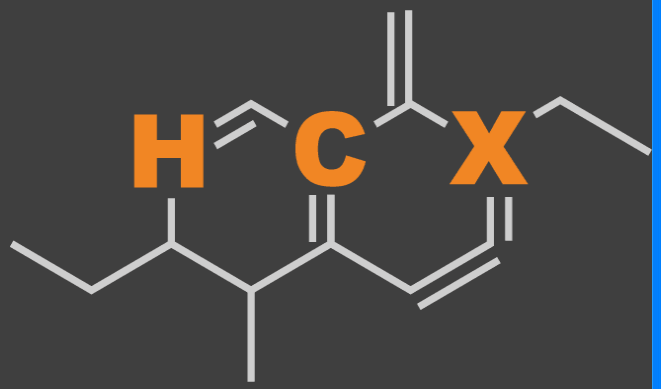


FARO90

Ethanol Blending in Gasoline - Costa Rica

June, 2023

Ethanol Blending in Latin America

There are important fuel quality and environmental impact of vehicle emission challanges in the Region.

- The use of ethanol improves gasoline quality and creates flexibility in gasoline production.
- Ethanol use is a cost-effective way to increase gasoline octane and to replace more expensive gasoline components.
- Ethanol contributes to transport decarbonization and air quality improvement.
- There are opportunities across Latin America to increase the ethanol blend level and implement new policies on the use of gasoline-ethanol blends.

Sixteen countries with potential and additional use of ethanol were studied: 1) gasoline market profiles; 2) Optimization of gasoline blends with ethanol and 3) Environmental impact of gasolines blended with ethanol.

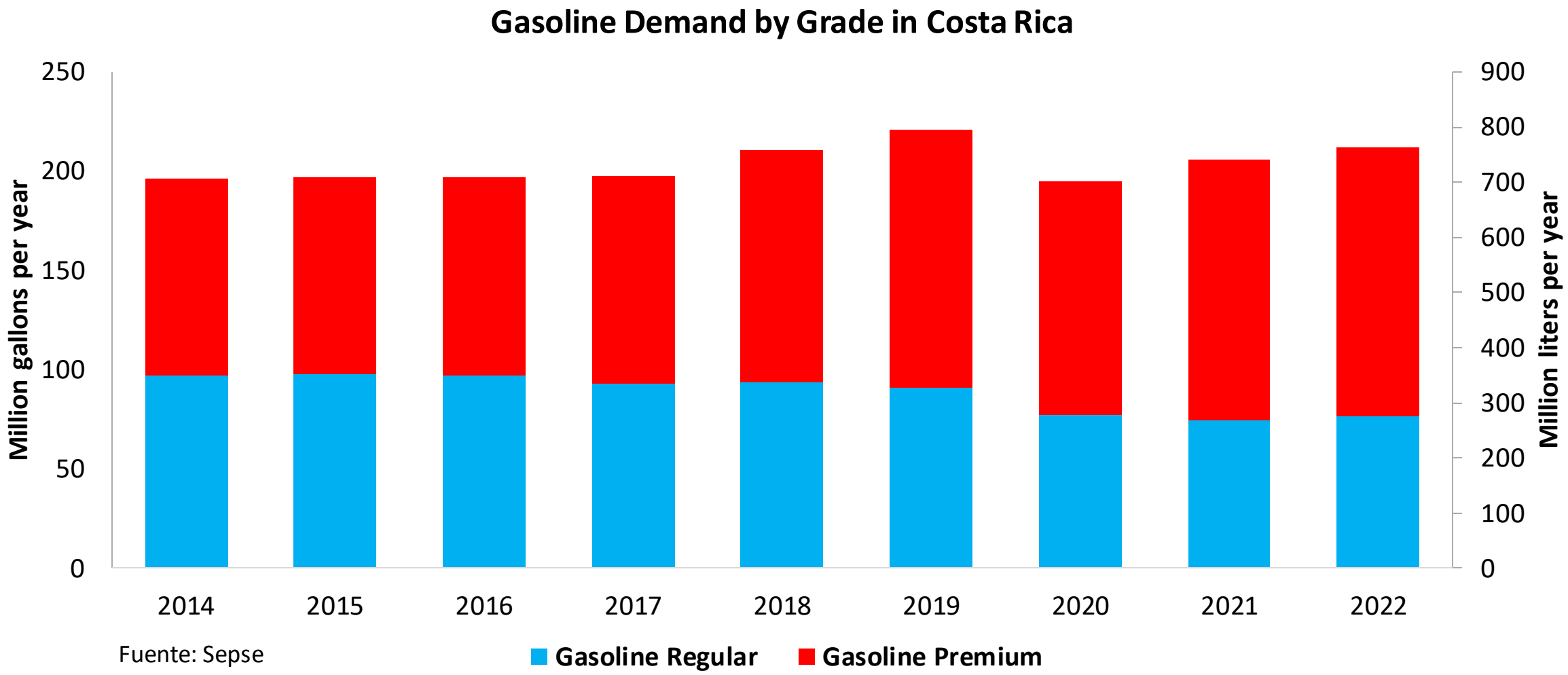
Ethanol Blending in Gasoline - Costa Rica

Costa Rica has two gasoline RON 95 and RON 91, with a market share of 51% for RON 91 and 49% for RON 95 in 2022. As it does not have refining capacity, gasoline blends are made only with components imported mainly from the United States and to a lesser extent from Europe.

Since 2010, it is allowed gasoline blends with up to 10% v/v of ethanol. However, this mandate is not yet reflected on the gasoline market. Current ethanol consumpition is less than 0.2%. In 2022, ethanol production was 4.7 million liters and ethanol exports mainly to Europe was 4.1 millon liters. Introduction of E8 is expected in 2024.

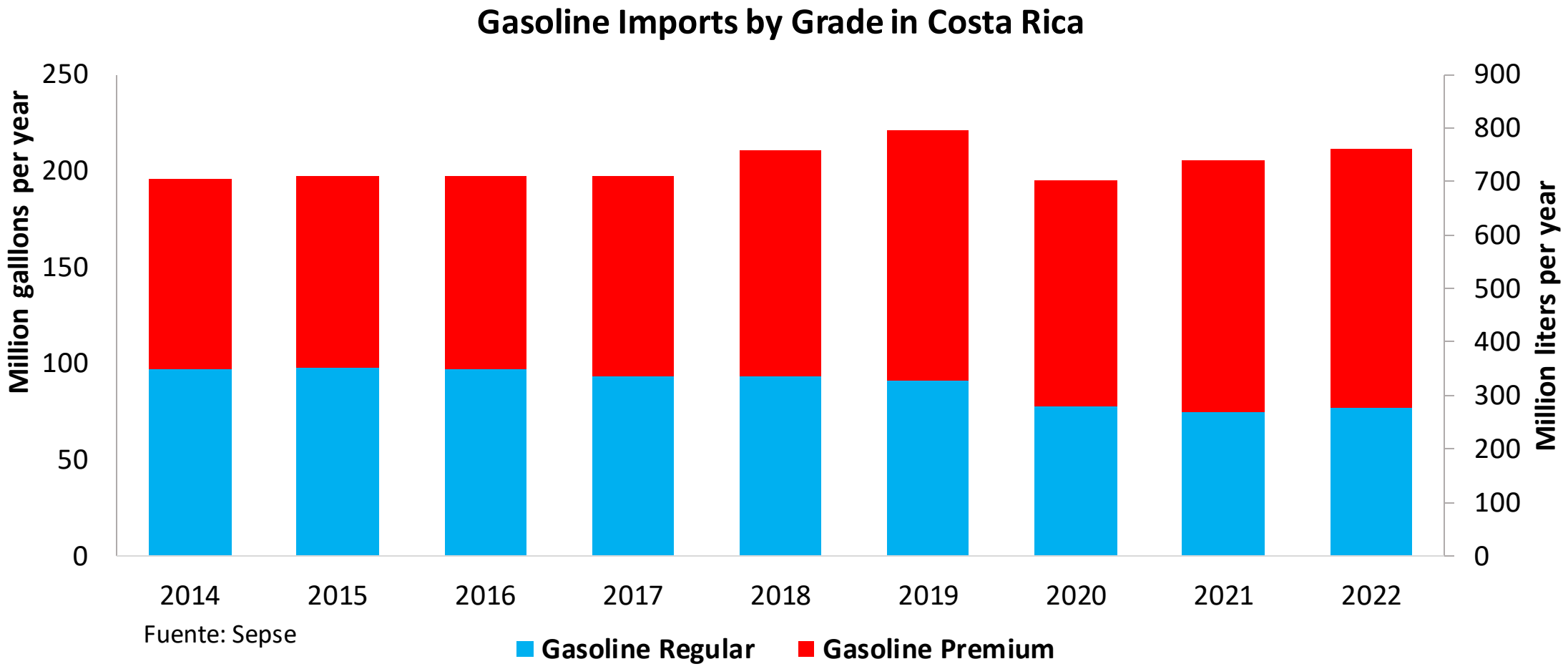
Source: Sepse

Gasoline Demand in Costa Rica



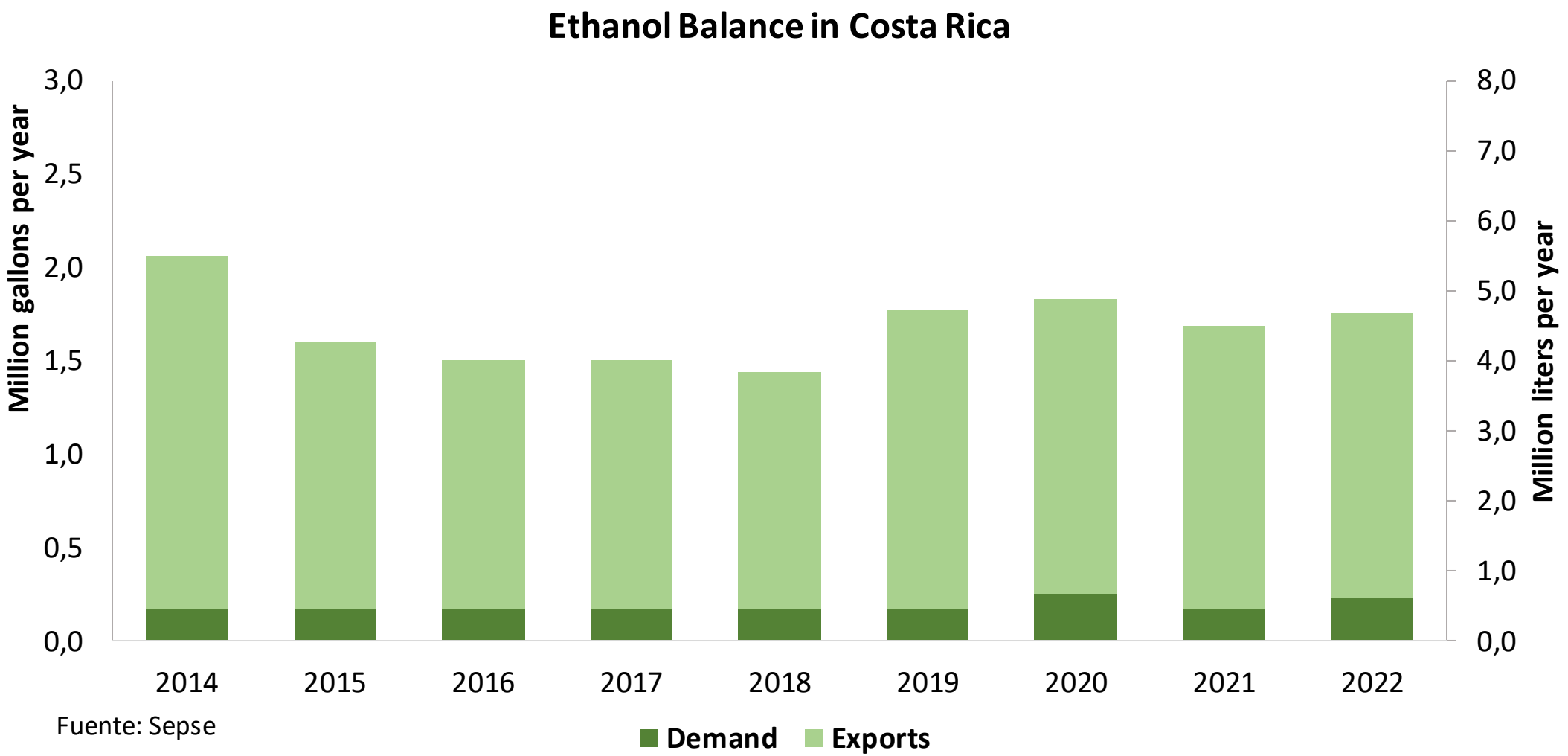
Fuente: Sepse

Gasoline Imports in Costa Rica



Fuente: Sepse

Ethanol Demand in Costa Rica



Fuente: Sepse

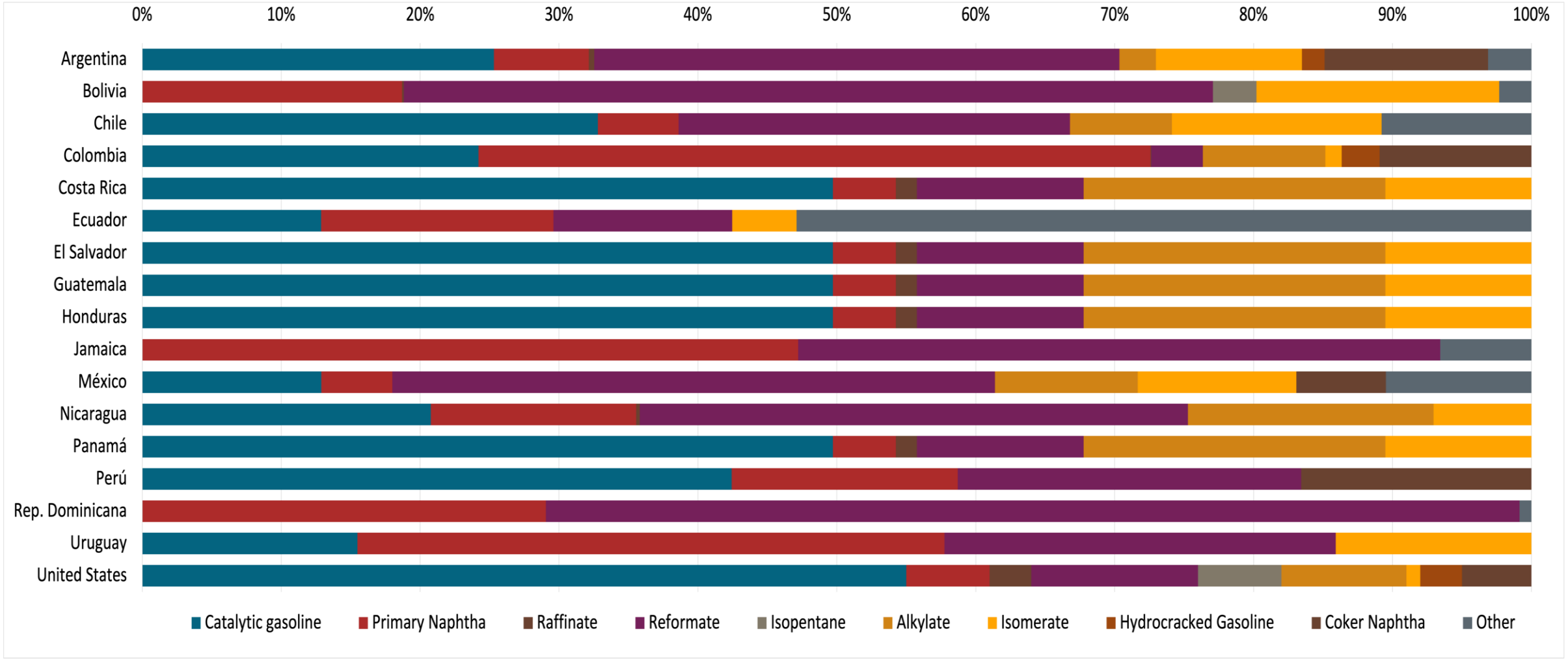
Gasoline Quality in Costa Rica

Name	INTE E1:2019		EN 228:2012 + A1:2017 (Euro 6 enabling)			
Implementation Date	2019		2017			
Applicability	Whole country	Whole country	All countries			
Selected Grade	RON 91	RON 95	RON 95 E5	RON 95 E10	RON 98 E5	RON 98 E10
Benzene Content	< 1,5% v/v	< 1,5% v/v	< 1 %v/v	< 1 %v/v	< 1 %v/v	< 1 %v/v
Aromatics	< 35% v/v	< 35% v/v	< 35 %v/v	< 35 %v/v	< 35 %v/v	< 35 %v/v
Olefins	< 18% v/v	< 18% v/v	< 18 %v/v	< 18 %v/v	< 18 %v/v	< 18 %v/v
Lead Content	< 0,013 g/l	< 0,013 g/l	< 5 mg/l	< 5 mg/l	< 5 mg/l	< 5 mg/l
Manganese	< 2,0 mg/l	< 2,0 mg/l	< 2,0 mg/l	< 2,0 mg/l	< 2,0 mg/l	< 2,0 mg/l
RON	> 91	> 95	> 95	> 95	> 98	> 98
MON	> 79	> 83	> 85	> 88	> 85	> 88
AKI						
Sulfur Content	< 50 mg/kg	< 50 mg/kg	< 10 mg/kg	< 10 mg/kg	< 10 mg/kg	< 10 mg/kg
Oxygen Content	2,7% m/m (3,7% m/m if ethanol is added)	2,7% m/m (3,7% m/m if ethanol is added)	<2,7 % m/m	<3,7 % m/m	<2,7 % m/m	<3,7 % m/m
Ethanol (EtOH)	< 10% v/v	< 10% v/v	<5 %v/v	<10 %v/v	<5 %v/v	<10 %v/v
RVP 37.8°C (Summer)	< 69 kPa (< 76 kPa if ethanol is added)	< 69 kPa (< 76 kPa if ethanol is added)	<> 60 - 70 kPa *Depends on the country, RVP is regulated in the EU Fuel Quality Directive			
RVP 37.8 °C(Winter)						
RVP 37.8°C (Transition)						
MTBE	-		-	-	-	-
Ehters 5 or more C Atoms	-		Based on oxygen content	<22 %v/v	Based on oxygen content	<22 %v/v

Source: INTECO

Gasoline Component Blending in Latin America

Gasoline is a blend of a base gasoline and other components. This blending is usually done at blending terminals as only 30% of the world's finished gasoline is distributed directly from refineries. Each component provides different properties to the final blend, for example, isomerates, alkylates and butanes increase the octane. The components commonly used in Latin America are:



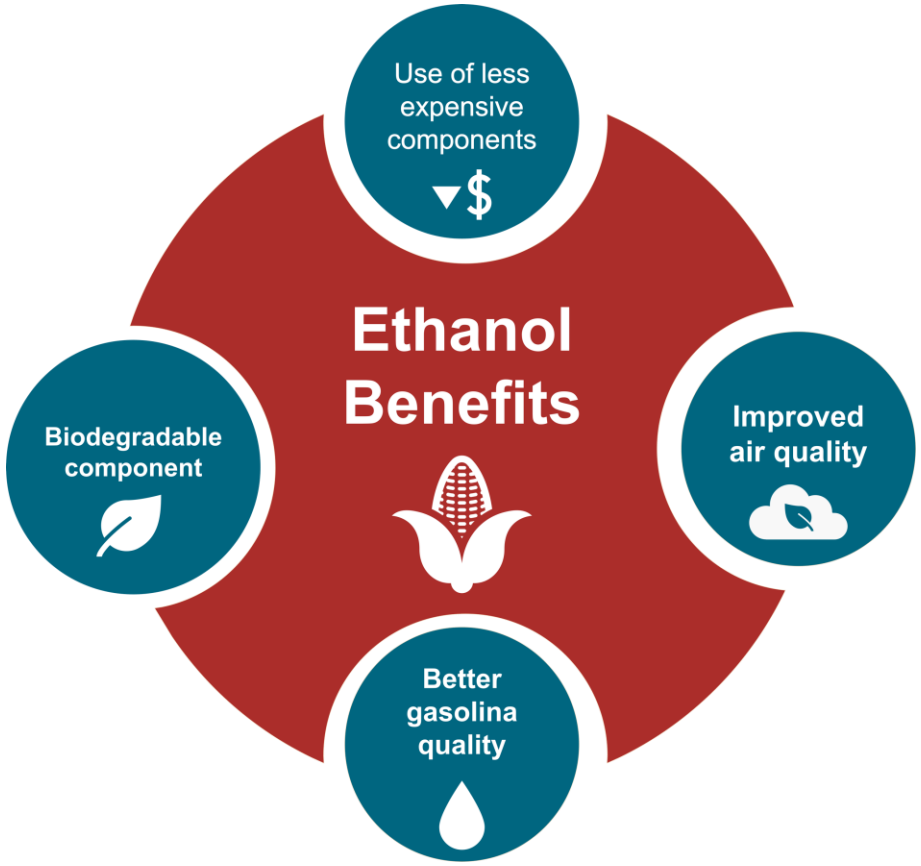
Gasoline Blending Optimization

In some parts of the world, ethanol is added to gasoline as a blending component.The advantages of ethanol include that it is a renewable fuel made of biomass; that it is an octane booster that helps to dilute sulfur; and that it allows the fulfillment of environmental objectives.To determine the optimal components to be blended with ethanol, a **blending model** was used. This model selects the components to add in the gasoline/ethanol blend based on:

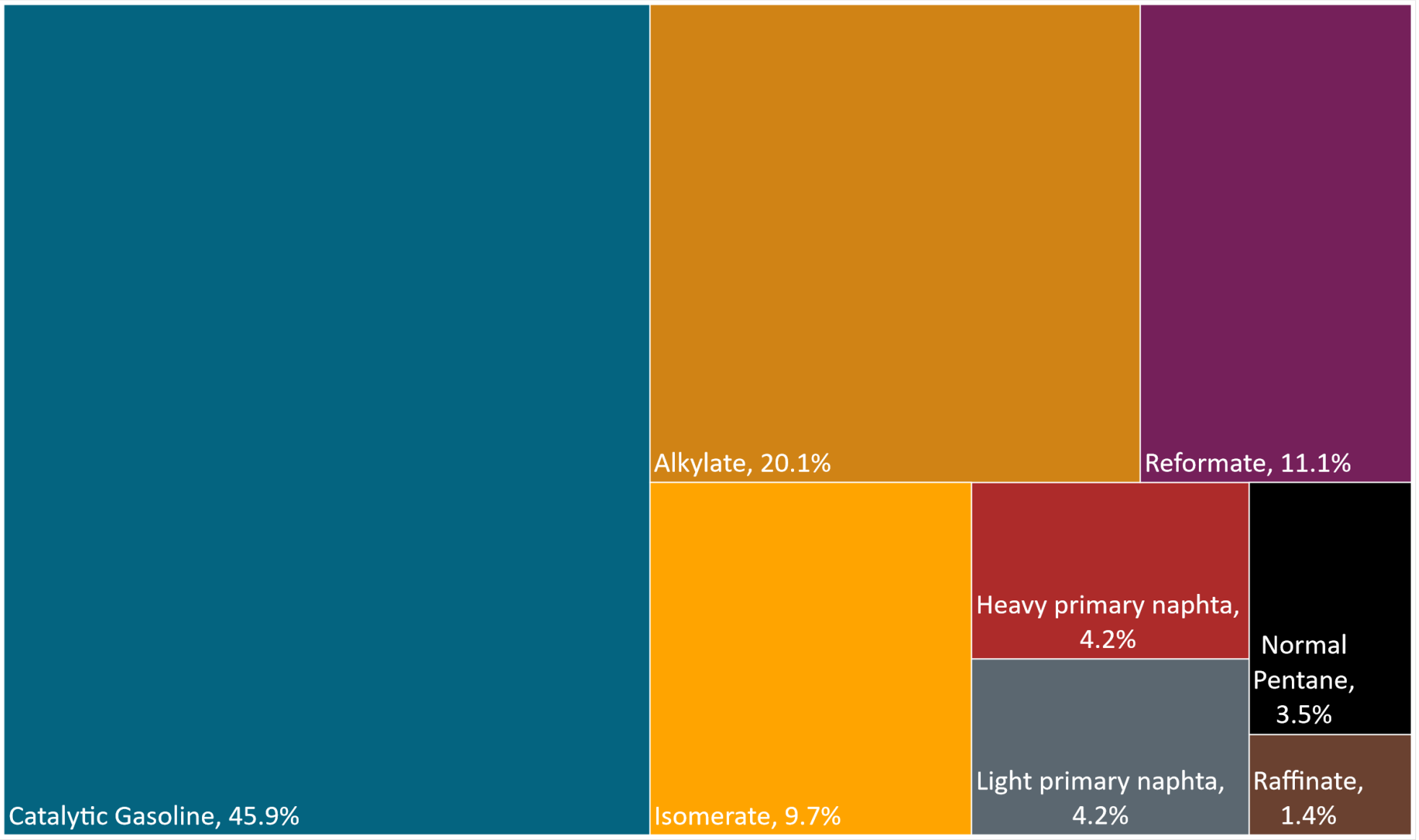
- Components prices,
- Properties each component affects,
- Quality parameters by country, and
- Component availability by country.

Through iterations, the model obtains the %v/v of the components to be blended with 10%, 15%, 20%, 25% and 30% of ethanol, in such a way that the final blend complies with the required properties of a finished gasoline by country.

The blending model uses gasoline component spot average prices January 2022 – February 2023 and provides fuel prices that do not include country distribution costs, local taxes and subsidies and import or gas station margins.

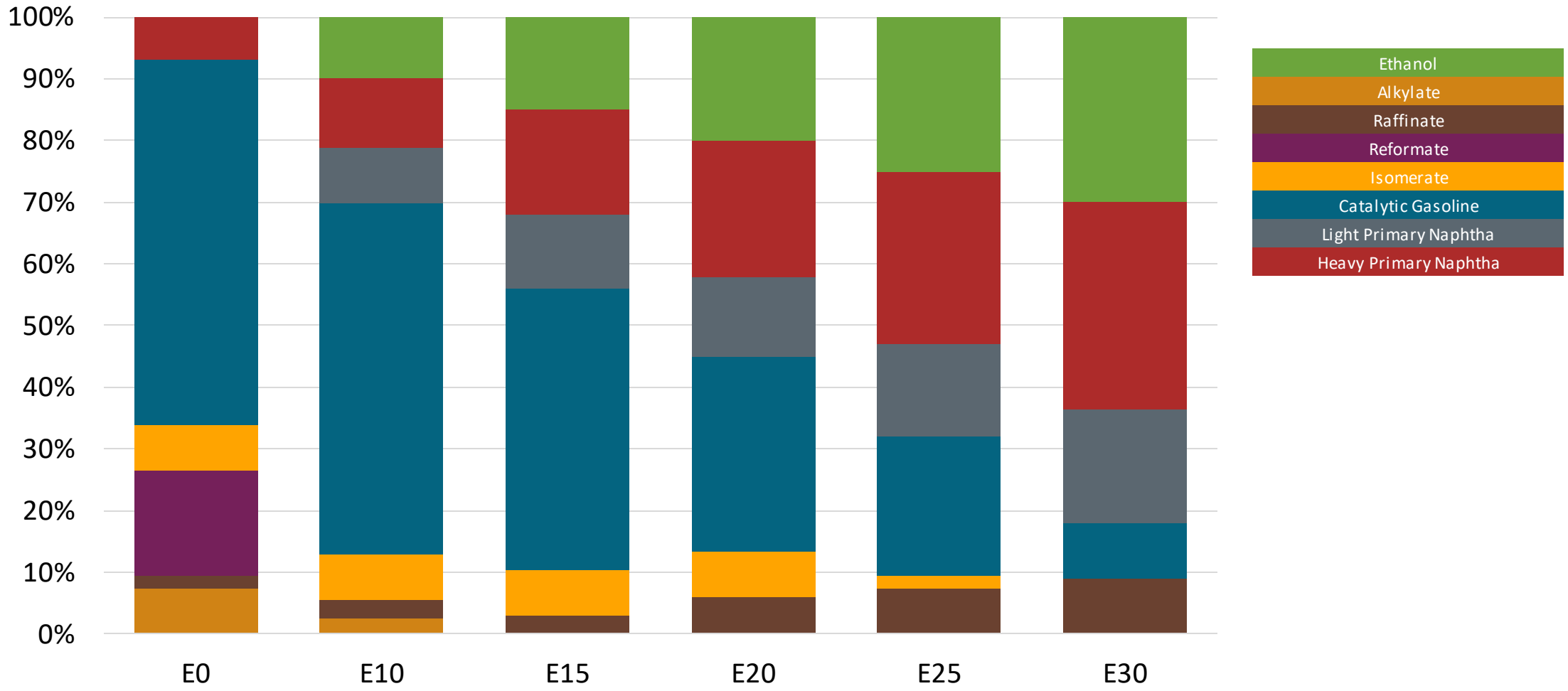


Available Blending Components



Source: Faro90

Ethanol Blending – Gasoline RON 91 – Constant Octane

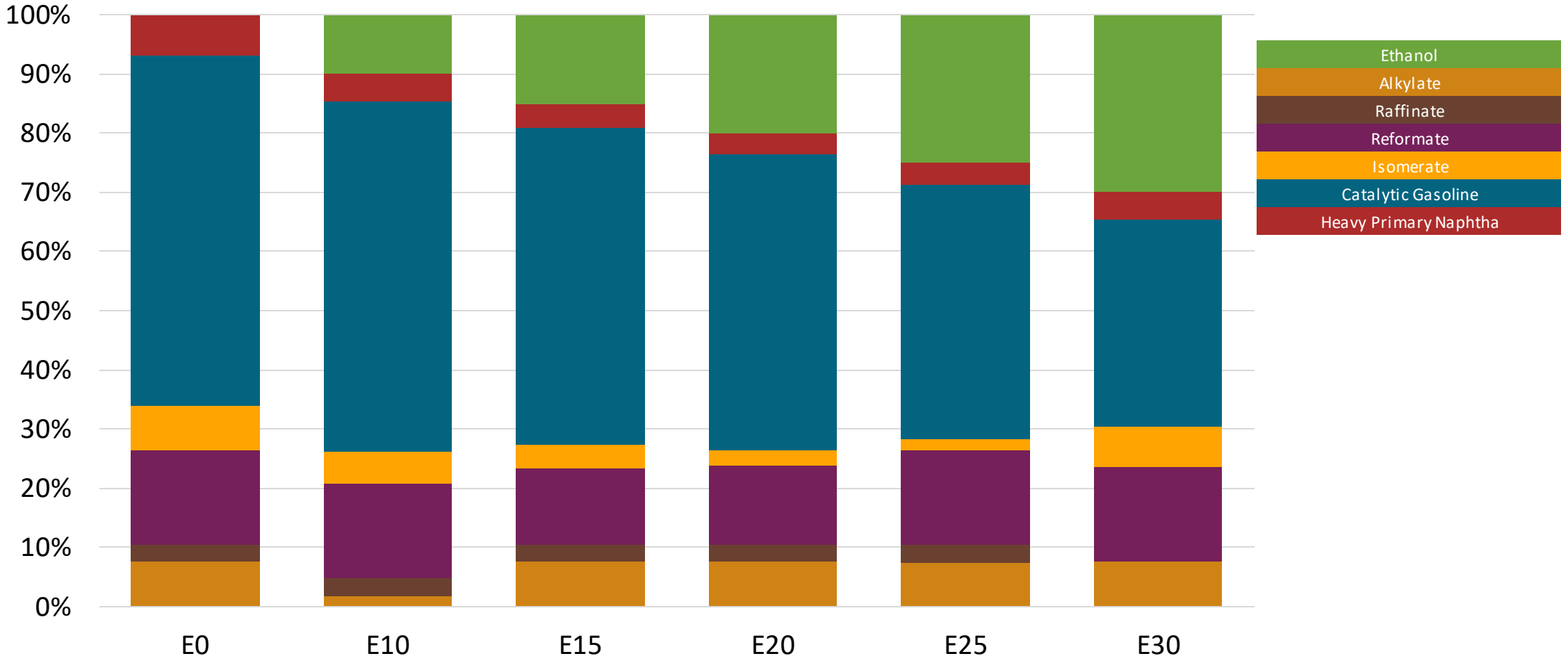


Octane (RON)	91.0	91.0	91.0	91.0	91.2	91.3
Price (USD/gal)	$2.36	$2.19	$2.13	$2.07	$2.01	$1.95

Prices are average Jan 22 – Feb 23.
They do not include local distribution costs, import or gas station margins, taxes and subsidies.

Source: Faro90

Ethanol Blending – Gasoline RON 91 – Octane Increment

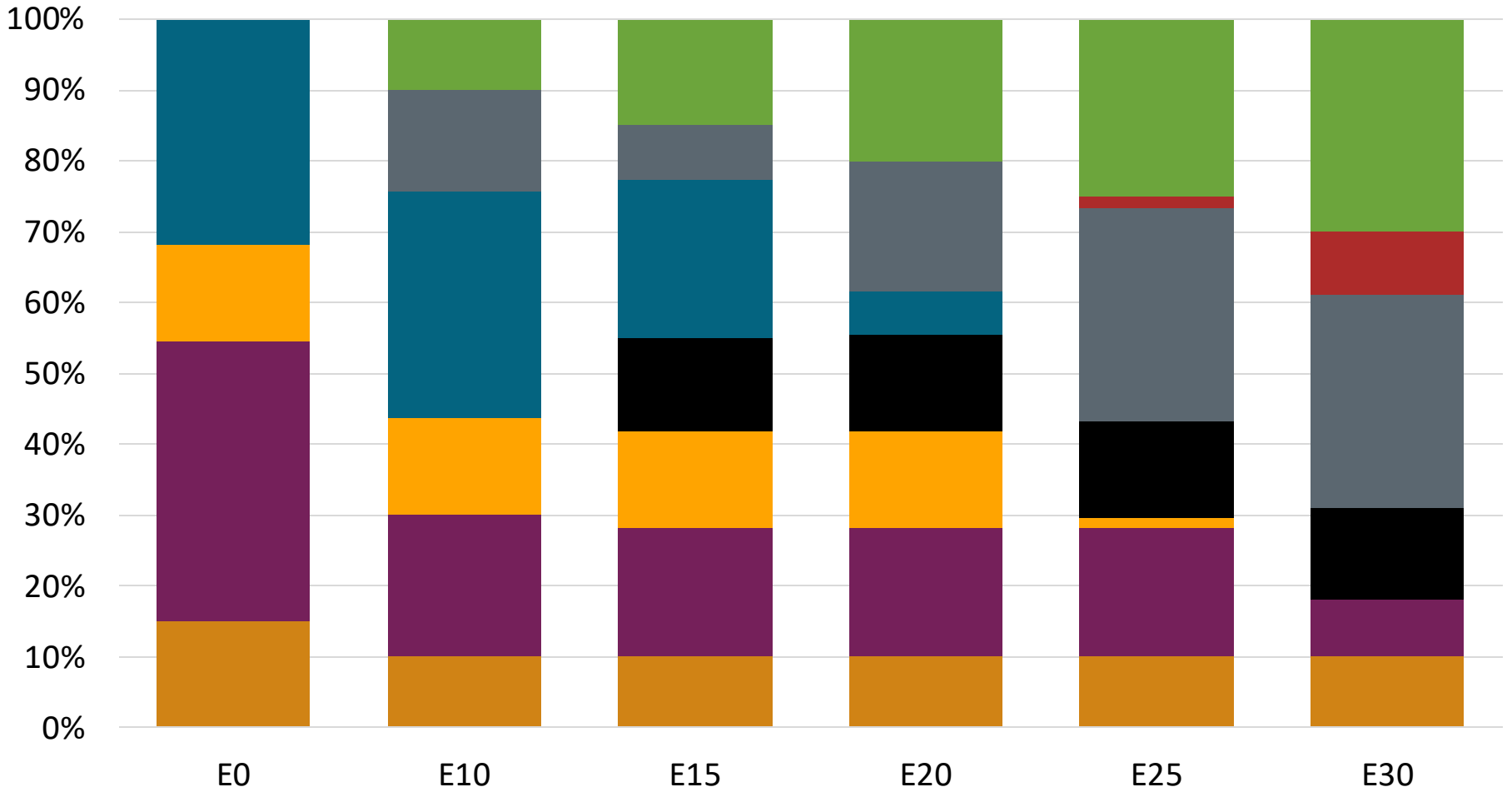


Octane (RON)	90.9	94.0	95.2	96.7	98.1	99.7
Price (USD/gal)	$2.35	$2.35	$2.35	$2.35	$2.35	$2.35

Prices are average Jan 22 – Feb 23.
They do not include local distribution costs, import or gas station margins, taxes and subsidies.

Source: Faro90

Ethanol Blending – Gasoline RON 95 – Constant Octane

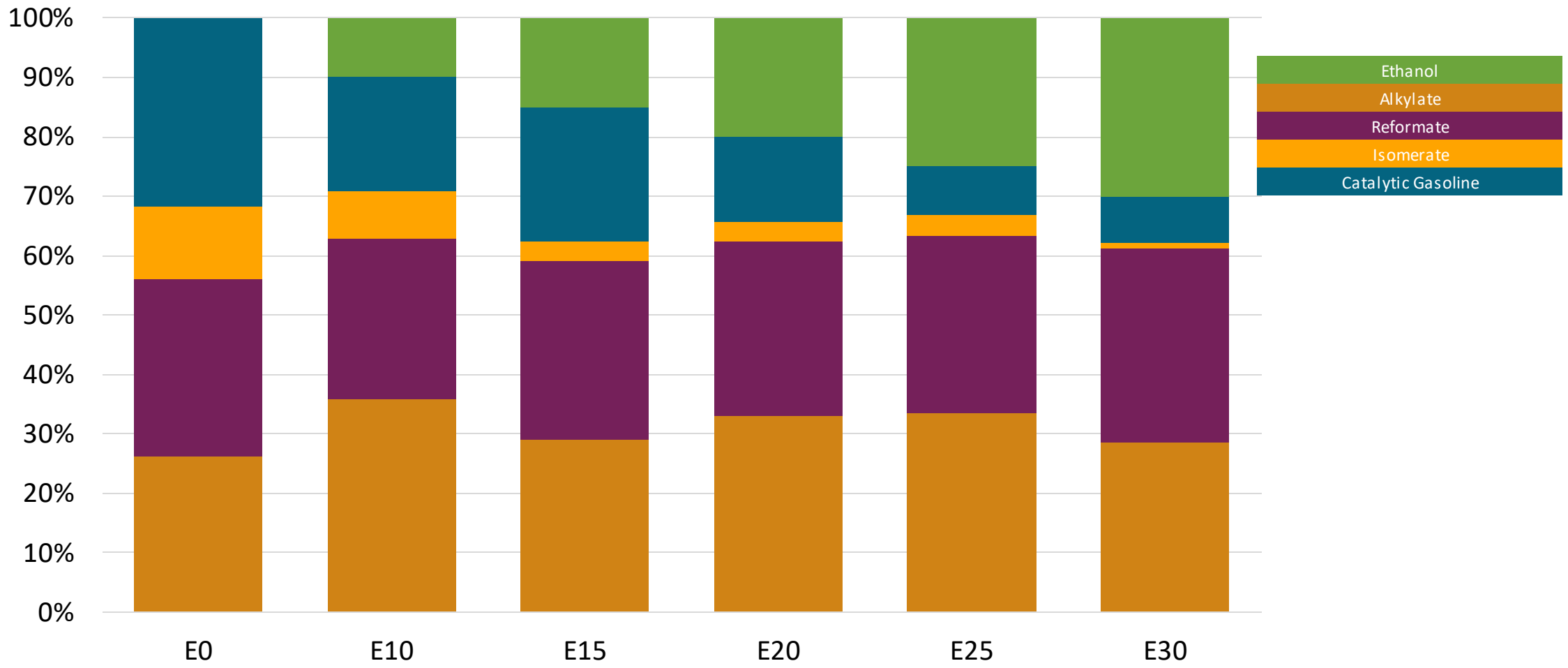


Octane (RON)	95.1	95.1	95.0	95.0	95.0	95.0
Price (USD/gal)	$2.50	$2.35	$2.22	$2.17	$2.12	$2.03

Prices are average Jan 22 – Feb 23.
They do not include local distribution costs, import or gas station margins, taxes and subsidies.

Source: Faro90

Ethanol Blending – Gasoline RON 95 – Octane Increment



Octane (RON)	95.0	99.1	101.5	103.2	105.0	106.8
Price (USD/gal)	$2.48	$2.48	$2.48	$2.48	$2.48	$2.48

Prices are average Jan 22 – Feb 23.
They do not include local distribution costs, import or gas station margins, taxes and subsidies.

Source: Faro90

Vehicle Emission Impact for Ethanol Gasoline Blending

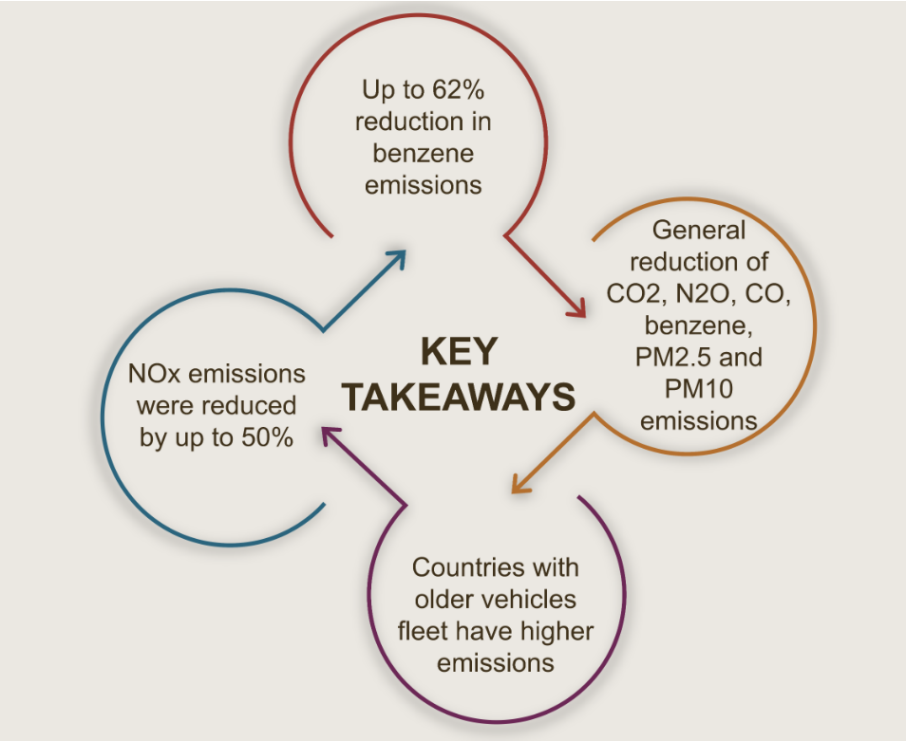
The model used in this analysis takes as a reference the **International Vehicle Emissions Model (IVE).**
The model uses the Base Emission Rates from IVE model, as well as its Adjustment Factors based on:

- Vehicle technology (cars, trucks, buses, motorcycles),
- Vehicle fleet average age,
- Average traveled distance per vehicle by country, as well as
- Geographical and climatic conditions (altitude, humidity, temperature).

Emissions of criteria pollutants, toxic pollutants, and greenhouse gases (GHG) were calculated and calibrated with emission inventories, using real gasoline quality data. The reduction rates for gasoline/ethanol blends were obtained from various sources (IPCC, US Grains, among others).

Emission estimations for different pollutants for gasoline and gasoline/ethanol blends (10%, 15%, 20%, 25% and 30% ethanol) were determined using the IVE Model. A comparison between the results and the European (Euro 6) requirements is made. Results are also compared with real emissions of the United States vehicle fleet*.

Main Results



Source: Bureau of transportation statistics.

Gasoline Vehicle Fleet - Costa Rica

Type	Motor	Tailpipe	Recuperator	Age	Number of vehicles
Auto/Sml Truck	Multi FI-Pt	Euro V	PCV Tank	>4years, >80 mkm	177.395
				4-8 years, 80-160 mkm	201.973
				<8 years, < 160 mkm	135.031
		Euro IV		<8 years, < 160 mkm	132.105
		Euro III		<8 years, < 160 mkm	125.379
		3-Ways		<8 years, < 160 mkm	278.379
Sml Engine	FI 4-cycles	Euro III	PCV	>4years, >80 mkm	52.143
				4-8 years, 80-160 mkm	29.684
		Euro II		4-8 years, 80-160 mkm	29.684
				<8 years, < 160 mkm	197.199
Truck	FI	Euro V	PCV	>4years, >80 mkm	36.587
				4-8 years, 80-160 mkm	41.656
				<8 years, < 160 mkm	27.850
		Euro IV		<8 years, < 160 mkm	27.246
		Euro III		<8 years, < 160 mkm	25.859
		3-Ways		<8 years, < 160 mkm	57.415

Vehicle Fleet: **1,575,585**
Average Age: **11 años**
Motorcycle: **19.6%**

Source: INEC , analysis Faro 90

Costa Rica – Gasoline Vehicle Emissions

Emissions	E0 g/km	E10 g/km	E15 g/km	E20 g/km	E25 g/km	E30 g/km	E10 - E0	E20 - E0	E30 - E0	Euro 6	TIER USA
CO	13.48	12.34	11.97	11.63	11.39	11.06	-8%	-14%	-18%	1	3.5
VOC	1.24	1.15	1.12	1.10	1.08	1.06	-7%	-11%	-15%	95	255
VOCevap	0.49	0.49	0.50	0.51	0.52	0.53	0%	4%	7%	0.1	0.273
NOx	0.63	0.44	0.41	0.39	0.36	0.34	-30%	-38%	-46%	0.06	0.203
SOx	0.01	0.01	0.01	0.00	0.00	0.00	-15%	-28%	-41%		
NH3	0.07	0.07	0.07	0.07	0.07	0.07	-2%	0%	1%		
Butadiene	0.01	0.01	0.01	0.01	0.01	0.01	-7%	-11%	-14%		
Acetaldehyde	0.02	0.03	0.04	0.06	0.06	0.08	68%	249%	372%		
Formaldehyde	0.06	0.07	0.08	0.09	0.09	0.10	13%	39%	68%		
Benzene	0.06	0.06	0.06	0.05	0.05	0.05	-9%	-11%	-18%		
CO2	278.82	264.88	259.56	256.92	254.37	249.68	-5%	-8%	-10%		
N2O	0.01	0.01	0.01	0.01	0.01	0.01	-1%	2%	4%		
CH4	0.27	0.27	0.28	0.28	0.29	0.29	0%	4%	7%		
PM 2.5	0.02	0.02	0.02	0.01	0.01	0.01	-22%	-43%	-65%		
PM10	0.03	0.03	0.02	0.02	0.02	0.01	-22%	-43%	-65%	0.005	0.007
THC	0.42	0.43	0.46	0.49	0.51	0.53	3%	16%	26%		

Source: Faro90