian Cities

PUBLIC HEALTH RISK FROM IMPROPER REUSE OF UCO IN FOODS

In India, public health risks (ICMR's Warning on Reused Oil: Best Practices for Safe Cooking and Sustainability) from improper reuse and disposal of UCO (NHRC notice to Health Ministry, FSSAI on 'widespread reuse of cooking oil' - The Economic Times, NHRC takes notice of widespread reuse of cooking oil across India)-particularly its diversion into informal and unsafe food channels-have led to regulatory intervention. In response, the Food Safety and Standards Authority of India (FSSAI), India's food safety regulator, introduced the Repurpose Used Cooking Oil (RUCO) initiative (FSSAI: About RUCO, FSSAI: guidance note UCO) to formalise UCO collection and channel it towards approved non?food end uses. This initiative has laid the foundation for an emerging UCO ecosystem in India. However, despite this progress, formal collection remains partial and uneven, with aggregation largely concentrated in organised HoReCa (Hotel, Restaurant, and Catering) and institutional segments.

Repeated use of cooking oil for deep frying leads to the accumulation of toxic degradation products that pose significant public health risks. FSSAI explicitly links prolonged use of degraded frying oil and elevated total polar compounds (TPCs) to cardiovascular and metabolic diseases, including hypertension, atherosclerosis, liver disorders, and neurological conditions. Scientific evidence further associates repeated dietary exposure to reused cooking oil with increased cardiovascular and cancer risk due to oxidised lipids, aldehydes, and other secondary oxidation products, while food vendors and kitchen workers face additional occupational exposure risks through inhalation of toxic cooking fumes under poor ventilation conditions. In India, diversion of UCO back into informal food use disproportionately affects urban consumers, street food vendors, and children, prompting the National Human Rights Commission to frame the issue as a public health and human rights concern.

References:

ICMR's Warning on Reused Oil: Best Practices for Safe Cooking and Sustainability

NHRC notice to Health Ministry, FSSAI on 'widespread reuse of cooking oil' - The Economic Times, NHRC takes notice of widespread reuse of cooking oil across India

FSSAI: About RUCO, FSSAI: guidance note UCO

1.3.1. UCO End-Use Landscape and Competing Demand Pathways

Globally, the dominant utilisation of UCO today is in biofuel production, including conventional biodiesel via transesterification and advanced renewable fuels such as Hydrotreated Vegetable Oil (HVO). These pathways are primarily driven by transport-sector decarbonisation mandates and supported by relatively mature collection and aggregation systems, typically involving multiple intermediaries due to the distributed nature of UCO generation.

More recently, UCO has emerged as an important feedstock for Sustainable Aviation Fuel (SAF), reflecting increased focus on aviation decarbonisation under frameworks such as ICAO's Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA). SAF produced from UCO offers a low-carbon, drop-in alternative to conventional aviation turbine fuel without requiring modifications to aircraft or fuel infrastructure.

Beyond energy applications, UCO can also serve as a renewable feedstock for oleochemicals, including soaps, fatty acids, glycerine, surfactants, lubricants, and polymer intermediates, enabling substitution of petrochemical feedstocks. Additional uses include incorporation into animal feed as an energy-dense fat, subject to stringent quality and safety controls.

Taken together, biodiesel, SAF, oleochemicals, and other applications form an integrated and competing demand ecosystem for UCO. The availability of UCO for chemical and material applications must therefore be assessed within this broader landscape of existing and emerging end uses.

1.3.2. Implications for Chemical and Material Supply-Chain Design

While existing UCO supply chains have evolved largely around fuel applications, their structure and optimisation are not aligned with the requirements of chemical and material value chains. Chemicals differ fundamentally from fuels in terms of quality consistency, traceability, supply reliability, and risk tolerance, while remaining heavily dependent on fossil-derived feedstocks as their primary source of carbon.

Developing a UCO-based supply chain for chemicals therefore represents a strategic opportunity to defossilise material value chains alongside energy transition pathways, enabling deeper, system-level emissions reduction. Unlike fuel-centric models, such supply chains must prioritise feedstock quality, process compatibility, and long-term reliability over volume alone.

UCO is generated in substantial quantities across households, restaurants, food manufacturers, institutions, and commercial establishments. However, current collection systems capture only a fraction of this potential, resulting in the loss of a valuable biogenic carbon resource. Unlocking the circular potential of UCO for chemical applications requires deliberate investment in aggregation, traceability, and supply-chain design to convert dispersed waste generation into an industrially reliable feedstock stream. An indicative architecture for such a supply chain is illustrated in the accompanying schematic.

1.4. Purpose and organisation of this paper

This paper assesses the opportunity to accelerate material transition in the Indian chemical industry using Used Cooking Oil (UCO) as a renewable, recycled feedstock for surfactants and polymers, substituting conventional petrochemical feedstocks. It examines key barriers to this transition and outlines the infrastructure, financing, and policy enablers required to realise this opportunity at scale.

In this context, RECEIC commissioned the study to develop a comprehensive understanding of the UCO ecosystem in India and to establish a strategic roadmap for mobilising UCO for chemical and material applications beyond its current dominant use in biodiesel and Sustainable Aviation Fuel (SAF).

Accordingly, the study undertakes a baseline assessment of UCO supply and demand across energy and chemical applications, evaluating its suitability as a chemical feedstock alongside competing uses. The analysis examines chemical characteristics, economic viability, and regulatory considerations, comparing petrochemical-based and UCO-based value chains for surfactants and polymers.

To improve readability, detailed quantitative data underpinning the economic and comparative analyses are consolidated in Annexure-II, while the main body focuses on interpretation, pathway logic, and cross-cutting insights.

CHAPTER 2

UCO ECOSYSTEM IN INDIA: DEMAND, SUPPLY, AND CHEMICAL OPPORTUNITIES

CHAPTER 2

UCO Ecosystem in India: Demand, Supply, and Chemical Opportunities

The overall ecosystem of UCO is centred around the consumption of edible oil. Used Cooking Oil is utilised across multiple established and emerging end-uses, including biodiesel, SAF, oleochemicals, chemical and material applications. Together, these end-uses form an integrated and competing ecosystem that influences UCO generation, collection incentives, aggregation economics, and availability for downstream uses.

A system-level understanding of demand and supply across these end-uses is therefore essential for evaluating the feasibility of establishing a resilient UCO supply chain for chemical applications. Accordingly, this chapter analyses UCO supply and demand across India, examining volumes, sources, aggregation structures, and competing end-uses to identify gaps and constraints relevant to the development of UCO-based chemical value chains.

2.1. UCO Supply Landscape

2.1.1. Estimating UCO Availability in India

The net availability of vegetable cooking oil in India is estimated by deducting annual exports from the combined total of domestic production and imports. Net availability increased from 11.15 million tonnes in 2004–05 to 16.47 million tonnes in 2011–12. The 2023–24 Net availability is 27.82 million tonnes (Figure-1).

It is estimated that of this around 80% of edible oil is used for cooking, 55% of which is consumed in commercial food establishments.[4] During repeated cooking and degradation beyond food-safety limits (FSSAI has fixed TPC limit at 25% (regulatory cutoff); beyond this, the oil "shall not be used" for frying to safeguard consumer health), it is assumed that around 70% of the oil mass is lost, leaving approximately 30% recoverable as UCO.[5] This leads to an estimate of 13.2% of Net availability, potentially available as UCO (Table-I, Annexure II).

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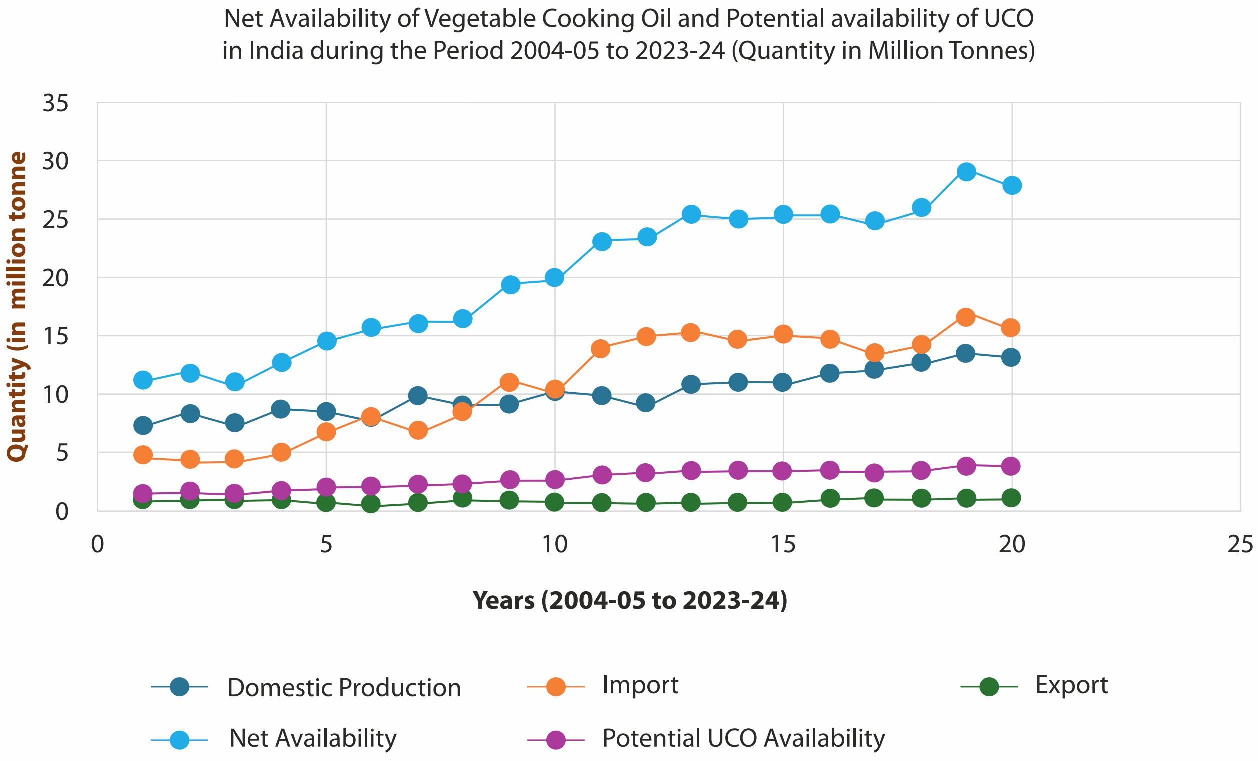
[5] Orjuela, Alvaro and Clark, James (2020), "Green Chemicals from Used Cooking Oils: Trends, Challenges and Opportunities", Current Opinion in Green and Sustainable Chemistry, White Rose Research Online, https://doi.org/10.1016/j.cogsc.2020.100369

[4] Waste Cooking Oil for Biofuel in India | Encyclopedia MDPI

Based on this allocation, the potential UCO availability is estimated. As can be seen, in Figure 1, its potential availability has consistently increased over time, from 1.47 million tonnes in 2004-05 to of approximately 3.7 million tonnes is estimated in 2024-25. (Table-II, Annexure-II).

Figure-1: Trend of Estimated Net Availability of Vegetable Oil in India



However, only a portion of this potential UCO availability is currently collected. While there are varying estimates of the actual amount of UCO being collected, further secondary research and validation is required to ascertain the actual amount of UCO collected. A portion of the collected is diverted to biodiesel, where, as per TERI (2023), 0.06 million tonne (55000 tonne) of UCO was mobilised for biodiesel production in the year (2021). This amounts to state that only 1.5 percent of net potential UCO supply is absorbed in biodiesel production.[6]

This reflects the present level of RUCO implementation, and concentration of collection in organised commercial food establishments. It also indicates that a substantial share of UCO continues to be diverted to other recycling purposes, most notably to produce second-grade edible vegetable oils, which is illegal and poses public health risks.

2.1.2. Existing UCO Collection Pathways & End Uses

At present, the only fully formalised supply-chain mechanism for UCO utilisation is the UCO-to-biodiesel pathway. This is primarily driven by the government policy support under the dedicated biodiesel policy, along with facilitation through the RUCO framework. Some basic filtering or pre-processing, to remove impurities such as water and food residues, are done before the UCO is supplied to biodiesel manufacturers.

More recently, the potential for use of UCO for Sustainable Aviation Fuel production has gained significance. India, and other countries including the United States, European Union member states

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[6] TERI (2023), Accelerating Biodiesel Blending in Inida, Policy Brief

have committed to SAF blending targets, and UCO (with intensive upgradation) being one of the possible feedstocks is relevant.

2.1.3. UCO Aggregation Landscape

UCO aggregation is typically characterised by many relatively small, localised and decentralised collection infrastructure, involving feedstock collectors, aggregators, and agents. In some cases, UCO is sent directly for end use, mostly biodiesel production.

UCO aggregators are a critical intermediary connecting dispersed sources of Used Cooking Oil to formal end-use industries. Under the RUCO framework, aggregators are empanelled to mobilise UCO from households, HoReCa establishments, and institutional kitchens and channel it towards approved end uses, typically biodiesel.

Current structure of the aggregation network (Table-III, Annexure-III): As of March 2026, India has 72 registered biodiesel production units, of which approximately 40% report no formal linkage with any UCO aggregator, highlighting significant gaps in organised feedstock mobilisation. Among the remaining plants, 26.4% are linked to a single aggregator, 13.9% to two aggregators, and only 19.5% to three or more aggregators. This results in an average of ~1.4 aggregators per biodiesel plant, indicating a narrowly distributed and weakly buffered aggregation network.[7]

From a system perspective, this distribution points to limited redundancy and low resilience in UCO mobilisation. A mature aggregation ecosystem typically requires multiple aggregators operating within a catchment area to manage variability in volumes, seasonal fluctuations, quality inconsistencies, and geographic dispersion of sources. The observed concentration of plants with zero or minimal aggregator linkages therefore reflects an under-developed aggregation layer, rather than saturation or efficiency.

Skew in aggregator alignment across end uses (Table-IV, Annexure-III): Beyond biodiesel, formal aggregator linkages to chemical end uses remain limited. Of the 133 aggregators identified nationally, 109 are linked to biodiesel units, while only 24 aggregators (≈18%) are linked to soap manufacturers. These soap-linked aggregators are geographically concentrated, with notable presence in a small number of states, including Karnataka, Kerala, Tamil Nadu, West Bengal, Punjab, and Telangana. Several high UCO-generating states show minimal or no linkage to surfactant or soap manufacturing despite having significant downstream chemical capacity.

This imbalance underscores that biodiesel has emerged as the dominant and default outlet for organised UCO aggregation, not necessarily because of superior system design, but due to early regulatory prioritisation and clearer demand signalling. In contrast, chemical applications—particularly soaps and surfactants—remain structurally under-served within the current aggregation framework.

Implications for ecosystem resilience and chemical applications: The present aggregation landscape reveals that UCO mobilisation in India is constrained less by generation potential and more by aggregation capacity and allocation logic. Expanding aggregation depth—both in terms of the number of aggregators per catchment area and the diversity of end-use linkages—is essential to improve recovery rates, enhance supply reliability, and enable quality differentiation.

For chemical and material applications, this has two direct implications. First, a biodiesel-centric aggregation network is not optimised for the quality consistency, traceability, and specification alignment required by chemcials. Second, without deliberate linkage of aggregators to chemical value

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[7] Analysis made from the data retrieved from Enrolled Biodiesel Manufacturers - RUCO : Repurpose Used Cooking Oil and Research Paper on Used Cooking Oil based Biodiesel of www.pahalindia.org

chains, UCO suitable for material applications risks being structurally absorbed into fuel pathways by default.

Strengthening and diversifying the aggregation layer—while remaining aligned with existing energy-transition pathways—is therefore a precondition for building a resilient UCO supply chain for chemicals. An ecosystem-level approach to aggregation can enable differentiated routing of UCO based on quality and end-use suitability, supporting both energy transition and material transition objectives without undermining either.

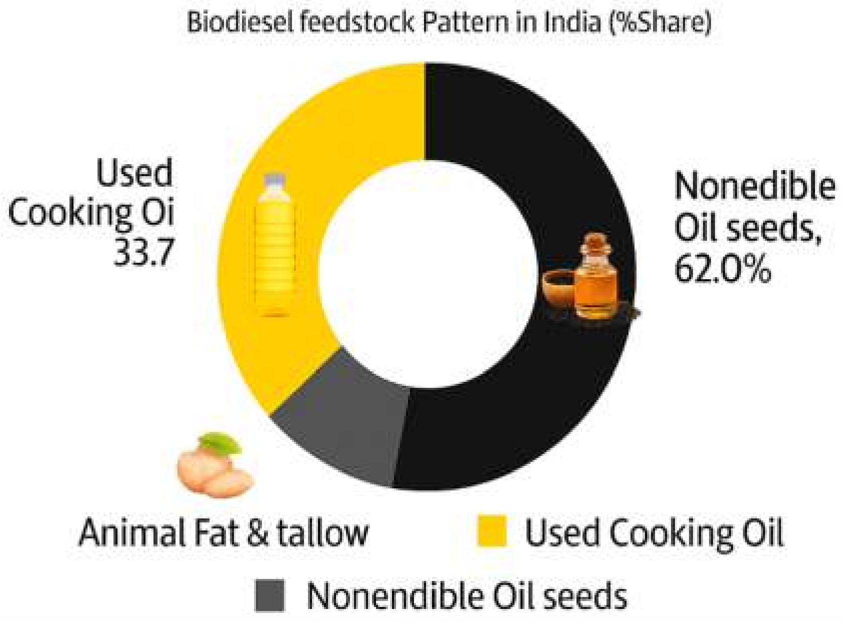
2.2. UCO Demand Landscape

2.2.1. Demand for Bio Diesel

India's biodiesel sector represents a clear and established demand for Used Cooking Oil (UCO). Based on recent production trends (Table-V, Annexure-III), average annual biodiesel output is ~ 160,000 tonnes, of which ~ 55,000 tonnes per year is produced using UCO, accounting for roughly one-third of total biodiesel production (Figure-2). Biodiesel production from UCO occurs via transesterification, which yields biodiesel at an approximately one-to-one mass ratio, with glycerine generated as a co-product. Accordingly, biodiesel output of 55,000 tonnes implies a corresponding demand of approximately 55,000 tonnes of UCO.[8]

Notably, the absolute quantity of UCO absorbed by biodiesel production has remained relatively stable over time, even as total biodiesel output has fluctuated with changes in non-edible oilseed supply. This suggests that UCO availability and aggregation, rather than conversion capacity, constrain further uptake. From a system perspective, biodiesel therefore constitutes a structurally significant and persistent demand sink for formally aggregated UCO, and this baseline requirement must be explicitly accounted for when assessing the availability of UCO for competing chemical and material applications.

Figure-2: Biodiesel Feedstock Pattern in India



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[8] Jamal F (2023). Accelerating Biodiesel Blending in Inida, The Energy and Resources Institute, New Delhi.

2.2.2. Demand for Sustainable Aviation Fuel (SAF)

SAF is a low-carbon alternative to conventional jet fuel driven by the decarbonisation imperative of the aviation sector. This is produced from renewable feedstocks and can be used in existing aircraft without technical modification. Currently blended (~ 0.3%[9]) with conventional Aviation Turbine Fuel (ATF), it is constrained by availability, cost, regulatory, and certification-driven considerations rather than a technical limitation. In India, the first commercial SAF production is being initiated by Indian Oil Corporation at its Panipat refinery, with a capacity of approximately 35,000 tonnes per year, with UCO envisaged as a key feedstock.

Therefore, SAF emerges as a significant end use for Used Cooking Oil (UCO). Driven by rapid growth in India's aviation sector and forthcoming blending mandates, India's annual jet fuel demand has increased to approximately 9.0 million tonnes in 2024–25 from around 2.7 million tonnes in 2004–05, notwithstanding the temporary COVID-19-related contraction (Table-VI, Annexure-III).

Under India's indicative SAF blending targets—1% by 2027, rising to 5% by 2030—even low blend levels translate into material SAF volumes. A 1% blend implies SAF demand of roughly 0.09–0.14 million tonnes per year, increasing to approximately 0.45 million tonnes at a 5% blend, based on projected jet fuel consumption.

Commercial SAF production from UCO is predominantly based on the HEFA-SPK pathway, which is relatively feedstock-intensive. Typical commercial yields indicate that 1.33–1.43 tonnes of UCO are required per tonne of SAF produced. Accordingly, meeting a 1% SAF blending requirement would require approximately 0.12–0.20 million tonnes of UCO annually, with demand rising proportionally at higher blend levels.[10]

This mass-balance relationship highlights SAF as a highly UCO-intensive demand sink, capable of absorbing a substantial share of any formally aggregated UCO even at modest blending levels. While SAF plays a critical role in India's energy transition and compliance with international aviation frameworks such as CORSIA, its emerging scale reinforces the need to explicitly account for aviation-driven UCO uptake when assessing availability for competing applications.[11] The following sections therefore shift focus from energy uses to material-transition pathways, examining the role of UCO in surfactants and polymers, where the primary objective is fossil-carbon substitution rather than fuel replacement.

2.2.3. Demand from Surfactant Sector

This UCO demand analysis for surfactants is intentionally restricted to surfactant value chains where substitution of fossil carbon delivers material greenhouse-gas reduction, rather than incremental circularity benefits. For the same reason, soap and fatty-acid-based surfactants are excluded, as they only provide marginal circularity benefits, as they already come from biogenic feedstocks. Therefore, Linear Alkylbenzene Sulphonates (LAS, via LAB), produced from fossil kerosene (benzene retained as fossil) and Alcohol Ethoxylates (AE), Alcohol Ether Sulphates (AES, including SLES) produced from synthetic alcohols have been selected.

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[9] IATA - Disappointingly Slow Growth in SAF Production

[10] https://economictimes.indiatimes.com/industry/transportation/airlines-/-aviation/indianoil-says-it-used-cooking-oil-to-produce-sustainable-aviation-fuel/articleshow/123342556.cms?from=mdr

[11] https://energy.economictimes.indiatimes.com/news/oil-and-gas/saf-association-calls-for-using-used-cooking-oil-to-produce-sustainable-aviation-fuel/129587943

In these applications, fossil-derived hydrophobes can be substituted (via mass balance attribution) with UCO-derived hydrophobes through established industrial pathways, offering high fossil-carbon displacement potential, albeit with increasing upgrading severity, hydrogen demand, and efficiency requirements as molecular equivalence to petrochemical feedstocks is pursued.

Table 1 shows the Indicative UCO demand from these surfactants, with UCO required per tonne of surfactant, and current surfactant volumes (see details in Table-VII, Annexure II).

Table-1: UCO demand linked to UCO intensity and Production Volume by Types of Surfactants

Surfactant	Fossil carbon replaced (via mass balance)	Indicative UCO required / Surfactant (w/w)	Production volumes of Surfactant (Million t/year)	Estimated UCO demand (Million t/year)
Linear Alkylbenzene Sulphonates LAS (via LAB)	Linear paraffins / olefins (C10–C13)	1.6-1.8	0.64	1.09
Alcohol Ethoxylates (AE)	Synthetic fatty alcohols (C12–C14)	1.5-1.7	0.25	0.40
Alcohol Ether Sulphates (AES / SLES)	Synthetic fatty alcohols	1.6-1.8	0.32	0.54
Total	-	-	-	≈ 2.0

** This represents the theoretical UCO requirement to defossilise selected surfactant value chains at current production volumes; it does not imply immediate adoption, access, or priority allocation*

The analysis in Table 1 indicates that de-fossilising these three fossil-dependent surfactant classes alone would require approximately 2.0 million tonnes of UCO per year, tied to 2024 (or 2023–24) volumes. This scale is material when compared with UCO demand from biodiesel and emerging SAF pathways and highlights the importance of explicitly accounting for material-transition demand when assessing UCO availability, allocation priorities, and supply-chain resilience.

2.2.4. Demand from Polymer Sector

Although polymers such as polyethylene (PE) and polypropylene (PP) are major users of fossil carbon, their relevance within a UCO-based material-transition framework is limited. Polyolefins are durable, long-lived materials in which embedded carbon remains sequestered over extended periods. As a result, substituting fossil feedstocks with UCO in polymer production avoids fossil carbon only at the point of material inception, however, does not deliver meaningful near- or medium-term greenhouse-gas abatement, and were hence deprioritised from material transition perspective. The UCO demand assessment therefore does not consider the polymer demand.

2.3. UCO Supply – Demand Gap

The reconciliation of Used Cooking Oil (UCO) supply and demand in this study is undertaken on a consistent and transparent basis, using potential UCO availability (and not actual UCO collected) as the supply envelope and considering only those end uses retained within the scope of analysis.

For 2024–25, potential UCO availability is estimated at approximately 3.7million tonnes, based on recoverable waste cooking oil generated primarily from commercial food establishments under realistic use and loss assumptions. The estimated UCO availability is further subject to significant uncertainty in behavioural, collection, and enforcement factors. This represents the upper-bound resource envelope used for supply–demand reconciliation in this study.

The reconciliation is therefore conducted at the level of system-wide potential availability, with collection and aggregation constraints treated separately and not double-counted in the supply figure.

On the demand side, the analysis aggregates UCO requirements across biodiesel, early-stage Sustainable Aviation Fuel (SAF), and priority surfactant value chains, which together define the effective demand envelope for UCO in the near term.

Biodiesel constitutes an established and persistent demand, SAF represents an emerging but potentially UCO-intensive sink under expected blending mandates, and surfactants represent the principal material-transition pathway retained within scope.

The balance between potential UCO availability and aggregated demand from these sectors defines the supply–demand gap explored in the following table 3, providing a basis for assessing allocation pressures, constraints, and the feasibility of scaling UCO-based pathways without assuming the existence of surplus or uncommitted feedstock.

Table-2: Indicative UCO Supply–Demand Balance (2024–25)

Item	Potential UCO Supply (Million Tonnes)	UCO Demand (Million Tonnes)
Total UCO availability (2024-25)	~3.7	-
Biodiesel (current utilisation)	-	~0.06
Sustainable Aviation Fuel (early mandate, ~1% blend equivalent)	-	0.12-0.20
Surfactants (LAS, AE, AES/SLES)	-	~2.0
Total effective UCO Supply/ demand	~3.7 (Actual collection is being estimated)	~2.2-2.3

N: B: This reconciliation represents an upper-bound, theoretical estimate of India's UCO availability. The current UCO collection limited to formal channels only happens through **FSSAI RUCO traceability system. PIB Government of India notes that 0.06 million tonne (about 550 lakh litres) of UCO were collected in the year 2024-25. [Press Information Bureau – Eat Right India: Safe, Healthy and Sustainable Food for All (July 2025)]. There is no other source of credible information regarding actual volume of UCO collection.**

It demonstrates that, in principle, available UCO volumes are sufficient to support existing biodiesel use, early-stage SAF deployment, and targeted surfactant material-transition pathways. However, this does not imply surplus or unconstrained feedstock. India's primary near-term constraint is not theoretical UCO potential (potential UCO availability), but the effectiveness of mobilisation, aggregation, quality segregation, and allocation. The effective gap in the system is therefore not one of resource availability, but of mobilisation and routing; strengthening formal collection and traceability could unlock enough UCO to meet these competing needs, while failure to do so will rapidly eliminate headroom as SAF mandates scale.

CHAPTER **3**

QUALITY AND ACCEPTABILITY OF UCO

CHAPTER 3

Quality and Acceptability of UCO

With Used Cooking Oil (UCO) utilised across multiple fuel and chemical end points, its suitability for any specific application is governed not only by availability but by quality and compositional fitness-for-use. Different end uses impose distinct requirements on contaminants, chemical composition, and variability, which in turn influence how UCO is allocated across competing pathways.

Collected UCO exhibits significant heterogeneity, arising both from its original vegetable-oil composition and from degradation during repeated cooking cycles and exposure to varying heat and process conditions. As a result, not all UCO streams are equally suitable for all downstream applications.

This section therefore evaluates the chemical composition, contaminant profiles, and acceptability thresholds of UCO in relation to intended chemical end-points. Through an analysis of key chemical parameters, the chapter assesses the compatibility of currently aggregated UCO with quality requirements for chemical and material applications, while recognising that these thresholds also shape competition with fuel and chemical pathways.

3.1. Chemical composition of Vegetable Oil & UCO

Given that the key feedstock for UCO is predominantly vegetable oil, it is important to dwell on the composition of vegetable oil, and its transformation during the cooking process.

Fresh cooking oils are largely non polar and composed almost entirely of intact triglycerides. During deep frying at 150-190°C, repeated exposure to air, moisture, and high heat progressively degrades the oil through hydrolysis, oxidation, and polymerisation. This breakdown converts triglycerides into non triglyceride by products such as free fatty acids, partial glycerides, aldehydes, trans fatty acids, polymers, and other secondary oxidation products, leading to the accumulation of total polar compounds and a progressive loss of oil quality with associated health risk [12,13].

There are different methods used to measure oil quality ranging from subjective visual inspection to more objective, scientific measurements, such as total polar materials (TPM) and free fatty acid values

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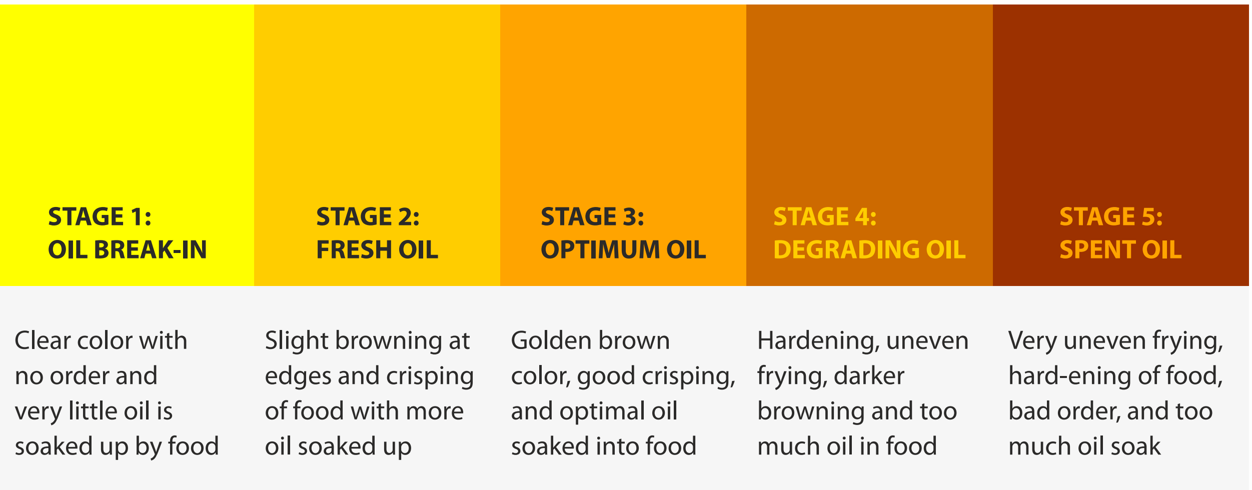
[12] Chemistry of Deep?Fat Frying Oils; Vol. 72, Nr. 5, 2007-Journal of Food Science

[13] International Journal of Food Science and Technology 2022, 57, 6763-6772

(FFA). In simple terms, they indicate the extent of fat breakdown. The flow chart levelling stages from Fresh cooking oil to Used Cooking oil in the process of repeated cooking is as shown in Figure 3.

Figure-3: Stages from Fresh Cooking Oil to Used Cooking Oil



STAGE 1: OIL BREAK-IN	STAGE 2: FRESH OIL	STAGE 3: OPTIMUM OIL	STAGE 4: DEGRADING OIL	STAGE 5: SPENT OIL
Clear color with no order and very little oil is soaked up by food	Slight browning at edges and crisping of food with more oil soaked up	Golden brown color, good crisping, and optimal oil soaked into food	Hardening, uneven frying, darker browning and too much oil in food	Very uneven frying, hard-ening of food, bad order, and too much oil soak

The chemical composition of UCO as per the study made by Harris and Phan (2023)[14] is shown in table 4, in comparison to the virgin cooking oil. Vegetable oils, due to exposure to high temperatures during cooking, undergo chemical changes. UCO contains only 43.09 wt.% triglycerides compared to 98.61 wt.% in virgin rapeseed oil. A significant amount of di-and mono-glycerides (27.64 wt.%), along with free fatty acids (12.43 wt.%) and fatty-acid esters (12.49 wt.%), are generated. Other chemical compounds observed in UCO include fatty acid esters, glyceryls, other hydrocarbons at low levels. Chemical classes are reported as grouped fractions based on GC-MS analysis; minor species have been combined into functional categories.

Table-3: Chemical Composition of UCO and Virgin Rapeseed oil (Weight %)

Sl.	Chemical Compounds	UCO	Vegetable oil (virgin rapeseed oil)
1	Water	0.12	0.12
2	Acetol	0.23	
3	FA	12.43	1.27
4	Glyceryl	1.8	
5	Fatty acid esters	12.49	
6	$C_{14\text{-}18}$ Hydrocarbons	1.47	
7	$C_{14\text{-}18}$ Aldehydes	0.73	
8	Monoglycerides	6.4	
9	Diglycerides	21.24	
10	Triglycerides	43.09	98.61
	Total	**100.0**	**100.0**

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[14] Harris, Jonnathan & Phan, Anh N (2023), Green Approach for "Chemical Production from West Cooking Oils", Sustainable Chemistry for Climate Action, Vol 2 Green approach for chemical production from waste cooking oils

3.2. Matching UCO Quality with End?Use Severity and Process Requirements

UCO's industrial suitability is governed by its degraded chemical composition resulting from cooking, and by the severity of upgrading required to meet end use specifications. Together, these factors determine which industrial pathways can technically accommodate UCO and at what economic and operational cost. Across major fuel and chemical applications, this gives rise to a clear hierarchy of end use severity, defined by increasing sensitivity to feedstock impurities and compositional variability.

At the most tolerant end of the spectrum, are surfactants, derived from fatty alcohols routes. i.e., Alcohol Ethoxylates (AE), Alcohol Ether Sulphates (AES / SLES). Linear Alkylbenzene Sulphonates, LAS (via LAB) requires mass balanced substitution of fossil paraffin at refinery and hence requires relatively higher levels of pre-treatment. These processes are inherently designed to handle lipid-based feedstocks with variable composition. High free fatty acid (FFA) levels-often problematic for fuels-are compatible or even desirable for fatty-acid splitting, soap manufacture, and certain surfactant intermediates. Moisture, partial glycerides, phosphorus, and trace metals can be effectively managed through established unit operations such as degumming, drying, hydrolysis, distillation, and hydrogenation. As a result, oleochemical feedstock procurement prioritises availability and cost efficiency, provided key contaminants remain within operationally manageable limits. Oleochemical pathways exhibit the widest tolerance to UCO quality variation, although lower grade UCO typically incurs higher pretreatment costs, yield penalties, and downstream quality management.

Biodiesel (FAME) production imposes a higher degree of constraint, as feedstock quality directly affects finished fuel stability, engine compatibility, and regulatory compliance. Elevated FFA, moisture, metals, and oxidation products promote corrosion, injector fouling, and oxidative instability. While pretreatment can mitigate part of this variability, biodiesel systems have more limited capacity to absorb severely degraded UCO compared to oleochemical routes, shifting greater emphasis to feedstock consistency and quality control.

Sustainable Aviation Fuel (SAF) production represents a further step change in severity. Hydrotreating-based SAF pathways are highly sensitive to oxygenates, sulphur, phosphorus, metals, and advanced oxidation products, all of which shorten catalyst life, increase hydrogen consumption, and reduce overall yields. In addition, aviation fuel performance requirements demand exceptional thermal and oxidative stability. Consequently, only UCO streams with low and stable contaminant levels can be economically routed to SAF without disproportionate pretreatment intensity and cost.

The Key chemical parameters for feedstocks used for oleochemical, surfactants, biodiesel and SAF is discussed in Table-VIII, Annexure-III, alongside the comparative chemical quality requirements of feedstocks for oleochemical, biodiesel and SAF (HEFA) manufacturing in Table-IX, Annexure-III

Overall, the comparison demonstrates a strong and systematic correlation between increasing process severity and decreasing tolerance for UCO degradation and contaminants. Surfactants derived from fatty alcohols retain the greatest flexibility, LAS, fuels impose progressively tighter constraints, with SAF at the high sensitivity. This hierarchy provides the technical basis for rational UCO allocation and directly underpins the industry-aligned grading and routing framework.

3.3. Industry?Aligned Classification of UCO for Chemical Use

Based on the analysis in preceding section, and what the industry informally trades, UCO is classified here in three quality grades, Grade A, Grade B and Grade C, defined by FFA, water/impurities, phosphorus/metals, and degradation levels (Figure 4). Further, a practical, industry aligned, mapping of Used Cooking Oil (UCO) grades to eligible end use markets discussed, viz., surfactants, biodiesel (FAME) and SAF, considering chemical quality thresholds, processing tolerance, and regulatory practice, can also be made.

Figure-4: UCO Classification Based on Chemical Specifications

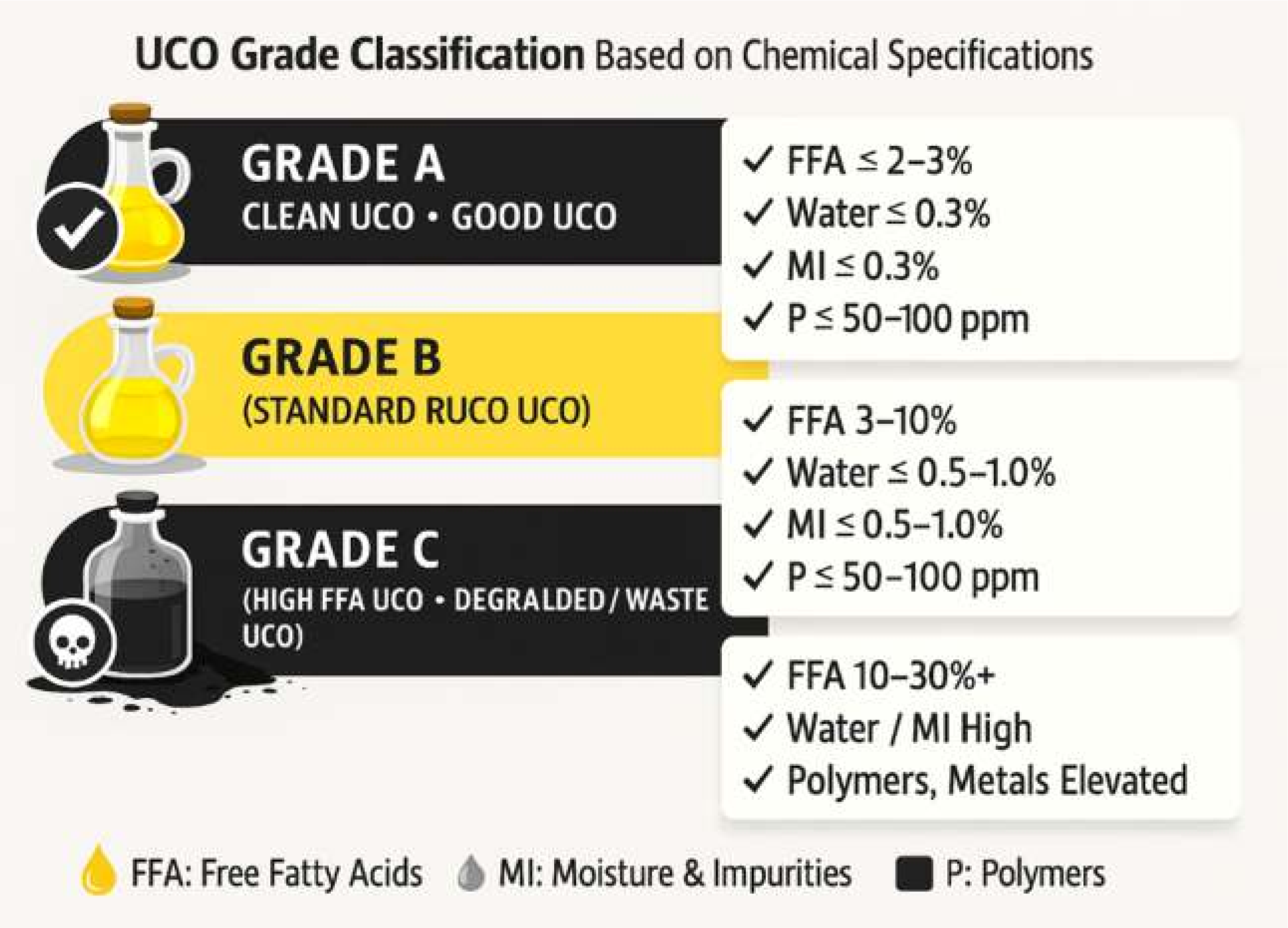


Table 4 represents the alignment of UCO Grades with the end use chemical requirement by sectors and explains acceptance and rejection of UCO by different type of manufacturing facilities.

Table-4: UCO Grades & Usage (Extended to Polymers)

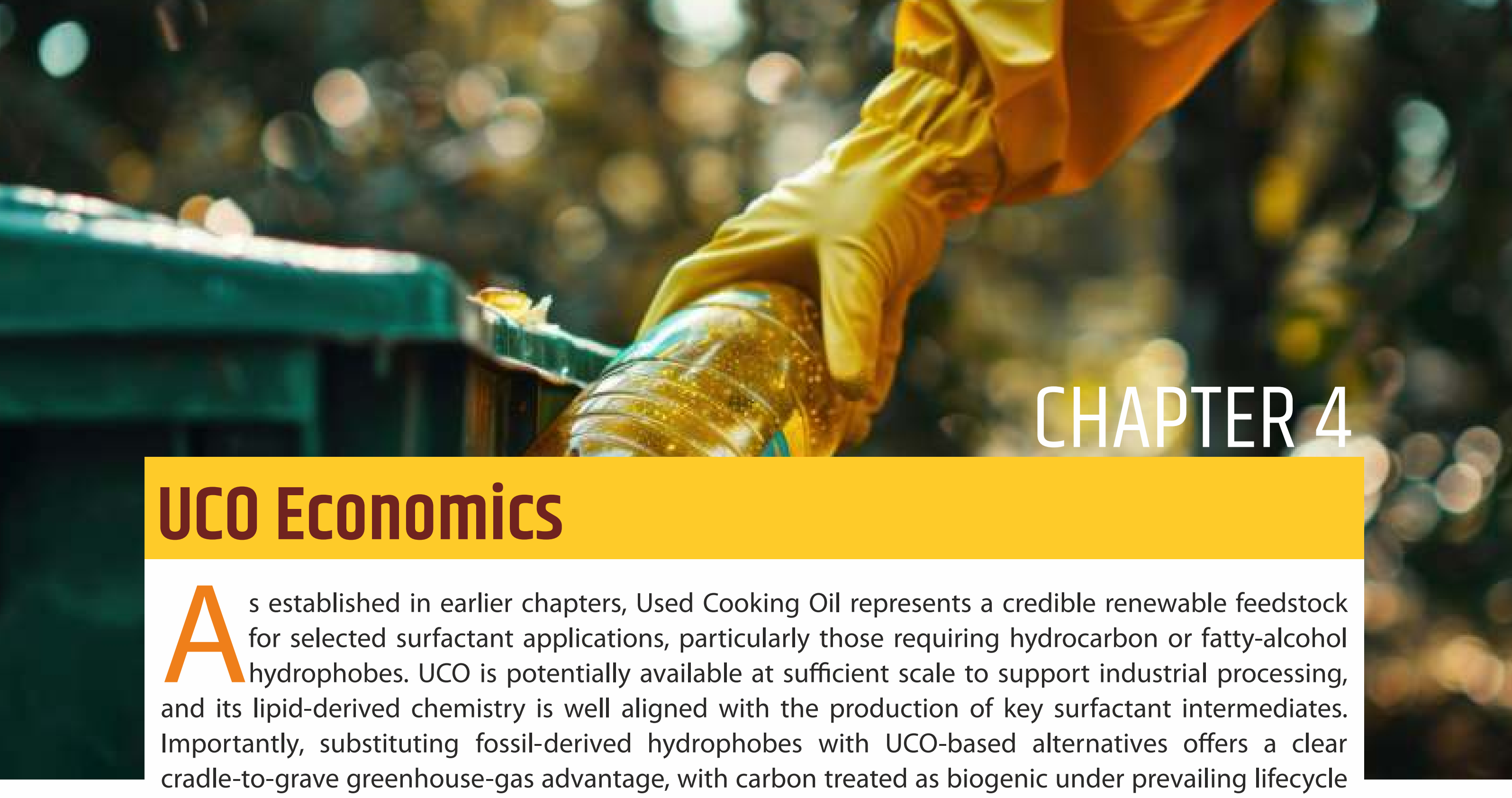
UCO Grade	Surfactants derived from fatty alcohols, i.e., AE, AES / SLES*	Biodiesel (FAME)	SAF (HEFA)/ Petrochemical Surfactants, e.g., LAB
Grade A	☑ Directly Accepted	☑ Preferred Feedstock	☑ Preferred Feedstock
Grade B	☑ Directly Accepted	☑ Accepted with Pretreatment	☑ Accepted with Pretreatment
Grade C	☑ Accepted (with limits)	☒ Generally Rejected	☒ Not Suitable / Generally Rejected

** LAS requires higher quality for refinery acceptance.*

This demonstrates that UCO could serve as a versatile renewable feedstock, with its cross-sector usability governed by increasingly stringent chemical thresholds as one move from surfactants, biodiesel and SAF. Effective segregation, grading, and pretreatment of UCO are therefore critical determinants of its technical and economic viability across different industrial value chains.

CHAPTER 4

UCO ECONOMICS



CHAPTER 4

UCO Economics

As established in earlier chapters, Used Cooking Oil represents a credible renewable feedstock for selected surfactant applications, particularly those requiring hydrocarbon or fatty-alcohol hydrophobes. UCO is potentially available at sufficient scale to support industrial processing, and its lipid-derived chemistry is well aligned with the production of key surfactant intermediates. Importantly, substituting fossil-derived hydrophobes with UCO-based alternatives offers a clear cradle-to-grave greenhouse-gas advantage, with carbon treated as biogenic under prevailing lifecycle accounting conventions. On this basis, UCO provides a relevant and scalable pathway for reducing the emissions intensity of surfactant manufacture.

However, these advantages alone is not a license to its adoption. Once of the key criterion is that the economics of adoption should work initially and be further attractive when scaled, when benchmarked with their fossil counterpart. The components of cost come from the cost of the feedstock (input UCO costs, plus that from the collection, transport and aggregation of the UCO), the level of pretreatment required to upgrade the quality of the UCO (setup and operational costs), the carbon efficiency in their adoption and finally the production of the end product (surfactant). The last is likely to be similar between the fossil and treated UCO as they could share the infrastructure and processing cost.

An economic assessment, at a screening level, is currently being conducted, and is designed to compare relative operating cost structures and sensitivities across alternative UCO end uses.

4.1. UCO as a Feedstock for Surfactants

As established in earlier chapters, Used Cooking Oil represents a credible renewable feedstock for selected surfactant applications, particularly those requiring hydrocarbon or fatty-alcohol hydrophobes. UCO is potentially available at sufficient scale to support industrial processing, and its lipid-derived chemistry is well aligned with the production of key surfactant intermediates. Importantly, substituting fossil-derived hydrophobes with UCO-based alternatives offers a clear cradle-to-grave greenhouse-gas advantage, with carbon treated as biogenic under prevailing lifecycle accounting conventions. On this basis, UCO provides a relevant and scalable pathway for reducing the emissions intensity of surfactant manufacture.

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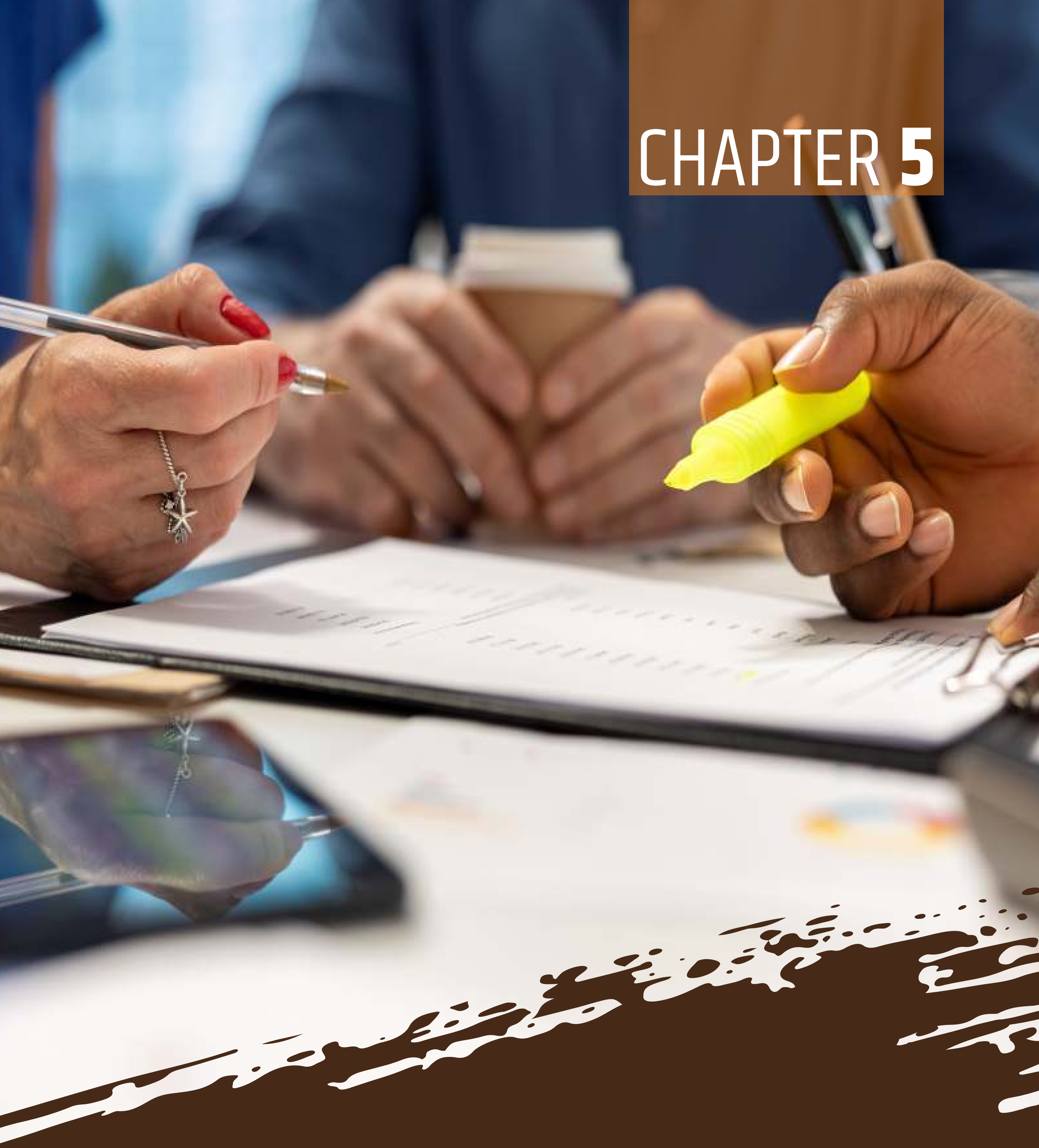

CHAPTER **5**

UCO REGULATORY CONTEXT AND POLICY DESIGN IMPLICATIONS

CHAPTER 5

UCO Regulatory Context and Policy Design Implications

The utilisation of Used Cooking Oil (UCO) as a renewable carbon resource is shaped less by technical feasibility than by how policy governs its collection, traceability, and allocation across competing end uses. While UCO has clear potential to support both energy transition and material transition, real-world outcomes depend primarily on regulatory design choices rather than feedstock availability alone.

In India, UCO sits at the intersection of food safety, waste management, energy transition, and industrial decarbonisation. As demand for UCO increases—driven by biodiesel blending, early Sustainable Aviation Fuel (SAF) mandates, and emerging interest from the chemical sector—the effectiveness of existing policy frameworks is increasingly tested. The central question is if current regulations optimise its deployment across energy and material transition objectives.

This chapter examines India's UCO policy architecture, diagnoses why fuel applications dominate by default, distils system-level principles from international experience, and identifies policy design gaps that constrain material-transition outcomes.

5.1. Current Governance of UCO in India

India's UCO governance framework has evolved primarily through food-safety and energy-transition objectives rather than an explicit material-transition lens. Collectively, existing instruments define how UCO is diverted from the food chain and which end uses are practically enabled.

At the upstream end, the Repurpose Used Cooking Oil (RUCO) initiative administered by the Food Safety and Standards Authority of India (FSSAI) treats UCO as a controlled waste stream. RUCO mandates diversion of degraded oil from food use, authorises collectors and aggregators, and establishes minimum traceability and disposal requirements. This framework plays a critical public-health role by suppressing unsafe reuse and legitimising formal UCO recovery.

Downstream, UCO is explicitly enabled within India's energy-transition policy architecture. The National Policy on Biofuels (2018) and its 2022 amendment recognise UCO as a preferred waste-derived feedstock for biodiesel, supported by indicative blending targets, procurement frameworks, and sale guidelines. Emerging SAF mandates, alignment with ICAO-CORSIA, and refinery-level co-processing policies further reinforce demand for UCO within fuel pathways.

Taken together, current policies strongly enable UCO mobilisation for fuels. However, they provide no explicit recognition, demand signals, or allocation logic for material-transition applications. Allocation beyond diversion from food use is therefore left to downstream incentives rather than governed by system-level optimisation.

5.2. Structural Bias in Policy Design: Fuels Dominant

The dominance of fuel pathways in UCO utilisation is not accidental, but a direct outcome of structural features embedded in the policy framework.

First, fuel pathways benefit from explicit demand creation. Biodiesel and SAF enjoy blending mandates, assured offtake, and refinery integration. In contrast, chemical and material applications face no comparable demand-side signals, even where they offer high fossil-carbon displacement potential.

Second, collection and aggregation systems prioritise volume over quality differentiation. Practices designed for biodiesel favour throughput and basic contamination control, while chemical value chains require graded quality, consistency, and tighter specification alignment.

Third, compliance regimes focus on safe disposal rather than optimisation. Once UCO exits the food chain, policy frameworks remain largely agnostic to how it should be routed across competing end uses. In this context, UCO predictably flows into the most policy-supported and logistically mature outlets—fuels.

As a result, fuel applications act as the default sink for UCO, not because they always maximise system-level climate value, but because they are the only pathways supported by a complete policy, market, and offtake architecture.

5.3. Lessons from International Experience

International experience shows that effective mobilisation and allocation of Used Cooking Oil (UCO) depend far more on policy design and enforcement than on feedstock availability. Countries that have achieved high formal recovery and stable industrial use of UCO have done so through a small set of deliberate system choices.

In the United States, large-scale UCO recovery is enabled through mandatory grease disposal requirements for commercial food-service establishments, enforced at municipal and state levels. This has resulted in consistently high collection from organised sources. However, because downstream incentives strongly favour fuels through the Renewable Fuel Standard, UCO is routed overwhelmingly into biodiesel and renewable diesel, with little participation from chemical applications. The lesson is clear: mandatory collection enables scale, but allocation follows demand signals.

The United Kingdom and European Union demonstrate the importance of traceability and differentiated incentives. Under the RTFO and the Renewable Energy Directive, UCO is explicitly recognised as a waste-derived feedstock eligible for enhanced crediting, supported by digital tracking and audit requirements. These measures have reduced food-chain leakage and fraud while rapidly increasing formal recovery. At the same time, SAF mandates under ReFuelEU Aviation have reinforced fuel demand, again showing that explicit policy incentives determine end use, not technical suitability.

Germany combines strict waste-management enforcement with strong aggregation networks, particularly in urban centres. Licensed collectors, quality requirements linked to biodiesel eligibility, and stable enforcement have created reliable, industrial-scale UCO supply. While most UCO still flows into fuels, Germany illustrates that collection depth and aggregation density are prerequisites for any higher-value optimisation.

In China, strong enforcement driven by public-health concerns has sharply reduced illegal reuse of waste cooking oil in major cities. Centralised collection systems have enabled rapid recovery gains. However, limited domestic allocation logic has led to fragmented outcomes, including large-scale conversion to biodiesel and export of UCO, demonstrating that enforcement alone is insufficient without coordinated allocation governance.

Japan highlights the limits of voluntary collection models. Recovery rates from commercial establishments are high due to clear compliance expectations and municipal support, but household-level collection remains weak where participation is voluntary. This reinforces the importance of clear thresholds and enforcement scope in determining realised supply.

Taken together, these examples show that successful UCO systems share three common features: mandatory and enforceable collection, credible traceability, and explicit differentiation across end uses. Where any one of these elements is missing, UCO flows default to the most strongly supported application—typically fuels—regardless of broader climate or material-transition value. The detailed international evidence supporting these conclusions is summarised in Annexure II.

Notably, even in jurisdictions with mature UCO ecosystems, material-transition applications remain largely incidental rather than policy-driven. No major economy has yet established explicit demand signals, prioritisation frameworks, or optimisation logic for UCO use in chemicals, despite clear technical feasibility and climate benefits. That said, early and uneven signals are emerging. In parts of the EU and Germany, UCO is increasingly accepted into oleochemical value chains where supply and specifications permit; in Japan, oleochemical and detergent producers routinely utilise waste-derived feedstocks without formal policy preference; and in China, UCO is already being used at scale in oleochemicals, soaps, lubricants, and industrial fatty acids, driven primarily by cost, availability, and industrial demand rather than coordinated material-transition policy. These examples indicate that material applications are technically viable and commercially relevant but remain uncoordinated and secondary to fuel-driven demand in the absence of explicit policy recognition.

5.4. Policy Gaps and Implications for India

Despite credible foundational regulation, India's UCO ecosystem has not translated into meaningful uptake for material-transition applications. Key gaps include:

- absence of chemical-specific demand signals,
- fuel-centric optimisation of aggregation systems,
- lack of quality-based routing mechanisms,
- fragmented governance across food safety, energy, and materials, and
- reliance on enabling rather than outcome-oriented policy design.

Addressing these gaps does not require dismantling existing energy-transition policies. Rather, it requires selective augmentation—introducing differentiated routing, recognising material-transition value, strengthening aggregation as core infrastructure, and integrating public-health, energy, and materials governance. These implications are taken forward in the concluding chapter.

CHAPTER 6

CURRENT STATUS AND NEXT STEPS

CHAPTER 6

Current Status and Next Steps

This paper represents an important step towards framing Used Cooking Oil (UCO) as a strategic circular-carbon resource for material and energy transition, rather than as a single-use feedstock. Through a combination of system framing, screening-level economics, and indicative greenhouse-gas logic, the analysis highlights both the opportunity and the complexity associated with allocating limited UCO resources across competing end uses.

At the current stage, three key questions remain and are only partially resolved and require further work.

First, while the report establishes an envelope for potential UCO availability, a clearer picture is needed of UCO volumes post-collection and their diversion across existing pathways. At present, collected UCO is often equated to volumes entering biodiesel supply chains, which risks obscuring the diversity of current and emerging uses, as well as losses and informal routing beyond regulated channels. A more granular understanding of post-collection flows is essential to assess realistic material availability for the chemical sector.

Second, while the paper develops a consistent, screening-level framework to compare the operating cost structure of UCO-based surfactant pathways against fossil benchmarks and competing fuel uses, the economics of converting UCO into surfactants remains directionally understood rather than decision-grade. Comparisons such as SAF (UCO) versus ATF (fossil) or biodiesel (UCO) versus HSD (fossil) benefit from established market references and policy signals, whereas equivalent comparators for surfactants are less mature. Further work is required to refine cost assumptions under realistic plant configurations, co-processing arrangements, and feedstock quality distributions.

Third, the value proposition for using UCO in surfactants requires deeper articulation beyond greenhouse-gas reduction alone. While the analysis demonstrates that surfactants can offer meaningful carbon avoidance with lower upgrading severity than fuels, questions remain around manufacturer incentives, ecosystem readiness, and demand pull. Addressing why UCO should be prioritised for surfactants over biodiesel or SAF will require integrating economic signals, carbon-efficiency metrics, regulatory design, and market adoption dynamics.

In this context, the present output should be viewed as a positioning and framing document, rather than a final allocation roadmap. The analysis deliberately avoids revenue-based or investment-grade conclusions and instead establishes a shared analytical foundation to guide discussion. The upcoming panel discussion at the symposium is expected to enrich this work by bringing practitioner perspectives on supply mobilisation, technology readiness, refinery integration, and policy alignment.

The final report will build on this input, alongside continued secondary research, to address the outstanding questions on UCO availability, surfactant economics, and system-level value creation. This iterative approach is intended to ensure that the final output is both technically robust and grounded in real-world feasibility, supporting informed decision-making on UCO allocation across India's energy and materials transition.

ANNEXURE-I:

International Evidence for UCO Policy and System Design

This Annexure provides select international evidence to support the policy and system-design analysis presented in Chapter 5. It does not aim to describe complete national UCO markets. Instead, it highlights how governance choices, enforcement mechanisms, and incentive structures shape UCO collection, aggregation, and allocation outcomes across different jurisdictions.

Across countries with mature or rapidly scaling UCO utilisation, outcomes are driven less by feedstock availability and more by how UCO is governed as a system—including mandatory collection, traceability, incentive design, and prioritisation of end uses. The cases below illustrate these design levers and their relevance for India's evolving UCO ecosystem.

2. United States / North America: Mandatory Collection with Fuel-Centric Allocation

In the United States, Used Cooking Oil—commonly referred to as "yellow grease"—is mobilised primarily through mandatory grease disposal requirements applied to commercial food-service establishments at state and municipal levels. These requirements ensure high recovery from restaurants, industrial kitchens, and institutional food providers, supported by licensed private collectors.

Once collected, UCO allocation is shaped downstream by energy-transition incentives rather than waste regulation. UCO-derived biodiesel and renewable diesel benefit from the Renewable Fuel Standard (RFS), where Renewable Identification Numbers (RINs) create clear monetisation pathways. Sustainable Aviation Fuel (SAF) can also earn incentives under the same framework. There are no equivalent policy instruments that recognise or prioritise chemical or material applications of UCO.

Outcome:
High formal recovery and strong traceability, coupled with default routing of UCO into fuel pathways.

Design lesson for India:

Mandatory collection is necessary for scale, but without differentiated end-use signals, UCO predictably flows to policy-supported fuel applications.

3. United Kingdom / European Union: Differentiated Incentives and Strong Traceability

The UK and EU illustrate how explicit incentive differentiation influences UCO outcomes. Under the Renewable Transport Fuel Obligation (RTFO) and the EU Renewable Energy Directive, UCO qualifies as a waste-derived feedstock eligible for enhanced crediting (commonly referred to as "double counting"). This feature explicitly favours UCO over virgin vegetable oils and has driven high formal recovery from the HoReCa sector.

Digital documentation, licensed collection networks, and audit-based traceability systems are integral to compliance, significantly reducing fraud and food-chain leakage. At the same time, recent SAF mandates under ReFuelEU Aviation and national SAF obligations reinforce demand from aviation, further strengthening fuel-centric pull.

Outcome:
Highly structured collection, strong traceability, and explicit policy steering—yet continued dominance of fuel and SAF end uses due to incentive alignment.

Design lesson for India:

Differentiated incentives and traceability work, but without explicit material-transition recognition, fuels remain the dominant sink.

4. Germany: Enforcement-Led Recovery with Aggregation Depth

Germany combines stringent waste-management enforcement with strong renewable energy mandates under the EU framework. UCO collection is dominated by commercial food-service establishments, supported by licensed collectors and enforcement at local levels. Quality standards tied to biodiesel eligibility incentivise basic segregation and contamination control.

Aggregation networks are dense in urban centres, enabling reliable mobilisation. While biodiesel remains the dominant outlet, refinery integration and policy certainty have ensured that UCO is treated as a regulated industrial feedstock rather than informal waste.

Outcome:
High recovery efficiency, quality-consistent aggregation, and stable industrial utilisation—predominantly fuel-oriented.

Design lesson for India:

Enforcement and aggregation depth are prerequisites for stability, even before allocation optimisation is attempted.

5. China: Strong Enforcement, Fragmented Allocation, and Export Orientation

China generates large volumes of Waste Cooking Oil (WCO) due to dietary patterns and urban scale. The government has implemented strict enforcement against illegal reuse, motivated by severe public-health risks. Centralised collection systems, municipal involvement, and licensing have significantly reduced food-chain leakage in major cities.

However, downstream allocation remains fragmented. A large share of legally recovered WCO is converted into biodiesel, with significant volumes exported. Only recently have oleochemical and chemical applications begun to emerge domestically, enabled by improved purification technologies and tightening environmental controls.

Outcome:
Rapid recovery gains driven by enforcement but limited domestic optimisation of UCO allocation.

Design lesson for India:

Enforcement can quickly improve collection, but without integrated allocation logic, system value may be lost or exported.

6. Japan: High Commercial Recovery, Weak Household Capture

Japan demonstrates the limits of voluntary and municipal-dependent collection models. Recovery of UCO from commercial food establishments is very high, supported by subsidies, public-sector procurement (e.g., municipal fleets), and strong compliance culture. In contrast, household-level UCO collection remains uneven, with participation varying widely across municipalities.

Advanced logistics and traceability systems are increasingly used for commercial streams, but fragmented household capture constrains total recovery.

Outcome:
Reliable commercial UCO supply, but constrained overall mobilisation due to weak household inclusion.

Design lesson for India:
Commercial UCO is easier to formalise than household UCO; policy thresholds strongly shape realised supply volumes.

7. Middle East (UAE): Import-Dependent UCO Utilisation

In the UAE, UCO utilisation is emerging through isolated initiatives, such as municipal partnerships and private biodiesel producers. However, domestic collection remains limited, and UCO supply is often import-dependent. As a result, buyers are exposed to global feedstock tightness, sustainability certification premiums, and external price volatility.

Outcome:
Limited domestic mobilisation and high dependence on international markets.

Design lesson for India:
Without domestic collection depth, UCO-based strategies inherit global scarcity and lose strategic resilience.

8. Other Developing Regions: Public-Health Driven Imperatives

In several developing regions, including parts of Africa, UCO is still widely recycled informally, particularly for reuse in food preparation. Weak collection infrastructure and enforcement lead to severe public-health risks, highlighting the social importance of creating regulated, value-creating industrial sinks.

Design lesson for India:
Formal UCO valorisation is not only a climate intervention, but a critical public-health measure.

8. Cross-Cutting Insight

Across all jurisdictions reviewed, one conclusion is consistent: UCO outcomes are determined by policy and system design, not by technical feasibility or feedstock availability. Mandatory collection, enforcement, traceability, and incentive alignment are prerequisites for scale. Allocation across fuels, chemicals, and materials follows design signals, not market neutrality. These international observations directly reinforce the analysis in Chapter 5 and demonstrate that India's challenges are design-related and solvable rather than structural or resource-driven.

ANNEXURE-II

Data Tables

Table-I: Estimated Net Availability of edible vegetable oil in India

Sl.	Year	Quantity of edible vegetable oil in Million Tonne			
		Domestic Production#	Import#	Export#	Net Availability
1	2004-05	7.25	4.75	0.85	11.15
2	2005-06	8.32	4.29	0.82	11.79
3	2006-07	7.37	4.27	0.78	10.86
4	2007-08	8.65	4.9	0.80	12.75
5	2008-09	8.46	6.72	0.70	14.48
6	2009-10	7.95	8.03	0.45	15.53
7	2010-11	9.78	6.91	0.59	16.10
8	2011-12	8.96	8.45	0.94	16.47
9	2012-13	9.22	11.01	0.84	19.39
10	2013-14	10.19	10.43	0.71	19.91
11	2014-15	9.80	13.85	0.59	23.06
12	2015-16	9.18	14.8	0.55	23.43
13	2016-17	10.74	15.31	0.65	25.40
14	2017-18	11.01	14.59	0.63	24.97
15	2018-19	10.95	15.02	0.60	25.37
16	2019-20	11.63	14.72	0.97	25.38
17	2020-21	12.14	13.54	0.98	24.70
18	2021-22	12.63	14.28	0.98	25.93
19	2022-23	13.4	16.52	0.98	28.94
20	2023-24	13.15	15.65	0.98	27.82
	CAGR (%)	3.18	6.48	0.78	4.93

Source: # Compiled from Annual Agricultural Statistics, Economics, Statistics and Evaluation Division, Ministry of Agriculture & Farmers' Welfare, Govt. of India.

Table-II: Estimated Potential UCO Availability

Sl.	Year	Quantity of edible vegetable oil in Million MT				
		Annual Demand in Industrial Sector @ 20 percent of net availability	Kitchen Demand (HHs & HoReCa) @ 80 percent of net availability	Commercial Kitchen (CK) Use @ 55 percent of Kitchen Demand	Household Kitchen use @ 45 percent of Kitchen Demand	UCO Supply [@30% for CK ##]
1	2004-05	2.23	8.92	4.91	4.01	1.47
2	2005-06	2.36	9.43	5.19	4.24	1.56
3	2006-07	2.17	8.69	4.78	3.91	1.43
4	2007-08	2.55	10.20	5.61	4.59	1.68
5	2008-09	2.90	11.58	6.37	5.21	1.91
6	2009-10	3.11	12.42	6.83	5.59	2.05
7	2010-11	3.22	12.88	7.08	5.80	2.13
8	2011-12	3.29	13.18	7.25	5.93	2.17
9	2012-13	3.88	15.51	8.53	6.98	2.56
10	2013-14	3.98	15.93	8.76	7.17	2.63
11	2014-15	4.61	18.45	10.15	8.30	3.04
12	2015-16	4.69	18.74	10.31	8.43	3.09
13	2016-17	5.08	20.32	11.18	9.14	3.35
14	2017-18	4.99	19.98	10.99	8.99	3.30
15	2018-19	5.07	20.30	11.16	9.13	3.35
16	2019-20	5.08	20.30	11.17	9.14	3.35
17	2020-21	4.94	19.76	10.87	8.89	3.26
18	2021-22	5.19	20.74	11.41	9.33	3.42
19	2022-23	5.79	23.15	12.73	10.42	3.82
20	2023-24	5.56	22.26	12.24	10.02	3.67
	CAGR (%)	4.93	4.93	4.92	4.94	4.93

NB: ## Orjuela, Alvaro and Clark, James (2020), "Green Chemicals from Used Cooking Oils: Trends, Challenges and Opportunities", Current Opinion in Green and Sustainable Chemistry, White Rose Research Online, ***https://doi.org/10.1016/j.cogsc.2020.100369***

Table-III: No. of aggregators linked with Biodiesel Production Units

Sl.	No. of Aggregators	No. of reporting biodiesel plants	%
1	1	19	26.4
2	2	10	13.9
3	3	7	9.7
4	4	2	2.8
5	5	1	1.4
6	6	2	2.8
7	7	1	1.4
8	11	1	1.4
9	Data Not available	29	40.3
	Total	72	100.0
Bio diesel plants also acting as aggregators		17	23.6
Mean Number of aggregators per bio diesel plant			1.4
Median Number of aggregators per bio diesel plant			3.5

Source: Analysis compiled from the data retrieved from ***Enrolled Biodiesel Manufacturers - RUCO : Repurpose Used Cooking Oil*** *and Research Paper on Used Cooking Oil based Biodiesel of* ***www.pahalindia.org***

Table- IV: State wise coverage of Aggregators and End Users

Sl.	States	Number of aggregators			
		Biodiesel	Soap Company	Total	% Share
1	Andhra Pradesh	6		6	4.5
2	Bihar	1		1	0.8
3	Gujarat	3		3	2.3
4	Haryana	8	1	9	6.8
5	Himachal Pradesh	1		1	0.8
6	Karnataka	2	7	9	6.8
7	Kerala	7	4	11	8.3
8	Madhya Pradesh	4		4	3.0
9	Maharashtra	9	1	10	7.5
10	Punjab	1	2	3	2.3
11	Rajasthan	12	1	13	9.8
12	Tamil Nadu	21	3	24	18.0
13	Telangana	6	2	8	6.0
14	Uttar Pradesh	22		22	16.5
15	Uttarakhand	1		1	0.8
16	West Bengal	5	3	8	6.0
	All states	109	24	133	100.0

Source: Analysis compiled from the data retrieved from ***Enrolled Biodiesel Manufacturers - RUCO : Repurpose Used Cooking Oil***

Table-V: Bio diesel Production in India

Sl.	Years	Quantity of Biodiesel produced by feedstock category (x1000 Tonne)	% of Biodiesel produced by feedstock category						
		Animal Fat and tallow	Nonedible Oilseeds	Used Cooking Oil	Total	Animal Fat and tallow	Nonedible Oil seeds	Used Cooking Oil	Total
1	2013	7	70	49	126	5.6	55.6	38.9	100.0
2	2014	6	75	50	131	4.6	57.3	38.2	100.0
3	2015	5	85	55	145	3.4	58.6	37.9	100.0
4	2016	6	90	55	151	4.0	59.6	36.4	100.0
5	2017	6	100	55	161	3.7	62.1	34.2	100.0
6	2018	8	110	60	178	4.5	61.8	33.7	100.0
7	2019	10	140	65	215	4.7	65.1	30.2	100.0
8	2020	9	145	50	204	4.4	71.1	24.5	100.0
9	2021	9	90	55	154	5.8	58.4	35.7	100.0
	Yearly average	7	101	55	163	4.3	62.0	33.7	100.0

Source: TERI (2023), Accelerating Biodiesel Blending in India, Policy Brief

Table-VI: Trend of Jet Fuel Demand in India and Potential demand for UCO (from SAF) during the period 2004-05 to 2024-25 (Million Tonne)

Sl.	Year	Jet Fuel Demand (MILLION TONNES)	Potential Demand for SAF at 1% blending target	Potential Demand for SAF at 2% blending target	Potential Demand for SAF at 5% blending target
1	2004-05	2.7	0.03	0.05	0.14
2	2005-06	3.0	0.03	0.06	0.15
3	2006-07	3.5	0.04	0.07	0.18
4	2007-08	4.0	0.04	0.08	0.20
5	2008-09	3.8	0.04	0.08	0.19
6	2009-10	4.1	0.04	0.08	0.21
7	2010-11	4.3	0.04	0.09	0.22
8	2011-12	4.7	0.05	0.09	0.24
9	2012-13	4.8	0.05	0.10	0.24
10	2013-14	5.2	0.05	0.10	0.26
11	2014-15	5.6	0.06	0.11	0.28
12	2015-16	6.0	0.06	0.12	0.30
13	2016-17	6.5	0.07	0.13	0.33

Sl.	Year	Jet Fuel Demand (MILLION TONNES)	Potential Demand for SAF at 1% blending target	Potential Demand for SAF at 2% blending target	Potential Demand for SAF at 5% blending target
14	2017-18	7.5	0.08	0.15	0.38
15	2018-19	8.3	0.08	0.17	0.42
16	2019-20	8.0	0.08	0.16	0.40
17	2020-21	3.7	0.04	0.07	0.19
18	2021-22	5.0	0.05	0.10	0.25
19	2022-23	7.4	0.07	0.15	0.37
20	2023-24	8.4	0.08	0.17	0.42
21	2024-25	9.0	0.09	0.18	0.45

Source: www.indiastat.com

Table-VII: Annual Surfactant Production in India during the Period 2004-05 to 2024-25 (Quantity in in Kilo Tonne/ Annum

Sl.	Year	Linear Alkylbenzene (LAB)	Sodium Lauryl Ether Sulphate (SLES)	Alcohol Ethoxylates (AE)	Alcohol Ether Sulphates (AES - excluding SLES grades)
1	2005	360	85	120	60
2	2006	375	90	125	62
3	2007	390	95	130	65
4	2008	405	100	135	67
5	2009	415	105	140	70
6	2010	430	110	145	72
7	2011	445	115	150	75
8	2012	460	120	155	77
9	2013	475	125	160	80
10	2014	490	130	165	82
11	2015	505	135	170	85
12	2016	520	140	175	87
13	2017	535	145	180	90
14	2018	550	150	185	92
15	2019	565	155	190	95
16	2020	555	150	185	97
17	2021	580	165	200	100
18	2022	600	180	215	105
19	2023	620	195	230	108
20	2024	640	210	250	110

Table-VIII: Key chemical parameters for feedstocks used for oleochemical, surfactants, biodiesel and SAF

Sl.	Parameter	Oleochemical Feedstock (Typical)	Surfactants (Chemical-grade)	Biodiesel - ASTM D6751 (B100)	Biodiesel - EN14214	SAF
1	Free Fatty Acid / Acid Value	0.1-15% FFA allowed (process-dependent)	Acid value ≤ 1.0-2.0 mg KOH/g (low corrosion, formulation stability)	Acid value ≤ 0.50 mg KOH/g	Acid value ≤ 0.50 mg KOH/g	≤ 1.0-2.0 (preferred ≤ 1.0) [% as oleic acid]
2	Moisture / Water	0.1-1.0%	≤ 0.1% (avoids hydrolysis, microbial growth)	≤ 0.05% vol (500 ppm approx.)	≤ 500 mg/kg	≤ 0.05 [wt% (≤ 500 ppm)]
3	Insoluble impurities	0.1-1.0%	≤ 0.05% (clarity, spray/dissolution performance)	≤ 0.05% vol (water +sediment)	≤ 24 mg/kg	≤ 0.01 [wt% (≤ 100 ppm)]
4	Phosphorus	≤ 10-100 ppm	≤ 5-10 ppm (discoloration, catalyst poisoning)	≤ 10 ppm (0.001%)	≤ 4 ppm	≤ 5-10 [ppm]
5	Sulphur	≤ 30-50 ppm	≤ 20-50 ppm (odor & color control)	≤ 15 ppm (S15 grade)	≤ 10 ppm	≤ 10 [ppm]
6	Alkali metals (Na +K)	Often ≤ 50-100 ppm	≤ 10-20 ppm (formulation stability)	≤ 5 ppm	≤ 5 ppm	≤ 5 [ppm]
7	Ca +Mg	Process-specific	≤ 20 ppm (prevents soap scum / precipitation)	≤5 ppm	≤ 5 ppm	≤ 5 [ppm]
8	Peroxide value	≤ 2-5 meq/kg	≤ 5-10 meq/kg (foaming + shelf life)	Not permitted (must be stable fuel)	Controlled via oxidation stability	≤ 5 [meq O_2/kg]
9	Unsaponifiables / polymers	≤ 1-1.5%	Controlled (can affect cloud point & clarity)	Not permitted	Not permitted	≤ 1.5 [wt%]
10	Oxidation stability	Not a buying criterion	Important (antioxidant-dependent shelf life)	≥ 3h	≥ 8h	≥ 6 [hours]
11	Glycerides / glycerol	Not specified	Not applicable	Strictly limited	Strictly limited	Triglycerides > 95% [wt%]
12	Color (APHA / Hazen)	Yellow-brown acceptable	≤ 50-200 APHA (appearance important)	Not critical		Controlled
13	Carbonyls / Aldehydes	Trace	≤ 0.1% (odour & stability)	Limited		Limited
14	Nitrogen compounds	Trace	Trace acceptable	Limited		Limited

Sl.	Parameter	Oleochemical Feedstock (Typical)	Surfactants (Chemical-grade)	Biodiesel - ASTM D6751 (B100)	Biodiesel - EN14214	SAF
15	Dienes / Acetylene	Not relevant	Not relevant	Not relevant		Not relevant
16	Purity / Main component	Mixed fatty chains	Active matter defined by formulation	FAME ≥ 96.5%		Paraffinic
17	Oxygenates	High	Allowed (EO-based)	High		Must be removed

Source: Compiled from multiple tender documents of Oleochemical Companies

Table-IX: Comparative chemical quality requirements of feedstocks for oleochemical, biodiesel and SAF (HEFA) manufacturing

Sl.	Parameters	Oleochemical Feedstock	Biodiesel (ASTM D6751 / EN14214)	SAF - HEFA Route
1	Free Fatty Acid / Acid Value	High FFA is desirable for fatty-acid splitting and soap manufacture, improving yield and reducing neutral oil losses[1].	High FFA promotes corrosion, injector fouling, and deposit formation; hence acid value is restricted to ≤0.50 mg KOH/g[2].	Low and stable FFA (typically ≤1%) ensures predictable hydrotreating performance and protects HEFA catalysts[3].
2	Moisture / Water	Water can be removed by degumming, drying, or distillation and is manageable within oleochemical processing[1].	Even trace moisture causes corrosion, microbial growth, and filter plugging; water ≤500 mg/kg is specified[2][4].	Highly detrimental as it deactivates hydrotreating catalysts, increases hydrogen consumption, and causes corrosion and instability[3].
3	Phosphorus and Metals	Moderate phosphorus and metal levels are tolerable and managed through pretreatment and refining[1].	Strong poisons for engine after-treatment systems; phosphorus ≤10 ppm (ASTM) and ≤ 4 ppm (EN)[2][4].	Very tight limits (≤5–10 ppm) are mandatory to protect high-value HEFA catalysts and sustain fuel yield[3].
4	Oxidation Stability	Oxidation products can be largely removed during fractionation and are not a primary purchasing criterion[1].	Biodiesel must resist oxidation during storage; stability ≥ 3h (ASTM) and ≥ 8h (EN)[2][4].	High stability is required to prevent gum formation, coke precursors, and feed degradation during storage and processing[3].
5	Unsaturated / Reactive Impurities	Unsaturation is inherent to lipid feedstocks and acceptable depending on the target oleochemical product[1].	Excessive unsaturation reduces oxidation stability and storage life of biodiesel[2].	Controlled to prevent side reactions and coke formation under severe hydrotreating conditions[3].

NB:

1. Oleochemical industry practice - Bailey's Industrial Oil and Fat Products; typical industrial fatty-acid and soap processing guidelines.
2. ASTM D6751 - Standard Specification for Biodiesel Fuel Blend Stock (B100).
3. ASTM D7566 / HEFA process guidelines - SAF production via hydro processed esters and fatty acids.
4. EN 14214 - Automotive fuels - Fatty acid methyl esters (FAME) for diesel engines.
5. (Reserved if further SAF property specifications are added.)
6. Polymer-grade ethylene specifications - Typical requirements for Ziegler-Natta and metallocene polymerization (petrochemical industry practice).
7. Polymer-grade propylene specifications - Requirements for polypropylene production and catalyst protection.

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About FICCI

Established in 1927, Federation of Indian Chambers of Commerce & Industry (FICCI) is the largest and oldest apex business organization in India. A non-government, not-for-profit organization, FICCI is the voice of India's business and industry. FICCI has direct membership of over 3000 corporate, including SMEs and MNCs, as well as public sectors and more than 500 chambers of commerce and business associations, and an indirect membership of companies from regional chambers of commerce. FICCI espouses the shared vision of Indian businesses and speaks directly and indirectly for over 250,000 business units.

FICCI maintains the lead as the proactive business solution provider through research, interactions at the highest political level and global networking. FICCI works closely with the government on policy issues, enhancing efficiency, competitiveness and expanding business opportunities for industry through a range of specialized services and global linkages. It also provides a platform for sector specific consensus building and networking. FICCI has a national network with 20 states.

FICCI serves as the first port of call for Indian industry and the international business community. Our presence is in regions such as Africa, Arab, Israel, Asia Pacific, East Asia, Europe, Latin America, the Caribbean, North America, South Asia, etc. FICCI is also involved with diaspora engagement, forum of parliamentarians, Commonwealth of Independent States (CIS), multilateral, international policy, and strategy

For more information and to join as a member, visit https://www.ficci.in/

Resource Efficiency
and Circular Economy
Industry Coalition

About RECEIC

The G20 New Delhi Leaders' Declaration acknowledges the critical role being played by circular economy, extended producer responsibility and resource efficiency in achieving sustainable development. Notably, the 'Green Development Pact for a Sustainable Future' declaration part of the G20 India Presidency in para 37 has mentioned the launching of Resource Efficiency and Circular Economy Industry Coalition.

RECEIC as envisaged is a G20 centric coalition driven by industry. It is first of its kind high-level initiative on encouraging resource efficiency and circular economy which is industry led, independent and self-sustaining, includes all sectors from across the globe, is inclusive and integrative.

FICCI has been entrusted with the responsibility of serving as the secretariat of RECEIC. The coalition is guided by 15 members Steering Committee and drive the agenda basis industry priorities in collaborative manner. With 60 global industries as its members, RECEIC currently has five operational working groups constituted on Packaging Reimagined – Alternate and innovative Solutions; Material Transition in Chemical Sector; Resource Efficiency & Circularity in Used Oil sector; Circularity in Textiles & Apparels sector & Dry Cell Batteries.

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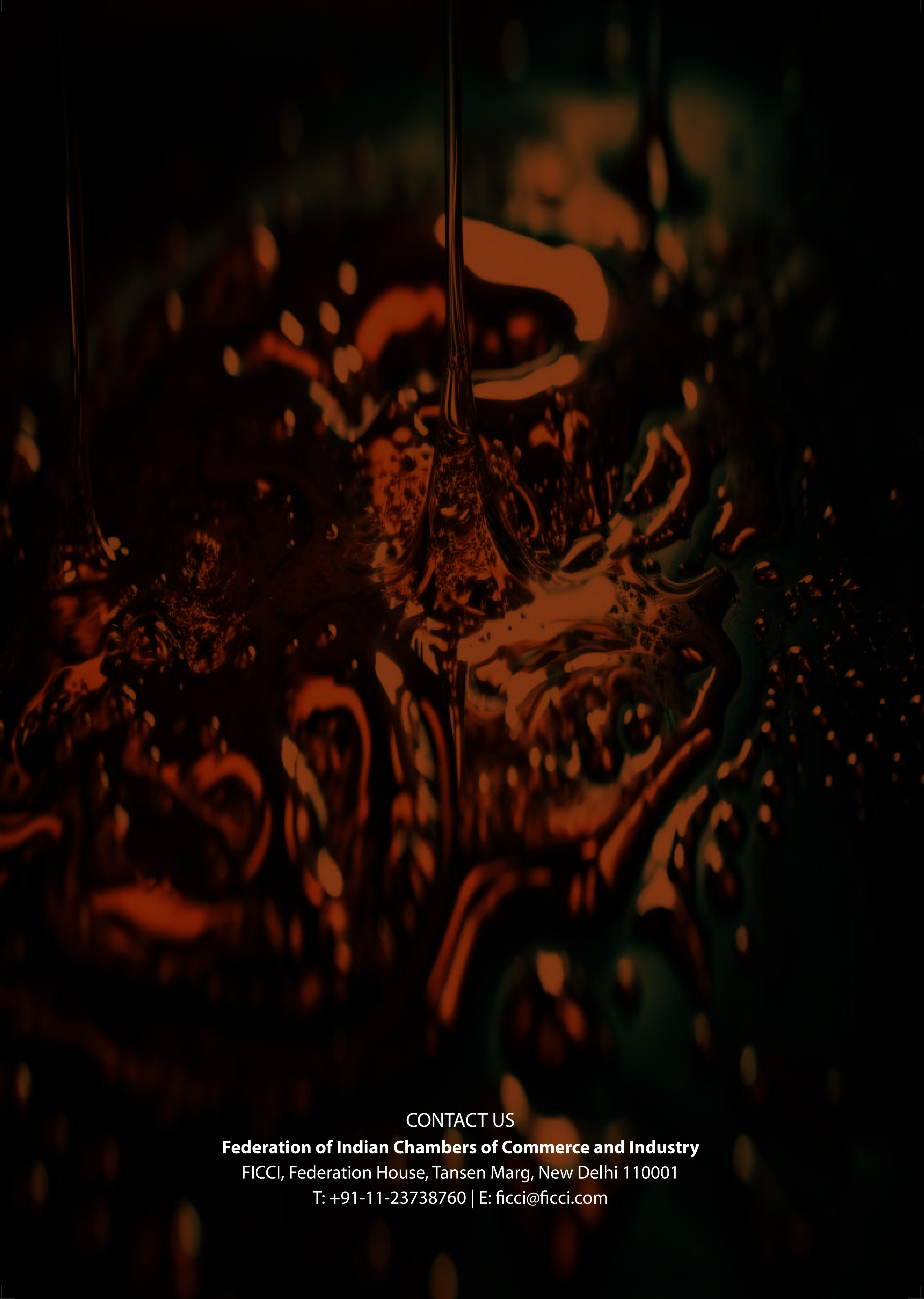

CONTACT US
Federation of Indian Chambers of Commerce and Industry
FICCI, Federation House, Tansen Marg, New Delhi 110001
T: +91-11-23738760 | E: ficci@ficci.com