VIEW POINT

HOW BLENDING ETHANOL WITH GASOLINE CAN HELP SAVE THE PLANET

Abstract

In the article, Ethanol and Transport – Its Role in Climate Change[1], the United Nations Climate Change (UNCC) body states:

Transport is the second biggest source of greenhouse gas (GHG) emissions in the world, accounting for more than one fifth of all emissions. Progress in reducing these emissions is among the slowest of all sectors.

Blending ethanol with petrol is an effective way to reduce vehicular emissions. This paper discusses the role of ethanol blending in combating climate change. It provides an overview of the state of ethanol blending worldwide, the pros and cons of this approach, and what can be done by various stakeholders across the transportation chain to propagate ethanol blending adoption. Lastly, the paper draws a comparison between the total cost of ownership of a conventional fuel vehicle versus an ethanol blended fuel vehicle from the perspective of the end consumer.

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Introduction

Global warming is a serious problem that needs immediate steps. Governments, businesses, society, and investors must join hands to combat the effects of climate change. At the Paris COP21 2015, countries committed to reducing greenhouse gas emissions to limit the rise in temperature in this century well below 2°C from the pre-industrial era.[2] Following this, participating countries have taken various measures toward the net zero emissions target. Ethanol blending in petroleum is one of the steps being taken to curb air pollution.

As a major generator of greenhouse gases, the transport sector must take active measures to contribute convincingly towards reducing global emissions. While exploring energy sources other than fossil fuels and the rollout of electric vehicles is under way, the rate of adoption of these new solutions is slow. Meanwhile, a simpler approach for transporters, vehicle manufacturers, and vehicle owners is to reduce the emissions due to gasoline or petrol using ethanol blending.

The Need for Ethanol Blends

An ethanol blend is a blended motor fuel containing ethyl alcohol (C_2H_5OH) that is at least 99% pure, derived from agricultural products, and blended exclusively with gasoline. Motorcycles, cars, buses, and trucks powered by fossil fuels are major contributors to air pollution as they release carbon monoxide, nitrogen oxides, hydrocarbons, and particulate matter into the air.

In 2018, the CO2 emissions from energy contributed by the transport sector was 24% of total emissions, at 8 billion tonnes of CO2. 74.5% of these transport emissions came from road vehicles such as passenger and freight vehicles on roads. The breakup is as shown in Table 1:[4]

Transport Category	Road (passenger) (includes cars, motorcycles, buses, and taxis)	Road (freight) (includes trucks and lorries)	Aviation	Shipping	Other (mainly transport of oil, gas, water, steam, and other materials via pipelines	Rail
% contribution	45.10%	29.40%	11.60%	10.60%	2.2.%	1%

Table 1: Breakdown of emissions by transport category

Ethanol is naturally produced when sugar is fermented by yeasts or through petrochemical processes like ethylene hydration. Familiar sources of ethanol include sugarcane juice, sugar syrup, molasses, damaged food grains, rice, and maize. Hence, ethanol is an environmentally friendly biofuel.

Ethanol blending offers significant advantages such as:

- Increase in the octane number of the blend
- Increase in fuel-embedded oxygen
- Higher flame speed

These chemical properties of ethanol help in complete combustion and reduce vehicular emissions such as carbon monoxide, hydrocarbon, and particulate matter.

Ethanol can be blended with gasoline in different proportions. As a common worldwide practice, the ethanol blended fuel is denoted by EX, where the letter 'E' stands for ethanol and 'X' is the proportion in which ethanol is mixed with gasoline. For example, E10 blended fuel contains 10% ethanol mixed with 90% gasoline. Similarly, E20 blended fuel contains 20% ethanol mixed with 80% gasoline. E0 indicates only gasoline. Likewise, E100 means only ethanol.

As the proportion of ethanol increases, the emission level decreases. Therefore, E0 fuel would have the highest emission level. E20 fuel would have an emission level lower than E10 fuel, and E100 fuel would produce the least emission.

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The Emergence of 2G Ethanol and Food Crops

Sugarcane is a highly water-intensive crop. Producing one liter of ethanol from sugarcane requires 2860 liters of water. Therefore, shifting to less water-intensive crops is advisable by providing appropriate incentives to farmers. Examples of less water-intensive substitutes of sugarcane are:

- Among grains, maize is the least water-intensive crop that can produce ethanol
- Inedible farm waste left over after harvest (corn cobs, wheat straw, rice husks, others) can be used to produce second-generation or 2G ethanol that is generated from a plant fiber called cellulose. We can find these resources in abundance

But sugarcane remains the most lucrative crop because the net returns per hectare and the conversion rate of sugarcane to ethanol are much higher than that of food grains.

Advantages of Ethanol Blend Fuel

Using ethanol blend fuel has several advantages over conventional fossil-based fuels.

- Reduces the emission level of vehicles. A country can rapidly move toward its target of achieving net zero
- Provides an economic advantage to countries that primarily import crude oil. By producing domestic ethanol and reducing dependence on imported oil, governments can save on import bills and improve forex reserves
- Helps combat inflation. Crude oil is a commodity that is highly price volatile. The OPEC+ nations largely control the per-barrel price of crude oil. If a country imports a large quantity of crude oil, it is highly vulnerable to global price fluctuations. This volatility directly affects inflation since it raises the costs of planning and transportation of goods. Hence, replacing imported oil with domestic ethanol is an excellent step toward becoming a self-reliant nation
- Producing ethanol can raise the income of farmers. The bargaining power of farmers increases as the revenue stream and demand increase

Typical Ethanol-Gasoline Blends Around the World

Table 2 indicates the current practices followed in major countries. Most countries aim to move to a higher ethanol blended petrol, mainly E20 fuel from the existing E10 fuel.

Sl. No.	Country	Mandate
1	Brazil	Mandates 18% - 27.5% of ethanol in gasoline (since 2015). Currently, the blend level is at 27%
2	United States	The average amount of ethanol in petrol in 2017 was 10.07%. The US government is currently pushing towards year-round E15 sales.
3	European Union	The vast majority (75%) of the EU petrol market already contains up to 5% of ethanol in volume (E5). Blends with up to 10% ethanol in volume represented 9.5% of the petrol market in 2016. The EU has mandated E10 since 2020.
4	China	Proposed the usage of E10 in 2017.
5	India	India has been at E10 since 2022 and aims to achieve E20 by 2025.
6	Argentina	Argentina has an E12 mandate.
7	Canada	Canada has a minimum federal requirement of 5% ethanol in petrol increasing up to 10% in various provinces.
8	Philippines	The Philippines moved to E20 in 2020.
9	Thailand	Thailand distributes E10 and E20.

Table 2: Common ethanol – gasoline blend level in different countries

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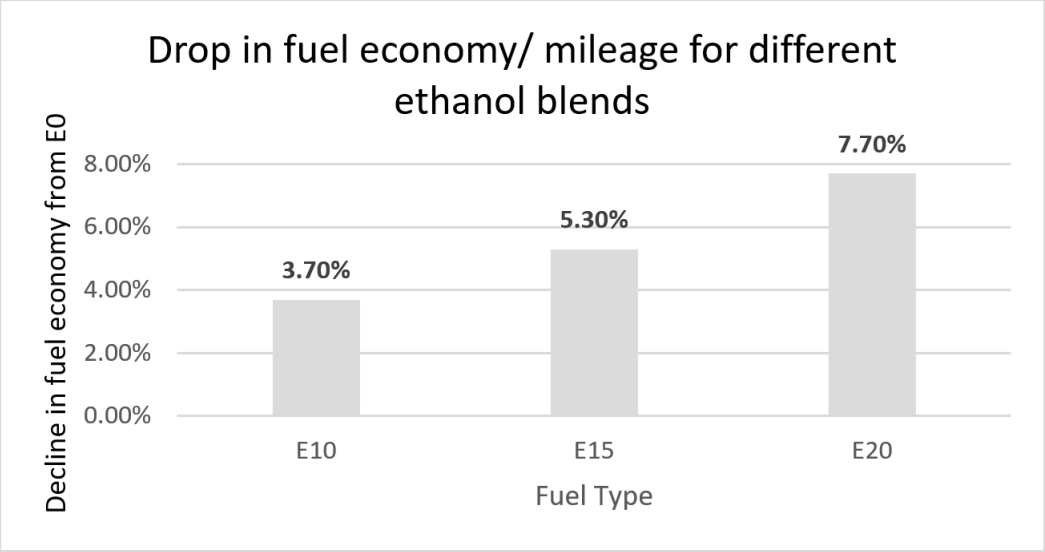
Impact of the Level of Ethanol Blend on Vehicle Technology

Major economies have created policies and roadmaps to move toward E20 fuel from the current E10 fuel. Therefore, it is important to understand whether the existing in-use vehicles compatible with E10 fuel are also compatible with E20 fuel. There are two critical aspects to consider:

- Material compatibility: As per a project undertaken by the Automotive Research Association of India (ARAI), Indian Institute of Petroleum (IIP), and Indian Oil Corporation (R&D) during 2014-15, it was identified that the metal and metal coating present in gasoline vehicles do not have any issue with E20 fuel. However, rubbers and elastomers showed inferior performance with E20 compared to gasoline. Also, plastic PA66 in existing test vehicles showed poor tensile strength when exposed to E20.[5]
- Engine compatibility: Ethanol inherently has a lower calorific value. This value is two-thirds of the calorific value of gasoline. A low calorific value implies that the heating value of the ethanol-gasoline blend decreases as the ethanol content increases. Hence more ethanol-gasoline blend fuel would be required to achieve the same engine power output. As we increase the content of ethanol, fuel efficiency and hence vehicle mileage decreases. Therefore, a conventional engine using E20 would have lower mileage than E0 fuel. On average, the fuel efficiency decreased by up to 6%.[6]



Graph 1: Drop in fuel economy/mileage for different ethanol blends

However, Honda R&D and Massachusetts Institute of Technology's joint studies show encouraging results. Their results indicate that the fuel efficiency can be improved by 20% in E20 compared to standard gasoline when the engine is appropriately tuned and calibrated to accommodate E20 fuel. This can be achieved by:

- Using superior plastic parts, rubberized components, and elastomers that are E20 compliant in vehicles
- The engine should be tuned to a high compression ratio because ethanol has a higher-octane number
- Optimal spark timing to negate the effect of lower calorific value of ethanol[5]

However, the total cost of ownership (TCO) of an E20-compliant vehicle is found to be lower than a standard gasoline vehicle, thus creating a lucrative proposition for consumers to buy. See Comparison of TCO Between a Gasoline-compliant and E20-compliant Vehicle for more information.

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Impact of required vehicle technology and hardware changes on various stakeholders

Impact on Consumers	Impact on Automobile OEMs	Impact on Component Manufacturers
• The cost of an E20-compliant vehicle will be higher, as it requires superior material quality to withstand E20 fuel, and engine re-calibration would be necessary. On average, E20-compliant four-wheelers will cost more by 1% compared to an ordinary gasoline vehicle. Similarly, E20-compliant two-wheelers will cost more by 2%-3%.	• Significant capital investment in R&D • Increase in testing costs (both time and capital) to check whether engines and components are E20 compliant. • Increase in supplier engagement to procure high-grade materials that are compliant with E20. • No significant impact on the vehicle assembly line.	• No significant structural changes in the components when migrating from E10 to E20. • Changes in the quality of materials that will be used to make the component when moving to E20 compliance.

Future of E10 After a Country Rolls Out E20 Fuel

A vehicle that is fully compliant with a higher ethanol blend (say E20 fuel) cannot run on a lower ethanol blend (say E0, E5, E10) fuel as the latter causes knocking which can damage the engine. Therefore, automobile OEMs expect all oil marketing companies (OMCs) to ensure E20 availability across the country. This is essential for OEMs to develop vehicles that are E20 compliant and without any loss in fuel efficiency or performance deterioration to customers.

Discontinuation of E10 fuel after the implementation of E20 fuel is a critical concern. This implementation can render the entire population of existing E10-compliant vehicles unusable as they will neither have material compatibility nor efficiency/performance optimized. This may cause material degradation, leading to leakage, and hence a result in safety issues, besides a decline in fuel efficiency and drivability. Therefore, E10 fuel availability as protection grade fuel for existing vehicles and customers is a must.

It is also practically impossible to retrofit materials and components in older vehicles to comply with higher ethanol blends. It is a humongous task for OEMs considering the large population of existing vehicle variants, parts design, and development issues, cost of retro-fitment, and finally, customer acceptance.

Therefore, it is strongly recommended to continue dispensing E10 fuel even after the deployment of E20 fuel. This practice has been followed in various countries during the transition period. Brazil, one of the most successful nations transitioning to a higher ethanol blend, took 30 years to transition to a higher mix. Citizens can find even E0 fuel as an option in Brazil today.

Flex-fuel Vehicles

A flex-fuel or flexible fuel vehicle has an internal combustion engine that can run on diverse types of fuel or even different blends of fuel. Over 80% of all new vehicles sold in Brazil (as of 2019) use the flex-fuel engine technology (FFE), a widely recognized concept. Brazil's flex fuel vehicles can run on E27, E100, or any blend between the two. Flex-fuel vehicles are priced higher because they use superior grade materials that can accommodate higher ethanol concentration and better engines that do not compromise fuel efficiency.

Since flex-fuel vehicles are an established and well-proven concept in Brazil, other countries planning to migrate to a higher ethanol blend can learn from this. Aspiring countries can partner with Brazil to know more about FFE vehicle technology, understand government policies in Brazil that led to an increase in the adoption of higher ethanol blend compliant vehicles nationwide, and study how Brazil built the infrastructure to create the ideal ecosystem.

How Migrating to a Higher Ethanol Blend Impacts Government Income

Governments charge tax on fuel from consumers. This tax contributes to a useful source of income for the Government. Graph 2 depicts the percentage tax for various countries for the year 2020.

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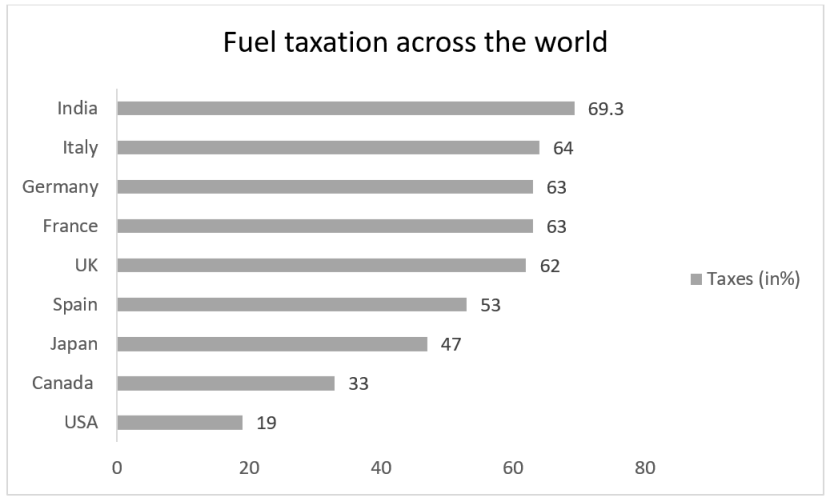

Graph 2: Fuel taxation across the world

India has the highest fuel tax. Studying the tax structure of India will provide insights into understanding the impact of ethanol blend on the revenue of the Government. Table 3 and Table 4 provide the tax breakup for ethanol and petrol respectively.

Description	Element	Unit	2022-23
Procurement price of ethanol	From C heavy molasses	Rs/lit	49.41
	From B heavy molasses	Rs/lit	60.73
Goods and Service Tax (GST) for ethanol: 5% Share of Government of India (GoI): 2.5%	From sugarcane juice/sugar/sugar syrup	Rs/lit	65.61
	Minimum GST earned by GoI (from C molasses)	Rs/lit	1.24
	Maximum GST earned by GoI (from B molasses)	Rs/lit	1.52
Goods and Service Tax (GST) for ethanol: 5% Share of respective State Govt: 2.5%	Minimum GST earned by State (from C molasses)	Rs/lit	1.24
	Maximum GST earned by State (from B molasses)	Rs/lit	1.52

Table 3: Tax breakup for ethanol

Element	Unit	Delhi (as on October 16, 2021)
Price charged to dealers	Rs/lit	44.4
Excise duty levied by the Government of India	Rs/lit	32.9
Sales tax/VAT levied by respective States	Rs/lit	24.3

Table 4: Tax breakup for petrol

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Central Government of India: The excise duty earned is Rs 32.9 per liter of petrol. The GST earned on ethanol varies between Rs. 1.24 to Rs. 1.52. Therefore, the tax earned on E20 blended fuel would be around Rs 26.6 per liter, incurring a loss of Rs 6.3 per liter.

State governments across India (using Delhi as an example): The Value Added Tax (VAT) earned is Rs 24.3 per liter of petrol. The GST earned on ethanol varies between Rs. 1.24 to Rs. 1.52. Therefore, the tax earned on E20 blended fuel would be around Rs 26.6 per liter, incurring a loss of Rs 4.6 per liter.

Challenges and Recommendations for Increasing the Ethanol Blend Rate from E10 to E20

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Challenges Faced by Ethanol Producers and Recommendations

Element	Challenges	Recommendations
Production constraints	• Unpredictable weather cycles such as monsoon/ floods/droughts. • Availability of sufficient feedstock inventory to meet the blending target nationwide. • Insufficient capital to scale up ethanol distilleries.	• Promoting the production of 2G ethanol. • Government should incentivize farmers and molasses-based distilleries to scale up their production by providing interest-subvention loans. Also, these loans should be processed quickly.
Regulatory constraints	• In some countries, the movement of denatured alcohol is not under the control of the central Government but under the purview of the respective state governments, hence limiting the interstate movement of ethanol. This is a hindrance when ethanol is moved from a surplus state to a deficit state.	• Interstate movement of denatured ethanol can be brought under the purview of the Central Government to facilitate ease of movement from an ethanol-surplus state to an ethanol deficit state. States should actively comply with scaling up the ethanol blending program. • The Government should launch a nationwide education campaign in partnership with OMCs to create awareness among citizens and state governments about the environmental benefits of ethanol blending.

Challenges Faced by Oil Marketing Companies and Recommendations

Element	Challenges	Recommendations
Increase in opex	• Making ethanol available across the country is a significant challenge. Transporting ethanol from ethanol-surplus states to ethanol-deficit states for blending will add to substantial transportation and logistical costs. • Earlier, OMCs incurred the cost of transporting only E10 fuel using trucks from one point to another. Now, OMCs must incur the cost of transporting E10 and E20 fuel in separate trucks.	• The Government should put in special efforts to attract investors to ethanol-deficit states. This can have a cascading effect in reducing the ethanol shipping costs for OMCs in the long run. • OMCs can include additional tankage jobs in a phased manner to store ethanol in deficit states. These big tanks can store sufficient ethanol before it is blended with gasoline, reducing the frequency at which ethanol is transported across states, and significantly reduce costs.
Increase in capex	OMCs will see a significant investment in infrastructure. • This includes deploying new oil marketing terminals or depots. • Ethanol-compatible dispensers must be introduced at the retail level. OMCs must continue to dispense E10 fuel for older vehicles long after E20 deployment. Retailers must ensure availability of E10 dispensers along with E20 dispensers. They must also deploy E100 dispensers for flex vehicles. • Along with new dispensing units, their associated underground tanks, pipes, and hoses must also be installed. • In addition to all these costs, a retailer must also deal with space constraints.	• OMCs need precise projections of ethanol storage, handling, blending, and dispensing unit requirements. • Government can provide significant subsidies to encourage OMCs to deploy E10, E20, and E100-compliant dispensing units and their associated underground tanks, pipes, and hoses. • To overcome space constraints, retailers can check the possibility of positioning the infrastructure of E10 and E100 so that E20 can be dispensed by mixing both in the right proportion. • To overcome space constraints, OMCs can place E10 dispensing units only in some retail outlets and E20 in others within the same cluster so both E10 and E20 fuel are available in close vicinity. Consumers can thus get easy access to both E10 and E20 fuel.

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Challenges Faced by Vehicle Manufacturers and Recommendations

Element	Challenges	Recommendations
Increase in compliance costs	• Provide support to vendors to develop E20-compliant components. • Design new engines that can run on E20 without compromising fuel efficiency. • Conduct extensive tests to certify that the vehicle is E20 compliant on both material and engine aspects.	• Provide tax benefits and incentives to manufacturers and consumers of vehicles compliant with E20. This benefit will bring down the price of E20-compliant vehicles and boost the demand in the market, like the tax incentives offered for electric vehicles. • Incentivize consumers to switch to higher ethanol blends reducing fuel costs. Retail prices of ethanol blend fuel should be made lower than standard petrol. The Government should prioritize tax breaks on ethanol as a fuel.

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Digital Platform to Drive Success for All E20 Stakeholders

Technology can be a great enabler in creating the desired E20 ecosystem. Policymakers and manufacturers can make more informed and faster decisions with the help of data and insights. In today's world, technology can be leveraged to create a unified platform where stakeholders can communicate.

Figure 1 shows the framework proposed to create a smart app where all stakeholders register including customers, vehicle retail partners, fuel retail partners, OEMs, OMCs, and the Government. Data collected from different sources will be aggregated into data visualization tools, and vehicle manufacturers and Government can analyze this to make informed and data-driven decisions.

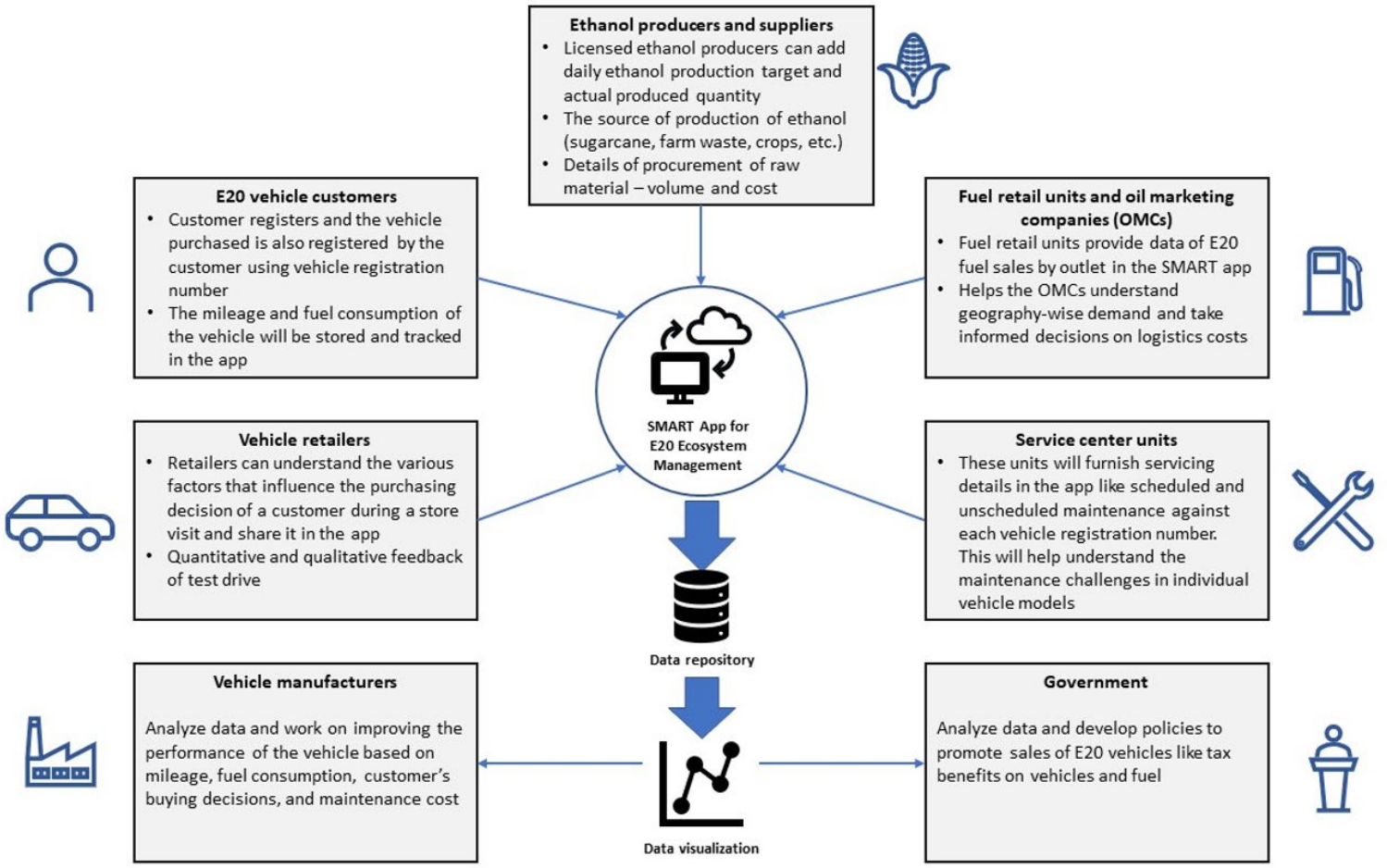

Figure 1: Smart app for E20 ecosystem management – a collaborative platform for all stakeholders

Comparison of TCO Between a Gasoline-compliant and an E20-compliant Vehicle

To make a fair comparison between the two types of vehicles, certain assumptions are needed:

- We are calculating the TCO for five years.
- Since India is the latest country set to migrate to the E20 program as early as 2025, we consider the scenario of a car model in India – Hyundai Venue. Hence, all calculations are in INR. Also, we assume that the same car has been modified to an E20-compliant vehicle (while calculating the TCO for an E20 compliant vehicle) for ease of calculation.
- The customer does not avail a car loan and pays for the car upfront. This will make our calculations simpler.
- Since a car is not an investment but an asset, it depreciates. The depreciation rate considered here is the inflation rate.
- RTO stands for Regional Transport Office. The cost is the vehicle registration cost.
- The total distance driven per month is assumed to be 1200 kilometers.
- Insurance is renewed each year. The insurance cost decreases as a factor of the depreciation rate as the serviceable life of the car decreases.
- The maintenance cost for the first year is assumed to be INR 10,500. This cost increases as a factor of the depreciation rate as the serviceable life of the car life decreases.
- The price of petrol increases each year at the inflation rate.

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TCO for a gasoline-compliant vehicle

Table 5 illustrates the calculation of TCO for a gasoline-compliant vehicle over a 5-year period.

A	Inflation	6%
B	Ex Showroom Price in Delhi (INR)	₹ 7,71,600
C	RTO (INR)	₹ 60,900
D	Insurance (INR)	₹ 44,798
E	Road Tax (15% of the cost)	₹ 1,15,740
F	On-Road Price (INR) [B+C+D+E]	₹ 9,93,038

	Running Cost of Car for 5 years	2023	2024	2025	2026	2027	Total
1	Total Kms driven per year (Km)	14400	14400	14400	14400	14400	
2	Total Insurance Cost per year (INR)	₹ 44,798	₹ 42,262	₹ 39,870	₹ 37,613	₹ 35,484	₹ 2,00,028
3	Maintenance Cost per year (INR)	₹ 10,500	₹ 11,130	₹ 11,798	₹ 12,506	₹ 13,256	₹ 59,189
4	Average Km/L (Mileage)	18	17	16	15	14	
5	Petrol Consumed (Litres)	800	848	899	953	1010	
6	Price of Petrol (INR/Litre)	₹ 100	₹ 106	₹ 112	₹ 119	₹ 126	
7	Total Petrol (INR)	₹ 80,000	₹ 89,888	₹ 1,00,998	₹ 1,13,482	₹ 1,27,508	₹ 5,11,876
8	Total Running Cost (INR) [2+3+7]	₹ 7,71,093					
9	Total Cost of Ownership (INR) [F+8]	₹ 17,64,131					

Table 5 – TCO for a gasoline-compliant vehicle

TCO for an E20-compliant vehicle

Assumptions

- The price of an E20-compliant car will go up by 1% as explained in the section Impact of required vehicle technology and hardware changes on various stakeholders.
- Government relaxes road tax to promote sales.
- The price of the E20 fuel will be lower than gasoline due to the subsidies provided by the Government of India to increase the adoption of E20 fuel.
- The mileage of an E20-compliant vehicle with an optimized and tuned engine will increase by 20% compared to a gasoline engine as explained in the section. **Impact of the Level of Ethanol Blend on Vehicle Technology.**

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Table 6 illustrates the calculation of TCO for an E20-compliant vehicle over a 5-year period.

A	Inflation	6%
B	Ex Showroom Price in Delhi (INR)	₹ 7,79,316
C	RTO (INR)	₹ 60,900
D	Insurance (INR)	₹ 44,798
E	On-Road Price (INR) [B+C+D]	₹ 8,85,014

	Running Cost of Car for 5 years	**2023**	**2024**	**2025**	**2026**	**2027**	**Total**
1	Total Kms driven per year (Km)	14400	14400	14400	14400	14400	
2	Total Insurance Cost per year (INR)	₹ 44,798	₹ 42,262	₹ 39,870	₹ 37,613	₹ 35,484	₹ 2,00,028
3	Maintenance Cost per year (INR)	₹ 10,500	₹ 11,130	₹ 11,798	₹ 12,506	₹ 13,256	₹ 59,189
4	Average Km/L (Mileage)	21.6	20	19	18	17	
5	Petrol Consumed (Litres)	667	707	749	794	842	
6	Price of Petrol (INR/Litre)	₹ 60	₹ 64	₹ 67	₹ 71	₹ 76	
7	Total Petrol Cost (INR)	₹ 40,000	₹ 44,944	₹ 50,499	₹ 56,741	₹ 63,754	₹ 2,55,938
8	Total Running Cost (INR) [2+3+7]	₹ 5,15,155					
9	Total Cost of Ownership (INR) [E+8]	₹ 14,00,169					

Table 6 – TCO for an E20-compliant vehicle

Comparison of TCO

The TCO of a gasoline-compliant vehicle at the end of 5 years is ₹ 1,764,131.

The TCO of an E20-compliant vehicle at the end of 5 years is ₹ 1,400,169. A government subsidy (say 10% on ex-showroom price) to promote sales can further reduce the TCO to ₹ 1,322,237. Based on this assumption, the TCO savings with an E20-compliant vehicle over 5 years is a substantial ₹ 4,41,894, with an even greater benefit of reduced impact on the environment.

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Conclusion

To combat climate change and achieve net zero, migrating to a higher ethanol blend is a necessary step as it will help reduce vehicle emissions and create a better environment worldwide. But any change presents its own set of challenges. To overcome these issues, participation from all stakeholders, including government, OEMs, OMCs, suppliers, and citizens is critical. Governments should define a clear roadmap and come forward with investment-friendly policies to create a conducive ecosystem for the success of this program. Businesses, on their part, must cooperate with the government to drive this change. They should use the incentives provided by the Government to strengthen their R&D, production capabilities, and supply chain to create a robust system.

Since ethanol blending is a well-proven concept in Brazil, other nations can partner with Brazil for knowledge transfer and best practices. Ethanol awareness campaigns should be taken to consumers through different channels to make them realize its benefits.

Working together we can achieve the target of net zero to help make a cleaner, greener planet.

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