PHD CHAMBER
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PETRON SCIENTECH INC USA

Decarbonizing Pathway

DENTED-CORN ETHANOL

Preferred Pathway
for
Food & Energy security

Dr. JP Gupta

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Corn ethanol represents a significant step toward reducing greenhouse gas emissions and fostering energy independence, making it a vital component in our quest for a sustainable and environmentally friendly future.

— DR. STEVEN CHU

NOBEL LAUREATE AND FORMER U.S. SECRETARY OF ENERGY

GLOBAL BIOFUELS ALLIANCE

Paving the way for the

4th International Climate Summit 2024

Decarbonizing Pathway: Dent Corn Ethanol

19th July, 2024 | Hotel Taj Palace, New Delhi

Energy Security and Food Security through Corn Ethanol- Preferred Pathway for "Decarbonization"

Why Corn?

Corn is versatile agriculture product for India. Besides, it is used in making Ethanol for Biofuels, Pharmaceutical, Industrial (solvent) and Distilled Spirits. Corn cob and stover (waste) is source of animal feed and Second generation ethanol (2G) as well.

- **Corn is primary source of " Corn Cooking oil" After Petroleum, India's second most $ (value) import is cooking oil. Corn oil is " Heart health friendly " and considered a very healthy cooking oil compared to Palm, Peanut, Mustard or other oils.**
- **Paper and Food industry requires Starch for which Corn is good source. India has shortage of Starch as well for industry.**
- **Fiber in Corn is good for digestive health (Isaf Ghol, Metamucil etc)**

Corn is the most produced crop globally with 1.1 billion tons, followed by wheat with 760.9 million tons and rice with 756.7 million tons.

www.agweb.com/markets/world-markets/who-produces-what-key-agriculture-st

DEDICATION

With genuine gratitude and warm regards,
the author dedicates this knowledge book
'Dented Corn Ethanol- Harnessing the Power of Biofuel.'

to

Hon'ble Prime Minister of India

Shri Narendra Modi

His visionary thoughts and proactive steps for self-reliant India concerning the energy roadmap for the country have immensely motivated the author to write the fourth volume of the knowledge book on the event of 4th International Climate Summit 2024: "Dented Corn Ethanol for Energy Security, Food Security and Decarbonization" at New Delhi, on 19th July 2024.

This Knowledge Book offers information and knowledge to investors, joint venture partners, and industrialists about the opportunities India offers in the production of 'Dented Corn Ethanol' for blending with petrol for automobiles, Sustainable Aviation Fuel, and replacement of LPG for cooking.

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ACKNOWLEDGEMENTS

The following members deserve special acknowledgment for their significant contributions in inspiring and supporting me in the completion of this book.

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I would like to express my special gratitude to my wife, my three daughters - Sarika, Radhika, Prerna and my sons-in-law for their continuing support during the long hours I spent in the office writing this book over the past six months. This period has been very challenging for me, as my wife, Dr. Purnima Gupta, fell ill and needed my care. She has been a very courageous, visionary, and understanding partner, always insisting that I complete the book, often downplaying her health problems to enable me to achieve my goal.

My little granddaughter, Omaira, also deserves acknowledgment for her constant inspiration. Omaira is a born genius and an emerging author- my role model.

I must also remember my late brother, Mr. Chander Mohan Mittal, who remained in contact with me through the eyes of my imagination, reminding me that the purpose of life is to give back to society. His divine message that my work on ‘Dented Corn Ethanol’ shall lead to a ‘Corn Revolution,’ uplifting the socio-economic conditions of farmers, has been a constant source of motivation for me.

My co-author, Yogendra Sarin would also like to thank for their enduring support and encouragement, his wife Archana Sarin, daughters, Drs. Pooja, Priya and Jaya, son in laws, and ever enthusiastic grandchildren. They all inspire me continuously. Thanks to my friend Jeewan Gupta for his dedication to this endeavour

Dr. JP Gupta

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I would like to take a moment to acknowledge my co-author and a dear friend, Mr. Yogendra Sarin who worked painstakingly with me over the last few months on the technical and creative aspects of this book. Collaborating with him has been an incredible experience, and I am deeply appreciative of his knowledge, dedication, and enthusiasm he brought to this project that significantly enhanced the quality of our book.

To say this book is "by Dr. J. P. Gupta" overstates the case. Without the significant contributions made by other people, this book certainly would not have existed. At the top of the list are the members of the editorial team. I have been truly blessed to have an extraordinary group of people dedicated to the project. In aggregate, they contributed about a month to the project, and the standard they set for themselves in the quality of their work set a very high standard for me to try to live up to. As I struggled with writing the book in the last months, I pictured all the hardworking members of the team, who dedicated time to this effort, looking over my shoulders and holding me accountable, challenging me to create a final manuscript that met their standards.

I hope this effort meets with their approval. Any failure to reach that standard rests entirely with me.

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PREFACE

Dr. JP GUPTA
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PHD Chamber of Commerce and Industry
Summit Chair, 4th International Climate Summit 2024: 'Dented Corn Ethanol'
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In the face of escalating environmental challenges and the pressing need for sustainable energy solutions, the role of bioethanol has emerged as a beacon of hope and progress. This book delves into the multifaceted world of ethanol, especially created via dented corn, tracing its historical roots, examining its current applications, and envisioning its future potential. As Chair of the Environment and Green Energy Committee at PHD Chamber of Commerce & Industry, I am honored to present this comprehensive exploration of ethanol's transformative impact on our journey towards a greener and self reliant India in energy needs.

The book is an attempt to provide a deep yet accessible story about dented-corn ethanol in light of the Global Biofuels Alliance formulated during the G20. From its early uses in beverages and lamp fuels to its pivotal role in the modern energy landscape, ethanol's evolution mirrors humanity's ingenuity and adaptability. Today, ethanol is a cornerstone of sustainable energy strategies, produced predominantly through the fermentation of diverse feedstocks, from sugar cane and cellulosic biomass to industrial waste gases. This versatility not only enhances our energy security but also significantly reduces our environmental footprint. The global perspective provided in this book underscores the vital role of corn in ethanol production, with an emphasis on the unique advantages of dented corn such as its 3x yield.

The heart of this book lies in its detailed examination of bioethanol, particularly within the Indian context and created using dented corn. India stands at a critical juncture, balancing growing energy demands with the imperative for sustainable development. The nation's ambitious Ethanol Blending Gasoline Program aims to achieve a 20% ethanol blend by 2025-26, a target that necessitates overcoming significant feedstock challenges. Here, the potential of corn ethanol becomes evident. Drawing lessons from the successes of the U.S. and Brazil, this book outlines how India can harness its agricultural resources to become a major player in the global biofuel market, thus advancing its commitments under the Paris Agreement and propelling rural economic growth.

This book also explores the transformative potential of Sustainable Aviation Fuel (SAF), highlighting its role in reducing the aviation industry's carbon footprint and promoting environmental conservation. Despite the challenges of scalability and cost competitiveness, the promise of SAF is undeniable, offering a renewable and lower-carbon alternative to conventional jet fuels.

A significant portion of this work is dedicated to exploring technological changes needed such as 1.5 Generation (1.5G) bioethanol technologies that can optimize ethanol production. This approach not only increases yield but also makes use of agricultural residues, thereby enhancing sustainability. India's agricultural landscape is ripe for a "Corn Revolution," an initiative aimed at transforming rural economies through the cultivation of non-edible corn for bioethanol production. This revolution promises to empower farmers, promote agricultural diversification, and enhance energy access, thereby driving socio-economic development and environmental sustainability.

Our roadmap for India's ethanol future is ambitious yet attainable. By setting up mega corn-based bio-refineries, promoting ethanol as a cooking fuel, and exploring its applications in the chemical and petrochemical industries, India can make significant strides towards carbon neutrality and decarbonization.

This book is a call to action for policymakers, industry leaders, and stakeholders. It provides a comprehensive overview of the challenges and opportunities in the dented-corn ethanol sector, offering strategic recommendations to harness the full potential of this renewable resource. By embracing the vision outlined in these pages, India can lead the global effort towards sustainable energy, economic prosperity, and environmental stewardship.

With deep gratitude to my colleagues, researchers, and all those who contributed to this endeavor, I present this book as a testament to our collective commitment to a sustainable future.

Dr. JP Gupta

FOREWARD

Erik Solheim
Former Executive Director
UN Environment Program and Under-Secretary-General of the United Nations
Former Chair of the Development Assistance Committee of the Organization for Economic Co-operation and Development
Norway's Minister of the Environment and International Development
2007 to 2012
Minister of International Development
2005 to 2007
UN Environment's ex-Special Envoy for Environment, Conflict and Disaster
Patron of Nature for the International Union for the Conservation of Nature

As we stand on the brink of a new era in sustainable energy, it is with great pride and a sense of urgent responsibility that we present this comprehensive 'Industry Insight' on "Corn to Ethanol: Bridging the Gap to a Sustainable Future." On the eve of the International Climate Summit, this publication aims to illuminate the pivotal role of biofuels in our global strategy to combat climate change and reduce our reliance on fossil fuels.

The transition to a low-carbon economy is not merely an option; it is an imperative. The escalating impacts of climate change demand immediate and concerted action from all sectors of society. Among the myriad solutions, biofuels, particularly ethanol derived from corn, have emerged as a viable and scalable option. This book provides an in-depth exploration of the science, economics, and environmental benefits associated with corn-based ethanol production.

Corn ethanol has the potential to significantly reduce greenhouse gas emissions compared to traditional gasoline. This book meticulously details the processes involved in converting corn into ethanol, the technological advancements that have made production more efficient, and the economic impacts on both local and global scales. Furthermore, it addresses the challenges and controversies surrounding biofuels, including food security concerns and land use changes, offering balanced perspectives and forward-looking solutions.

This work represents the collective effort of leading experts in the fields of agriculture, renewable energy, environmental science, and economics. It synthesizes the latest research and presents it in a manner that is accessible to policymakers, industry stakeholders, academics, and the general public. By providing a clear and comprehensive understanding of the corn-to-ethanol pathway, we hope to foster informed decision-making and inspire innovative approaches to biofuel production and utilization.

As an avid environmentalist, as a former leader of the UN Environment Program and as a former Minister of Environment for Norway, I am honoured to endorse this book. It stands as a testament to our commitment to sustainable development and our relentless pursuit of solutions that balance environmental stewardship with economic growth.

The International Climate Summit is a time for reflection, collaboration, and action. It is my sincere hope that this 'Industry Insight' will serve as both a resource and a catalyst for change, encouraging stakeholders around the world to embrace biofuels as a key component of our sustainable future. Let us move forward with determination and optimism, knowing that every step we take towards cleaner energy is a step towards a healthier planet.

With gratitude and hope,

Eric Solheim

FOREWARD

Nobuo Tanaka
Chair
Study Group on Next Generation Nuclear Energy Utilization at Canon Institute of Global Studies (CIGS)
Chair
The Steering Committee of Innovation for Cool Earth Forum (ICEF)
Executive Director Emeritus
International Energy Agency (IEA)
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It gives me immense pleasure to announce, on the eve of the 4th International Climate Summit 2024 on July 19th, the publication of a knowledge paper titled "Corn Ethanol for Energy Security, Food Security, and Decarbonization: The Preferred Pathway for India." This significant work, by Dr. J. P. Gupta, a distinguished scientist, presents a comprehensive roadmap for India's decarbonization journey.

At the outset, I extend my heartfelt congratulations to Dr. Gupta for his outstanding contribution. His work underscores the critical role of ethanol in transforming India's energy and transport sectors. The potential for India to become a leading exporter of Sustainable Aviation Fuel (SAF), leveraging the local availability of ethanol, is particularly noteworthy. Furthermore, ethanol's application as a replacement for LPG in cooking and its importance as a raw material in the production of chemicals, including ethylene and ethylene oxide (EO) derivatives, highlights its multifaceted utility.

The PHD Chamber of Commerce and Industry is honoured to benefit from Dr. Gupta's vision and dedication. This knowledge paper is poised to be an invaluable resource for industries, researchers, investors, and policymakers. Given India's agricultural foundation, a "Corn Revolution" could significantly accelerate the socio-economic development of our farmers, fostering rapid growth and sustainability.

In this context, it is essential to recognize the technical aspects of ethanol production and utilization, including advanced fermentation and distillation processes that maximize yield and efficiency. Additionally, the integration of ethanol into the energy grid requires robust infrastructure for blending, distribution, and usage in various sectors. Embracing these technical advancements will be crucial for achieving the outlined goals.

I wish my friend, Dr. J. P. Gupta, a long, healthy, and fulfilling life, abundant with happiness.

Nobuo Tanaka

MESSAGE FROM THE PRESIDENT PHDCCI

Sanjeev Agrawal
President, PHDCCI
& Chairman – MMG Group

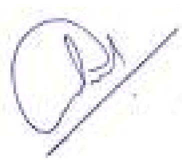
There has never been a more pressing need for increased awareness and decisive action to protect our ecosystems and communities in the face of the escalating effects of climate change. I am pleased to share with you all that the PHD Chamber of Commerce and Industry is organizing the 4th International Climate Summit 2024: "Bioenergy for Energy Security and Agricultural Growth Accelerating Green Transition of MSMEs" on Friday, 19th July, 2024 at The Taj Palace, New Delhi.

The summit provides a distinctive opportunity to highlight India's capabilities in the biofuels sector, thereby facilitating significant investment opportunities, particularly for the micro, small, and medium-sized enterprises (MSMEs). The summit will serve as an essential platform for the promotion of sustainability through bioenergy, as well as the improvement of energy security, farmer incomes, and decarbonization initiatives.

Following the official launch of the Global Biofuel Alliance (GBA) by our Hon'ble Prime Minister Mr. Narendra Modi Ji at the G-20 Summit in September 2023, ICS 2024 will serve as a catalytic platform, promoting global collaboration for the widespread adoption and advancement of biofuels.

I am delighted to share that the PHD Chamber of Commerce and Industry has consistently been at the forefront of policy advocacy, supporting the industries, particularly the MSME sector, and facilitating international partnerships to promote economic growth in India. I am confident that this knowledge book will be highly beneficial to all stakeholders.

I wish this Summit a grand success followed by fruitful actionable outcomes.



Sanjeev Agrawal

VISION STATEMENT

for the

4th International Climate Summit 2024
Decarbonizing Pathway: Dented-Corn Ethanol

Yogendra Sarin
President & CEO,
Petron Scientech USA

Dr. JP Gupta
Summit Chair
Chair, Environment & Green Energy Committee,
PHD Chamber of Commerce & Industry

India stands at the cusp of a transformative journey towards energy security, sustainable development, and economic prosperity. The development of a robust Corn to Ethanol ecosystem is a pivotal strategy in this journey, aligning with global efforts to mitigate climate change and foster sustainable growth. With this International Climate Summit 2024 and its specific focus on Corn-to-Ethanol, we have envisioned the strategic framework for establishing a comprehensive Corn to Ethanol ecosystem in India, with due emphasis on its potential benefits, technical requirements, and strategic initiatives. The development of a Corn to Ethanol ecosystem in India presents a unique opportunity to drive sustainable development, enhance energy security, and foster economic growth. By leveraging its agricultural strengths and embracing innovative technologies, India can position itself as a global leader in the ethanol sector. This vision requires concerted efforts from government, industry, and academia to create a sustainable and prosperous future for the nation. Let us embark on this transformative journey, paving the way for a greener, more sustainable, and economically vibrant India – a 'Viksit Bharat'.

Dr. JP Gupta
AUTHOR

DR. JEEWAN PRAKASH GUPTA, an accomplished and innovative engineer, has earned numerous accolades for his groundbreaking contributions across various domains, Net Carbon Zero initiatives, Green Hydrogen Production, Energy & Sustainability and Circular Economy, etc. He has also pioneered on bioenergy particularly on bio ethanol.

Dr. Gupta is at the forefront of India's efforts to achieve global environmental leadership and climate resilience. He has established five Centres of Excellence in India, specializing in process safety for Hydrogen, at IIT-Delhi, Shriram Institute of Industrial Research, SRICT University, UPL Ankleshwar, Indian Oil Corporation Ltd., Faridabad and PHD Chamber of Commerce & Industry.

A prolific writer, Dr. Gupta has several publications and has coauthored three knowledge books on Green Fuel and Green Hydrogen. He is one of India's most cited technocrats, having delivered over 100 orations at esteemed forums.

His academic journey began with a Gold Medal at LIT, Nagpur, followed by an M. Tech degree from I.I.T. Delhi with the distinction of achieving the first rank. Subsequently, he completed his Ph.D. at the University of Toronto, with patents and several international publications. Among his achievements is the establishment of the first-ever Monoethylene Glycol from Cane Sugar Molasses. He brought Degussa AG of Germany to India to set up first silica project and headed it as Managing Director. His portfolio also boasts patents for producing Lychee, Mango, and Ayurvedic wines, a pioneering effort in India. Dr. Gupta's extensive experience includes serving as Chairman (Industry-II) for Environmental Clearance with Ministry of Environment, Forest and Climate Change for six years. He has been involved in selecting members and member secretaries for institutions such as the National Green Tribunal (NGT) and the Central Pollution Control Board (CPCB) and has been member of Quality Council of India.

EXECUTIVE SUMMARY

The history of ethanol spans over 13,000 years, beginning with its first isolation from wine in the 1100s. Initially used in beverages, ethanol found diverse applications over the centuries, such as lamp fuel and engine fuel by the 1800s. Today, ethanol production predominantly involves the fermentation of sugars using yeast, leveraging various feedstocks like sugar cane, cellulosic biomass, and industrial waste gases. The shift from synthetic ethanol to fermentation-based production for fuel blending has not only made ethanol more accessible but also broadened its applications to include fuels, solvents, disinfectants, and pharmaceuticals. Pure ethanol (E100) offers significant environmental benefits and serves as a clean cooking fuel and a base for sustainable aviation fuel (SAF). As a renewable feedstock, ethanol supports green chemical and polymer production, contributing to a sustainable chemical industry.

Additionally, dented corn is more advantageous than normal corn for ethanol production due to 70-75% starch content which is much higher than the 20-30% starch in the normal corn. This leads to greater ethanol yield of 2.8 gallons per bushel vs 1 gallon per bushel for the normal corn and more efficient fermentation. It is also more cost-effective and widely available, thanks to its primary use in livestock feed and industrial applications. Agronomically, dented corn offers better resistance to pests and diseases, ensuring a reliable supply. Its use in ethanol production reduces competition with the food supply and provides valuable byproducts like animal feed and corn stover for additional bio-based products, enhancing both economic and environmental sustainability.

The modern G1.5 technology in ethanol production combines aspects of both first- and second-generation methods by utilizing the starch and fiber from corn kernels to increase yield and efficiency, offering a more sustainable and cost-effective approach.

India's journey towards energy security and sustainable development has seen the successful implementation of a 10% ethanol blend with petrol, utilizing feedstocks such as molasses, non-edible food grains, and broken rice. The country aims to increase this blend to 20% by 2025-26, a target that offers challenges for adequate feedstock availability, especially with additional demands for Sustainable Aviation Fuel (SAF) and as an alternative cooking fuel to LPG. This paper explores corn ethanol's potential to address these challenges, offering a renewable, clean, and cost-effective solution that enhances energy security, reduces greenhouse gas emissions, and supports socio-economic growth. By adopting corn ethanol, India can emulate the successes of the U.S. and Brazil, achieving significant foreign exchange savings, CO2 emission reductions, and crude oil substitution, aligning with its Paris Agreement commitments.

The aviation industry is under increasing pressure to reduce its carbon footprint, and Sustainable Aviation Turbine Fuel (SATF), or bio jet fuel, derived from sustainable feedstocks like agricultural residues, algae, waste oils, and non-food crops, offers a renewable and lower-carbon alternative to conventional jet fuel. SATF helps mitigate the aviation sector's climate impact, enhances energy security, and promotes environmental conservation by reducing land use change, water consumption, and deforestation. However, SATF faces significant challenges such as scalability, feedstock availability, cost competitiveness, and regulatory support. Overcoming these barriers requires substantial investments in research, development, and infrastructure, along with clear regulatory frameworks at both national and international levels. The EU and UK have set ambitious SAF blending mandates to increase SAF use significantly by 2030, promoting sustainable development and job creation in the sector.

The transition from LPG to bioethanol for household cooking is gaining momentum as a sustainable solution to the challenges of climate change and energy security. Bioethanol, produced from renewable biomass sources such as sugarcane, corn, and cellulosic materials, offers significant environmental and economic benefits. Unlike finite fossil fuels, bioethanol is a renewable resource that can be sustainably grown and replenished, reducing reliance on imported energy and enhancing energy security. The combustion of bioethanol results in lower greenhouse gas emissions compared to LPG, contributing to a reduced carbon footprint and mitigation of climate change. Additionally, innovations in ethanol-compatible stoves and cooktops ensure safe and efficient use, with proper ventilation and adherence to safety guidelines.

In rural India, a transformative "Corn Revolution" is underway, aimed at addressing energy needs and economic challenges through bioethanol production from non-edible corn. This initiative promotes agricultural diversification, job creation, and improved energy access, enhancing the socio-economic development of rural communities. By cultivating high-yielding, pest-resistant corn varieties, farmers achieve better yields and sustainability. The government's support includes technology adoption, extension services, access to quality inputs and credit, infrastructure development, and market interventions to ensure remunerative prices. These efforts empower farmers as innovators and stewards of the land, driving a circular economy that supports energy security, food security, and climate change mitigation, fostering a sustainable and thriving future for rural India.

India has the potential to become a global leader in Sustainable Aviation Fuel (SAF) production by leveraging its abundant agricultural resources and strategic global positioning. The government's focus on promoting high-yield corn cultivation and leveraging existing biofuel infrastructure can transform India into a global SAF export hub. By addressing challenges through targeted policies and fostering an investment-friendly environment, India can lead the global effort to combat climate change and promote sustainable aviation. Additionally, promoting ethanol for other industries and achieving carbon neutrality with bioethanol underscores the strategic benefits of ethanol in fostering sustainable development and economic growth. Comprehensive support to farmers, including financial, educational, infrastructural, and technological assistance, is crucial for building a resilient corn-to-ethanol sector that enhances energy security, economic growth, and environmental sustainability.

Policy tools employed should include

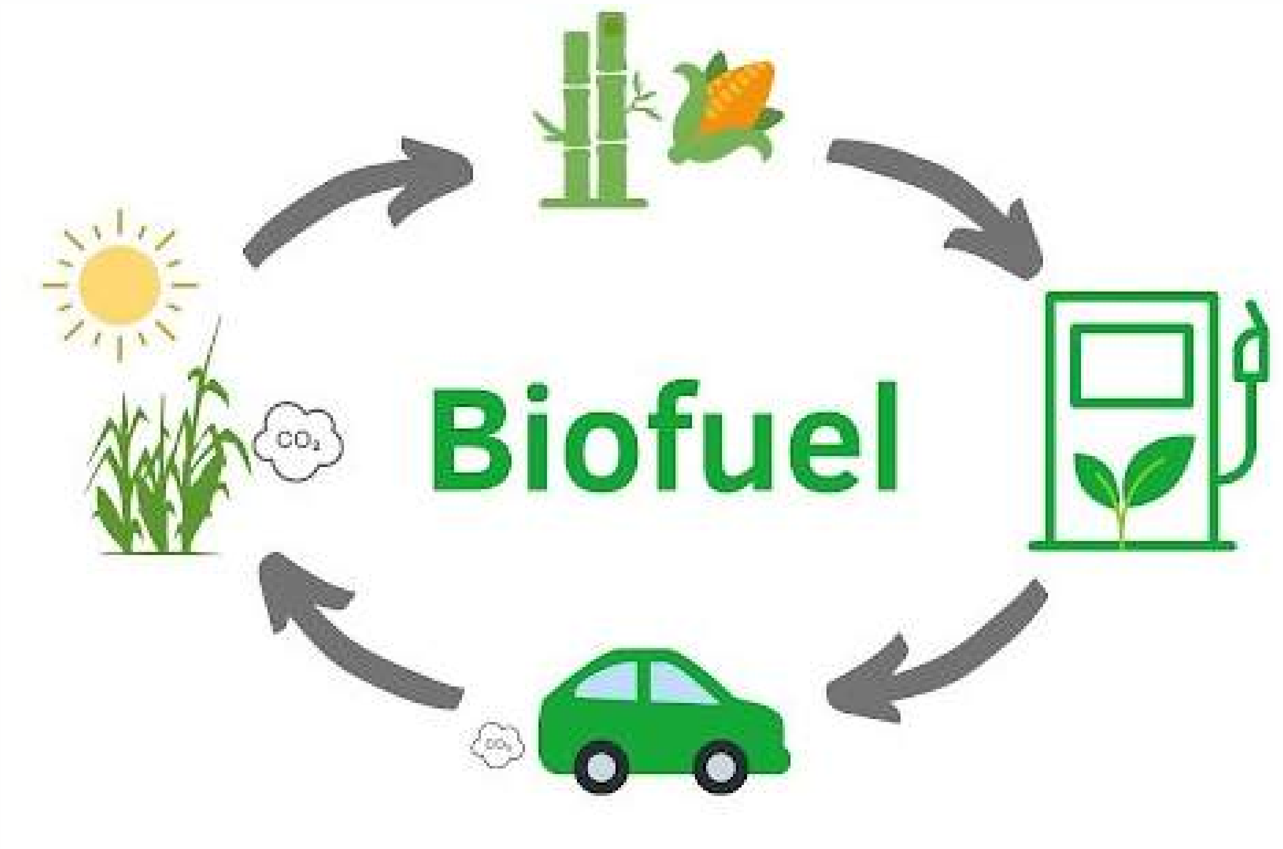
- Excise tax credits for biofuels blending
- Biofuels blending mandates
- Tariffs on imported petroleum / biofuels
- Loan guarantees and grants to support investment in biofuels production
- Grants to support advanced biofuels research and development, and
- Grants to support investment in biofuels retail and distribution infrastructure
- Public service advertising campaigns promoting the benefits of biofuels for climate change mitigation programs.

For the purposes of this book, we will limit our discussion to the elements of these policies which focus on Corn as feedstock.

OVERALL RECOMMENDATIONS

The knowledge book provides a comprehensive overview of dented-corn ethanol and recommendations at the various levels viz. policy and regulations, infrastructure, technology, financial and educational

Here is a one-page summary of the recommendations for quick perusal and the key support pillars needed for India to usher a corn revolution



OVERALL RECOMMENDATIONS

- The Indian government should formulate and implement a comprehensive policy framework and financial support mechanisms to develop the corn-to-ethanol sector, drawing on the successful strategies employed by the United States of America.
- The Govt. of India should put concerted efforts across the multiple fronts to fully unlock the potential of corn ethanol such as increased use in blending and corn (especially non-edible yellow dented corn) cultivation, etc.
- Increase the mandatory blending percentage of corn ethanol in petrol to incentivize demand for corn ethanol and stimulate investment in corn-ethanol production capacity.
- Allow non-edible yellow dented corn imports (with no or concessional duties) for say, 5 years or till the time the required domestic production is achieved, whichever is earlier.
- Provide technical assistance, training, and financial support to farmers to encourage the cultivation of corn ethanol feedstock and ensure fair and remunerative prices for their produce including financial assistance for purchasing high-yield, drought-resistant, and pest-resistant corn seeds (earlier the Punjab Govt. provided financial incentives to farmers to switchover from water guzzling sugarcane / rice to maize crops) and training in advanced corn farming techniques and best practices
- The government should provide financial incentives and subsidies to promote corn-ethanol production, including tax breaks, grants for infrastructure development, and price support mechanisms for corn ethanol producers.
- Research and Development should be undertaken to further develop G1.5 and G2.0 technologies for ethanol production, enhance crop yields, and develop sustainable feedstock supply chains.
- Facilitate market access for corn-ethanol producers by streamlining regulatory processes, reducing bureaucratic hurdles, and promoting public-private partnerships for corn ethanol distribution and marketing.
- Develop and implement certification standards for sustainable corn-ethanol production to ensure environmental integrity and social responsibility across the corn-ethanol value chain.
- Invest in infrastructure development, including corn ethanol biorefineries, storage facilities, and transportation networks to support the expansion of corn ethanol production and distribution capacity.
- Educate farmers on modern agricultural techniques such as soil health management, crop rotation, pest management, and water conservation to help them adopt more efficient and sustainable practices.
- Organize public awareness campaigns to highlight the importance of supporting farmers and sustainable agriculture. Engaging local communities through workshops, demonstrations, and field days to showcase successful farming practices and inspire others to adopt similar methods.
- Utilizing Technology: Digital platforms and mobile applications can bridge the information gap for farmers in remote areas. E-learning modules, online webinars, and mobile advisory services offer accessible and timely information on best practices.
- Involving the Youth: The younger generation is key to the future of agriculture. Integrating agricultural education into school curricula and encouraging youth participation in farming can ensure the continuity of knowledge and innovation. Youth-led initiatives and agribusiness incubators can also drive entrepreneurial ventures, within the agricultural sector.
- Role of Technology Upgradation: Technology upgradation is vital for maintaining competitiveness in a globalized economy. Advances in automation, artificial intelligence (Al), and the Internet of Things (IoT) can streamline manufacturing processes, reduce costs, and improve product quality
- Public-Private Partnerships (PPPs): PPPs are collaborative agreements between the public and private sectors to finance, build, and operate infrastructure projects. These partnerships leverage private sector efficiency and innovation while sharing the risks and benefits. Governments can incentivize PPPs through favourable regulatory frameworks and financial support.
- Promote international Trade Agreements like the setting up of Global Fuel Alliance.

Investing in corn and ethanol production is a strategic move for the nation's future and should be strongly encouraged by the government. This investment not only promises good returns (IRR) but also offers numerous additional benefits, as highlighted throughout this knowledge paper.

DECARBONIZING PATHWAY

India's biofuel roadmap, guided by the National Policy on Biofuels, targets 20% ethanol blending by 2030, with a primary focus on bioethanol production from non-food feedstocks like agricultural residues to ensure food security and manage waste. Financial incentives, including tax exemptions, subsidies, and low-interest loans, specifically support bioethanol production and innovation. These efforts are complemented by schemes such as the Pradhan Mantri JI-VAN Yojana, which promotes advanced bioethanol refineries. Public-private partnerships and international collaborations foster technological advancements and knowledge exchange, while educational campaigns aim to increase public awareness of bioethanol's environmental and economic benefits. This comprehensive approach positions India to enhance energy security, reduce greenhouse gas emissions, and promote rural development through a robust bioethanol sector.

Financial Support

Educational Support

Infrastructure Support

Technology Support

Policy & Regulation Support

FINANCIAL SUPPORT

Financial support in the following forms by the Government of India can play a crucial pillar in India's roadmap towards propelling bioethanol industry

Subsidies and Grants:

Seed Subsidies: Financial assistance for purchasing high-yield, drought-resistant, and pest-resistant corn seeds.

Fertilizer and Pesticide Subsidies: Subsidies to reduce the cost of eco-friendly fertilizers and pesticides.

Equipment Grants: Grants for purchasing modern farming equipment such as tractors, planters, and harvesters.

SAF incentives: The government should provide financial incentives, such as subsidies and tax breaks, to encourage investment in SAF production facilities.

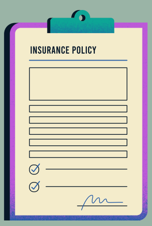
Lowering import tariffs on dented corn can make it more affordable for local businesses. and an attractive option for industries reliant on corn as a raw material.

Low-Interest Loans:

Agricultural Loans: Provision of low-interest loans specifically for corn cultivation and ethanol production infrastructure.

Flexible Repayment Options: Loans with flexible repayment schedules and grace periods to reduce financial pressure on farmers.

Crop Insurance:



Comprehensive Insurance: Insurance policies that cover crop losses due to natural disasters, pests, and diseases.

Affordable Premiums: Subsidized insurance premiums to make policies affordable for small and marginal farmers.

EDUCATIONAL SUPPORT

Educational support in the following forms by the Government of India can play a crucial pillar in India's roadmap towards propelling bioethanol industry

Training Programs:

Modern Farming Techniques: Training on advanced corn farming techniques and best practices

Sustainable Agriculture: Education on sustainable farming methods, soil health management, and water conservation.

Extension Services:

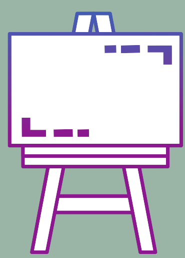
Agricultural Extension Officers: Deployment of extension officers to provide on-ground support and advice.

Demonstration Farms: Establishment of demonstration farms to showcase modern techniques and technologies in bioethanol production.

Knowledge Dissemination:

Workshops and Seminars: Regular workshops and seminars for knowledge sharing and skill enhancement.

Digital Platforms: Development of digital platforms and mobile apps to disseminate information on corn farming, weather forecasts, and market prices.



INFRASTRUCTURE SUPPORT

Infrastructure support in the following forms by the Government of India can play a crucial pillar in India's roadmap towards propelling bioethanol industry

Irrigation Systems:

Micro-Irrigation: Promotion of drip and sprinkler irrigation systems for efficient water use.

Water Harvesting: Development of water harvesting infrastructure to store rainwater for irrigation.

Storage Facilities:

Warehouses and Silos: Construction of modern storage facilities to prevent post-harvest losses.

Cold Storage: Provision of cold storage units for perishable corn products.

Transportation and Roads:

Logistics Network: Development of a robust logistics network for efficient transportation of corn to markets and ethanol production facilities. Existing LPG storage and distribution centers can be adapted to handle ethanol. These centers should be equipped with safety measures to store ethanol, which is more flammable than LPG.

Rural Roads: Improvement of rural road connectivity to ensure easy access to markets and processing units.

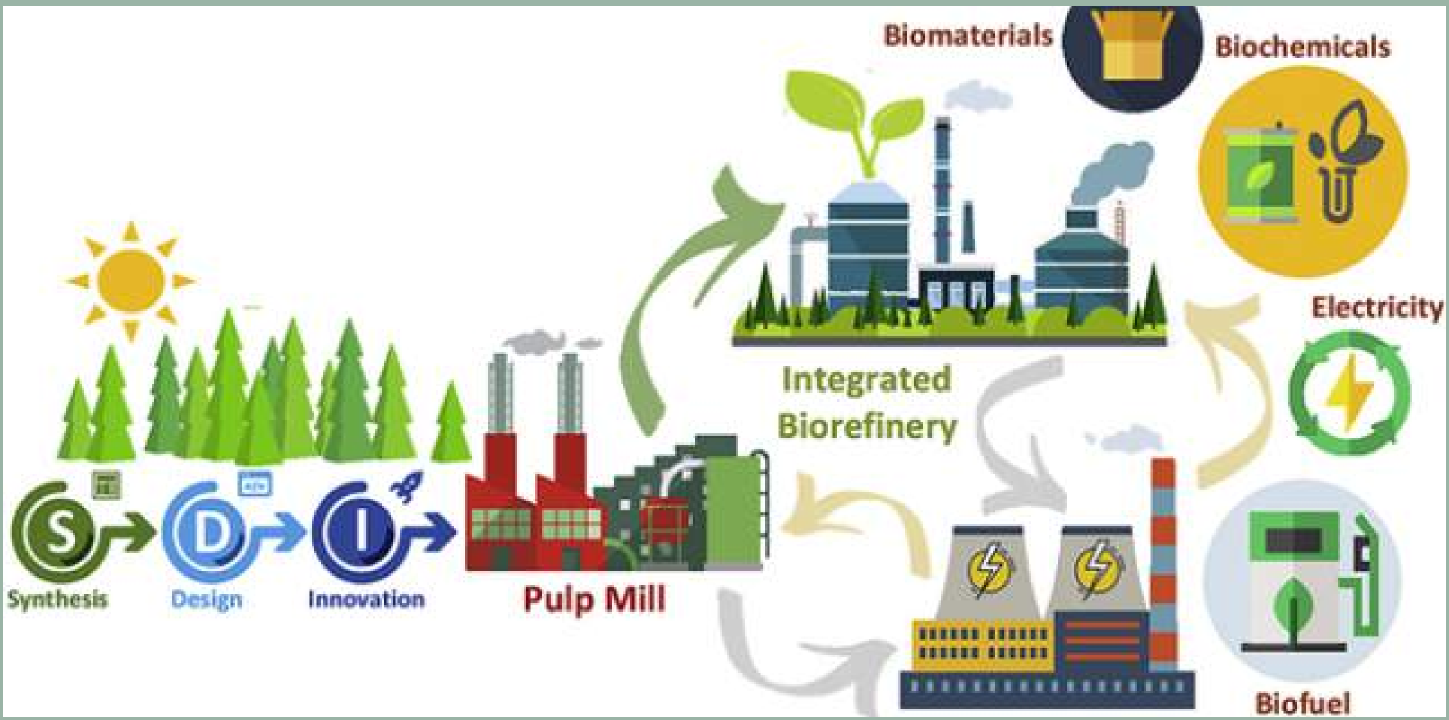
Continue ....

INFRASTRUCTURE SUPPORT

Infrastructure support in the following forms by the Government of India can play a crucial pillar in India's roadmap towards propelling bioethanol industry

State of the art biorefineries:

Establishing new ethanol production plants and upgrading existing bio-refineries are critical. These facilities should be strategically located near agricultural hubs to ensure a steady supply of raw materials like corn, sugarcane, and agricultural residues.



INTEGRATED BIO REFINERY HUB

As part of the infrastructure support, The concept of an integrated Bio-Refinery model or Bio-park is being envisioned by the Govt of India which will encompass integration of the following facilities:

INTEGRATED BIO-REFINERIES

1. 2G Ethanol plant:

Second Generation or 2G ethanol plant can convert agricultural residues like rice straw, wheat straw, energy crops etc. to ethanol. With around 160 MMT of surplus agricultural residues generated in India annually, 2G ethanol plants offer significant opportunity in India. A 100 kl per day plant can utilize 2 lakh tons per annum of agricultural residue to generate around 3 crore liters of ethanol per annum.

2. Grain based 1G Ethanol Plant:

Grain based First Generation or 1G Ethanol Plant can convert the starch present in grains like rice, corn etc. to ethanol. Some by-products like CO2 & Dried Distillers Grains with Solubles (DDGS) are also generated which can generate additional revenue. A 100 kl per day 1G plant is estimated to incur capital expenditure of around `170 to 200 crores

3.CBG Plant:

Compressed Bio Gas (CBG) or Bio-CNG can be produced from agricultural residue, Municipal Solid Waste (MSW), cow dung etc. CBG can easily replace CNG. The bio-manure produced in the plant is an additional source of revenue. The estimated capital expenditure for a 15 tons per day CBG plant is around Rs.60-100 crores, depending on the feedstock and the land requirement of approx. 15 acres.

4. Production of Chemicals:

Production of bio-chemicals in the Bio-refinery will improve its economics significantly. Some technologies for production of bio-chemicals are ready for commercialization while many are still in development stage.

5. Cogeneration Plant:

Setting up of a Cogen plant by using Lignin (generated in 2G plant) & Biogas (CBG plant) can ensure continuous & reliable power supply to the Bio-Refinery.

Technology solutions such as Ethanol compatible stoves can be a gamechanger for ethanol adoption in India. For this, the Indian households, the government and private sector must work together to ensure a steady supply of ethanol fuel, provide subsidies or financial incentives to make the stoves affordable, and conduct extensive awareness campaigns

ETHANOL-COMPATIBLE STOVES

CleanCook Stove

The CleanCook stove, developed by Project Gaia, is a well-known example of an ethanol-compatible stove. It is designed to use liquid ethanol fuel and offers a clean, efficient, and safe cooking experience. The stove has been successfully implemented in several countries in Africa and Latin America, providing a viable model for India. Its high-efficiency burners minimize fuel consumption and reduce emissions, making it an ideal solution for rural and urban households.

8 Kgs **Wood saved per day by using an ethanol stove on 1L of ethanol**

TECHNOLOGY SUPPORT

Technology support in the following forms by the Government of India can play a crucial pillar in India's roadmap towards propelling bioethanol industry

Research and Development:

Seed Development: Investment in R&D for high-yield, drought-resistant, and pest- resistant corn varieties.

Farming Technologies: Support for the development of new farming technologies and techniques.

Precision Agriculture:

Remote Sensing and Drones: Promotion of remote sensing technologies and drones for crop monitoring and management.

Soil Health Management: Provision of tools and technologies for real-time soil health assessment and management.

Ethanol Production:

Production Technologies: Investment in research for efficient and cost-effective ethanol production technologies.

Processing Units: Establishment of decentralized ethanol production units to reduce transportation costs and ensure a steady supply chain.

POLICY & REGULATION SUPPORT

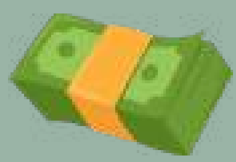
Policy and Regulation support in the following forms by the Government of India can play a crucial pillar in India's roadmap towards propelling bioethanol industry

Ethanol Blending Mandate:

Blending Targets: Setting clear time bound targets for ethanol blending in petrol to create a consistent demand for ethanol. Additionally , Establishing mandatory SAF blending targets for the aviation industry can drive demand and provide market s tability for producers

Compliance Monitoring: Implementation of robust monitoring mechanisms to ensure compliance with blending mandates.

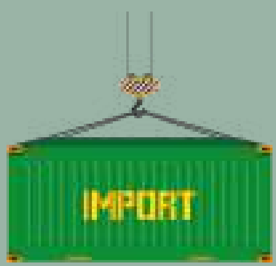
Market Linkages and MSP:



Minimum Support Price (MSP): Ensuring a fair and stable MSP for corn to protect farmers against market volatility.

Direct Market Linkages: Facilitating direct linkages between farmers and ethanol producers to eliminate intermediaries and ensure fair prices.

Import-Export Policies:



Protective Tariffs: Adjustment of import tariffs to protect domestic corn producers from international competition.

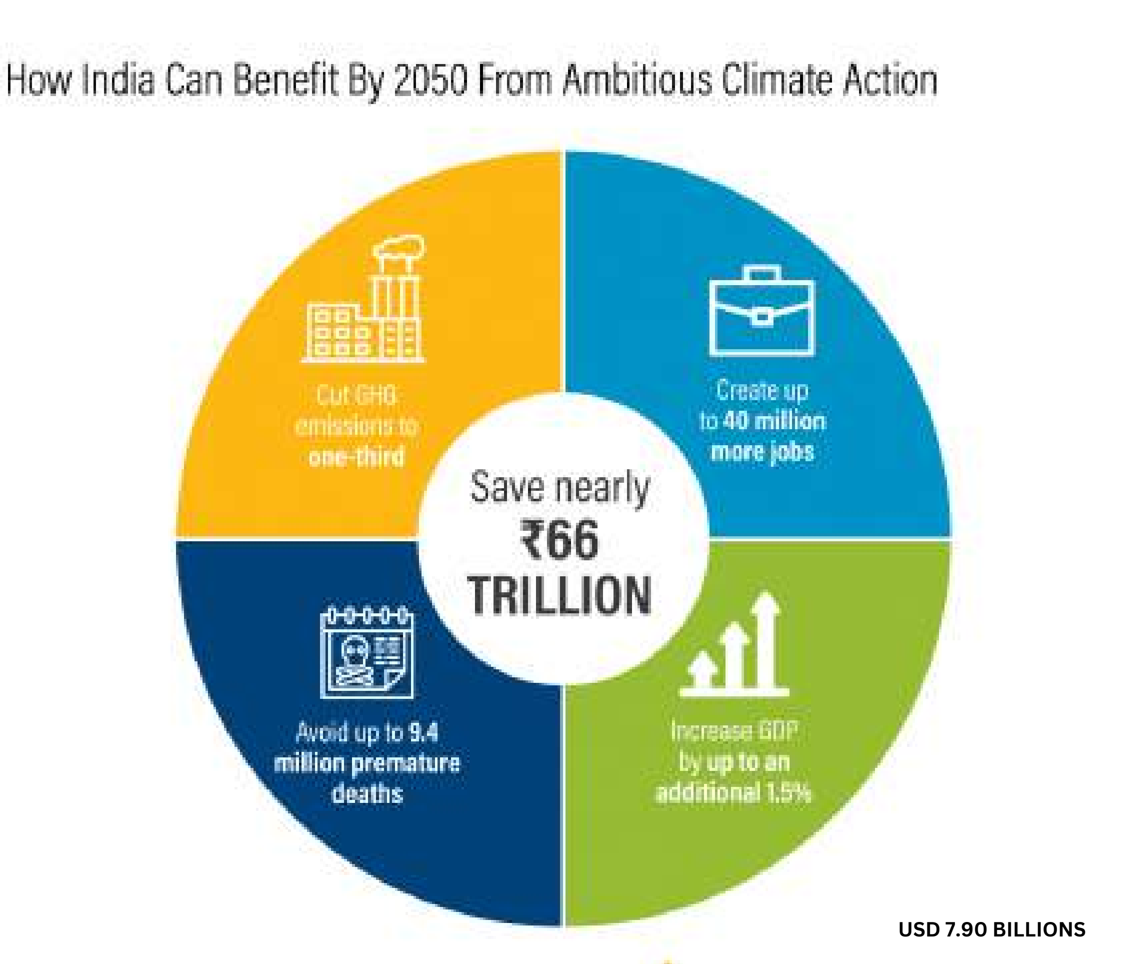
Export Incentives: Provision of incentives for exporting surplus corn to stabilize domestic prices.

POLICY & REGULATION SUPPORT

Policy and Regulation support in the following forms by the Government of India can play a crucial pillar in India's roadmap towards propelling bioethanol industry

GHG Mandates

India's commitment to international climate goals and its participation in initiatives like the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) necessitate the adoption of cleaner fuels. SAF, produced domestically, can play a crucial role in helping the industry meet these environmental targets.



1 INTRODUCTION

An Overview

INTRODUCTION

India's quest to meet its soaring energy demands and cut carbon emissions is steering the nation towards biofuels, with ethanol emerging as a pivotal player. Corn, a critical feedstock for ethanol, stands at the forefront of this transition. With the government's ambitious goal to hit a 20% ethanol blend by 2025, the spotlight is shifting to corn. Diversifying ethanol sources isn't just about meeting targets; it's about bolstering energy security, promoting agricultural diversification, and slashing the environmental toll of fossil fuels - which is the focus of the 4th ICS summit

This promising path is fraught with challenges—balancing food security, managing water resources, and building robust supply chains are critical hurdles that must be overcome.

With an annual corn production of approximately 30 million metric tons, India is well-positioned to embrace this shift, provided these issues are deftly navigated. The future of corn and ethanol in India's energy matrix is not just a matter of policy but a crucial step towards a sustainable, self-reliant energy future.

A BRIEF HISTORY OF ETHANOL

The first reported fermentation of sugars to ethanol dates back 13,000 years. In spite of being produced for thousands of years, ethanol was not isolated from wine until the 1100's. In the 1800's, a mixture of turpentine and alcohol was a popular lamp-lighting fuel. In the same century ethanol found its use as an engine fuel.

From its beginning 13,000 years ago through the present day, ethanol has been and continues to be produced by fermentation of sugars. While technology has improved significantly, producing higher yield at lower cost, the process generally uses yeasts to convert sugar into ethanol. The sugars can either be present in the feedstock, such as with sugar cane, sugar beets and sweet sorghum, or by enzymatic hydrolysis of starch, such as with non-food biomass corn, wheat, cassava, sorghum, and rice. More recently cellulosic biomass can be converted to sugars through the combined use of pre-treatment and enzyme.

New technology is available to convert industrial waste gases from refineries, steel plants and power plants into ethanol.
Synthetic ethanol can also be produced by reacting water with ethylene. This was a leading source of ethanol for non- food purposes, prior to the growth of production via fermentation, which was spurred by demand for fuel blending. Today, many synthetic ethanol plants are no longer operating. Today ethanol has found its way into a range of applications from its original application as beverage (wine and beer) to use as a fuel, a chemical solvent, a disinfectant (hand sanitizer), pharmaceuticals, cleaning, production of renewable hydrogen, cosmetics, perfumes, and as a feedstock for the production of chemicals.

The first report use of ethanol as an engine fuel was in 1826 by Samuel Morey developed an engine that ran on ethanol and turpentine and its first use to fuel an internal combustion engine was in 1876 by Nicolaus Otto, the inventor of the modern four-cycle internal combustion engine. In 1896, Henry Ford built his first automobile that ran on pure ethanol.

The blending of ethanol into gasoline got its foothold in both the United States and Brazil, and both countries are no longer net importers of crude oil. In Brazil E100 sells for a lower price than gasoline and in the United States, both E15 and E85 sell for less than E10 and both have a higher-octane number than E10. (E10 is the conventional gasoline sold in the United States) . In the United States, the blending of ethanol into gasoline for use as an automotive fuel began in the 1970's due to the high petroleum prices and growing health and environmental concerns over the use of lead in gasoline created a need for a new source of "octane". The value of ethanol as a "fuel oxygenate" to control carbon monoxide emissions was recognized, which resulted in increased production in the 1980's and the 1990's.In 2005, the Renewable Fuels Standard law (RFS) drove significant growth in ethanol.

A second round of rapid growth of ethanol fuel blending began with the Energy Independence and Security Act of 2007, also known as RFS-2.


Try! CORN
ALCOHOL
GASOLINE
10% BLEND
CORN
ALCOHOL
BLEND

Ethanol production in Brazil began in 1933 as a way to overcome excess sugar cane production. In the early 1970's, as the result of the First (Global) Oil Crisis Brazil enacted the Proálcool plan to reduce its dependence on foreign fossil fuels by blending petrol with ethanol.

Ethanol burns cleaner than Gasoline and is currently blended into fuel in many countries around the globe, including India. India started blending ethanol in a pilot program in 2001.In the U.S. the majority of gasoline sold today has a minimum of 10% ethanol, E10. Today in Brazil all gasoline has a mandatory ethanol blend requirement of 27% (soon to be 30%). Cars in Brazil can switch between any gasoline-ethanol blend up to 100% ethanol.

Blending ethanol into fuel produces a range of benefits. By displacing hydrocarbons like aromatics in gasoline, ethanol reduces toxic air emissions, particulate matter PM2.5, carbon monoxide, nitrous oxides, and exhaust hydrocarbons. In many countries, including India, using domestically produced ethanol will reduce the imports of the price volatile crude oil. In addition, producing ethanol from corn produces low-cost protein in the form of DDGS. In general, the cost per unit of protein in DDGS is only 30% of the cost per unit of protein in the grain itself. Lastly, production of ethanol creates jobs in the agricultural and other sectors of the economy. Ethanol provides the foundation for decarbonization of a large portion of the chemicals industry.

The benefits obtained by blending ethanol in fuel are even greater by using E100, 100% ethanol, as an automotive fuel.

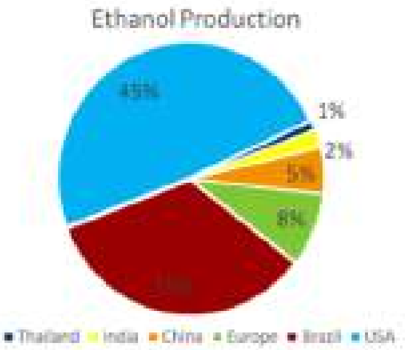
All of the previously stated benefits of blending ethanol would be multiplied several times over by using E100. The history of the use of E100 in Brazil has proven that E100 is an effective and cost-efficient fuel.

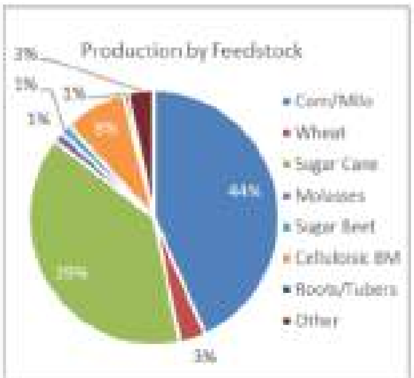
As demonstrated in Brazil, E100 can be used with some design modifications to the engine to account for the higher oxygen content in the fuel and the slightly higher volume of fuel that must be supplied to the engine. An engine that is properly modified to capitalize on the higher octane of E100, can deliver high power and good milage. E100 is a clean burning fuel that does not add any net CO2 to the atmosphere as it is effectively recycling the CO2 present in the atmosphere.

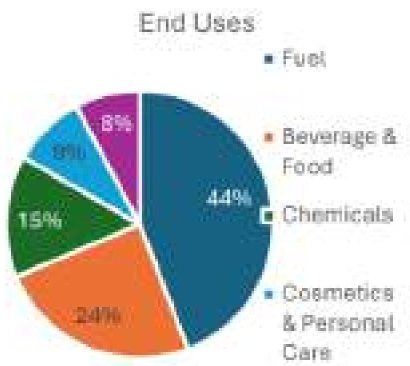
Use of clean burning E100 will reduce pollution, including OM 2.5 particulates that choke the lungs of children living in India's cities. Switching to E100 will be faster and easier than switching to both hydrogen fuelled vehicles and EVs. The main reason is that the current gasoline supply chain and infrastructure can be used for E100. Brazil serves as good example as the path to making E100 available in India. However, it will not happen on its own. Making E100 available will only happen if driven by government regulations and enforcement of such. India needs to require that all cars sold beginning in 2030 be capable of running on E100.

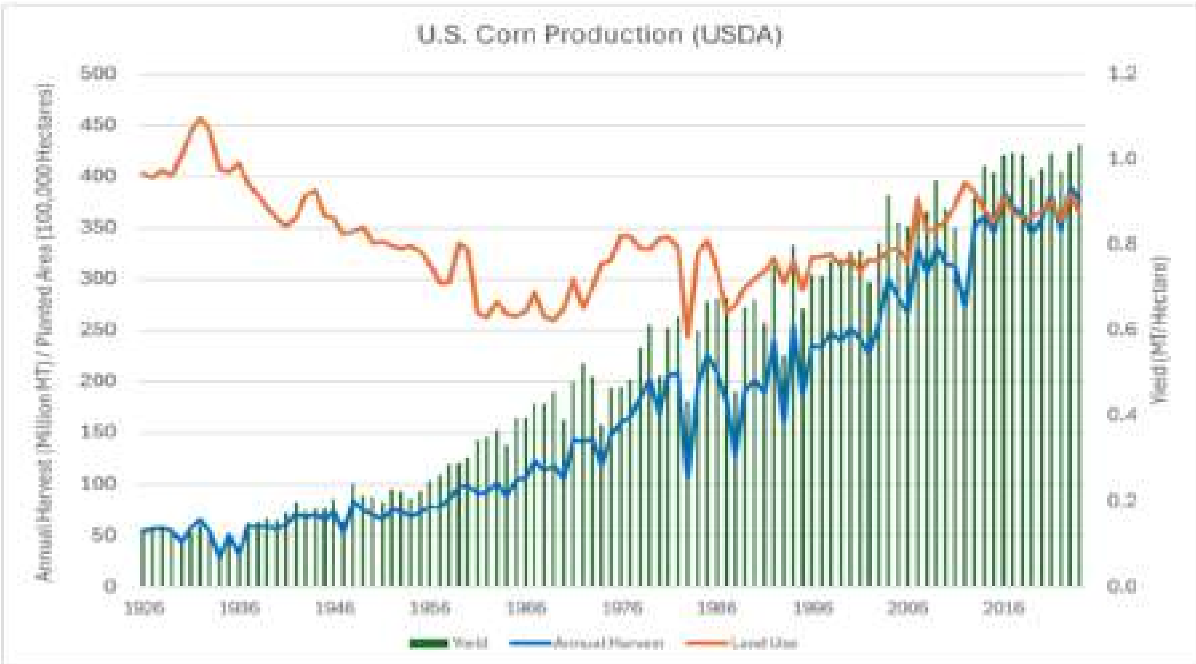
KEY METRICS OF GLOBAL ETHANOL IMPACT

Global Ethanol Production 2023	112 Billion Litres
Average Ethanol Plan Capacity in the USA	1,100 KLPD
Average Ethanol Plant Capacity in India	130 KLPD









Ethanol as Clean Renewable Cooking Fuel:

In many area of the world, traditional biomass fuels like wood, charcoal, dung, crop residues are used for cooking. These fuels generate harmful smoke particles, especially when used indoors. The World Health Organization estimates that approximately 3.2 million persons (2021 data) annually die prematurely due to health conditions that arise from exposure to indoor air pollutants from traditional fuels. Ethanol is a proven alternative to these fuels. Ethanol is an effective clean burning cooking fuel that reduces emissions of carbon monoxide, particulate matter, and other pollutants. Ethanol is safer and easier to use, store and transport than biomass fuels. It does not produce smoke, sparks, or ash, and does not require chopping or drying of wood or charcoal. Bioethanol is one of the cooking fuels considered to be clean based on the 2014 WHO guidelines.

Ethanol is the Foundation for Sustainable Aviation Fuel

The aviation sector creates 13.9% of the emissions from transport, making it the second largest source of transport GHG emissions. Through both government regulations and voluntary commitment, the sector has set ambitious goals to reduce its GHG emissions. The use of growing proportions of sustainable aviation fuel (SAF) is absolutely required to meet the targets. According to some estimates the global annual demand for SAF is expected to exceed 18 billion litres by 2030.

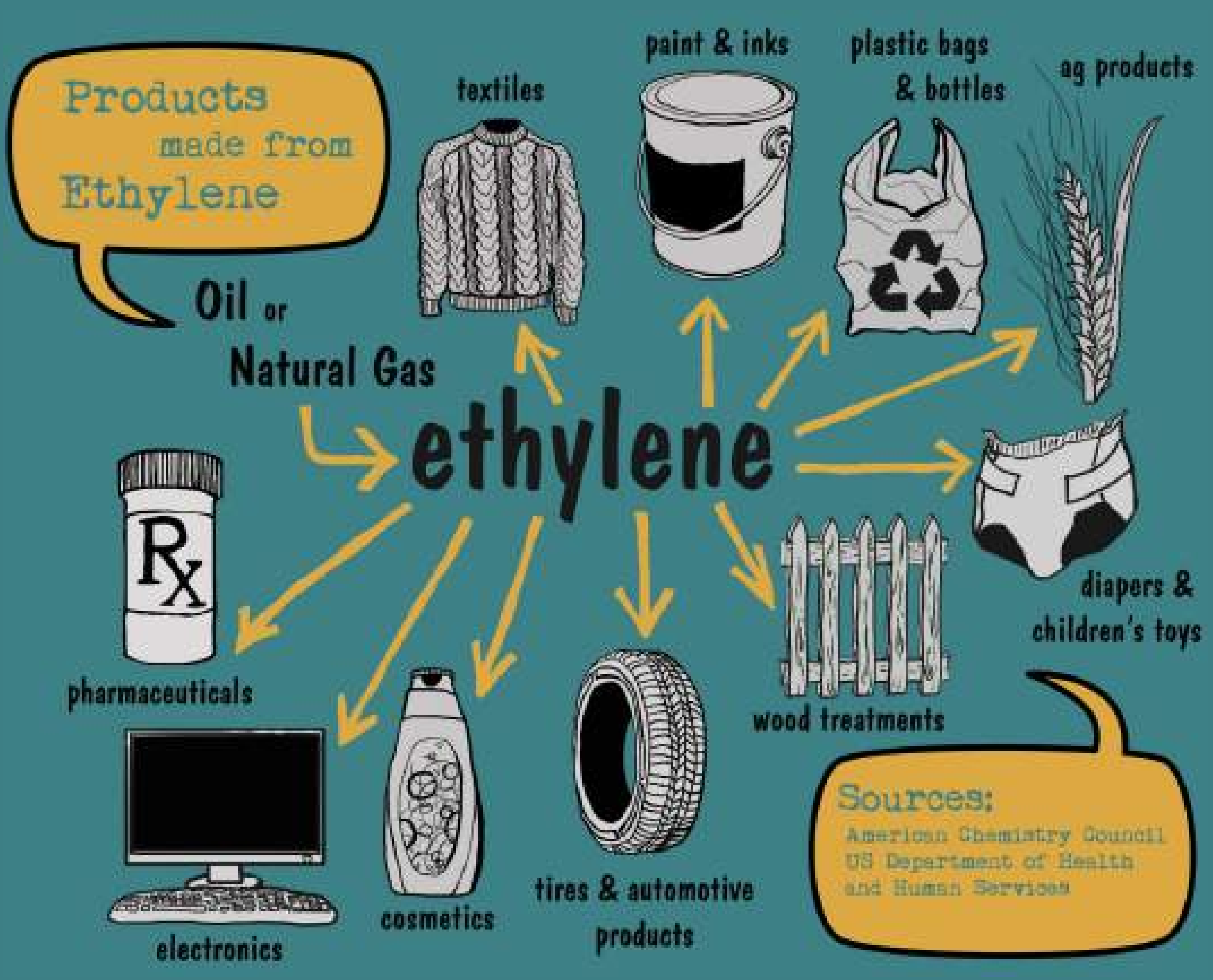
Over the past 10,000-plus years, ethanol has become a molecule whose true value and growing versatility have only been demonstrated over the past few decades. The versatility of ethanol is like that of crude oil, except for some significant and important differences. Ethanol is sustainable, renewable, and does not depend on imports from volatile areas of the world. Ethanol can be used to produce vehicles and jet fuels, along with a range of value-added chemicals and polymers. Ethanol must be a foundational component of India's drive to reduce its GHG emissions with the need to develop new technologies.

Leading the Way for Chemical Industry Decarbonization

When it comes to producing chemicals, ethanol is foundation chemical for producing a range of renewable chemicals having low carbon intensities. Just as petroleum can be used to produce ethylene from which a range of many important chemicals and polymers are produced, ethanol can be used to produce ethylene in world-scale plants.

Ethylene is the heart of today's trillion-dollar global petrochemicals market. Petron Scientech technology for the conversion of ethanol to ethylene has been in commercial use for over thirty years and provides very efficient energy utilization, low CAPEX, and low OPEX while offering a low carbon intensity.

ETHANOL TO ETHYLENE



As a general rule-of-thumb, each metric ton of ethanol produced from ethanol saves three metric tons of GHG emissions. The ethylene produced from ethanol is a drop-in replacement for petrochemical ethylene with no changes to the downstream process being required. Just as with petroleum-based ethylene, renewable ethylene from ethanol can be used to produce wide range of green sustainable chemicals and polymers, making them wholly or partially renewable.

Some examples are:

Ethylene oxide: used to produce surfactants, household cleaners, personal care items, and as sterilant for medical items.
Ethylene glycols: used for automotive engine coolants, polyester fibres, PET beverage bottles and other packaging, brake fluids, inks, solvents, paints, and cosmetics.
Propylene and butanes: used as comonomers to produce polymers.

Polyethylene: as the largest volume polymer produced globally, polyethene is used in many applications that include packaging film, bottles, bags, wire/cable insulation, agricultural mulch, toys, juice and milk containers, crates, and food packaging and housewares.

PET (polyethylene terephthalate): 30% renewable PET can be produced using renewable ethylene glycol for use in bottles for carbonated soft drinks, water, food packaging, bottles for personal care and household items

PVC (polyvinyl chloride): building and construction materials, health care, electronics, automotive, and other industries, including piping and building siding, blood bags and tubing, wire and cable insulation, windshield system components to name a few.

Ethylbenzene, Styrene and polystyrene: for use in industrial applications and in beverage cups. Renewable ethylene can also be used as a refrigerant and as a ripening agent for fruits and vegetables.

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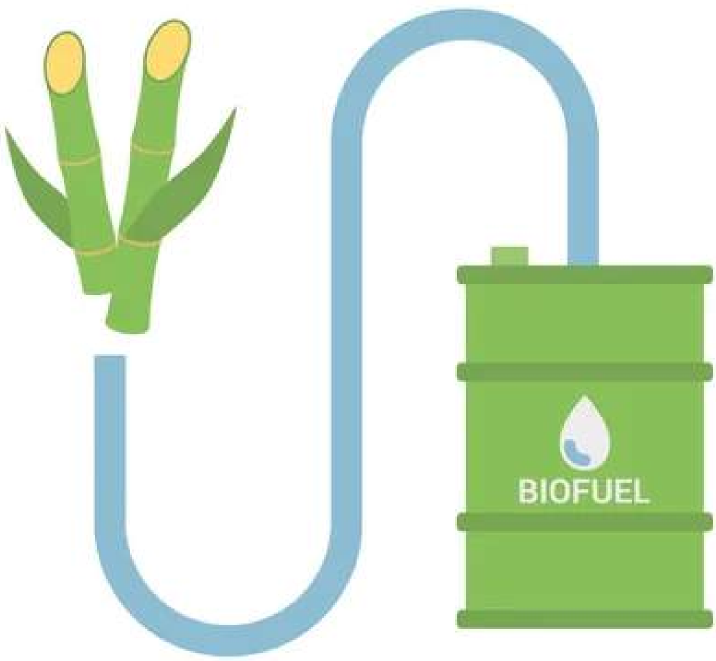
2 BIO-ETHANOL

2.1 WHAT IS BIO-ETHANOL ?

Bioethanol is a renewable biofuel made from fermenting sugars found in crops like corn, sugarcane, and wheat. It serves as an alternative to gasoline, reducing greenhouse gas emissions and pollutants. Produced domestically, bioethanol enhances energy independence and stimulates rural economies by creating jobs and additional revenue for farmers.

Commonly blended with gasoline to form E10 or E85 fuels, bioethanol supports a move towards a sustainable energy future. Despite its benefits, sustainability concerns like land use and water consumption are being addressed through technological advancements and the use of non-food crops.



2.2 STRATEGIC SIGNIFICANCE TO INDIA

India stands at a critical juncture in its quest for energy security and sustainable development. The country's growing energy demand, coupled with concerns over environmental degradation and climate change, necessitates a transition towards cleaner and more sustainable energy sources.

India's biofuel initiatives have been successful in achieving a 10% ethanol blend with petrol (E10). Additionally, molasses from sugar factories has served as adequate feedstock for ethanol, supplemented by non-edible food grains and broken rice. However, increasing ethanol to 20% (E20) is likely to face an acute shortage of feedstock. Furthermore, ethanol will be needed for the production of Sustainable Aviation Fuel and alcohol could potentially replace LPG for cooking. Look at the yield of 450 litre of ethanol per million kilo of rice. This is unsustainable. There is a considerable momentum for corn-based ethanol in the US and sugar-based ethanol in Brazil.

Energy Security and increased farming and reduction in green house gases are compelling reasons to go for alternate feedstock, such as dented corn, for ethanol production.

Corn Ethanol, derived primarily from agricultural feedstock such as sugarcane, corn, and dented corn, offers a viable solution to these pressing challenges. This paper aims to explore the potential of corn ethanol to transform India's energy landscape, mitigate environmental degradation, and stimulate socio-economic growth.

Corn Ethanol is hailed as a renewable, clean, and cost-effective alternative to traditional fuels like gasoline and cooking LPG, holds immense potential for India. Its utilization not only bolsters energy security but also aligns with decarbonisation efforts, crucial in combating the looming specter of climate change.

The strategic blending of corn ethanol with petrol not only enhances combustion efficiency but also curtails harmful emissions, thereby mitigating the adverse impacts of vehicular pollution—a pressing concern in India's urban centers. Moreover, the substitution of ethanol for LPG presents a revolutionary shift, mitigating risks associated with single-fuel dependency ethanol offers advantages over using LPG heavy cylinders with reduction in substantive cost associated with maintaining infrastructure for LPG. Uses ethanol emerges as a competing alternative with other fossil fuels with least pollution.

78,118 INR Cr

Foreign Exchange Savings in the last decade for India (9350 Mn USD)

426L MT

Reduction in the CO2 emissions in the last decade in India

30%

Forecast growth in global biofuels demand from 2023-2028

38 Billions L

Forecast volume for Biofuels needed in the world in 2028

2.3 GLOBAL COMMODITY

The global precedence set by leading corn ethanol producers such as the United States and Brazil serves as a beacon of inspiration for India.

Globally, corn stands as a pivotal agricultural commodity, with production surpassing one billion metric tons annually. In this vast market, the United States, China and Brazil dominate, contributing significantly to both global supplies and the dynamics of international trade. While not among the top producers, India has shown remarkable growth in corn production, aimed both at domestic consumption and export markets.

2.4 BENEFITS OF ETHANOL

Ethanol, a versatile and sustainable biofuel, holds immense potential beyond its use as a fuel. It can serve as a crucial raw material in the chemical and petrochemical industries, offering a sustainable alternative to traditional feedstocks derived from crude oil. As India looks to diversify its industrial base and reduce dependence on imported oil, leveraging ethanol for chemical production presents a strategic opportunity.

Raw materials for other industries

Ethylene Production: Ethanol can be dehydrated to produce ethylene, a fundamental raw material for the manufacture of a variety of polymers and chemicals, including polyethylene, ethylene oxide, and ethylene glycol. Ethylene is a critical component in the production of plastics, detergents, and antifreeze.

Acetaldehyde and Acetic Acid: Ethanol can be oxidized to produce acetaldehyde, which is further processed to produce acetic acid. Acetic acid is a key raw material for producing vinyl acetate monomer (VAM), used in paints, adhesives, and coatings.

Ethyl Acetate: Ethanol reacts with acetic acid to produce ethyl acetate, a solvent widely used in the production of paints, varnishes, adhesives, and cleaning fluids.

Butadiene and Synthetic Rubber: Ethanol can be converted into butadiene, an essential component in the production of synthetic rubber. Synthetic rubber is used in various applications, including tires, footwear, and industrial products.

Strategic and Economic Benefits

Import Substitution: Utilizing ethanol as a feedstock for the chemical and petrochemical industries can reduce India's dependence on imported crude oil and petrochemical intermediates. This can lead to significant savings in foreign exchange and enhance energy security.

Value Addition: Transforming ethanol into higher-value chemical products can create substantial economic value. This value addition can spur industrial growth, create jobs, and generate revenue for both the public and private sectors.

Rural Development: Increased demand for ethanol can stimulate agricultural production, providing farmers with additional revenue streams and promoting rural development. This can help reduce rural-urban migration and support sustainable agricultural practices.

Environmental Impact

Reduced Carbon Footprint: Ethanol, derived from renewable resources, has a lower carbon footprint compared to petrochemical feedstocks. Its use in the chemical industry can help reduce greenhouse gas emissions and contribute to global climate goals.

Waste Utilization: Ethanol production can make use of agricultural residues and waste materials apart from Corn, promoting a circular economy.

BENEFITS OF CORN ETHANOL

Developing the corn to ethanol sector in India is a strategic initiative that supports the country's NDCs under the Paris Agreement. By reducing GHG emissions, enhancing energy security, and promoting sustainable development, the sector presents a comprehensive solution to address climate change challenges while fostering economic growth.

India' NDC targets

Developing the corn to ethanol sector offers a viable solution to meet India's commitment to the Paris Agreement, supplementing India's Nationally Determined Contributions (NDCs) while driving economic growth and energy security.

GHG Emission Reduction

By promoting the use of ethanol-blended fuels, India can significantly reduce its transportation sector's carbon footprint, aligning with its NDC commitment to lower GHG emissions intensity by 33-35% by 2030 from 2005 levels.

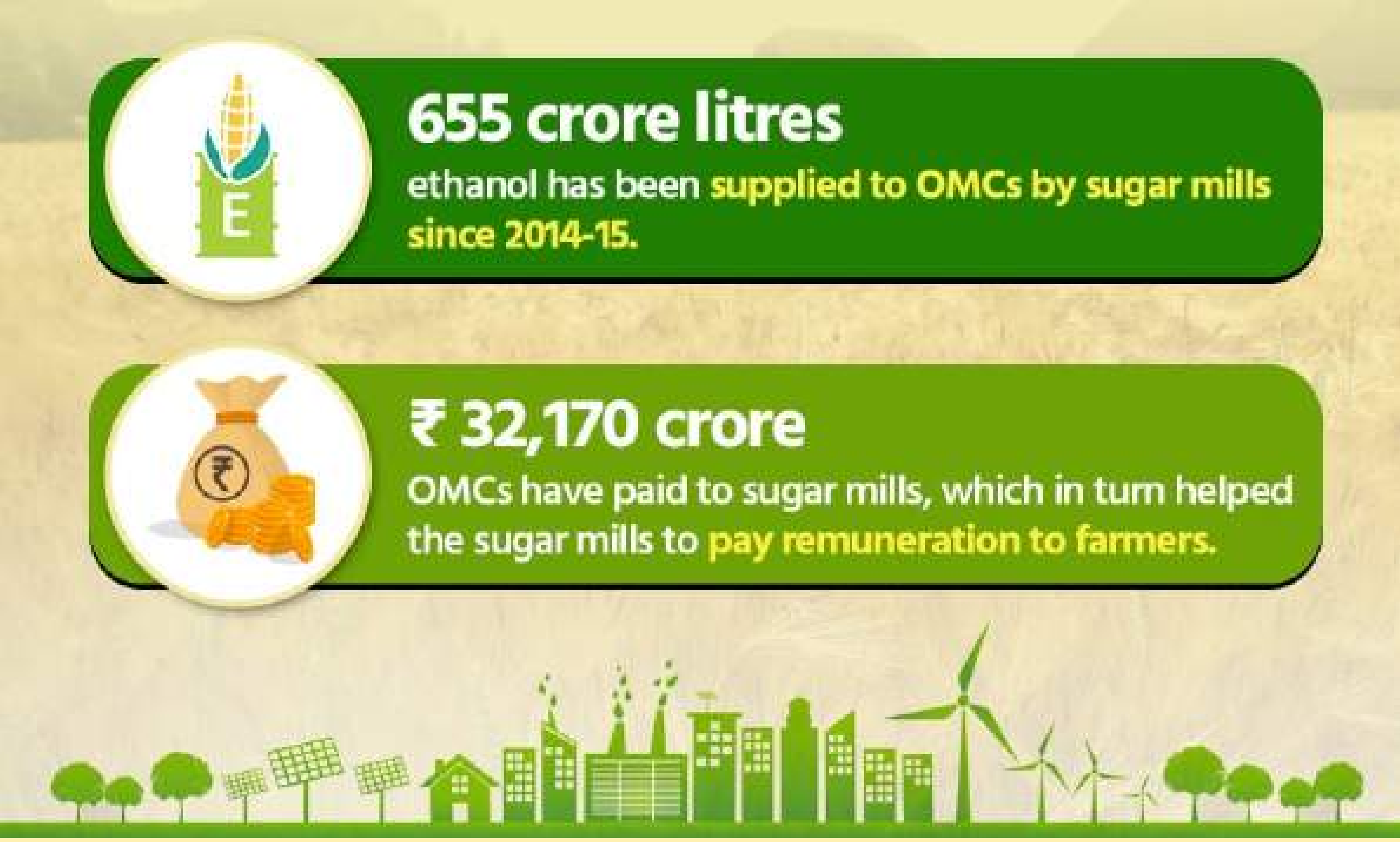
Renewable Feedstock Utilization

Ethanol production from corn and other agricultural residues utilizes renewable biomass. This contrasts with the extraction and burning of non-renewable fossil fuels, contributing to a sustainable energy cycle and further reducing net carbon emissions.

Energy Security and Employment

Ethanol production reduces India's dependence on imported crude oil, enhancing national energy security. It stimulates rural economies by providing farmers with additional revenue streams and creating employment opportunities. This in turn addresses poverty and enhances living standards in rural areas.

ETHANOL BLENDED PETROL



An Overview

2.5 GOVT'S ETHANOL –GASOLINE BLENDING PROGRAM

In recent years, the global conversation surrounding energy has shifted dramatically towards sustainability and environmental responsibility. As a result, the quest for alternative fuel sources has gained momentum, with a particular focus on reducing carbon emissions and dependence on fossil fuels.

In this pursuit, blending programmes like E-20 and E-30 have emerged as promising solutions, offering a pathway towards a greener, more sustainable future. The transportation sector is a significant contributor to greenhouse gas emissions and air pollution, primarily due to the combustion of gasoline and diesel fuels in vehicles.

In India, where rapid urbanization and industrialization are driving increased demand for energy, the need to curb emissions and reduce reliance on imported fossil fuels has never been more urgent. Traditional gasoline contains high levels of toxic compounds such as benzene, toluene, and xylene, which pose serious health risks and contribute to environmental degradation. Moreover, the extraction and refining of crude oil for gasoline production are associated with environmental pollution, habitat destruction, and geopolitical tensions.E-20 and E-30 blending programmes offer a compelling alternative to traditional gasoline by incorporating ethanol—a renewable, bio-based fuel derived from agricultural feedstocks such as sugarcane, corn, or biomass—into gasoline blends.

E20: GASOLINE BLENDED WITH 20% ETHANOL

E30: GASOLINE BLENDED WITH 30% ETHANOL

ADVANTAGES OF ETHANOL BLENDING

E-20 and E-30 blending programmes offer a compelling alternative to traditional gasoline by incorporating ethanol—a renewable, bio-based fuel derived from agricultural feedstocks such as sugarcane, corn, or biomass—into gasoline blends. This leads to significant concomitant advantages

01 — Reduced Emissions

Ethanol burns cleaner than gasoline, emitting fewer harmful pollutants such as carbon monoxide, particulate matter, and volatile organic compounds. As a result, vehicles running on ethanol blends produce lower levels of greenhouse gases and contribute less to air pollution and climate change

02 — Renewable Resource

Ethanol is produced from renewable biomass sources, making it a sustainable alternative to finite fossil fuels. By promoting the use of ethanol blends, countries can reduce their dependence on imported oil and support domestic agriculture and biofuel industries.

03 — Improved Engine Performance

Ethanol has a higher octane rating than gasoline, which enhances engine performance and reduces engine knock and pinging. Vehicles running on ethanol blends often experience smoother operation and improved acceleration.

Continue ....

04 — Economic Benefits

Blending ethanol with gasoline creates new markets for agricultural producers and biofuel manufacturers, stimulating rural economies and creating jobs in farming, processing, and distribution sectors. Additionally, ethanol blending can help stabilize fuel prices by diversifying energy sources and reducing price volatility associated with crude oil markets.

05 — Environmental Protection

Ethanol production from biomass feedstocks offers environmental benefits such as carbon sequestration, soil conservation, and reduced water consumption compared to conventional fossil fuel extraction and refining processes.

CHALLENGES OF ETHANOL BLENDING

While E-20 and E-30 blending programmes offer significant advantages, their widespread adoption faces several challenges and considerations:

Infrastructure Compatibility

Ethanol blends require compatible fuelling infrastructure, including storage tanks, dispensers, and pipelines. Retrofitting existing infrastructure or building new facilities can be costly and time-consuming, presenting a barrier to adoption.

Feedstock Availability

The availability and cost of feedstocks for ethanol production can vary depending on agricultural productivity, land use policies, and competing demands for food and feed. Ensuring a sustainable and reliable supply of feedstocks is essential for ethanol

Engine Compatibility

While most modern vehicles are designed to accommodate ethanol blends up to E-20, higher ethanol concentrations may require engine modifications or upgrades to ensure compatibility and performance.

Policy Support

The success of ethanol blending programmes depends on supportive policy frameworks, including incentives, mandates, and regulatory standards, research and development, and implementation of blending targets

WHERE INDIA STANDS TODAY

As of today, India has made significant strides in both ethanol production and consumption, driven by various policy initiatives, technological advancements, and growing awareness of the need for sustainable energy sources.

India is one of the world's largest producers of **sugarcane-based** ethanol. The country's sugar industry, which produces ethanol as a byproduct of sugarcane processing, has been a key contributor to ethanol production.
States like Uttar Pradesh, Maharashtra, Karnataka, and Tamil Nadu are among the leading producers of sugarcane ethanol.

In addition to sugarcane, **molasses**, a byproduct of sugar production, is another significant feedstock for ethanol production in India. Distilleries across the country utilize molasses to produce ethanol, contributing to the country's overall ethanol output.

India has also been exploring the production of cellulosic ethanol from agricultural residues, such as **rice and wheat straw**, as well as non-food **biomass sources** like switchgrass and bamboo. While still in the early stages, research and pilot projects are underway to commercialize cellulosic ethanol production technologies.

India has implemented ethanol blending mandates to promote the use of ethanol-gasoline blends as automotive fuels. The government has set targets for blending ethanol with petrol, with the aim of reducing fossil fuel consumption, cutting emissions, and promoting energy security. The current blending target is 10% (E10) across various states, with plans to increase it further.

- **Automotive Sector:** The automotive sector plays a crucial role in ethanol consumption, as vehicles compatible with ethanol-gasoline blends are increasingly prevalent in the Indian market. Flex-fuel vehicles capable of running on various ethanol blends are gaining popularity, while manufacturers are also producing vehicles optimized for higher ethanol blends like E20 and E85.

- **Cooking Fuel:** Ethanol is being explored as a cleaner alternative to traditional cooking fuels such as liquefied petroleum gas (LPG) and kerosene. Bioethanol stoves and clean cooking solutions are being promoted in rural areas to improve indoor air quality, reduce health risks, and provide affordable cooking options.

PROGRESS IN EBP PROGRAM

DEC 2014
Govt. Re-introduced administered price mechanism for ethanol to be procured under the EBP Programme.

JAN 2015
Opened alternate route for ethanol production (2nd Generation including Petrochemical). Government has since directed Oil Public Sector Enterprises to set up bio-refineries

ESY 2014-15
Eased tender conditions – Multiple EOIs being floated, transportation slabs and rates

MAY 2016
IDR Act Amendment on 14th May, 2016 to clarify on the roles of Central and State Government for uninterrupted supply of ethanol to be blended with petrol under the EBP Programme.

ESY 2016-17
Regular Interaction with States and all other stake holders to address issues pertaining to EBP Programme. This is a continuous exercise.

JUN 2018
Notified forward looking and updated National Policy on Biofuels – 2018 involving all stakeholders.

JUL 2018
Interest Subvention Scheme for enhancement and augmentation of ethanol production capacity in the Country

ESY 2018-19
Allowed conversion of B heavy molasses, sugarcane juice and damaged food grains to ethanol. Fixed differentiated ex-mill ethanol price and procurement priority based on raw material utilized for ethanol production. Marked beginning of an era of differentiated ethanol pricing, based on raw material utilized for ethanol production.

MAR 2019
Opened a fresh window for inviting applications under interest subvention scheme for ethanol projects based on cane and molasses.

APR 2019
Extension of EBP Programme to whole of India except Island UTs of Andaman Nicobar and Lakshadweep islands

SEP 2019
New sources sugar & sugar syrup introduced for ethanol production and fixed remunerative price.

OCT 2019
Published "Ethanol Procurement Policy on a long-term basis under EBP Programme"

JUN 2020
OMCs have enhanced their ethanol storage capacity from 5.39 crore litres in November, 2017 to 17.8 crore litres in December 2020. With the current capacity, about 430 crore litres of ethanol can be handled annually considering 15 days of coverage period.

AUG 2020
One time registration of ethanol suppliers for long term, including giving them visibility of ethanol demand for 5 years

SEP 2020
OMCs started to provide Off-take guarantee letter and consent to sign tripartite agreement with ethanol suppliers and bankers to support the ethanol capacity expansion projects

SEP 2020
Opened fresh window for inviting applications under interest subvention scheme for ethanol projects based on cane and molasses.

OCT 2020
Further ease of tender conditions by OMCs like one time document submission, quarterly bank guarantees, multiple transportation rate slabs and transportation rates being linked to retail selling price (RSP) of diesel, reduction in security deposit and applicable penalty on non-supplied quantity etc.

OCT 2020
Approval of National Biofuel Coordination Committee (NBCC) to utilize surplus stock of rice lying with Food Corporation of India (FCI) to be released to the distillers for ethanol production.

NOV 2020
Approval of NBCC10 to utilize maize for ethanol production

JAN 2021
Interest subvention scheme for enhancement and augmentation of ethanol production capacity extended to grain based distilleries & distilleries producing ethanol from other feed stocks like sorghum, sugar beet etc apart from molasses-based distilleries.

ROADMAP FOR ETHANOL BLENDING IN INDIA 2020-25

In view of changing world energy requirements, a research road-map for the bio-refineries is mandatory. This will contribute towards sustainability in terms of energy. Various researchers are trying to come up with cellulosic approaches to enhance the economics of the corn to ethanol process. Progress towards attaining these goals requires new technologies, better quality hybrids, accelerated plant domestication programs, improved management practices and enough research funding to develop a future renewable energy source. The demands in future bio refineries will stimulate further advancement in the agriculture to produce more and more improved biomass for ethanol production. Such approaches can lead to a bio-fuel industry that will satisfy improved vehicle efficiency and in overall, will meet the energy security and climate change imperatives of the nation and the world because energy and environment implications of ethanol production are more important than others.

The **"Roadmap for Ethanol Blending in India 2020-25"** by the GOI lays out an annual plan to increase domestic ethanol production in line with target of the amended National Policy on Biofuels (2018) as well as with its Ethanol Blended Petrol (EBP) Program to reach a blending of 20% of ethanol in petrol (E20) by 2025-26.

The roadmap proposes the following milestones:

- Raise pan-India ethanol production capacity from the current 700 to 1500 crore liters.
- Phased rollout of E10 fuel by April 2022.
- Phased rollout of E20 from April 2023, its availability by April 2025.
- Rollout of E20 material-compliant and E10 engine-tuned vehicles from April 2023.
- Production of E20-tuned engine vehicles from April 2025.
- Encourage use of water-sparing crops, such as maize, to produce ethanol.
- Promote technology for the production of ethanol from non-food feedstock.

Meeting the growing demands of ethanol for E-20 and E-30 blending programs requires a comprehensive approach that addresses various aspects of ethanol production, distribution, infrastructure, and policy support. Here are several strategies to achieve this:

Increase Ethanol Production Capacity:

Scaling up ethanol production capacity is essential to meet the growing demand for E-20 and E-30 blending. This can be achieved through investments in new ethanol plants, expansion of existing facilities, and adoption of advanced production technologies. Encouraging private sector participation and providing financial incentives can stimulate investment in ethanol production infrastructure.

Diversify Feedstock Sources:

Expanding the range of feedstock sources for ethanol production can enhance supply resilience and mitigate price volatility. In addition to traditional feedstocks such as sugarcane and molasses, exploring non-food biomass sources like agricultural residues, woody biomass, and energy crops can increase feedstock availability and sustainability.

Promote Second-Generation Ethanol:

Investing in second-generation (2G) ethanol production technologies, which utilize non-food biomass feedstocks like agricultural residues, forest residues, and municipal solid waste, can unlock additional ethanol production potential. Research and development initiatives, pilot projects, and commercial-scale deployments can accelerate the development of 2G ethanol technologies.

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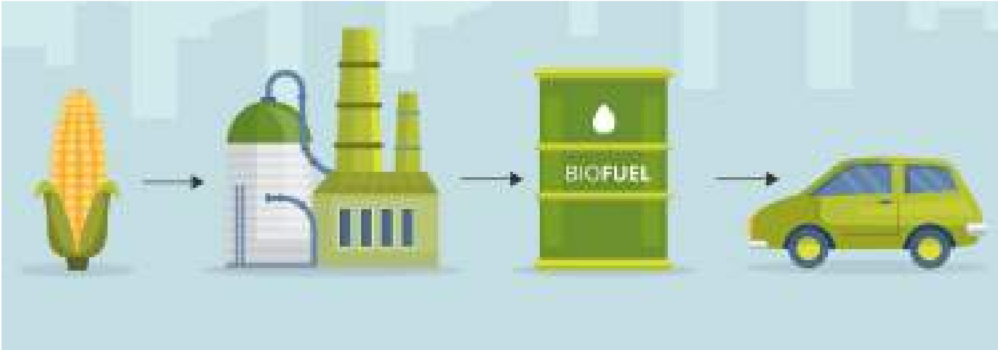


Improve Ethanol Distribution Infrastructure:

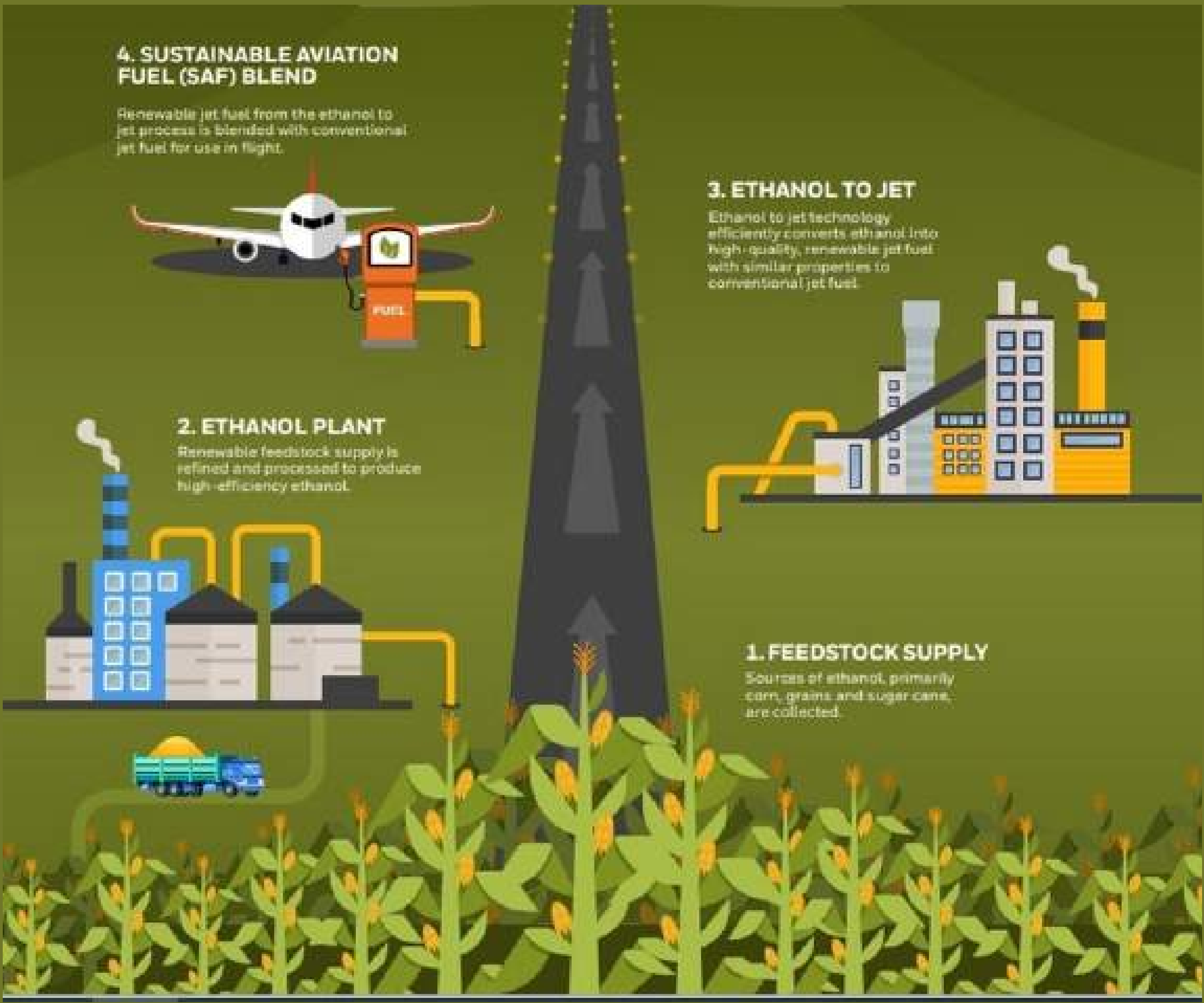
Enhancing the infrastructure for ethanol distribution, storage, and transportation is crucial to ensure efficient supply chains and seamless integration into thefuel market. Investing in ethanol blending terminals, storage tanks, pipelines, and distribution networks can facilitate the movement of ethanol from production centers to blending facilities and retail outlets.

Upgrade Vehicle Compatibility:

Ensuring that vehicles are compatible with higher ethanol blends like E-20 and E-30 is essential to increase market penetration. Encouraging the production and adoption of flex-fuel vehicles (FFVs) capable of running on various ethanol-gasoline blends can expand the market for higher ethanol blends and provide consumers with fuel choice.

Implement Supportive Policies:

Enacting supportive policies, regulations, and incentives can create a conducive environment for E-20 and E-30 blending programs. Measures such as blending mandates, tax incentives, regulatory frameworks, and public awareness campaigns can drive demand for ethanol and encourage investment in blending infrastructure.


4. SUSTAINABLE AVIATION FUEL (SAF) BLEND
Renewable jet fuel from the ethanol to jet process is blended with conventional jet fuel for use in flight.
FUEL
3. ETHANOL TO JET
Ethanol to jet technology efficiently converts ethanol into high-quality, renewable jet fuel with similar properties to conventional jet fuel.
2. ETHANOL PLANT
Renewable feedstock supply is refined and processed to produce high-efficiency ethanol.
1. FEEDSTOCK SUPPLY
Sources of ethanol, primarily corn, grains and sugar cane, are collected.

2.6 SUSTAINABLE AVIATION FUEL (SAF) THROUGH ETHANOL

In an era where climate change and environmental sustainability are at the forefront of global concerns, the aviation industry faces increasing pressure to reduce its carbon footprint. One promising avenue towards greener skies is the development and adoption of Sustainable Aviation Turbine Fuel (SATF). Sustainable Aviation Turbine Fuel, also known as biojet fuel, is derived from sustainable feedstocks such as agricultural residues, algae, waste oils, and non-food crops. Unlike traditional jet fuel, which is derived from fossil sources, SATF offers a renewable and lower-carbon alternative for powering aircraft.

This diversification of energy sources enhances energy security and resilience in the face of geopolitical and market uncertainties. The production processes can be designed to minimize environmental impacts such as land use change, water consumption, and deforestation. By prioritizing sustainable feedstocks and production methods, SATF contributes to broader environmental conservation goals. Finally the development of SATF fosters innovation and research in renewable supply chains and creates new economic opportunities in related industries.

PROMISES AND CHALLENGES IN SAF

The adoption of SATF will also provide a lot of benefits related to improving the environment and sustainability. SATF offers significant greenhouse gas emissions reductions compared to conventional jet fuel, as it is derived from renewable feedstocks that sequester carbon dioxide during growth. By displacing fossil-based jet fuel, SATF can help mitigate the aviation industry's contribution to climate change. It also reduces reliance on finite fossil fuel reserves by utilizing renewable feedstocks that can be sustainably produced and replenished over time.

However while SATF holds great promise for sustainable aviation, several challenges must be addressed to realize its full potential in terms of scalability, feedstock Availability, Cost Competitiveness and regulatory support.

There will be a need for significant investments in research, development, and infrastructure.

Collaboration among governments, industry stakeholders, and research institutions is essential to overcome barriers to scalability.

Competition with food production, land use conflicts, and biodiversity concerns must be carefully managed to prevent negative environmental and social impacts. SATF currently faces cost competitiveness challenges compared to conventional jet fuel, due in part to higher production costs and limited economies of scale.

There is need for continued technological innovation, policy support, and market incentives to drive down costs and improve competitiveness. A clear enabling environment to provide certainty and guidance for SATF producers and consumers. Harmonizing standards, certification processes, and incentives at the national and international levels can facilitate market uptake and investment in SATF.

GLOBAL ADOPTION OF SAF

The European Union and the UK are driving the adoption of Sustainable Aviation Fuel (SAF) through ambitious mandates. However, the industry faces significant adoption challenges, with SAF currently accounting for less than 1% of total aviation fuel.

The EU's ReFuelEU Aviation initiative mandates a minimum SAF blend of 2% by 2025 and 6% by 2030, while the UK is considering a 10% SAF requirement by 2030. Challenges include ensuring sustainable feedstock availability, scaling up production capacity, closing the cost gap, and financing SAF production.

Various pathways produce SAF, each with advantages and disadvantages. HEFA-SPK dominates due to wider feedstock availability and established technology but is controversial due to imported Used Cooking Oil (UCO). Other pathways include Alcohol-to-Jet (AtJ), Synthesised Iso-Paraffins (SIP), Methanol-to-Jet (MtJ), Fischer-Tropsch (FT), Power-to-Liquid (PtL), Solar Fuels, and Hydrothermal Liquefaction (HTL), at varying maturity stages.

Hydrothermal Liquefaction (HTL) and Solar Fuels are promising pathways that could revolutionise the sector. HTL converts wet biomass, including waste, into SAF, offering 90% CO_2 lifecycle reductions. Solar Fuels harness solar energy directly for fuel production, potentially improving efficiency and reducing costs.

*DETAILS ON PATHWAYS IN APPENDIX I

SAF and airline emissions

50%
of comparable emissions from 2005 levels is the aim for the global aviation industry by 2050

23.7%
is the share of fuel in airline operating costs in 2019, compared with 13% in 2001

6%
annual growth in global air traffic for 5 years before the pandemic

2.8%
of the total global greenhouse gas (GHG) emissions come from air transport

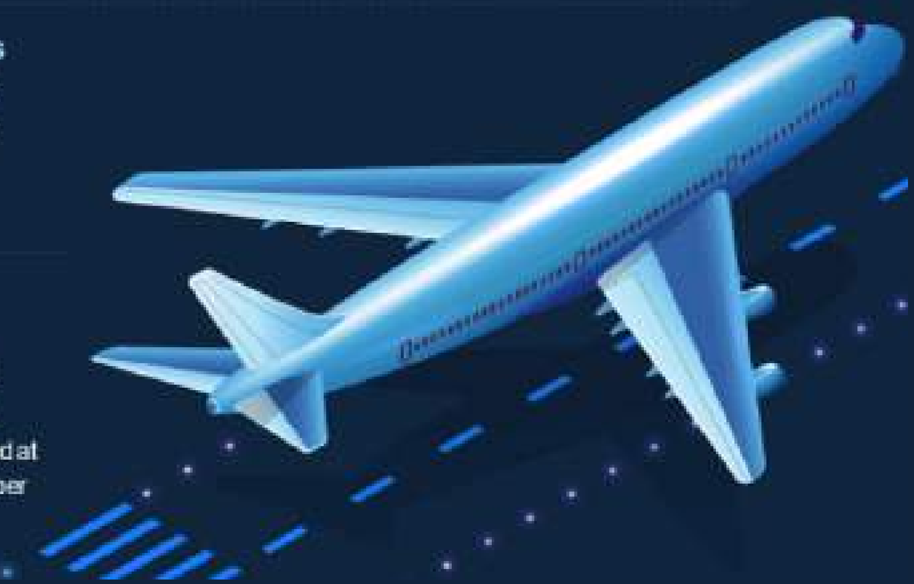
0.004%
of total jet fuel used globally in 2017 was SAF

915 million tonnes (mt)
of CO2 emissions produced by flights worldwide in 2019

12,000 tonnes
of bio aviation fuel produced in 2018

215,000
flights by 40 airlines used SAF between 2008-2019. 38.9 million commercial flights took off in 2019 alone

4.8 million tonnes (mt)
in sustainable fuel forward purchase agreements existed at the end of December 2019



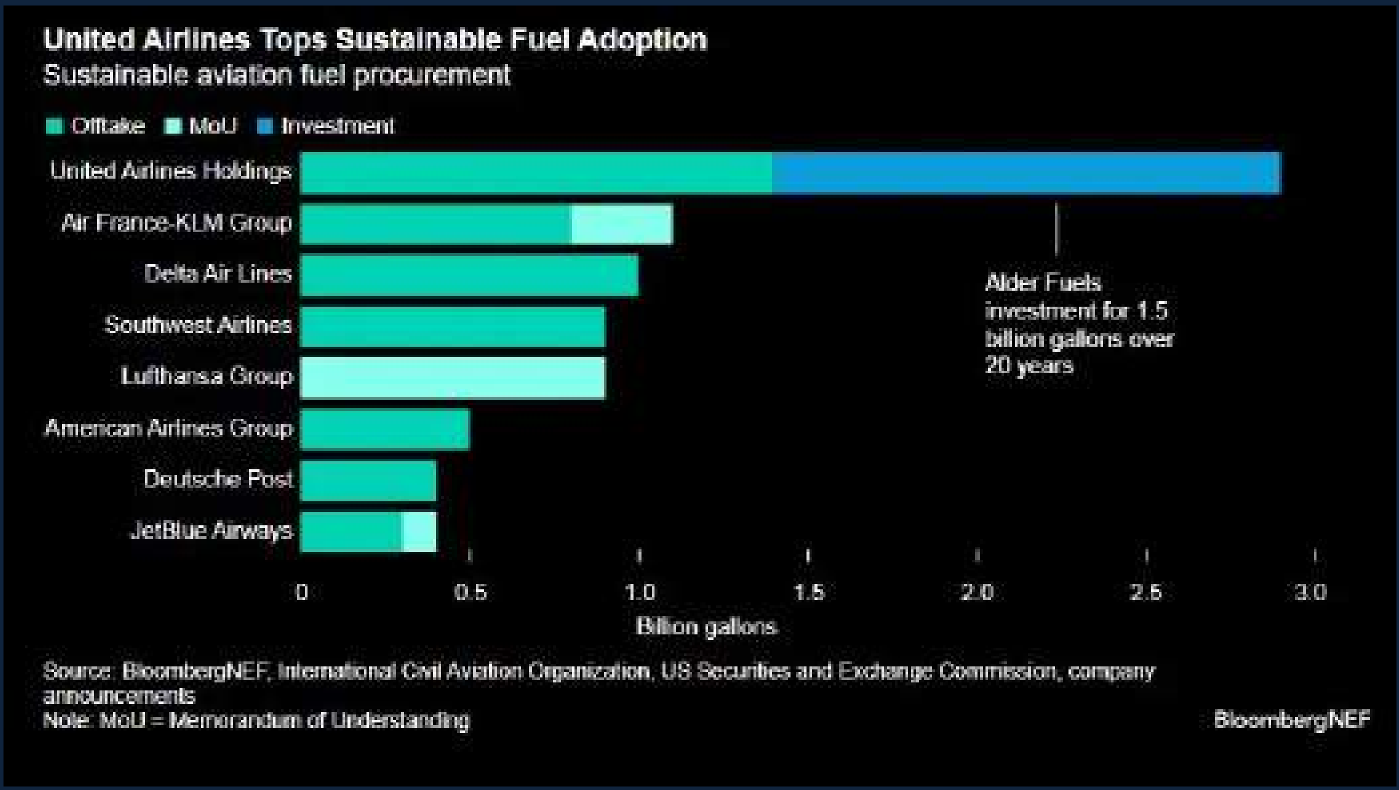
GLOBAL ADOPTION OF SAF - CHALLENGES

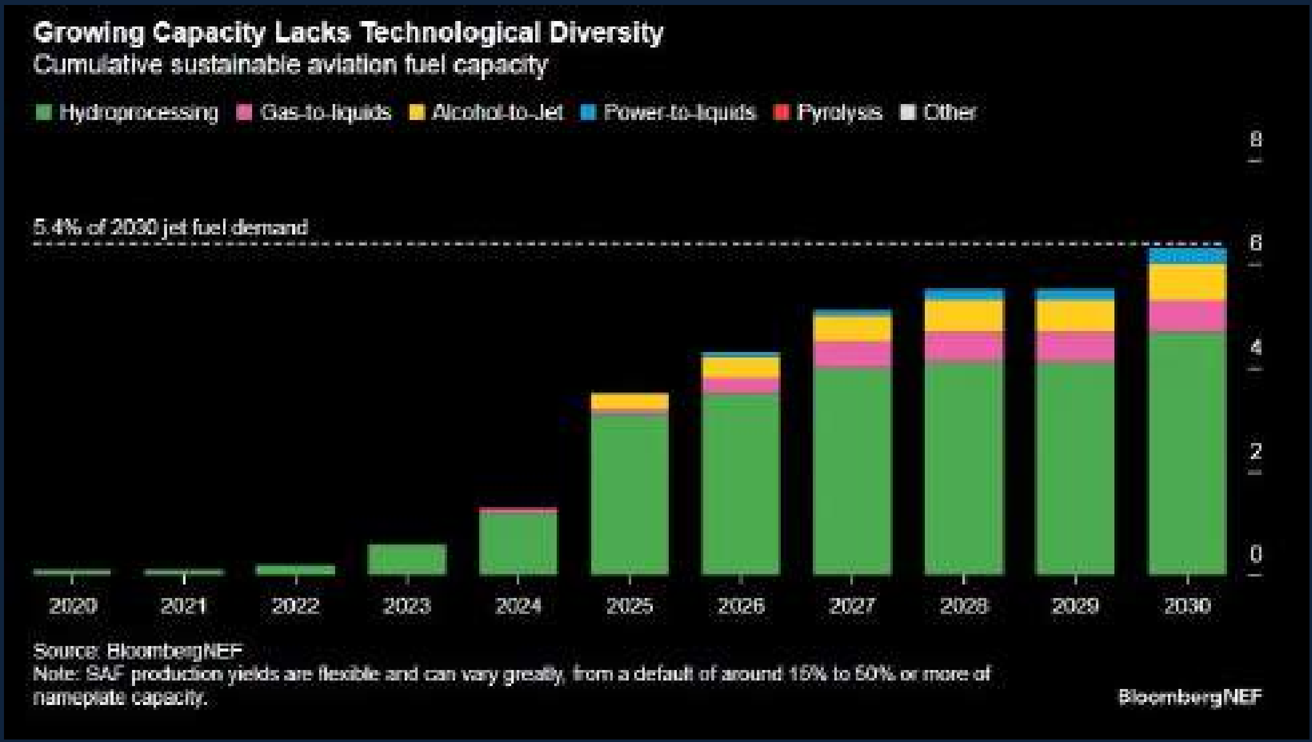
Environmental and climate groups criticise SAF for not addressing non-CO_2 emissions and potentially delaying the transition to zero-emission solutions. Concerns exist around the sustainability of certain feedstocks and the potential for fraud. Critics argue that over-reliance on SAF may hinder investments in hydrogen or electric-based propulsion systems.

E-fuels, produced from green hydrogen and captured CO_2, are a long-term SAF solution but face renewable energy challenges. Pink hydrogen, produced using nuclear energy for electrolysis, may offer a more cost-effective and efficient alternative.

Significant investments are required to build SAF refineries and bridge the cost gap with traditional jet fuel. Funding sources include government incentives, venture capital, private investors, bank debt, and contributions from corporate and individual passengers. Book-and-claim systems allow corporates to offset Scope 3 emissions by purchasing SAF. Frequent flyer taxes are also a potential financing mechanism.

*DETAILS ON PATHWAYS IN APPENDIX I


United Airlines Tops Sustainable Fuel Adoption
Sustainable aviation fuel procurement
Offtake
MoU
Investment
United Airlines Holdings
Air France-KLM Group
Delta Air Lines
Southwest Airlines
Lufthansa Group
American Airlines Group
Deutsche Post
JetBlue Airways
Alder Fuels investment for 1.5 billion gallons over 20 years
0
0.5
1.0
1.5
2.0
2.5
3.0
Billion gallons
Source: BloombergNEF, International Civil Aviation Organization, US Securities and Exchange Commission, company announcements
Note: MoU = Memorandum of Understanding
BloombergNEF

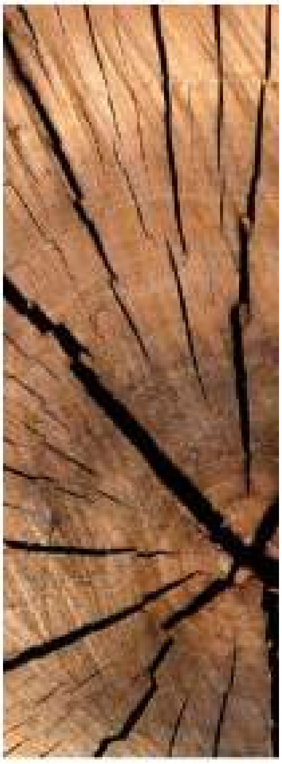

Growing Capacity Lacks Technological Diversity
Cumulative sustainable aviation fuel capacity
Hydroprocessing
Gas-to-liquids
Alcohol-to-Jet
Power-to-liquids
Pyrolysis
Other
5.4% of 2030 jet fuel demand
8
6
4
2
0
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
Source: BloombergNEF
Note: SAF production yields are flexible and can vary greatly, from a default of around 15% to 50% or more of nameplate capacity.
BloombergNEF

QUICK PREVIEW ON SAF PATHWAYS

HEFA-SPK

- Feedstock: Used cooking oils, animal fats, plant oils
- Currently, the HEFA-SPK pathway is the predominant method for producing SAF due to the broad availability of feedstocks and the maturity of the technology. However, this approach has sparked controversy because of the importation of UCO from countries such as China, Indonesia, and Malaysia. Nonetheless, Airlines for Europe (A4E) states that, in the short term, "HEFA is the only viable solution".

Alcohol-to-Jet (AtJ)



- Feedstocks: Ethanol derived from sugars (sugarcane, sugar beets), starches (corn, grains), cellulosic biomass (wood waste, agricultural residues), or Butanol (ethyl alcohol) produced through fermentation or advanced chemical processes from biomass.
- The cost-effectiveness of AtJ compared to HEFA is debatable. In 2022, a rise in the cost of vegetable oil feedstocks made AtJ the cheaper pathway. However, currently, the cost of producing SAF via AtJ is believed to be higher than HEFA. AtJ has potential advantages, such as diverse feedstocks and room for efficiency improvements through ongoing technology development.
- Currently, only one AtJ facility is operational worldwide, the LanzaJet Freedom Pines Fuels facility in Soperton, Georgia. However, more AtJ plants are in development, including in Europe. For example, a Swedish company plans to bring 400,000 metric tons (approximately 130 milliongallons) of SAF annually to the Swedish market by building three new AtJ plants, equating to around 40% of the annual jet fuel consumption at Stockholm's Arlanda Airport.

Synthesised Iso-Paraffins (SIP)

- SIP uses a similar array of feedstocks to AtJ but represents a newer pathway for producing SAF.
- SIP fuels are created through a process that typically involves the fermentation of sugars to produce an intermediate chemical (such as farnesene), which is then hydrogenated to form iso-paraffins. These iso-paraffins are similar to conventional jet fuel, making SIP a promising option for SAF production.

Methanol-to-Jet (MtJ)

- Feedstocks: Methanol is produced by gasifying biomass such as agricultural residues or municipal waste, or from captured CO2 and H2"similar to the PtL pathway.
- Although MtJ is still a relatively early-stage SAF pathway, advocates claim it is more efficient and less energy-intensive than other production methods.

Fischer-Tropsch (FT)

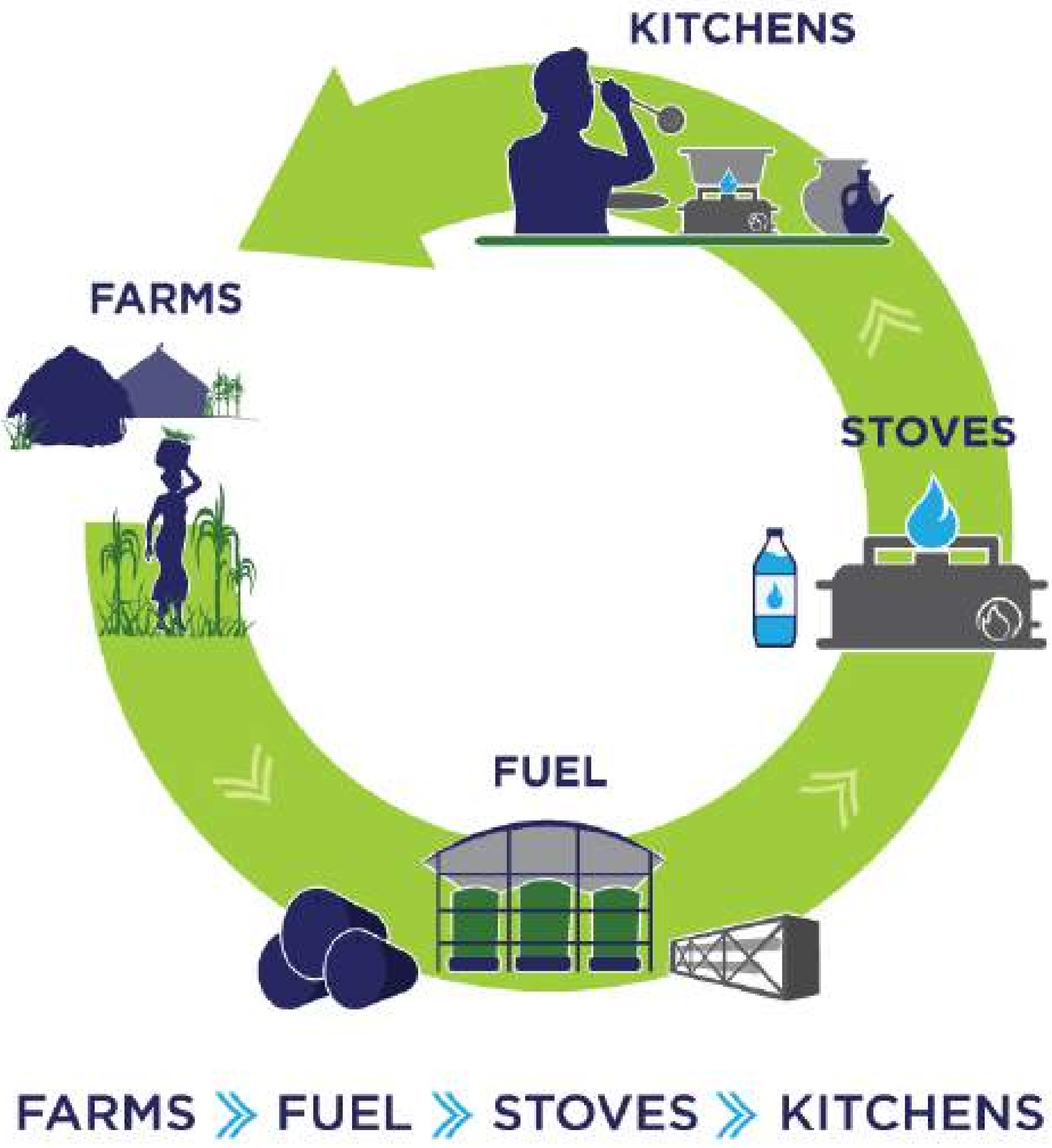
- In the FT method, biomass (wood waste, agricultural residues, waste) is gasified, and the resulting syngas is used in the Fischer-Tropsch process to create SAF.
- FT is a well-established method for producing synthetic fuels, having been created in 1925.
- Companies turning municipal waste into SAF typically use FT. However, it is considered relatively inefficient, with 42% or more energy losses.

Power-to-Liquid (PtL)

- Commonly known as e-fuels or electrofuels, the core idea is to use renewable electricity to produce liquid fuels.
- The basic ingredients are green hydrogen, made using renewable energy to split water (H20) into hydrogen and air through electrolysis and captured CO2.
- The green hydrogen is combined with the captured CO2 to produce syngas, which is then put through a Fischer-Tropsch (FT) reactor to make jet fuel
- Some e-fuel companies claim to have disrupted the FT process to create their own more efficient way of making e-fuels.
- PtL has several advantages, such as a CO2 lifecycle reduction of 90% or more (compared to 50-80% for other forms of SAF), less feedstock intensity, and the ability to be deployed in locations with abundant renewable energy and access to CO2 sources (industrial or direct-air capture).
- However, PtL also has disadvantages, including high costs due to capital and amounts of renewable energy to be operating expenses and the need for produced at scale. A report by the World Fund on 'Electrofuels for Aviation' projected that replacing just 8% of European aviation fuel with e-fuel by 2040would necessitate the total electricity consumption of a country like Sweden or the Netherlands.
- Despite these challenges, policymakers are promoting and mandating the use of e-fuels. The European Union's ReFuelEU Aviation program requires jet fuel suppliers to include 1.2% of e-fuels in the overall fuel mix by 2030, increasing to 35% by 2050.

Lignocellulosic biomass-to-jet fuel

- This is a process that converts non-food biomass, such as agricultural residues (e.g. straw, corn stover), woody biomass (e.g., forest residues, sawdust), and energy crops (e.g., switchgrass, miscanthus), into synthetic jet fuel.
- This conversion process involves several key steps and can be achieved through various biochemical and thermochemical methods,
- Lignocellulosic biomass is tough to break down due to its tightly bound components. Pre-treatment helps to make the components more accessible.
- After pre-treatment, the cellulose and hemicellulose are broken down into simple sugars, often using enzymes.
- Microorganisms can then ferment the sugars to produce alcohols like ethanol or the entire biomass can be turned into syngas, which is then processed further.


KITCHENS
FARMS
STOVES
FUEL
FARMS » FUEL » STOVES » KITCHENS

2.7 ETHANOL AS A COOKING FUEL

As the world grapples with the dual challenges of climate change and energy security, the search for sustainable alternatives to traditional fossil fuels has intensified. In the realm of household energy, liquefied petroleum gas (LPG) has long been a popular choice for cooking and heating. However, the environmental impact and limited availability of LPG have prompted a shift towards renewable alternatives such as bioethanol. Bioethanol has emerged as a potential replacement for LPG to foster a cleaner, greener energy transition.

Bioethanol, a renewable fuel derived from organic materials such as sugarcane, corn, or cellulosic biomass, has gained traction as a viable alternative to traditional fossil fuels. In the context of household energy, bioethanol offers several advantages over LPG as it is produced from biomass feedstocks that can be sustainably grown and replenished.

By harnessing the power of renewable resources, bioethanol reduces reliance on imported fossil fuels and contributes to energy security.Bioethanol combustion produces fewer greenhouse gas emissions compared to LPG, as the carbon dioxide released during combustion is offset by the carbon dioxide absorbed during the growth of the feedstock crops. By using bioethanol for cooking and heating, households can shrink their carbon footprint and mitigate climate change.Bioethanol production can be decentralized, with small-scale ethanol distillation units located close to biomass sources. This decentralized approach empowers communities to produce their own fuel locally, reducing dependence on centralized energy infrastructure and fostering economic development in rural areas. Ethanol-fueled appliances offer similar performance and convenience to their LPG counterparts, with the added benefit of using a renewable, environmentally friendly fuel.

ADVANTAGES OF BIO ETHANOL VS LPG

E-20 and E-30 blending programmes offer a compelling alternative to traditional gasoline by incorporating ethanol—a renewable, bio-based fuel derived from agricultural feedstocks such as sugarcane, corn, or biomass—into gasoline blends. This leads to significant concomitant advantages

01 — Renewable Resource

Unlike LPG, which is derived from finite fossil fuel reserves, bioethanol is produced from biomass feedstocks that can be sustainably grown and replenished. By harnessing the power of renewable resources, bioethanol reduces reliance on imported fossil fuels and contributes to energy security.

02 — Reduced Emissions

Bioethanol combustion produces fewer greenhouse gas emissions compared to LPG, as the carbon dioxide released during combustion is offset by the carbon dioxide absorbed during the growth of the feedstock crops. By using bioethanol for cooking and heating, households can shrink their carbon footprint and mitigate climate change.

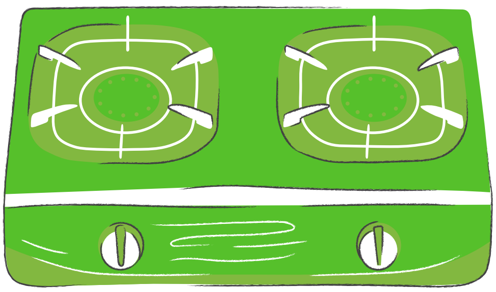
03 — Local Production

Bioethanol production can be decentralized, with small-scale ethanol distillation units located close to biomass sources. This decentralized approach empowers communities to produce their own fuel locally, reducing dependence on centralized energy infrastructure and fostering economic development in rural areas

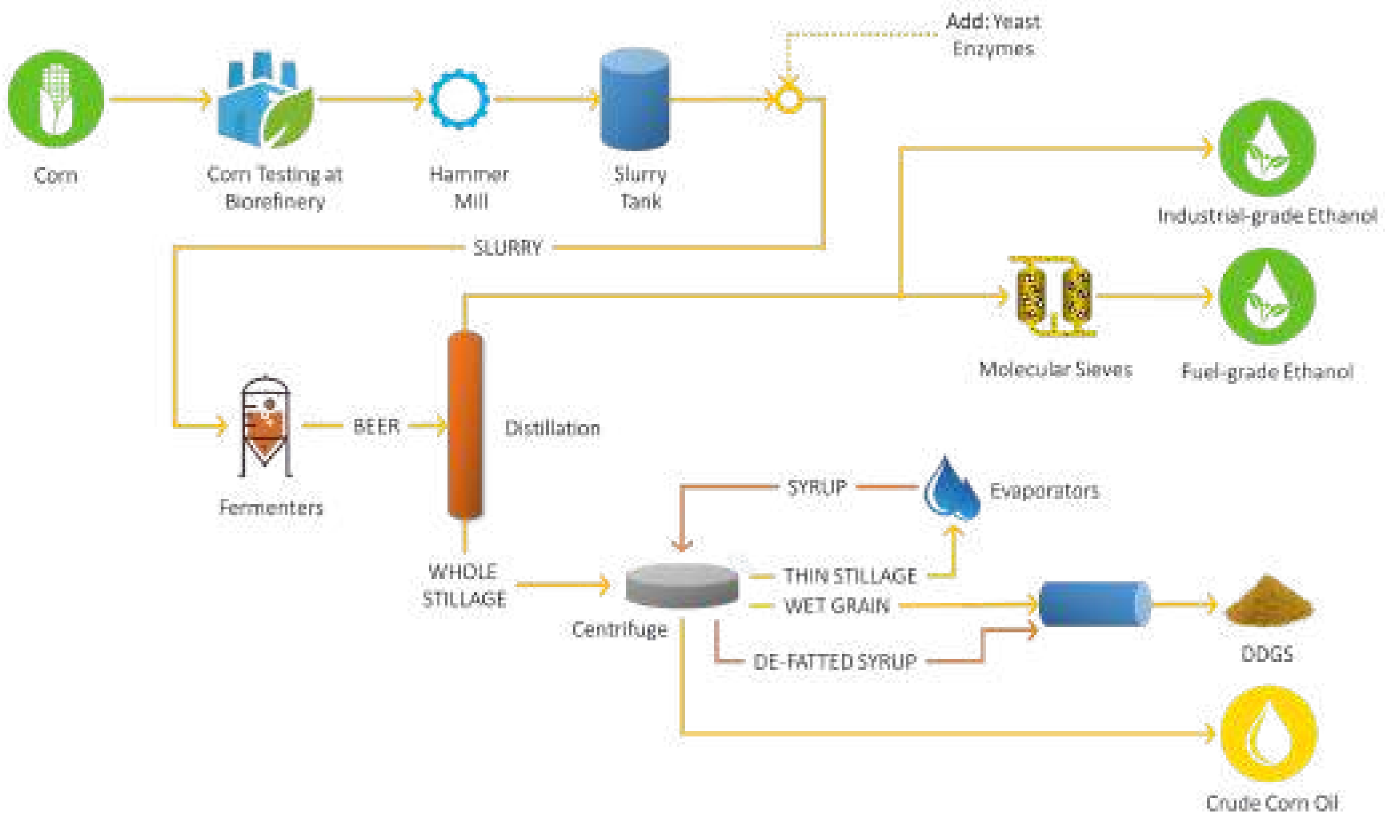
04 — Versatility

Bioethanol can be used in a variety of household appliances, including ethanol stoves, cookers, and heaters, making it a versatile replacement for LPG. Ethanol-fueled appliances offer similar performance and convenience to their LPG counterparts, with the added benefit of using a renewable, environmentally friendly fuel.

Replacing Liquefied Petroleum Gas (LPG) with ethanol for cooking in the kitchen can be a feasible and sustainable transition, offering numerous benefits in terms of environmental impact, health, and energy security. Ethanol for cooking will need ethanol-compatible stoves or cook tops. Ethanol stoves are specially designed to burn bioethanol efficiently and safely. These stoves come in various designs, including tabletop models and built-in cook tops, and are available in the market from different manufacturers. Ethanol stoves require adequate ventilation to ensure the safe combustion of ethanol and to prevent the build up of indoor air pollutants. Ensure that the kitchen is well-ventilated with windows, exhaust fans, or ventilation hoods to remove any fumes or emissions generated during cooking. There is a need to ensure use of high-quality, denatured ethanol specifically formulated for use in cooking stoves. It's essential to follow safety guidelines and instructions when using ethanol stoves. This includes proper handling and storage of ethanol fuel, as well as safe lighting and operation of the stove.



Technologies Involved In Ethanol Production



2.8 TECHNOLOGIES FOR PRODUCING BIOETHANOL

G1 Technology

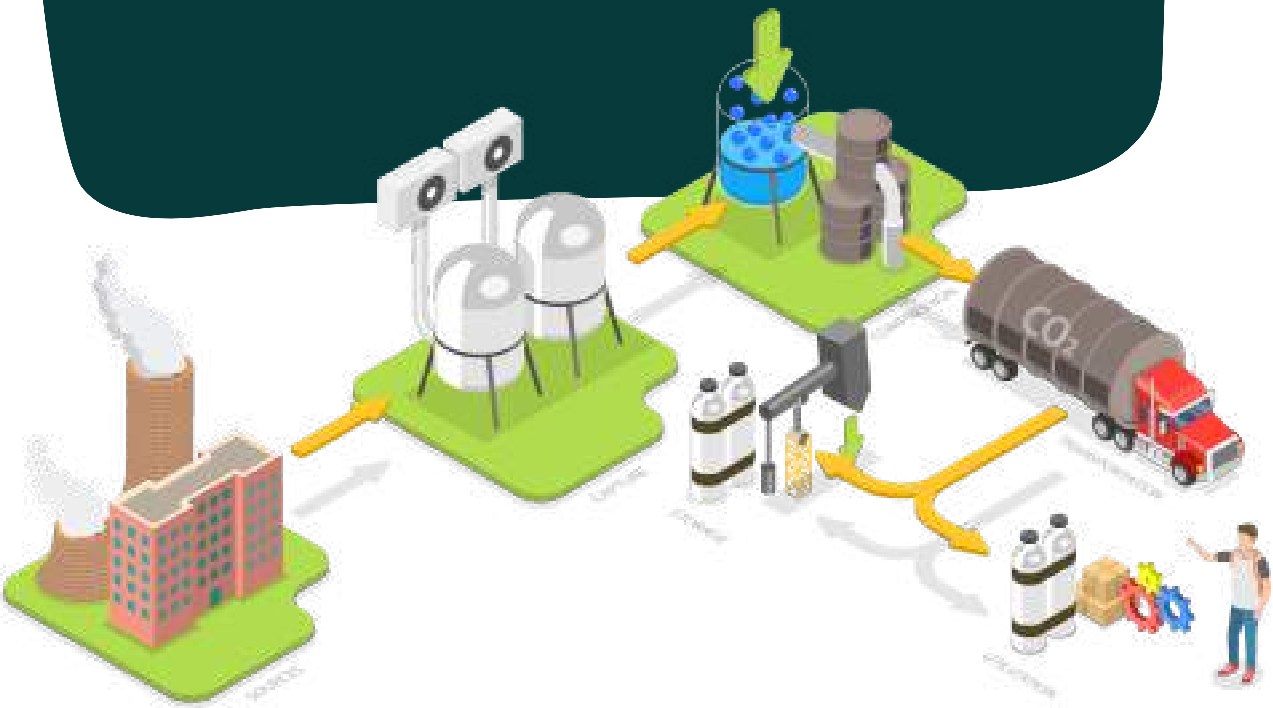
First generation (G1) facilities produces bioethanol by fermenting sugars from sugar cane, sugar beet or cereals seeds

G2 Technology

Second generation facility uses sugars found in lignocellulosic biomass (agricultural residues, lignocellulosic crops)

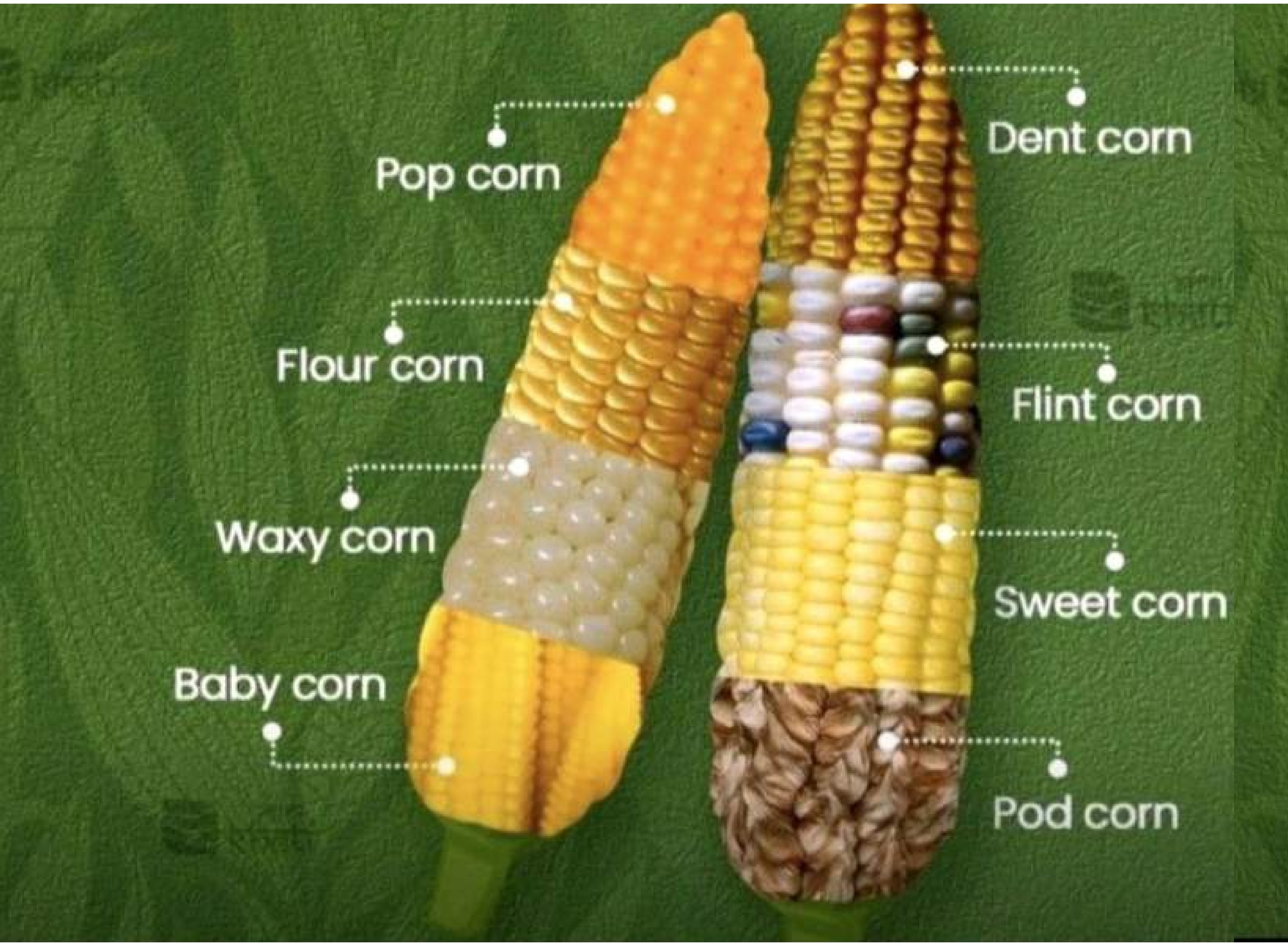
G1.5 Technology:

There is a special mode of hybridization that take advantage of the cellulosic sugars hidden in the corn kernel fiber. Known commonly as 1.5 Generation, the ability to convert corn kernel fiber to ethanol is the bridge the gap between the production of ethanol from corn and cellulosic ethanol.



3 DENTED-CORN

3.1 Types of CORN



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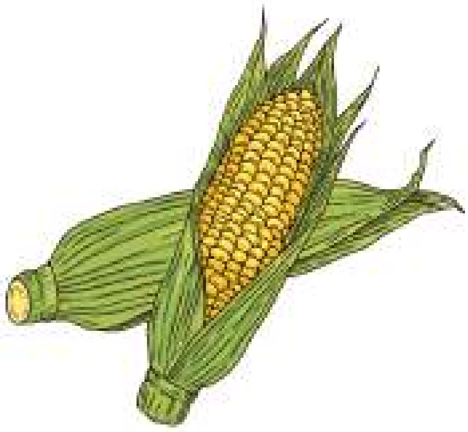


Popcorn and sweet corn

Used for human consumption

Flint corn

Used for ornamentation

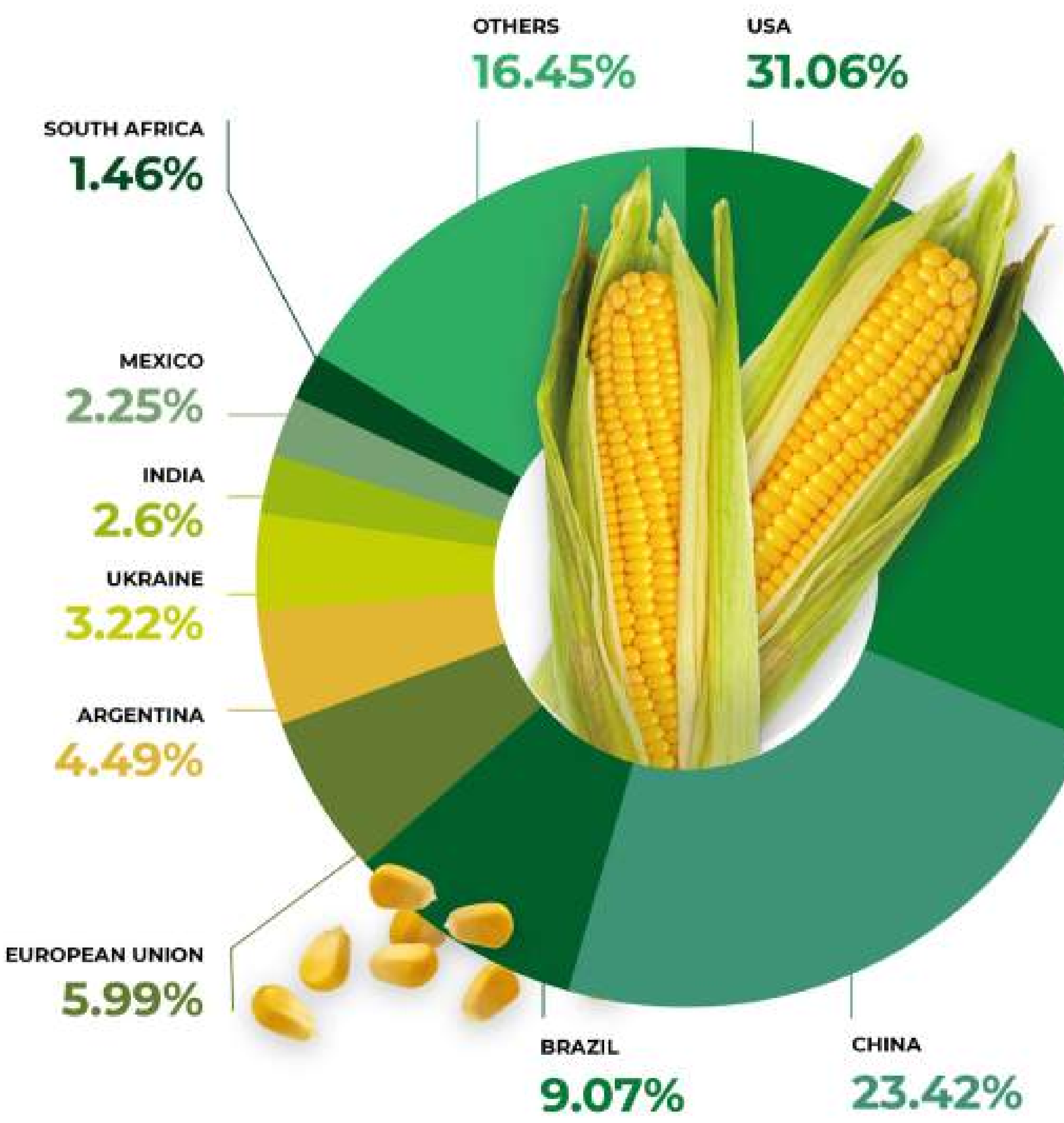
Yellow Dent Corn

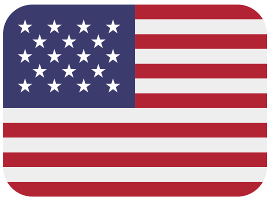
Yellow Dent No. 2 corn, also known as field corn, is not used as is for human consumption and is a globally traded commodity.

99% on corn grown in the U.S. is Yellow Dent No. 2 and select hydride varieties of Yellow Dent No. 2 corn are specifically optimized for higher ethanol yields. Other hydrides are optimized for other industrial uses such as starch production.

Valuable feed components of protein (as DDGS) and oil remain in the food chain with ethanol production.

3.2 CORN GROWTH ACROSS THE WORLD





USA

The United States is the world's largest producer of corn, with vast expanses of farmland dedicated to corn cultivation. A significant portion of the corn harvested in the U.S. is used for ethanol production, primarily through the dry milling process. Corn ethanol production accounts for the majority of ethanol production in the U.S.corn and cellulosic ethanol.

BRAZIL

Brazil is primarily known for sugarcane ethanol production, but corn ethanol production has been gaining traction in recent years. Brazil's favorable climate and agricultural conditions make it suitable for both sugarcane and corn cultivation.

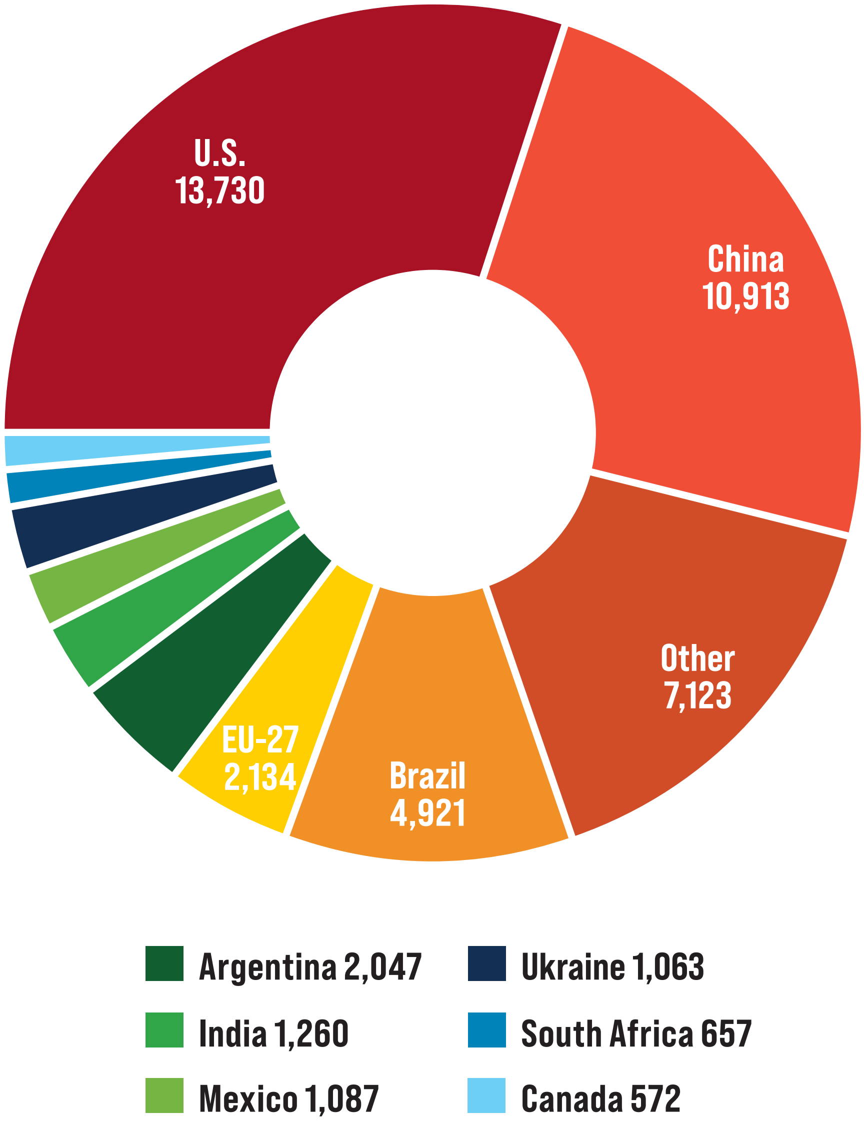
OTHER COUNTRIES

Countries such as Argentina, China, Canada, and the European Union have ethanol industries that utilize corn and other feedstocks for biofuel production.

WORLD CORN PRODUCTION

2022 – 2023*

(million bushels)



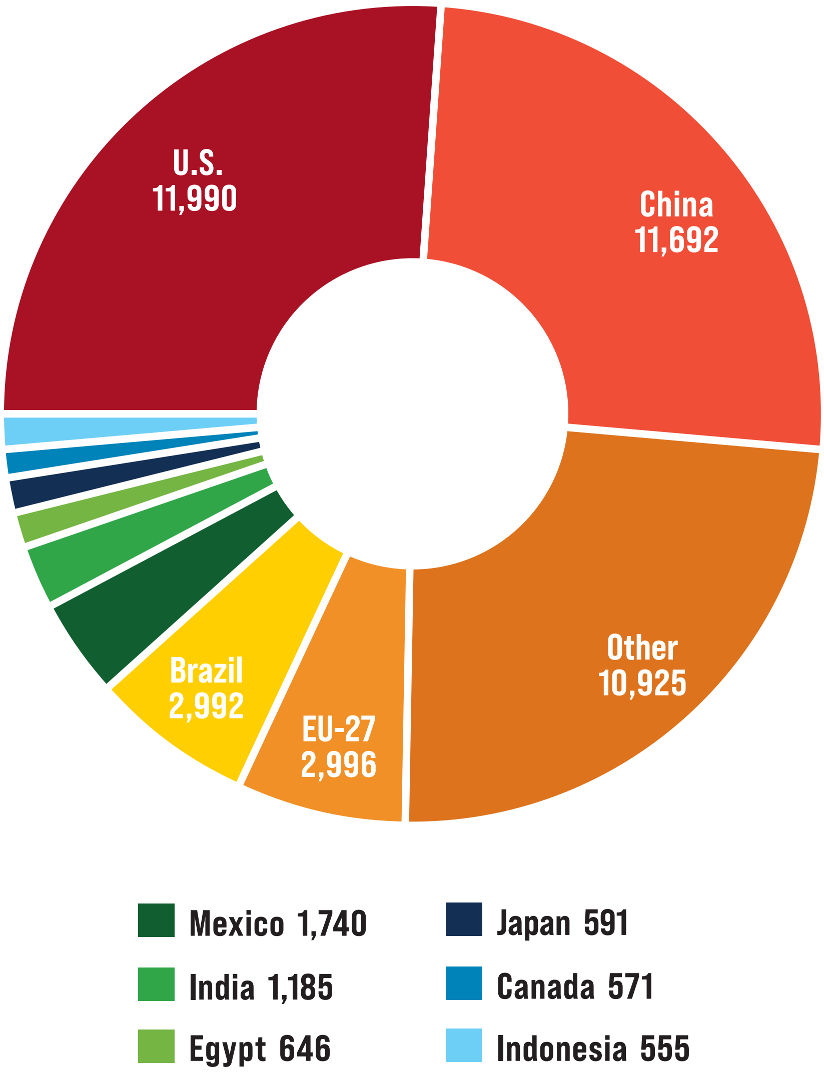
WORLD TOTAL
45,507

Source: USDA, FAS Grain: World Markets and Trade, Jan. 12, 2023

WORLD CORN CONSUMPTION

2022 – 2023*

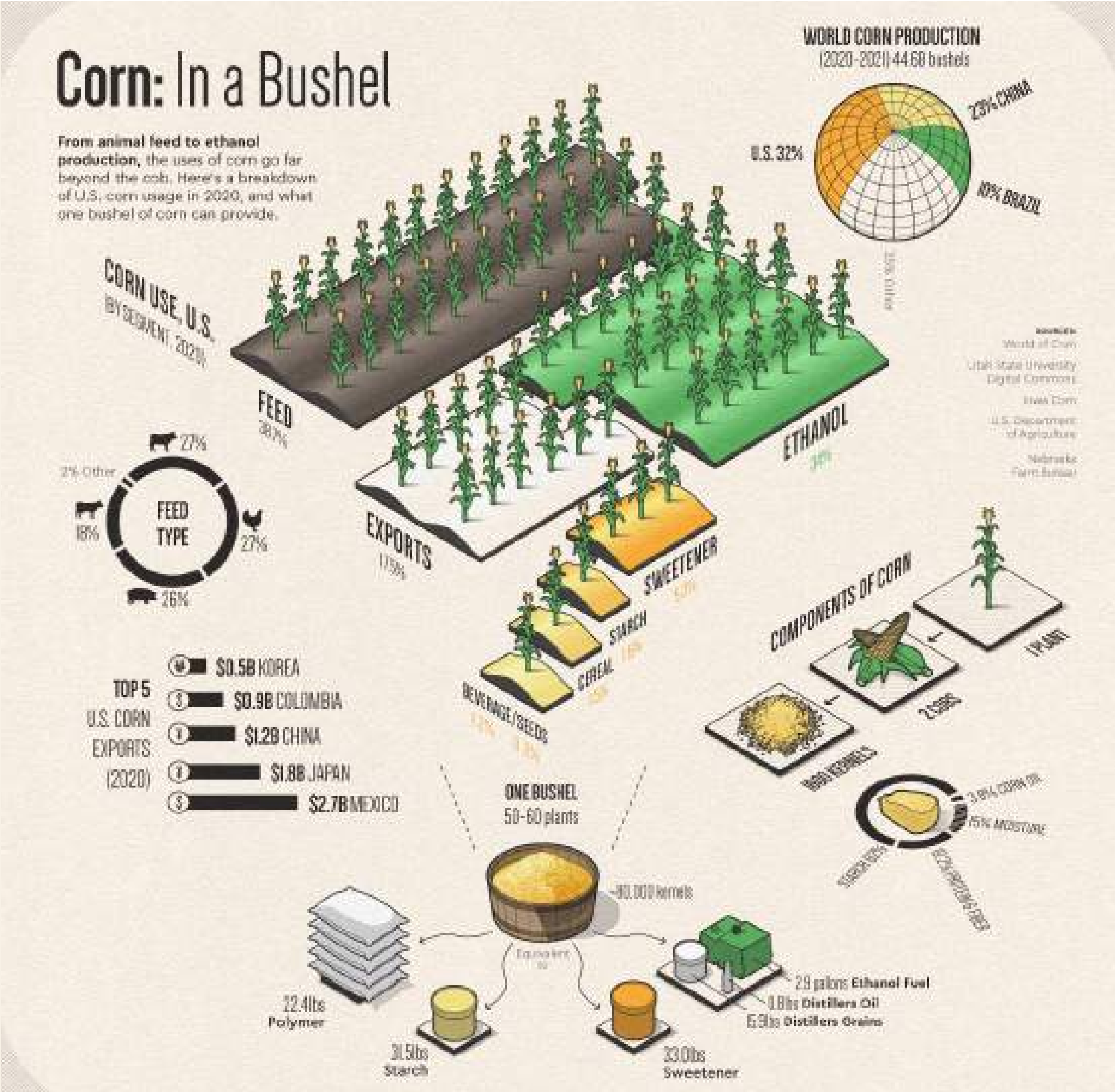
(million bushels)



WORLD TOTAL
45,882

Source: USDA, FAS Grain: World Markets and Trade, Jan. 12, 2023

WORLD CORN TRADE



Five global companies handle most of the world's grain trading.

ADM (Archer Daniels Midland)
US-based corporation operating in 75 countries run 265 processing plants converting corn, wheat and cocoa into food and animal feed and for energy.

Louis Dreyfus
French company founded in 1851, now operates in more than 50 countries. Transports 70m tons of food a year.

Bunge
Founded in the Netherlands in 1818, now with its headquarters in New York state. Employs 35,000 people in 40 countries, processing oilseeds, wheat, corn and sugar cane.

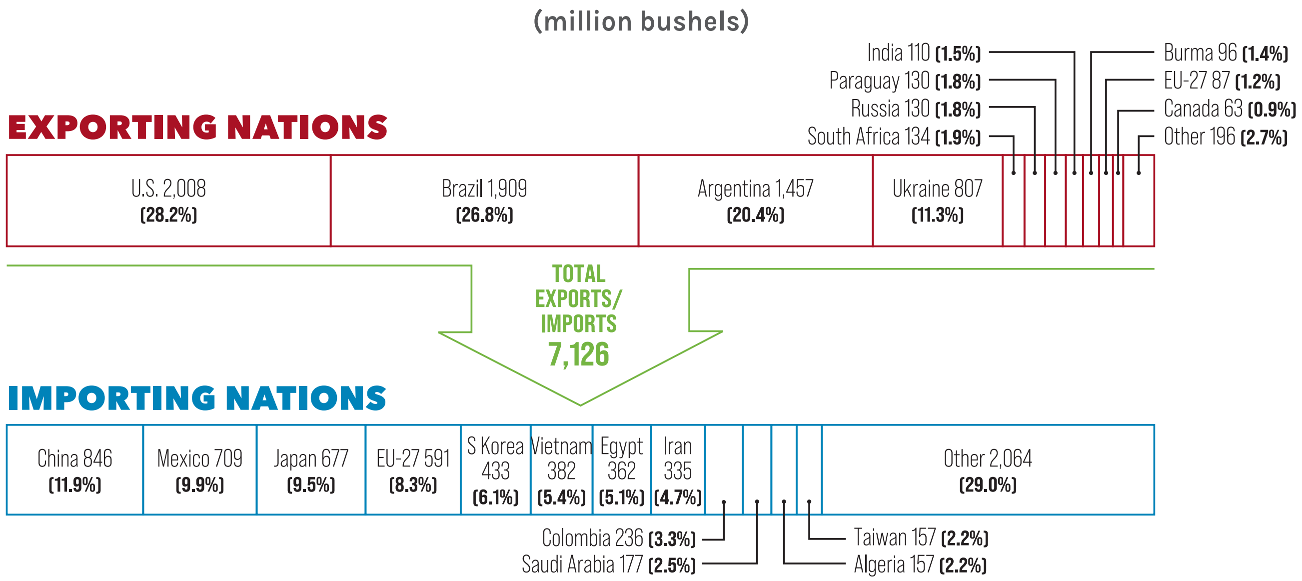
Glencore International
Anglo-Swiss multinational has about one-tenth of the grain market. Also, distributes oilseeds and sugar.

Cargill
Based in the United States, a 145-year-old company employing 142,000 people in 65 countries. Distributes grain and oilseeds.

Corn Trade Flows: Four Countries Supply > 80% of Exports. Imported corn is readily available from any of several countries. A decrease in exports from any region due to weather, drought
for example, is easily made up by supply from other regions.

The United States leads as the largest exporter, accounting for about 30-40% of global corn exports, with annual exports reaching around 50 million metric tons. Brazil and Argentina follow, contributing significantly with exports of approximately 30-35 million metric tons and 25-30 million metric tons, respectively. Ukraine is another key player, exporting around 25 million metric tons annually.

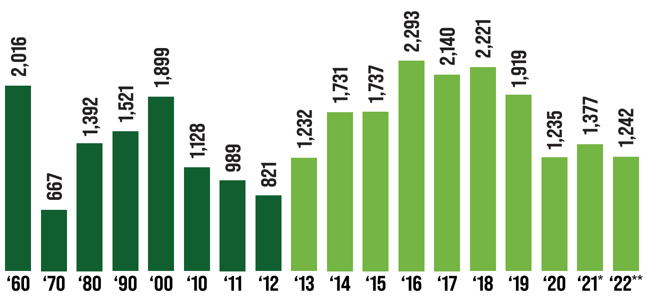
Major importers include China, which imported over 26 million metric tons in recent years, and the European Union, with imports exceeding 15 million metric tons. Trade agreements, tariffs, and geopolitical factors significantly influence the global corn market, impacting prices and availability. Additionally, advancements in biotechnology and farming practices have enhanced crop yields, further boosting trade volumes. However, the market is also subject to volatility due to factors such as weather conditions, crop diseases, and shifts in policy, highlighting the complexity and importance of the global corn trade in ensuring food security and economic stability.



Source: USDA, FAS Grain: World Markets and Trade, Jan. 12, 2023

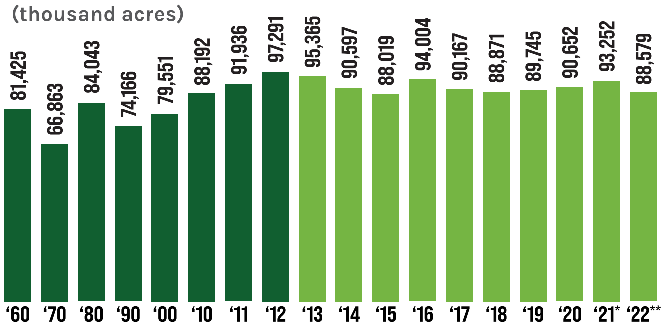
US CORN STATISTICS

U.S. CORN ENDING STOCKS
1960– 2022
(million bushels)



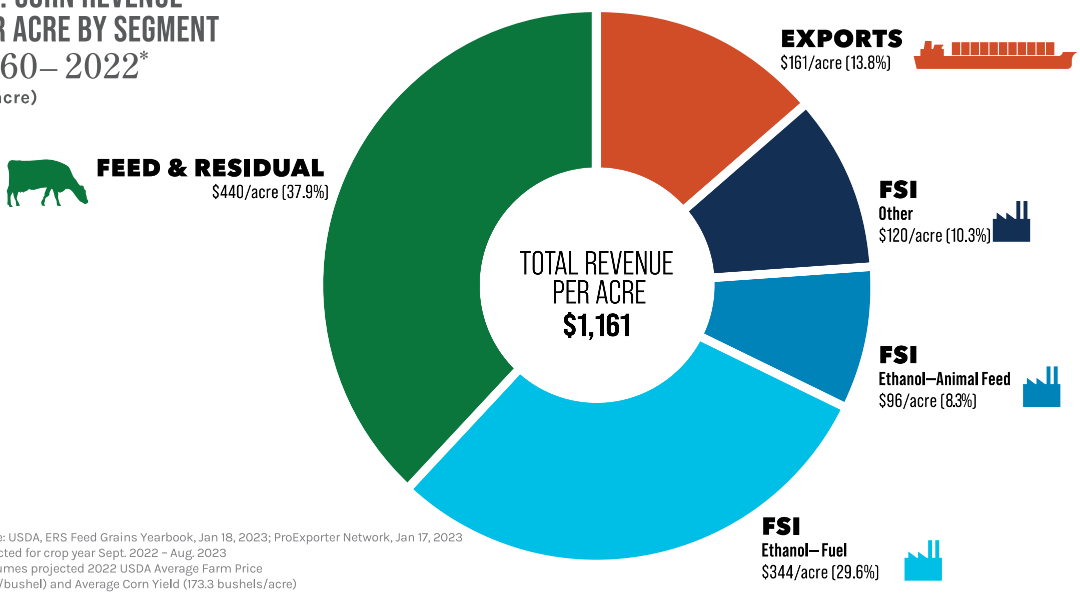
Source: USDA, ERS, Feed Grains Yearbook, Jan. 18, 2023

U.S. CORN ACRES PLANTED
1960– 2022
(thousand acres)



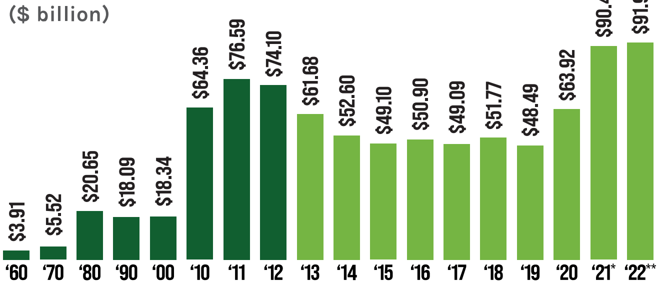
Source: USDA, NASS, Quick Stats, Jan. 12, 2023

U.S. CORN REVENUE PER ACRE BY SEGMENT
1960– 2022*
($/acre)

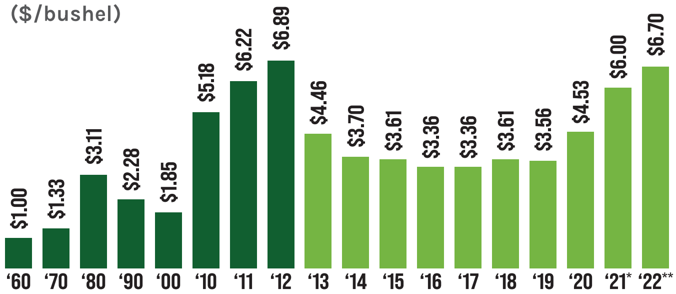


Source: USDA, ERS Feed Grains Yearbook, Jan 18, 2023; ProExporter Network, Jan 17, 2023
*projected for crop year Sept. 2022 – Aug. 2023
**Assumes projected 2022 USDA Average Farm Price ($6.70/bushel) and Average Corn Yield (173.3 bushels/acre)

U.S. CORN CROP VALUE
1960– 2022
($ billion)



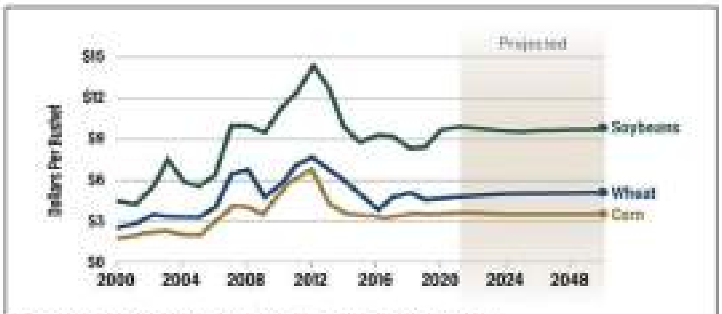
U.S. CORN PRICES
1960– 2022
($/bushel)



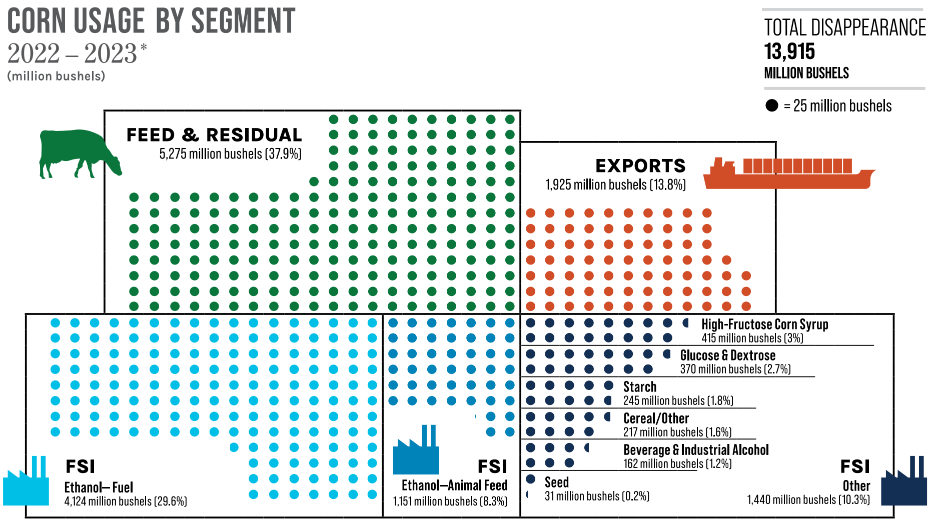
US CORN STATISTICS

US Corn Versus Crude (1986-2023)

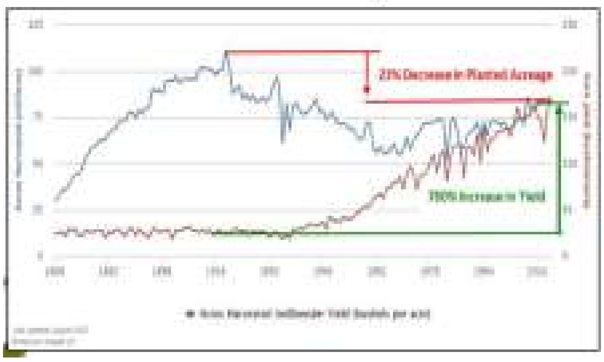
US – Corn Soybean and Wheat Prices



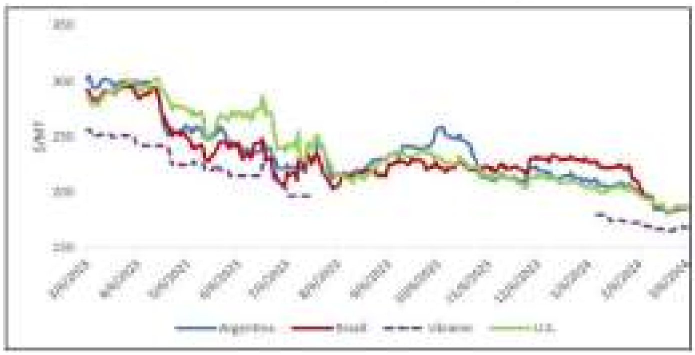
Prices for most crops remain low or stable relative to the recent past. Wheat prices are expected to nominally increase.



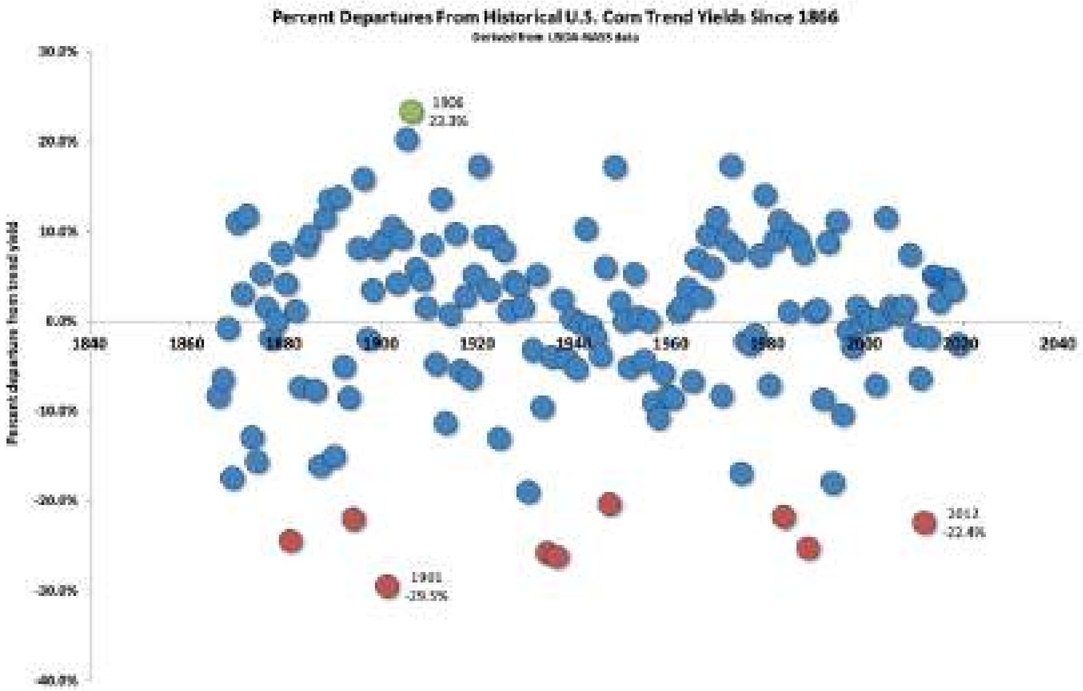
US Corn Productivity & Land use

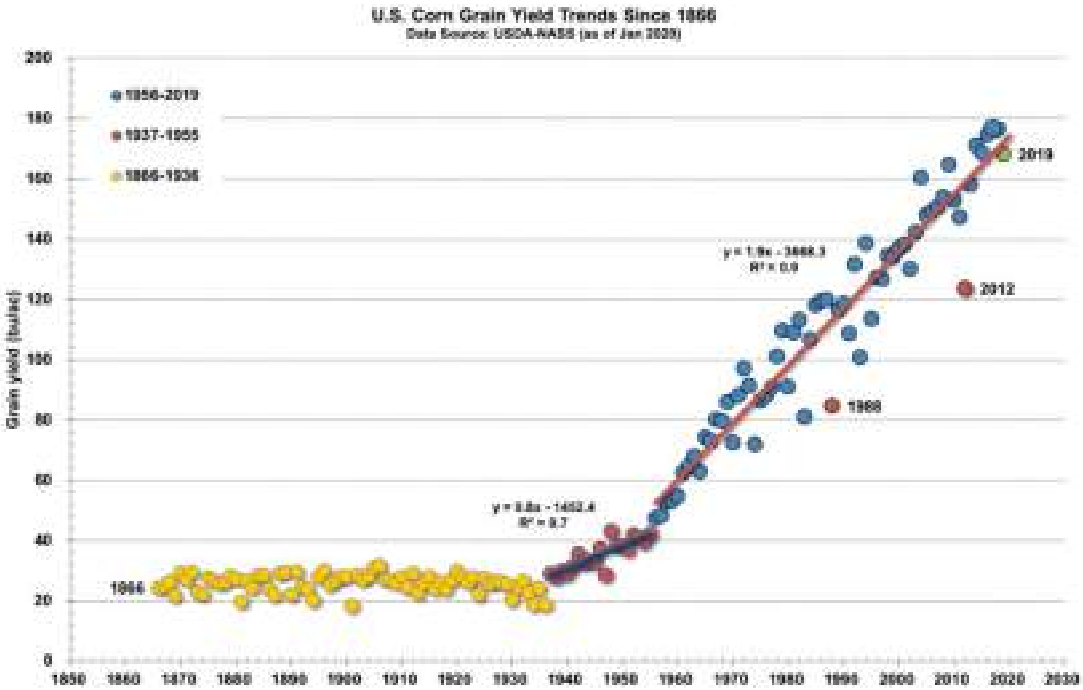


Corn Prices – Selected Export Bids (FOB)



US CORN STATISTICS





3.3 INDIA'S POSITIONING IN DENTED CORN

India's production of dented corn, also known as feed corn, is not as significant as in countries like the United States and Brazil. India's corn production primarily focuses on varieties suitable for human consumption, with a focus on yellow maize and white maize for food, feed, and industrial purposes. Dented corn, which typically refers to corn kernels with physical imperfections, is more commonly used as animal feed rather than for bioethanol production in India.

However, it's important to note that India's agriculture sector is dynamic and continually evolving. With increasing demand for biofuels and renewable energy, there may be potential for the expansion of corn cultivation specifically for ethanol production, including the utilization of dented corn as a feedstock. Factors such as government policies, market dynamics, technological advancements, and environmental considerations will influence the future trajectory of corn production and its utilization in India

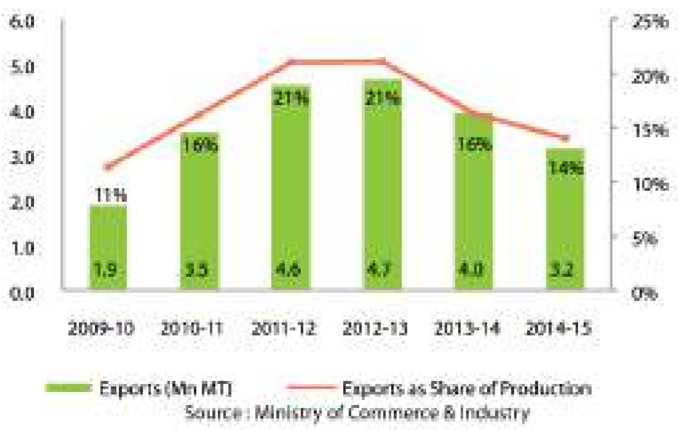
Furthermore, India has been exploring various feedstock options for biofuel production, including sugarcane, sorghum, and non-food biomass sources such as agricultural residues and energy crops. As the country seeks to enhance energy security, promote sustainable agriculture, and reduce greenhouse gas emissions, there may be opportunities to diversify feedstock sources for bioethanol production, potentially including dented corn.

In summary, while India's production of dented corn is **not currently a prominent feature of its agricultural landscape**, the country's evolving energy and agricultural policies, coupled with global trends in renewable energy, could influence the future role of dented corn in India's bioenergy sector. Monitoring developments in biofuel policies, agricultural practices, and technological innovations will provide insights into India's position in dented corn production and its potential contributions to bioethanol production in the future.

Higher price of Indian corn (USD 220 / MT compared to global prices at USD 175/ MT) coupled with lower quality (low grain weight) has impacted exports of corn from India. Policies around price correction and initiatives to improve quality can be key drivers of corn exports from India in the coming years.

INDIAN CORN EXPORTS

Indian corn exports dropping down due to higher prices, increased MSP, oversupply in the key corn producing countries



1.8%

Percentage of global corn exports by India in 2022

7.4%

Forecast CAGR of Indian corn demand by 2030

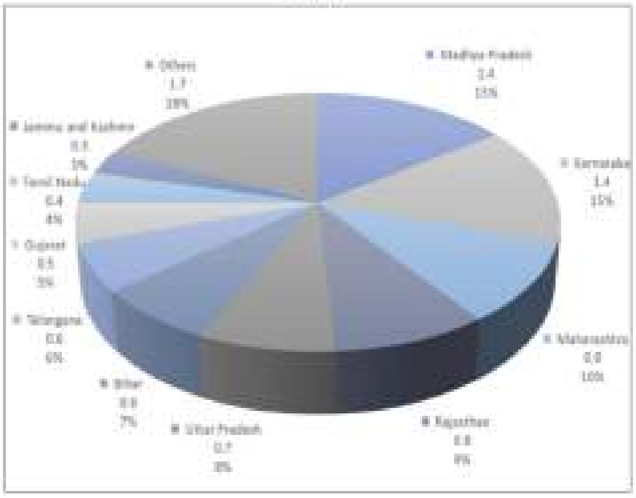
About 14% of the total production in India in 2014-15 was exported which is a clear dip from the 2011-12 and 2012-13 levels. In the past two years, due to changes in MSP, price of Indian maize is ~20% higher compared to global prices. Key corn producing nations in North and South America have experienced an over supply, enabling them to lower prices. As a result, Indian exports since Oct’14 are estimated to be 0.6 Mn MT and overall exports in marketing year 2014-15 are expected to be restricted to 2 Mn MT.

345 M $ **Corn exports to Bangladesh in 2023 from India**

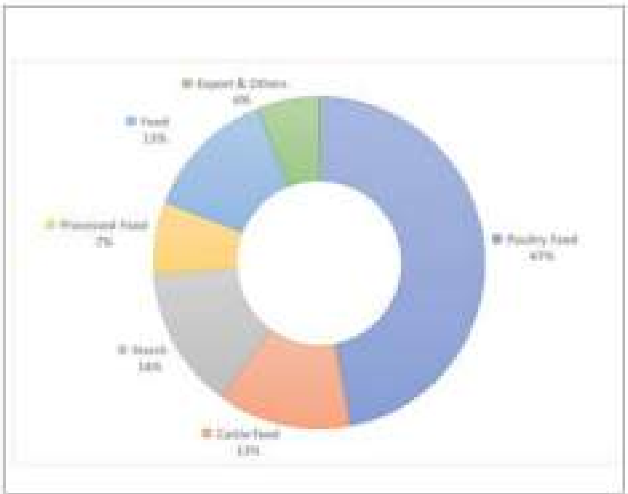
INDIAN CORN MARKET

Corn Area Cultivation -State wise

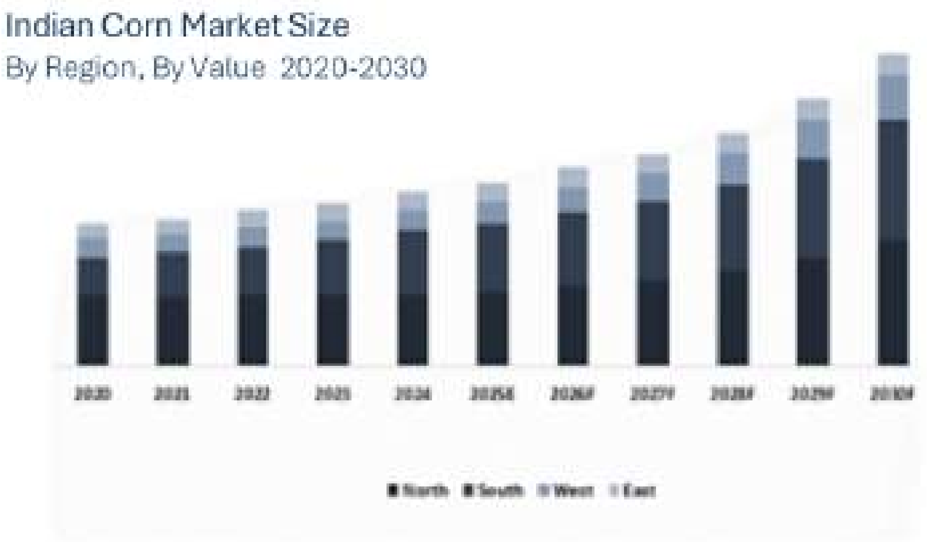
Million Ha



Corn Uses in India



INDIAN CORN MARKET



Indian Corn Market is US$ 1.28 Billion as of 2024

INDIA'S POSITIONING IN DENTED CORN

India has the 7th position in Corn production in the world and the 4th position in terms of Corn cultivation area. In percentage share, India's Corn production is approx. 2% of the total Corn production and covers 4% of the overall Corn cultivation area. Within India, Karnataka is the 1st in the top Corn producer states, and Madhya Pradesh and Maharashtra are in the next positions.

Corn stands as a pivotal cereal crop within the agricultural spectrum of India. Following rice and wheat, it secures its position as the third most crucial crop cultivated in the country. Its significance extends beyond a mere dietary component, finding applications in diverse industries such as food, animal husbandry, and raw material production.

India's diverse agro-climatic conditions favour Corn cultivation in several states. Corn can be grown as both a Kharif and Rabi crop. Notably, Kharif Corn accounts for 83% of the total Corn cultivation area and Rabi crops for 17%. More than 70% also grow Kharif Corn under rainfed farming.

In 2023, India sees a changing Corn cultivation with Karnataka the top producer followed by Madhya Pradesh and Maharashtra. Together these states produce more than 40% of total national Corn production. Notable contributors are Maharashtra, Uttar Pradesh, Bihar, Telangana and Gujarat which all have geographic advantage and adopt modern farming methods.

Agro-climatic conditions in Tamil Nadu and Jammu and Kashmir also play important roles. This collective effort in the name of innovation, government support and sustainable agriculture practices defines India's Corn production reflecting a resilient and diverse agricultural sector in the country.

In 2024, India witnessed significant Corn production across several states, contributing to the nation's agricultural output. The map highlights the top 10 Corn-producing states based on their yield and cultivation practices. Corn cultivation is a vital component of India's agricultural landscape, supporting food security, livestock feed, and various industrial applications.

3.4 BENEFITS OF IMPROVING INDIA'S POSITIONING

In India, agriculture is not just a livelihood; it's a way of life deeply rooted in tradition and culture. As the nation strives for agricultural sustainability and food security, there's a growing recognition of the importance of diversifying crops and adopting innovative farming practices. Cultivating corn can be a game changer in this regard

01

Crop Diversification

Cultivating dented corn allows Indian farmers to diversify their crop portfolios, reducing reliance on traditional crops and spreading agricultural risk. Dented corn can be grown alongside existing crops, providing an additional source of income and enhancing farm resilience against climate variability and market fluctuations.

02

Enhanced Livestock Feed

Dented corn serves as a nutritious feed ingredient for livestock and poultry, offering a cost-effective alternative to conventional feed grains. Rich in carbohydrates, proteins, and essential nutrients, dented corn can help improve animal health and productivity, leading to higher yields and better returns for farmers

03

Improved Soil Health

Incorporating dented corn into crop rotations can benefit soil health and fertility, thanks to its deep root system and biomass production. Dented corn residues left after harvest can be plowed back into the soil, enriching it with organic matter and promoting soil structure, water retention, and nutrient cycling.


9 Years
Seva, Sushasan
and Garib Kalyan
Enhancing
Market
Linkages
Promotion of
Farmer Producer
Organisations
(FPOs)
Handholding
support to 10000
new FPOs for 5 years
Budget outlay of
₹6800 cr+ till 2027-28
2500 FPOs
registered so far
5.87 lakh farmers
mobilized

3.5 STRATEGIES TO IMPROVE INDIA'S POSITIONING

01

Market Linkages

Facilitating market linkages and value chain integration for dented corn enables farmers to access markets, fetch better prices for their produce, and create sustainable income opportunities.

02

Access to Seeds and Inputs

Ensuring availability of quality seeds, fertilizers, and agrochemicals tailored for dented corn cultivation enables farmers to obtain the necessary inputs for starting their cultivation journey.

03

Education of the Farmers

To encourage Indian families to cultivate dented corn, educational initiatives and extension services play a crucial role in providing farmers with the knowledge, skills, and resources needed for successful cultivation. These initiatives can take various forms:

Training Programs

Conducting training programs and workshops on dented corn cultivation, agronomy, and best management practices

Demonstration Plots

Establishing demonstration plots or model farms showcasing successful dented corn cultivation techniques

Extension Services:

Leveraging agricultural extension services, farmer cooperatives, and community-based organizations

Productivity Improvement Initiatives and Best Practices

Inputs

- Seed selection, seed rate, seed treatment
- Fertilizer usage
- Weed control
- Insect and disease control

Farming Practices

- Land preparation and tilling – level of mechanization
- Sowing- techniques and mechanization
- Irrigation and drainage
- Intercropping

Harvest and Storage

- Harvesting technology and mechanization – minimizing losses
- Drying and storage technologies and pest management

Access to Markets and Pricing

- Support in forming farmer organization for better access to markets and key customers
- Technology support to provide access to price information and ensure better price discovery
- MSP support

Support Required (including role of Kisan Organizations)

- Access and support for inputs (seeds, fertilizers, etc)
- Support for mechanization – machine leasing, subsidies
- Access to credit
- Access to crop insurance
- Assistance in obtaining new seed varieties with higher yield/ biotic and abiotic stress resistance, etc
- Technology enabled knowhow support
- Unified market platform offering better market access to corn producers

↓

Increase in productivity and profitability

3.6 INITIATIVES TO IMPROVE INDIA’S POSITIONING

The Indian government has implemented various policies and schemes to support the cultivation of corn (Corn) in the country. These policies are aimed at enhancing productivity, ensuring farmers' welfare, promoting sustainable agricultural practices, and boosting the overall Corn production.

Many of them are also a part of the broader “Farm to Fork” set of policies promulgated by the Government of India

Minimum Support Price (MSP)

The government sets minimum support prices for various crops, including Corn, to ensure remunerative prices to farmers. MSP serves as a floor price for the sale of Corn and provides price stability to farmers.

Crop Insurance

The Pradhan Mantri Fasal Bima Yojana (PMFBY) is a crop insurance scheme that provides financial support to farmers in case of crop failure due to natural calamities, pests, or diseases.

Subsidies and Input Support:

The government provides subsidies on seeds, fertilizers, and pesticides to encourage farmers to adopt modern agricultural practices and improve Corn productivity.

Research and Extension Services

The Indian Council of Agricultural Research (ICAR) and state agricultural universities conduct research and development activities to introduce high-yielding Corn varieties, innovative farming techniques, and pest management strategies

Promotion of Value-Added Products

Efforts are made to promote the processing and value addition of Corn into products like corn starch, corn syrup, corn oil, and animal feed, which can enhance the income of farmers and create employment opportunities in rural areas

4

INDIA’S ROADMAP FOR BIOFUELS

4.1 LEARNING FROM OTHER COUNTRIES

India's roadmap for the development of biofuels over the next decade is poised to focus on enhancing energy security, reducing greenhouse gas emissions, and promoting sustainable agricultural practices. The National Policy on Biofuels, revised in 2018, sets an ambitious target of achieving 20% ethanol blending in petrol and 5% biodiesel blending by 2030. To facilitate this, the government is encouraging the production of biofuels from non-food feedstocks, including agricultural residues, municipal solid waste, and non-edible oilseeds.

Financial incentives, such as viability gap funding and interest subvention schemes, are being introduced to support biofuel production infrastructure and research into advanced biofuel technologies.

To further the development of biofuels, the Indian government plans to implement comprehensive regulatory frameworks and support mechanisms. The establishment of Biofuel Promotion Centers across various states aims to streamline the supply chain and ensure the availability of feedstocks. Policies promoting the integration of the agricultural sector with biofuel production will incentivize farmers to cultivate biofuel crops, thereby enhancing rural incomes. Additionally, public-private partnerships will be encouraged to foster innovation and investment in biofuel technologies. The government will also focus on building robust quality control mechanisms to ensure that biofuels meet international standards, thus enhancing their marketability both domestically and internationally.

Investing in research and development is critical for achieving the goals outlined in India's biofuel policy roadmap.

The government plans to allocate significant funding to research institutions and universities for developing second-generation (2G) and third-generation (3G) biofuels, which offer higher efficiency and lower environmental impact compared to traditional biofuels. Collaboration with international bodies and countries experienced in biofuel technology will also be a priority to leverage global expertise and best practices. Furthermore, public awareness campaigns and capacity-building programs will be essential to educate stakeholders about the benefits of biofuels, driving adoption and support at the grassroots level. By implementing these strategic measures, India aims to transform its biofuel sector, contributing to a greener and more sustainable energy future.

Learnings from others

USA IN CORN ETHANOL

India can draw several valuable lessons from the USA's experience in developing corn-based ethanol, a sector where the U.S. has established a robust and mature industry.

Firstly, the USA's success in corn-based ethanol is largely attributed to strong government policies and incentives. The **Renewable Fuel Standard (RFS) program**, which mandates blending renewable fuels with gasoline, has been a cornerstone in driving demand for ethanol. India can adopt similar policy frameworks to ensure a steady demand for ethanol, providing stability and growth opportunities for producers. Moreover, subsidies and tax incentives for ethanol production and infrastructure development have significantly contributed to the sector's expansion in the USA, and similar financial mechanisms could be beneficial in India.

Secondly, the USA has heavily invested in **research and development (R&D)** to improve the efficiency of ethanol production and reduce its environmental impact. Advances in biotechnology have led to the development of high-yield corn varieties and more efficient enzymes for ethanol production. India can focus on enhancing its R&D efforts to develop better feedstock varieties and more efficient production technologies. Collaborations between Indian research institutions and their American counterparts can facilitate the transfer of knowledge and technology.

Additionally, **developing infrastructure** for ethanol production, including refineries and distribution networks, is crucial. Learning from the U.S. experience, India should invest in creating a comprehensive supply chain network to support large-scale ethanol production and distribution.

Finally, the USA's approach to **stakeholder engagement and public awareness** has played a significant role in the acceptance and growth of corn-based ethanol. Educational campaigns highlighting the benefits of ethanol as a renewable energy source and its role in reducing greenhouse gas emissions have garnered public and political support. India can implement similar strategies to build a positive perception of biofuels among its citizens, emphasizing the environmental and economic benefits.

Furthermore, the USA's emphasis on **sustainability standards and certifications** for ethanol production can guide India in establishing robust quality and sustainability benchmarks, ensuring that its ethanol industry grows in an environmentally responsible manner. By incorporating these lessons, India can develop a more resilient and sustainable ethanol industry.

Learnings from others

BRAZIL IN ETHANOL

India can learn several valuable lessons from Brazil's successful corn-based ethanol development, even though Brazil primarily uses sugarcane for ethanol production. The principles and strategies Brazil employed in creating a robust ethanol industry can be adapted to support India's growing interest in corn-based ethanol.

Integrated Agricultural Practices:

Brazil has achieved remarkable success in ethanol production by integrating agricultural practices with biofuel production. Indian policymakers can promote the cultivation of corn specifically for ethanol alongside food crops. Brazil's use of advanced agricultural techniques to maximize yield and minimize environmental impact can be emulated. Implementing crop rotation and intercropping systems can improve soil health and increase overall productivity, benefiting both food and biofuel crop production.

Supportive Policies and Infrastructure Development:

Brazil's Proálcool program provided a strong policy framework, including subsidies, low-interest loans, and price supports, which were crucial in establishing its ethanol industry. India can adopt similar policies to encourage investment in corn-based ethanol production. Additionally, developing infrastructure such as ethanol refineries, storage facilities, and distribution networks is essential. Learning from Brazil, India can implement a coordinated approach involving government support, private sector investment, and public-private partnerships to build the necessary infrastructure for a thriving ethanol industry.

1.

Flex-Fuel Vehicles and Market Development:

Brazil's widespread adoption of flex-fuel vehicles, which can run on varying ethanol-gasoline blends, has significantly boosted domestic ethanol consumption. India can encourage the use of flex-fuel vehicles through incentives and regulations, ensuring a steady demand for ethanol. Public awareness campaigns highlighting the benefits of ethanol, including reduced greenhouse gas emissions and enhanced energy security, can drive consumer acceptance. Furthermore, India can create a favorable market environment by ensuring competitive pricing and availability of ethanol-blended fuels across the country.
By learning from Brazil's integrated agricultural practices, supportive policies, infrastructure development, and market strategies, India can effectively develop its corn-based ethanol industry. This approach will not only enhance energy security but also support rural economies and contribute to sustainable development goals.

Learnings from others

EUROPEAN UNION IN POLICY MAKING

India can gain valuable insights from the European Union's approach to developing a robust biofuel industry, particularly in the areas of policy frameworks, sustainability practices, and technological innovation.

Comprehensive Policy Frameworks:

The EU has established strong regulatory frameworks, such as the Renewable Energy Directive (RED), which sets clear targets for renewable energy usage, including biofuels. This directive mandates a specific percentage of renewable energy in transport fuels, providing a stable and predictable market for biofuels. India can benefit from implementing similar directives that set ambitious, yet achievable targets for biofuel blending. Additionally, the EU's policies emphasize the use of advanced biofuels made from non-food feedstocks, which India can adopt to ensure food security while promoting biofuel production.

Sustainability and Environmental Standards:

The EU has stringent sustainability criteria for biofuels to minimize environmental impact. These criteria include reducing greenhouse gas emissions compared to fossil fuels and avoiding deforestation and land-use changes that could harm biodiversity. India can incorporate these sustainability standards into its biofuel policies to ensure that biofuel production does not negatively impact the environment. Adopting certifications and sustainability protocols similar to those used in the EU can help India produce environmentally responsible biofuels that meet international standards.

1.

Technological Innovation and Research

The EU invests significantly in research and development to advance biofuel technologies, focusing on second-generation (2G) and third-generation (3G) biofuels derived from waste materials and algae. Collaborative projects and funding programs, such as Horizon 2020, have propelled innovation in the sector. India can enhance its R&D efforts by fostering collaborations between domestic research institutions, industries, and international partners to develop cutting-edge biofuel technologies. Emphasizing innovation can help India improve the efficiency and sustainability of its biofuel production processes.

By learning from the EU's comprehensive policy frameworks, commitment to sustainability, and focus on technological innovation, India can build a more resilient and sustainable biofuel industry. Implementing these practices will support India's energy security goals, reduce greenhouse gas emissions, and promote economic growth in rural areas.

4.2 COMPETITIVE STRENGHTS OF INDIA

India has several competitive strengths that position it well for adopting biofuels as a significant component of its energy mix. These strengths include its vast agricultural resources, diverse biomass availability, government support, and a growing emphasis on sustainability and rural development.

1.Abundant Agricultural Resources

India's extensive agricultural sector provides a substantial base for biofuel production. The country produces a significant amount of agricultural residues, such as rice straw, wheat straw, and sugarcane bagasse, which can be utilized as feedstock for biofuels. Additionally, India has large areas of land suitable for growing biofuel crops like jatropha, which does not compete with food crops. This abundance of raw materials can support large-scale production of biofuels without compromising food security.

2. Diverse Biomass Availability

India's diverse climatic conditions and biodiversity contribute to a wide range of biomass sources, including forestry residues, agricultural waste, and municipal solid waste. This diversity allows for the development of various types of biofuels, such as ethanol, biodiesel, and biogas, tailored to different regional strengths and feedstock availability. The utilization of municipal solid waste for biofuel production also addresses waste management issues in urban areas, creating a dual benefit of waste reduction and energy production.

3. Government Support and Policy Initiatives

The Indian government has demonstrated strong support for the biofuel sector through policies and initiatives. The National Policy on Biofuels aims to achieve 20% ethanol blending in petrol and 5% biodiesel blending by 2030. Various schemes, such as the Pradhan Mantri JI-VAN Yojana, provide financial assistance for setting up advanced biofuel refineries. Additionally, the government offers fiscal incentives, including tax exemptions and subsidies, to promote biofuel production and usage. These policies create a favorable environment for investment and growth in the biofuel sector.

4. Technological Advancements and Innovation

India has made significant strides in technological advancements and innovation in the biofuel sector. Research institutions, universities, and private companies are actively engaged in developing advanced biofuel technologies, such as second-generation (2G) and third-generation (3G) biofuels. Collaborations with international organizations and countries experienced in biofuel technology further enhance India's capabilities. The focus on developing efficient and sustainable biofuel production methods positions India as a competitive player in the global biofuel market.

4.3 CHALLENGES FACED BY INDIA

While India has significant strengths in adopting biofuels, several challenges must be addressed to realize the full potential of the biofuel sector. These challenges include feedstock availability and logistics, technological and infrastructural limitations, financial and economic barriers, policy and regulatory hurdles, and environmental and social concerns.

1. Feedstock Availability and Logistics

The availability of feedstock for biofuel production, such as agricultural residues, can be highly seasonal and inconsistent. This variability poses challenges in maintaining a steady supply for biofuel production plants. Additionally, the collection, transportation, and storage of biomass can be logistically complex and costly, particularly in rural areas with inadequate infrastructure.

2. Technological and Infrastructural Limitations

While India has made progress in research and development, advanced biofuel technologies like second-generation (2G) and third-generation (3G) biofuels are still in nascent stages of commercialization. Scaling these technologies to industrial levels requires significant investment and technological breakthroughs. The biofuel industry requires substantial infrastructure for production, processing, and distribution. In many parts of India, especially rural areas, this infrastructure is underdeveloped.

3. Financial and Economic Barriers

The production costs for biofuels, particularly advanced biofuels, can be higher than those of conventional fossil fuels. Without sufficient subsidies or financial incentives, biofuel production may not be economically viable for many producers. Securing funding for biofuel projects can be challenging, especially for small and medium enterprises. Investors may be hesitant due to perceived risks and uncertainties in the biofuel market. Access to affordable credit and investment is crucial for the growth of the biofuel sector.

4. Policy and Regulatory Hurdles

Policy inconsistency and lack of clarity can deter investment in the biofuel sector. For example, fluctuating subsidy regimes, changing blending mandates, and bureaucratic red tape can create uncertainty for investors and producers. Establishing and enforcing quality standards for biofuels is essential to ensure their performance and compatibility with existing engines and infrastructure. However, developing these standards and regulatory frameworks can be complex and time-consuming.

5. Environmental and Social Concerns

Expanding biofuel production can lead to competition for land with food crops, raising concerns about food security. Ensuring that biofuel crops do not displace food production or lead to deforestation and habitat loss is critical. Biofuel crops, particularly those like sugarcane, can require significant water resources. In water-scarce regions, this can exacerbate water stress and affect local water availability for other uses. Public awareness and acceptance of biofuels are essential for their adoption. Misinformation or lack of understanding about biofuels' benefits and impacts can hinder their acceptance. Engaging communities and stakeholders through education and outreach programs is necessary.

6. Integration with Existing Systems

Ensuring that biofuels are compatible with existing vehicle engines and fuel infrastructure is a technical challenge. The automotive industry needs to support and adapt to biofuel use through research and development. Creating a robust market for biofuels involves not only production but also the development of distribution channels, retail networks, and consumer demand. This requires coordinated efforts across various sectors.

4.4 KEY PILLARS OF ROADMAP

Government to Support Farmers to Start 'Corn Revolution

The development of the corn to ethanol sector in India holds significant potential for enhancing energy security, promoting sustainable agricultural practices, and reducing greenhouse gas emissions.

Setting up of Mega Corn Based Bio-Refineries

Establishing mega-size corn to ethanol bio-refineries offers a multifaceted solution that addresses pressing energy issues. By involving large companies, Public Sector Undertakings (PSUs), and petroleum refineries, India can lead the charge

Making India an Export Hub for Sustainable Aviation Fuel

India, with its vast agricultural resources and strategic position in the global market, holds immense potential to become a leading supplier of SAF, particularly through the corn ethanol route.

Infrastructure For Ethanol To Replace LPG For Cooking

The shift from Liquefied Petroleum Gas (LPG) to ethanol as a cooking fuel in India offers a sustainable solution to enhance energy security, reduce greenhouse gas emissions, and stimulate rural economies.

Taking up Selected Value Added Chemicals using Ethanol

There is immense potential of ethanol as a key feedstock for developing a wide range of chemicals and petrochemicals. Efforts are made to promote the processing and value addition of Corn into products like corn starch, corn syrup, corn oil etc

Achieving Carbon Neutrality

Bioethanol has the potential of not just being carbon neutral but also carbon negative, therefore helping India achieve the GHG targets and a world leader in climate change.

CORN REVOLUTIONIZED

From start to finish, corn seed development that change farning

A. GOVERNMENT TO SUPPORT FARMERS TO START 'CORN REVOLUTION'

The development of the corn to ethanol sector in India holds significant potential for enhancing energy security, promoting sustainable agricultural practices, and reducing greenhouse gas emissions. A comparative analysis with the United States, a global leader in corn to ethanol production, underscores the importance of robust government support and incentives in realizing this potential.

Lessons from the United States:

The United States has become a leading producer of corn-based ethanol due to extensive federal support, including the Renewable Fuel Standard (RFS) that mandates renewable fuel use in transportation. Enforced laws that require ethanol blending, Tax tax credits, grants, and loan guarantees have spurred investment in ethanol production, reducing financial risks for investors.

Economic Benefits:

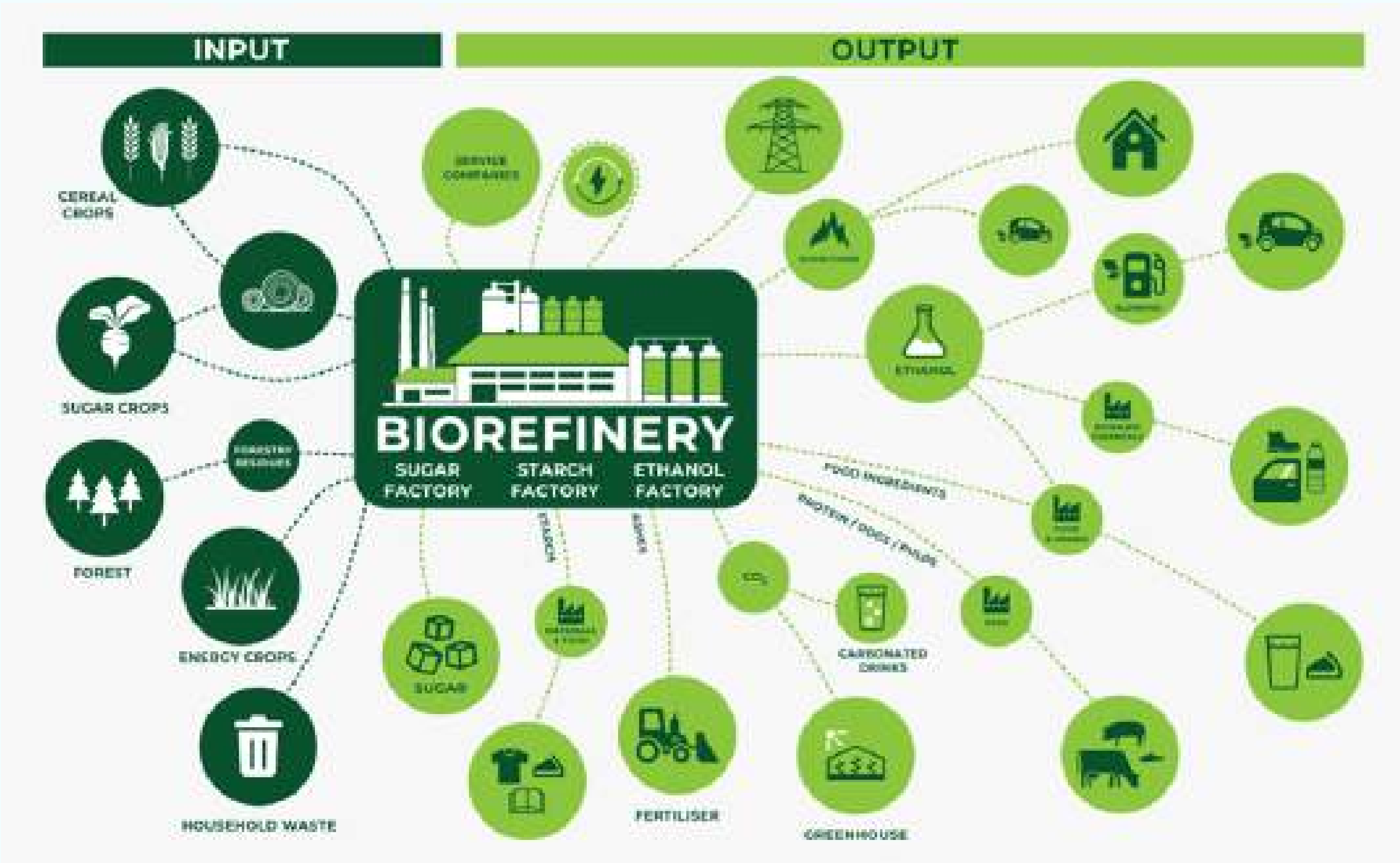
The US corn to ethanol industry has created numerous jobs and provided farmers with a stable market, boosting rural economic development. It has also diversified the energy supply, reducing reliance on imported oil and enhancing energy security.

Environmental Impact:

Ethanol, as a renewable fuel, significantly lowers greenhouse gas emissions compared to gasoline. The US experience shows ethanol's critical role in national strategies for climate change mitigation.

To successfully initiate the 'Corn to Ethanol Revolution' in India, the government needs to provide comprehensive support to farmers across multiple dimensions.

The Indian Government also recognizes the potential of corn as a strategic crop and has embarked on a mission to support a "Corn Revolution" on a war footing. There is a focus to promote High-Yielding Varieties, empower farmers with the latest agronomic practices and technologies, Enhanced Access to Inputs and Credit, better infrastructure and market linkages and price support. Focus is also on driving innovation and research in corn cultivation is critical for unlocking the crop's full potential and addressing emerging challenges.


INPUT
OUTPUT
CEREAL CROPS
SUGAR CROPS
FOREST
ENERGY CROPS
HOUSEHOLD WASTE
BIOREFINERY
SUGAR FACTORY
STARCH FACTORY
ETHANOL FACTORY
ETHANOL
FOOD INGREDIENTS
SUGAR
FERTILISER
CARBONATED DRINKS
GREENHOUSE

B. SETTING UP MEGA CORN BASED BIO-REFINEIRES

India stands at the crossroads of a transformative energy revolution. The need to enhance energy security, stimulate rural economies, and combat climate change has never been more urgent. Establishing mega-size corn to ethanol bio-refineries offers a multifaceted solution that addresses these pressing issues. By involving large companies, Public Sector Undertakings (PSUs), and petroleum refineries, India can lead the charge in producing transportation fuel, sustainable aviation fuel, and ethanol for household use, replacing LPG.

This initiative promises to catalyse economic growth, foster energy independence, and promote environmental sustainability.

Energy Security and Diversification

India's heavy reliance on imported crude oil strains its economy and poses geopolitical risks. Mega-size corn to ethanol bio-refineries can produce substantial volumes of ethanol, reducing the need for imported oil and enhancing energy security.

Diversifying Energy Sources:

Diversifying the energy mix with ethanol-based fuels can provide a buffer against global oil price fluctuations, ensuring a more stable and predictable energy supply.

Economic Benefits

Establishing large-scale bio-refineries in rural areas will create significant employment opportunities, invigorate local economies, and provide farmers with a lucrative market for their corn produce. A stable demand for corn can incentivize better agricultural practices and higher productivity, contributing to rural prosperity and agricultural sustainability.
The development of mega bio-refineries will attract substantial investments, both domestic and international, fostering industrial growth and technological advancement.

Environmental Benefits

Ethanol burns cleaner than fossil fuels, resulting in lower greenhouse gas emissions. This can help India meet its climate goals and reduce air pollution in urban areas.

Encouraging the cultivation of corn for ethanol can promote sustainable farming practices, reduce soil degradation, and make use of agricultural residues, minimizing waste.

Production of Transportation Fuel

Mega bio-refineries can produce ethanol for blending with gasoline, reducing the carbon footprint of transportation fuels. This aligns with India's Ethanol Blending Program (EBP) targets.

Cost-Effective and Clean Energy

Ethanol-blended fuels are not only environmentally friendly but also cost-effective in the long run, contributing to affordable and sustainable transportation.

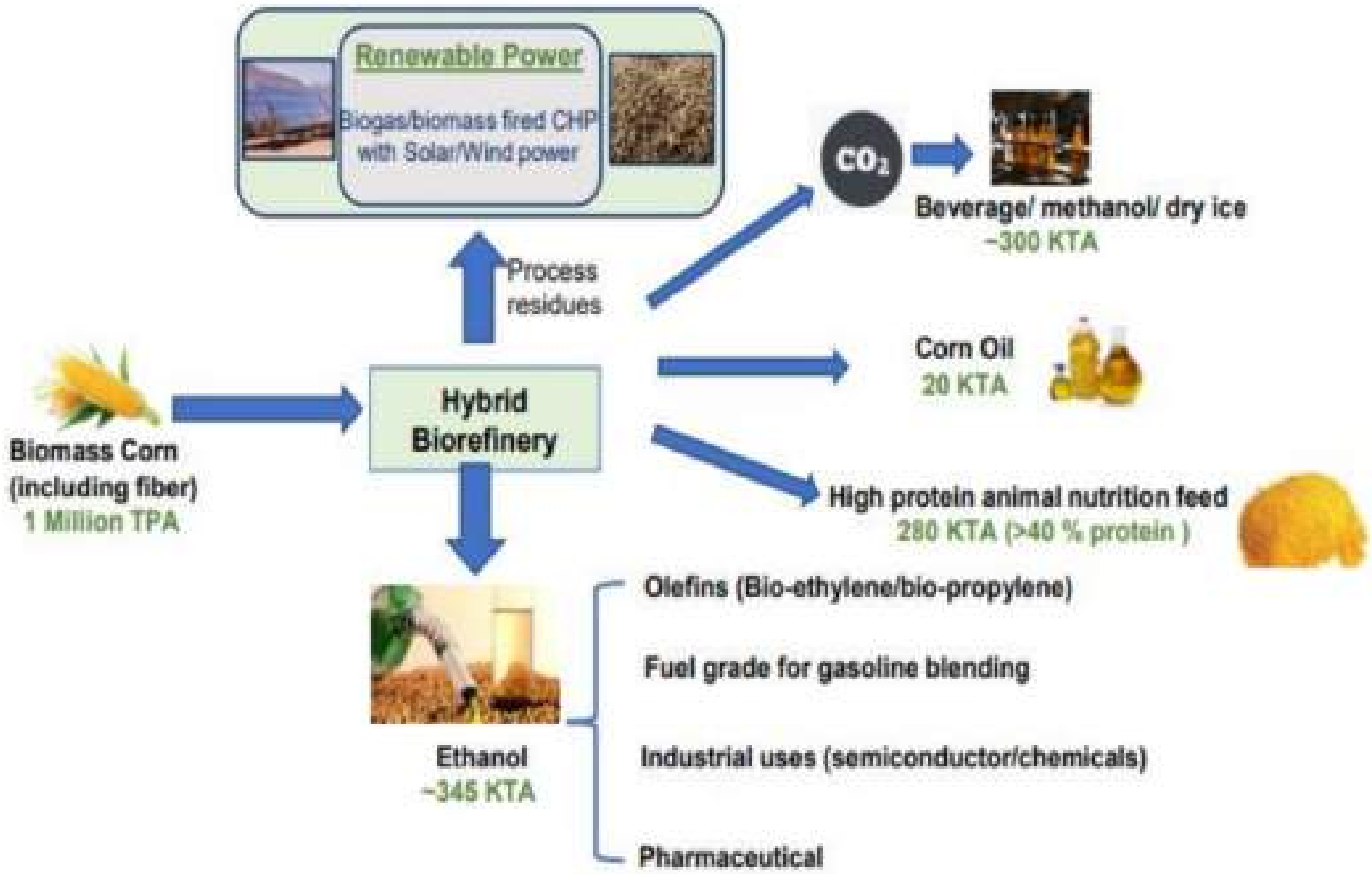
Integrated Hybrid Bio-refinery Concept Phase 1

Feedstock and Corn Oil

These sustainable biorefineries utilize non-edible biomass corn and also Cellulosic Biomass as the feedstocks to produce bio-ethanol of various grades. Valuable components in corn (protein and oil) extracted to produce high protein animal nutrition feed and Corn Oil – only the waste starch residue converted to ethanol

Additional Revenue

- Additional revenues via capture of CO2 produced in fermentation for various uses - food/beverage/bio-methanol or sequestration
- Integrated configuration offers significant CAPEX and OPEX savings via extensive heat integration.

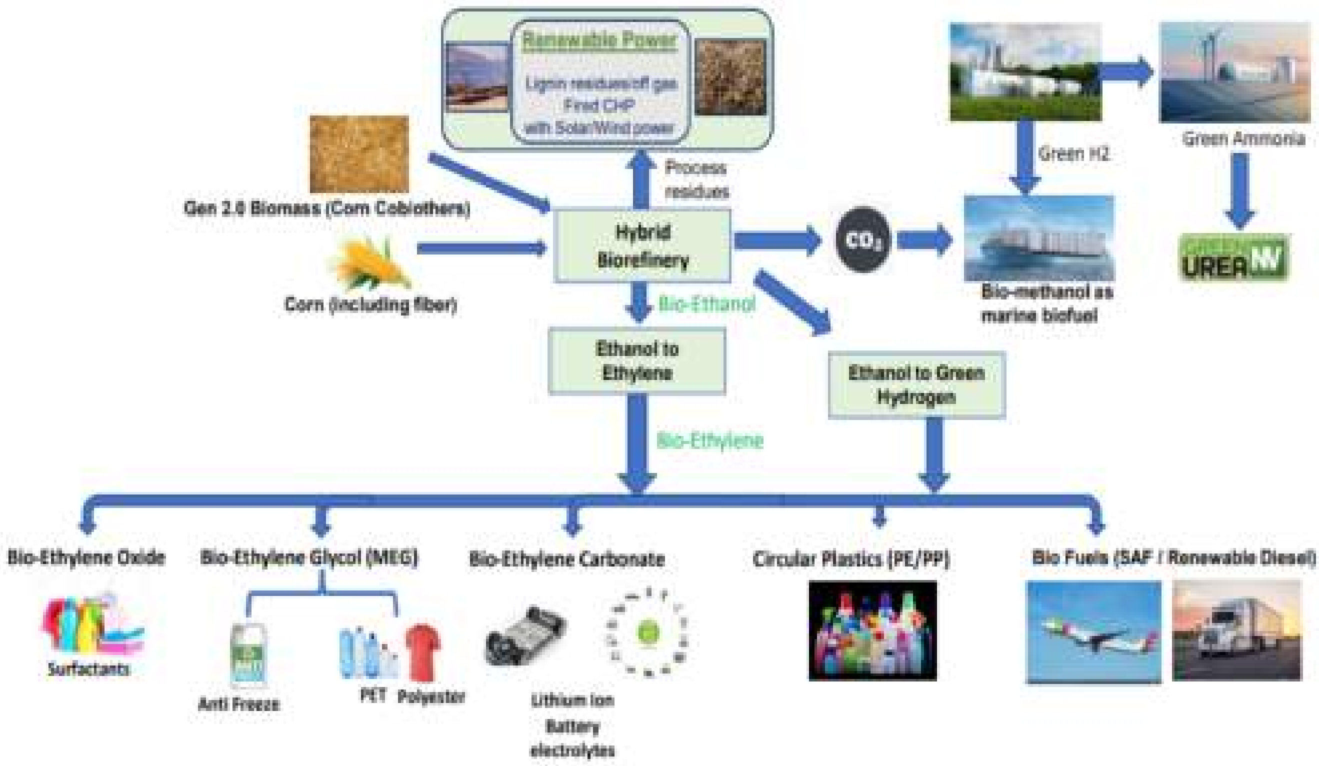


Integrated Hybrid Bio-refinery Concept Phase 2

In addition to phase 1, phase 2 would potentially involve phase 1 expansion and CO_2 utilization to produce various biofuels and bioproducts.

Bio-ethylene produced from ethanol could be converted into various bioproducts and downstream chemicals. Phase II shows some of the potential products which can be produced from bio-ethylene (such as EO/EC/PE/PP) and from green H_2 via electrolysis (such as ethanol, green ammonia, green urea) – Ethanol to Green Hydrogen can also be produced.

More details shall be determined during project feasibility stage.



C. TO MAKE INDIA AS EXPORT HUB FOR SUSTAINABLE AVIATION FUEL (SAF)

As the world shifts towards sustainable energy sources to combat climate change, the aviation industry is under significant pressure to reduce its carbon footprint. Sustainable Aviation Fuel (SAF) has emerged as a pivotal solution in this endeavour. India, with its vast agricultural resources and strategic position in the global market, holds immense potential to become a leading supplier of SAF, particularly through the corn ethanol route.

Potential of SAF in India

India's aviation industry is experiencing rapid growth and is poised to become one of the largest aviation markets globally.

This burgeoning sector makes a compelling case for the production of Sustainable Aviation Fuel (SAF). As air travel demand continues to soar, the country's requirement for aviation fuel will increase steeply in the coming years. India is projected to become the third-largest aviation market by 2025. With rising passenger numbers and increased freight traffic, the demand for aviation fuel is expected to grow exponentially. This creates a significant opportunity for SAF to meet the industry's fuel needs while reducing its carbon footprint.

India’s Agricultural Strength

India is already a major producer of corn and has the potential to become one of the world's top producers. By dedicating more arable land to corn cultivation through concerted efforts to develop the corn ethanol sector, India can significantly boost its production capacity. The country's diverse climatic conditions and extensive agricultural expertise provide a robust foundation for scaling up corn production specifically for ethanol, ensuring a steady and sustainable supply for bio-refineries.

Rural Development:

Promoting corn cultivation for ethanol can stimulate rural economies, providing farmers with additional income sources and creating jobs in agriculture and related industries.

Technological and Infrastructural Readiness

India has made significant strides in biofuel production, with existing ethanol plants and blending mandates. Leveraging this infrastructure for SAF production is a logical progression. Indian research institutions and private companies are actively engaged in biofuel research, developing advanced technologies for efficient ethanol production and conversion to SAF.

Economic Benefits

The establishment of SAF production facilities will create numerous jobs across the value chain, from agriculture to refining and distribution. The growing global demand for SAF presents lucrative opportunities for domestic and international investors to fund bio-refineries and related infrastructure in India. India can capitalize on the increasing international demand for SAF, positioning itself as a key exporter. This can significantly boost foreign exchange earnings and trade balances.

Environmental Impact

SAF produced from corn ethanol can reduce lifecycle greenhouse gas emissions by up to 80% compared to conventional jet fuel. This substantial reduction is critical for meeting global climate targets. Developing a robust SAF industry can enhance India’s energy security by reducing reliance on imported fossil fuels and diversifying energy sources. By investing in SAF production, India can position itself as a leader in the renewable energy sector, influencing global standards and practices.


GREEN DEVELOPMENT

D. INFRASTRUCTURE FOR ETHANOL TO REPLACE LPG FOR COOKING

In recent years, the quest for sustainable energy sources has gained considerable momentum, driven by the urgent need to mitigate climate change and reduce dependency on fossil fuels. One promising avenue in this endeavour is the utilization of ethanol as a cooking fuel, offering a cleaner and more environmentally friendly alternative to liquefied petroleum gas (LPG).

However, the widespread adoption of ethanol for cooking hinges not only on the availability of the fuel itself but also on the development of a robust infrastructure capable of supporting its distribution and utilization on a large scale. The shift from Liquefied Petroleum Gas (LPG) to ethanol as a cooking fuel in India offers a sustainable solution to enhance energy security, reduce greenhouse gas emissions, and stimulate rural economies. Leveraging the existing LPG distribution network can facilitate this transition, making ethanol accessible and affordable for households across the country.

The following outlines the necessary steps to develop the infrastructure for ethanol as a cooking fuel.

Production Infrastructure

Ethanol Production Facilities: Establishing new ethanol production plants and upgrading existing bio-refineries are critical. These facilities should be strategically located near agricultural hubs to ensure a steady supply and reduce logistical shipping costs of raw materials like corn, sugarcane, and agricultural residues. Investment in advanced technologies to increase production efficiency is essential.

Feedstock Supply Chain:

Developing a reliable supply chain for feedstocks involves encouraging farmers to grow corn crops suitable for ethanol production. This can be supported through initiatives such as contract farming, subsidies, and access to farming resources.

Distribution Networks:

Establishing an efficient distribution network to transport ethanol from production facilities to end-users is crucial. This may involve retrofitting existing fuel distribution infrastructure or building new pipelines, storage facilities, and transportation fleets optimized for ethanol delivery

Utilizing Existing LPG Distribution Network Storage and Distribution Centres:

Existing LPG storage and distribution centres can be adapted to handle ethanol. These centres should be equipped with safety measures to store ethanol, which is more flammable than LPG.

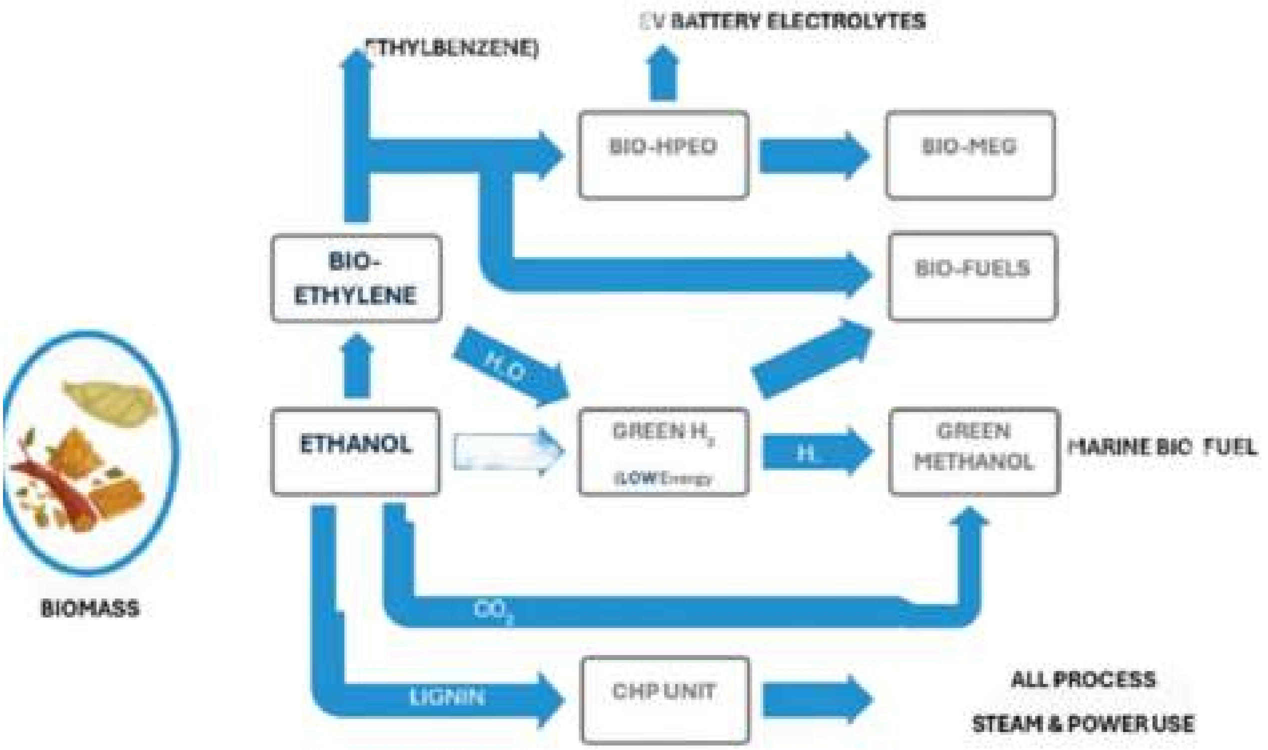
Transportation Infrastructure:

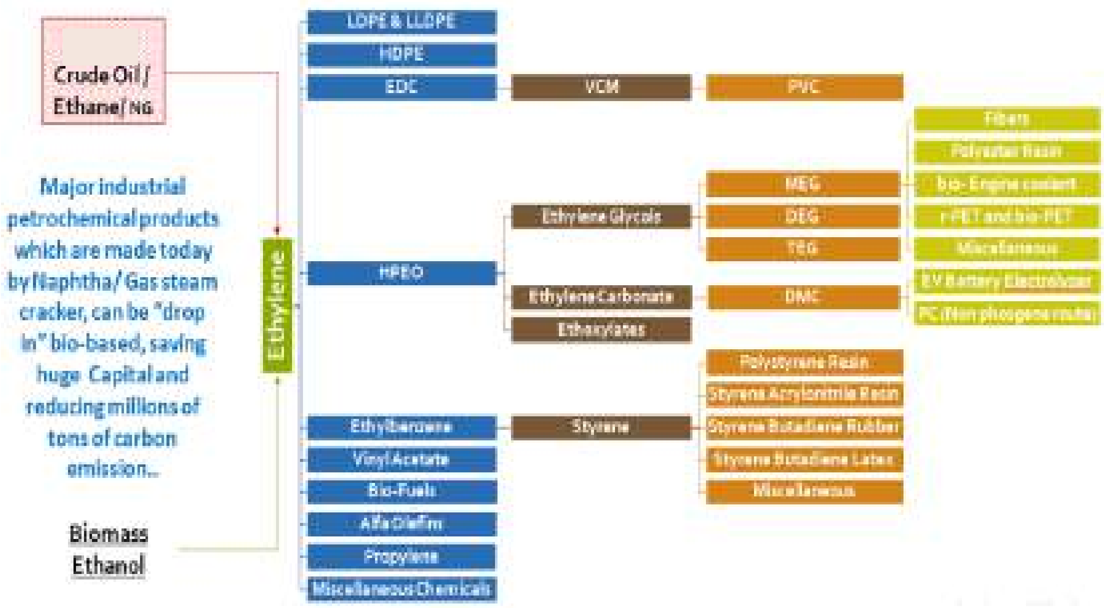
LPG tankers and pipelines can be modified to transport ethanol. This approach minimizes the need for new infrastructure and reduces costs. Efficient logistics management will ensure timely and cost-effective delivery of ethanol to distribution points.

Retail Outlets:

LPG distribution points, including fuel stations and local retailers, can be used to sell ethanol. This widespread network ensures easy accessibility for consumers. These outlets should be equipped with ethanol-compatible dispensing systems and safety features.

SELECTED VALUE-ADDED CHEMICALS USING BIOETHANOL





E. TAKING UP SELECTED VALUE-ADDED CHEMICALS

Ethanol, a versatile and sustainable biofuel, holds immense potential beyond its use as a fuel. It can serve as a crucial raw material in the chemical and petrochemical industries, offering a sustainable alternative to traditional feedstocks derived from crude oil. As India looks to diversify its industrial base and reduce dependence on imported oil, leveraging ethanol for chemical production presents a strategic opportunity.

Here is the potential of ethanol as a key feedstock for developing a wide range of chemicals and petrochemicals.

Chemical Intermediates:

Ethanol can be converted into various chemical intermediates that are essential for producing a broad spectrum of chemicals and petrochemicals. These include ethylene, acetaldehyde, acetic acid, ethyl acetate, and more. These intermediates serve as building blocks for numerous industrial applications.

Sustainable Production:

Ethanol is produced from Corn is a renewable resource makes ethanol a more sustainable and environmentally friendly feedstock compared to traditional petrochemical feedstocks derived from non-renewable crude oil.

Strategic and Economic Benefits:

Utilizing ethanol as a feedstock for the chemical and petrochemical industries can reduce India's dependence on imported crude oil and petrochemical intermediates. This can lead to significant savings in foreign exchange and enhance energy security.

Transforming ethanol into higher-value chemical products can create substantial economic value. This value addition can spur industrial growth, create jobs, and generate revenue for both the public and private sectors.

Value Addition:

Transforming ethanol into higher-value chemical products can create substantial economic value. This value addition can spur industrial growth, create jobs, and generate revenue for both the public and private sectors.

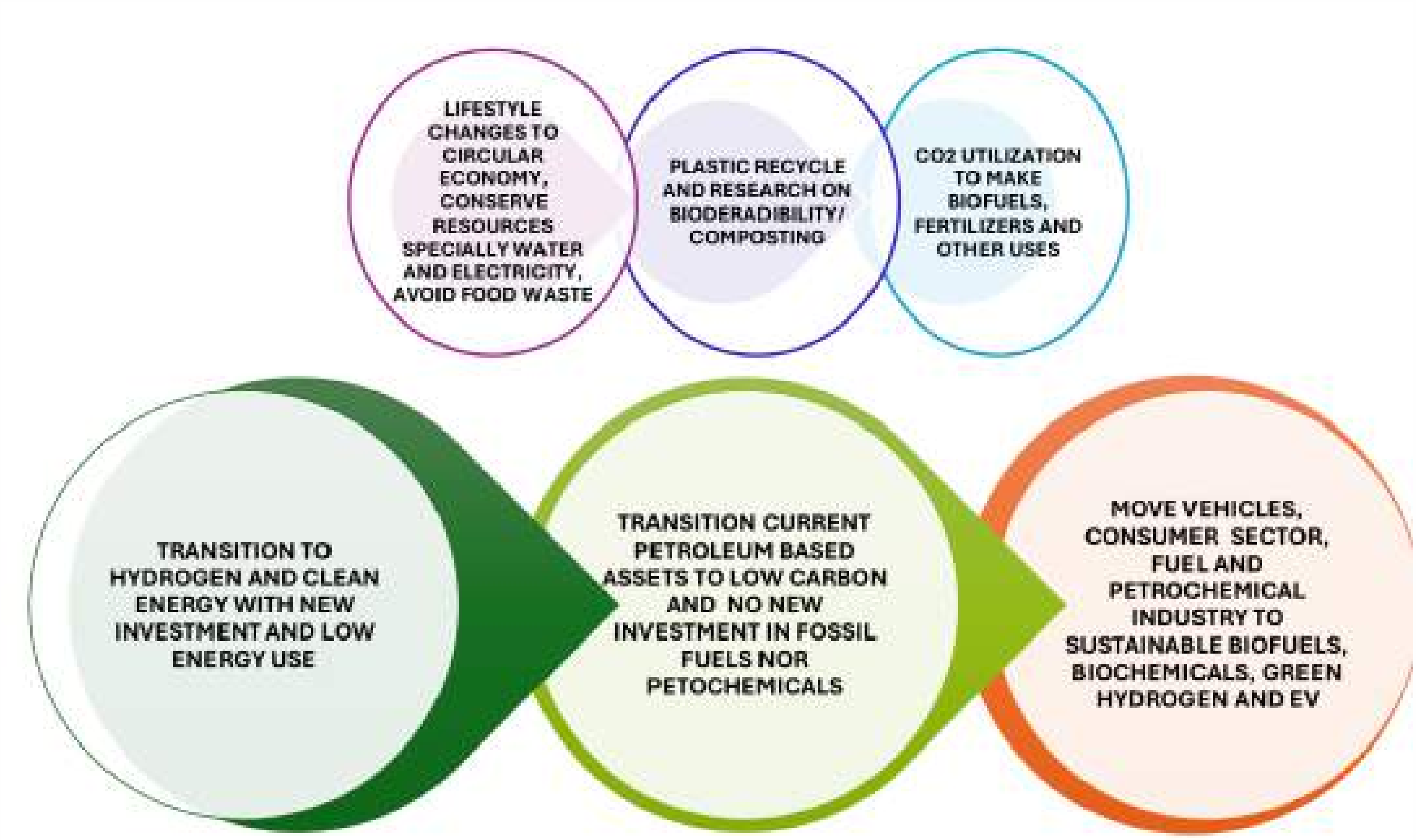
Potential Applications in the Chemical Industry

Ethylene Production: Ethanol can be dehydrated to produce ethylene, a fundamental raw material for the manufacture of a variety of polymers and chemicals, including polyethylene, ethylene oxide, and ethylene glycol. Ethylene is a critical component in the production of plastics, detergents, and antifreeze.

Acetaldehyde and Acetic Acid: Ethanol can be oxidized to produce acetaldehyde, which is further processed to produce acetic acid. Acetic acid is a key raw material for producing vinyl acetate monomer (VAM), used in paints, adhesives, and coatings. Acetaldehyde is also used in the manufacture of perfumes, flavours, and plasticizers.

Ethyl Acetate: Ethanol reacts with acetic acid to produce ethyl acetate, a solvent widely used in the production of paints, varnishes, adhesives, and cleaning fluids. Ethyl acetate is also used in the pharmaceutical and food industries.

Butadiene and Synthetic Rubber: Ethanol can be converted into butadiene, an essential component in the production of synthetic rubber. Synthetic rubber is used in various applications, including tires, footwear, and industrial products.


LIFESTYLE CHANGES TO CIRCULAR ECONOMY, CONSERVE RESOURCES SPECIALLY WATER AND ELECTRICITY, AVOID FOOD WASTE
PLASTIC RECYCLE AND RESEARCH ON BIODERADIBILITY/ COMPOSTING
CO2 UTILIZATION TO MAKE BIOFUELS, FERTILIZERS AND OTHER USES
TRANSITION TO HYDROGEN AND CLEAN ENERGY WITH NEW INVESTMENT AND LOW ENERGY USE
TRANSITION CURRENT PETROLEUM BASED ASSETS TO LOW CARBON AND NO NEW INVESTMENT IN FOSSIL FUELS NOR PETOCHEMICALS
MOVE VEHICLES, CONSUMER SECTOR, FUEL AND PETROCHEMICAL INDUSTRY TO SUSTAINABLE BIOFUELS, BIOCHEMICALS, GREEN HYDROGEN AND EV


CO2

F. ACHIEVING CARBON NEUTRALITY

Bioethanol is a fuel derived from organic matter such as plant material which when produced sustainably can be a promising renewable resource for reducing greenhouse gas emissions and achieving carbon neutrality. Bioethanol combustion releases carbon dioxide, but if the plants used to create it were grown by capturing carbon dioxide from the atmosphere, the net effect on greenhouse gases can be minimal. This makes bioethanol a potential alternative to fossil fuels for transportation and other applications.

Thus, Bioethanol has the potential to be a carbon-neutral fuel source and has the following benefits.

Renewable and Sustainable:

Unlike finite fossil fuels, biofuels resources are renewable, making bioenergy a sustainable energy option. Proper management of biomass resources ensures continuous availability without depleting natural reserves.

Greenhouse Gas Reduction:

Bioethanol contributes to mitigating climate change by offering a carbon-neutral or even carbon-negative energy source. The carbon dioxide released during combustion is offset by the carbon dioxide absorbed during biomass growth, resulting in a closed carbon cycle.

Waste Management:

Production of bioethanol from Waste materials such as agricultural residues, municipal solid waste, and can be an effectively solution to manage waste.

Decarbonization:

Use of Bioethanol as fuel contributes to decarbonization by displacing fossil fuels in various sectors such as transportation, heating, and industrial processes. For instance, biofuels like biodiesel and bioethanol can be blended with or substituted for gasoline and diesel, reducing emissions from vehicles. By substituting fossil fuels with biofuels, we can mitigate the release of CO2 and other greenhouse gases, thereby reducing the carbon footprint of energy production and consumption.

Rural Development:

Bioethanol production can stimulate rural economies by creating employment opportunities in biomass cultivation, harvesting, and processing. What Crude oil and fossil fuels can do; agriculture products, waste, biomass and sugars can fulfil the same needs, while also providing food and cleaning the air, saving millions of tons of carbon reduction and helping to preserve our world.

PETRON SCIENTECH INC USA

ABOUT PETRON SCIENTIFIC USA- TECHNOLOGY PARTNER

Petron Scientech is a global Leader in Global warming mitigation, Renewable & sustainable low carbon intensity technologies, end-to-end biorefinery technology solutions, Project development for Clean Energy, Biofuels, CO2 utilization, SAF, Renewable chemicals/polymers, Green Ethylene & derivatives, Green Hydrogen Petron is laser focused on contributing to the global mandate for Net Zero by 2050,by bringing technology solutions to minimize climate change through its differentiated commercial and new technologies, R&D and providing opportunities for ESG focused investments.

Since its formation over 30 years ago, Petron Scientech, www.petronscientech.com has been an innovative technology focused company in key low carbon emitting and sustainable green technologies. Together with local partners, Petron is in the process of developing integrated biorefineries to produce renewable chemicals, polymers and fuels worldwide, including in India, utilizing Petron's and its partners' technologies.

Working with our multinational and reputed engineering and EPC partners, Petron is involved globally as a developer for sustainable technology Projects from concept to commissioning globally, acting as a complete Solution Integrator for technology developments (R&D), process Licensing, engineering design preparation, catalyst development & supply, project management, EPC supervision, plant startups/operations, and operator training. For these 30+ years Petron has been the leader in developing and implementing sustainable green technologies replacing fossil (petroleum) feedstock-based products for its current and prospective customers.

Petron is in advantageous position to expand with dominant market share in the renewable green chemical industry including industrial conversion of biomass into ethanol, ethanol value addition to a variety of important chemical feedstocks, specifically, ethylene production which is at heart of trillion-plus dollar global petrochemical, plastics, and essential consumer industries. Petron's Ethylene technology has been independently acknowledged as the most energy efficient and cost-effective solution available to manufacture bio-Ethylene from ethanol. Over the last 4 years, Petron has added cellulosic ethanol produced from biomass feedstocks including agricultural residuals, and Green Hydrogen technologies to its portfolio with 100 patents globally.

With over 30+ years of firsthand experience across 25+ licensed projects around the world, Petron is recognized by the industry as the leading innovator/ solution provider for biofuels, clean energy, renewable ethylene, and its derivatives such as ethyleneoxide/ glycols and other consumer focused sustainable products.

Locations: Petron maintains its headquarters in Princeton, New Jersey, USA. Petron maintains qualified engineering personnel in Portugal and India. The Petron staff in these locations bring a combined industry experience exceeding 200+ years in design, engineering, and plant operations.

ANNEXURE - I

SAF PATHWAYS

SAF Pathway	Feedstock	Advantages	Disadvantages	Maturity
Hydroprocessed Esters and Fatty Acids - Synthetic Paraffinic Kerosene (HEFA-SPK)	Used cooking oils, animal fats, plant oils	Wider feedstock availability and established technology. Currently the dominant method	Controversial due to import of UCO from countries like China, Indonesia, and Malaysia	Highly mature and widely adopted
Alcohol-to-Jet (AtJ)	Ethanol derived from sugars, starches, cellulosic biomass, or Butanol produced through fermentation or advanced chemical processes	Potential for diverse feedstocks. Room for efficiency improvements	Only one operational facility worldwide, but more in development. Issues around crop-based feedstocks	Emerging, with ongoing development and one operational facility
Synthesised Iso-Paraffins (SIP)	Similar to AtJ	Promising for SAF production due to its similarity to conventional jet fuel	A relatively new pathway, potentially less developed than others	Early stages
Methanol-to-Jet (MtJ)	Biomass such as agricultural residues or municipal waste, or from captured CO2 and H2	Supposedly more efficient and less energy-intensive than other methods	Relatively early-stage pathway. Specific examples of development or implementation are limited	Early-stage development with interest from major companies
Fischer-Tropsch (FT)	Syngas (gasified biomass, e.g., wood waste, agricultural residues, waste)	Well-established method for synthetic fuels. Can be used to turn municipal waste into SAF	Relatively inefficient with high energy losses	Mature technology but considered inefficient for SAF production
Power-to-Liquid (PtL)	Hydrogen and captured CO2	High CO2 reduction potential. Less feedstock intensive. Can be deployed widely	High-cost, energy-intensive process	Policy support present, but the technology faces significant economic and energy efficiency challenges
Catalytic Hydrothermolysis (CHJ)	Waste oils, fats, greases, and non-food biomass such as algae and wood waste	Can be co-processed with petroleum in existing refineries. Can be made from a wide variety of feedstocks	Still in the very early stages of commercialisation	Very early stages

Continue ....

ANNEXURE - I

SAF PATHWAYS

SAF Pathway	Feedstock	Advantages	Disadvantages	Maturity
Lignocellulosic biomass-to-jet fuel	Non-food biomass, such as agricultural residues, woody biomass, and energy crops	Can be produced from a wide range of agricultural and forestry residues and dedicated energy crops, offering significant potential feedstock availability	The need for effective pre-treatment processes adds complexity and cost. High costs of enzymes for hydrolysis and catalysts for upgrading processes can make the fuel more expensive	Less mature, with ongoing research and development efforts
Pyrolysis	Biomass feedstocks, including agricultural residues, forestry residues, energy crops, municipal solid waste	• Can process a diverse range of biomass feedstocks • Can contribute to waste reduction and a circular economy • Biochar produced during pyrolysis can be used as a soil amendment or for other applications. • Pyrolysis plants can be built at a smaller scale compared to some other SAF pathways	Compared to some other SAF pathways, pyrolysis may have lower overall yields of liquid fuels due to the production of biochar and non-condensable gases	Commercial-scale production of SAF via this pathway is still limited, with most projects at the demonstration or pilot scale
Solar Fuel	Solar energy	Improved efficiency and reduced costs through direct solar energy conversion	Similar disadvantages to e-fuels regarding cost and energy, but with potential for improvements in efficiency	Very early stage, primarily in the research and demonstration phases
Hydrothermal Liquefaction (HTL)	Biomass feedstocks, such as municipal waste, agricultural waste, algae, and even sewage	Can convert a wide range of wet biomass. Turns waste into a useful commodity	Very early stage of development. Technical and economic feasibility yet to be fully demonstrated	Experimental phase, with startups exploring the technology

Continue ....

ANNEXURE - II

SAF PRODUCERS

Agrisoma
Founded: 1956
Country: Austria
agrisoma.com

OMV Group
Founded: 1956
Country: Austria
omv.com

Ørsted
Founded: 2006
Country: Denmark
orsted.com

Steeper Energy
Founded: 2011
Country: Denmark
steeperenergy.com

Topsoe
Founded: 1940
Country: Denmark
topsoe.com

Kaidi
Founded: 2016
Country: Finland
kaidi.fi

Neste
Founded: 1948
Country: Finland
neste.com

UPM Biofuels
Founded: 1996
Country: Finland
upmbiofuels.com

Axens
Founded: 2001
Country: France
axens.net

Elyse Energy
Founded: 2020
Country: France
elyse.energy

Engie (ReUze)
Founded: 2008
Country: France
reuze.eu

H2V
Founded: 2016
Country: France
h2v.net

Continue ....

ANNEXURE - II

SAF PRODUCERS

Haffner Energy **Founded:** 1993 **Country:** France haffner-energy.com	**Technip Energies** **Founded:** 2021 **Country:** France investors.technipenergies.com
TotalEnergies **Founded:** 1992 **Country:** France aviation.totalenergies.com	**Atmosfair** **Founded:** 2005 **Country:** Germany atmosfair.de
Caphenia **Founded:** 2011 **Country:** Germany caphenia.tech	**COLIPI** **Founded:** 2022 **Country:** Germany colipi.com
EDL (HyKero) **Founded:** 1991 **Country:** Germany edl.poerner.de	**ENERTRAG** **Founded:** 1998 **Country:** Germany enertrag.com
HCS Group **Founded:** 2011 **Country:** Germany h-c-s-group.com	**Hy2gen** **Founded:** 2017 **Country:** Germany hy2gen.com
INTERATEC **Founded:** 2016 **Country:** Germany interatec.de	**P2X-Europe** **Founded:** 2021 **Country:** Germany p2x-europe.com
SARIA Group **Founded:** 1998 **Country:** Germany saria.com	**Siemens Energy** **Founded:** 2020 **Country:** Germany siemens-energy.com

Continue ....

ANNEXURE - II

SAF PRODUCERS

Spark e-fuel **Founded:** 2021 **Country:** Germany sparkefuels.com	**Sunfire** **Founded:** 2010 **Country:** Germany sunfire.de
Uniper (SkyfuelH2) **Founded:** 2016 **Country:** Germany uniper.energy	**IðunnH2** **Founded:** 2020 **Country:** Iceland idunnh2.com
Tessomo Technologies **Founded:** 2018 **Country:** Ireland tessomotechnologies.com	**XFuel** **Founded:** 2010 **Country:** Ireland xfuel.com
Eni **Founded:** 1953 **Country:** Italy eni.com	**Nordic Electrofuel** **Founded:** 2015 **Country:** Norway nordicelectrofuel.no
Norsk e-fuel **Founded:** 2019 **HQ:** Norway norsk-e-fuel.com	**Silva Green Fuel** **Founded:** 2015 **Country:** Norway statkraft.com
The Navigator Company **Founded:** 1953 **Country:** Portugal renewable-carbon.eu/news	**Abengoa** **Founded:** 1941 **Country:** Spain abengoa.com
Cepsa **Founded:** 1929 **Country:** Spain aviation.cepsa.com	**Greenalia** **Founded:** 2013 **Country:** Spain greenalia.es

Continue ....

ANNEXURE - II

SAF PRODUCERS

Repsol
Founded: 1986
Country: Spain
repsol.com

Colabit
Founded: 2013
Country: Sweden
colabit.com

Preem
Founded: 1994
Country: Sweden
preem.se

SCA (Biorefinery Östrand)
Founded: 2017
Country: Sweden
sca.com

St1
Founded: 1995
Country: Sweden
st1.com

Swedish Biofuels
Founded: 2000
Country: Sweden
swedishbiofuels.com

Vattenfall
Founded: 1909
Country: Sweden
group.vattenfall.com

Metafuels
Founded: 2021
Country: Switzerland
metafuels.ch

Synhelion
Founded: 2016
Countyr: Switzerland
synhelion.com

VARO Energy
Founded: 2012
Country: Switzerland
varoenergy.com

Sasol
Founded: 1950
Country: SA / GER / DEN / SWDN
sasol.com

SHV Energy
Founded: 1896
Country: The Netherlands
shvenergy.com

SkyNRG
Founded: 2009
Country: The Netherlands
skynrg.com

Avioxx
Founded: 1923
Country: United Kingdom
avioxx.co.uk

Continue ....

ANNEXURE - II

SAF PRODUCERS

air BP
Founded: 1909
Country: United Kingdom
bp.com

Carbon Neutral Fuels
Founded: 2022
Country: United Kingdom
cnf.energy

Circulairity
Founded: 2023
Country: United Kingdom
-

Firefly Green Fuels
Founded: 2022
Country: United Kingdom
firefly.uk

Johnson Matthey
Founded: 1817
Country: United Kingdom
matthey.com

Nova Pangea Technologies
Founded: 2008
HQ: UK
novapangea.com

OXCCU
Founded: 2021
Country: United Kingdom
oxccu.com

Shell Aviation
Founded: 1921
Country: United Kingdom
shell.com

Sustineri Fuels
Founded: 2020
Country: United Kingdom
sustinerifuels.com

Velocys
Founded: 2004
Country: United Kingdom
velocys.com

Willis Sustainable Fuels
Founded: 2022
Country: United Kingdom
willissustainablefuels.com

Zero
Founded: 2020
Country: United Kingdom
zero.co

Alfanar Energy
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