FARO90

U.S. GRAINS COUNCIL

Ethanol Blending in Gasoline - Chile

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.

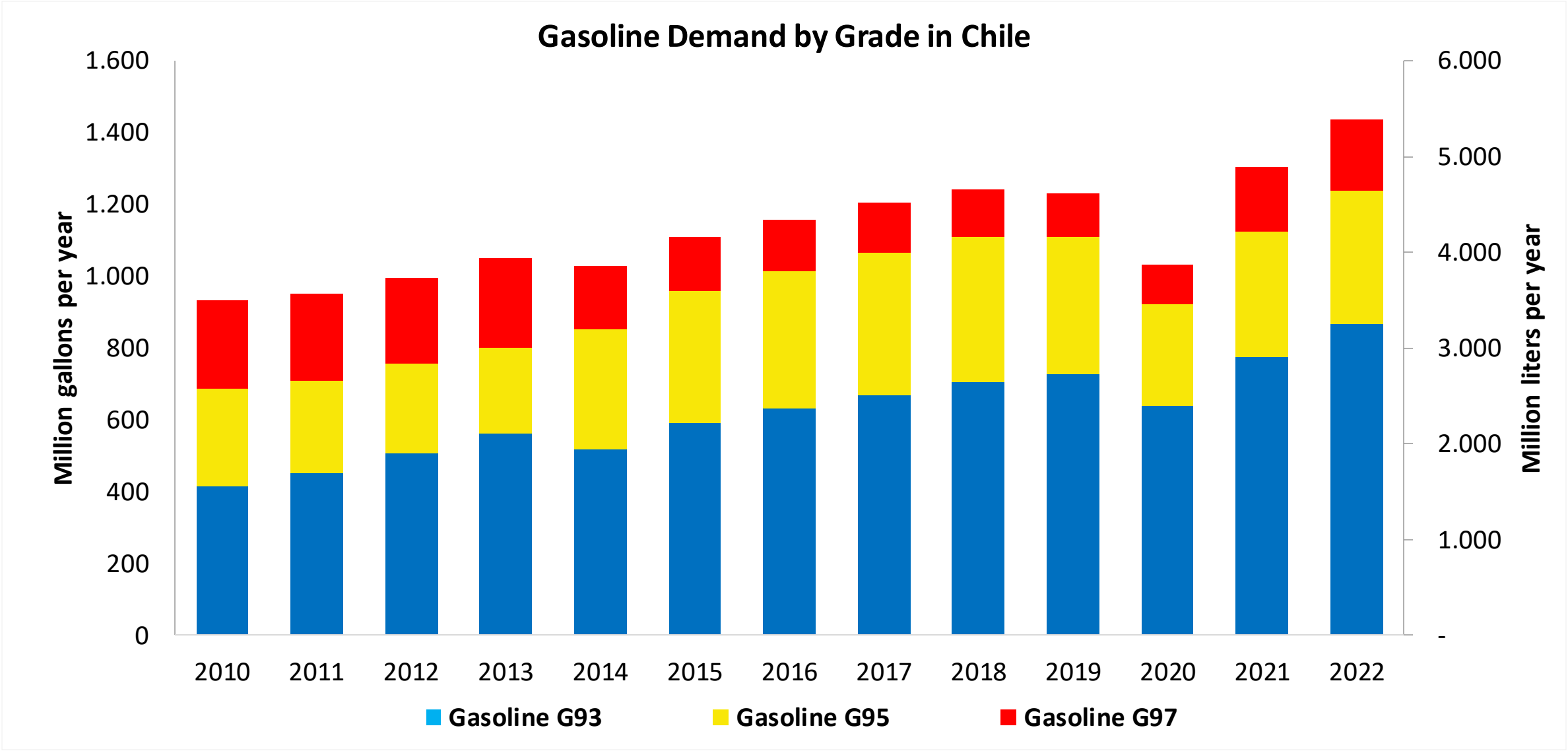
Ethanol Blending in Ethanol - Chile

Chile's gasoline consumption is currently over 1,400 millon gallons per year (5,000 million liters) in three grades: RON 93 (AKI 87), RON 95 (AKI 88) and RON 97 (AKI 92). There is a more stringent quality specification for Santiago Metropolitan Area. In 2022, the market share of RON 93 gasoline was 28%. Government company ENAP produces 80% of the total demand. Gasoline imports made in the country come mainly from Europe and the United States. Refineries only produce RON 93 and RON 97 gasoline, gasoline RON 95 is blended from these grades in gas stations.

Ethanol can be blended up to 5% v/v. However, ethanol is not used as a fuel or blended with gasoline.

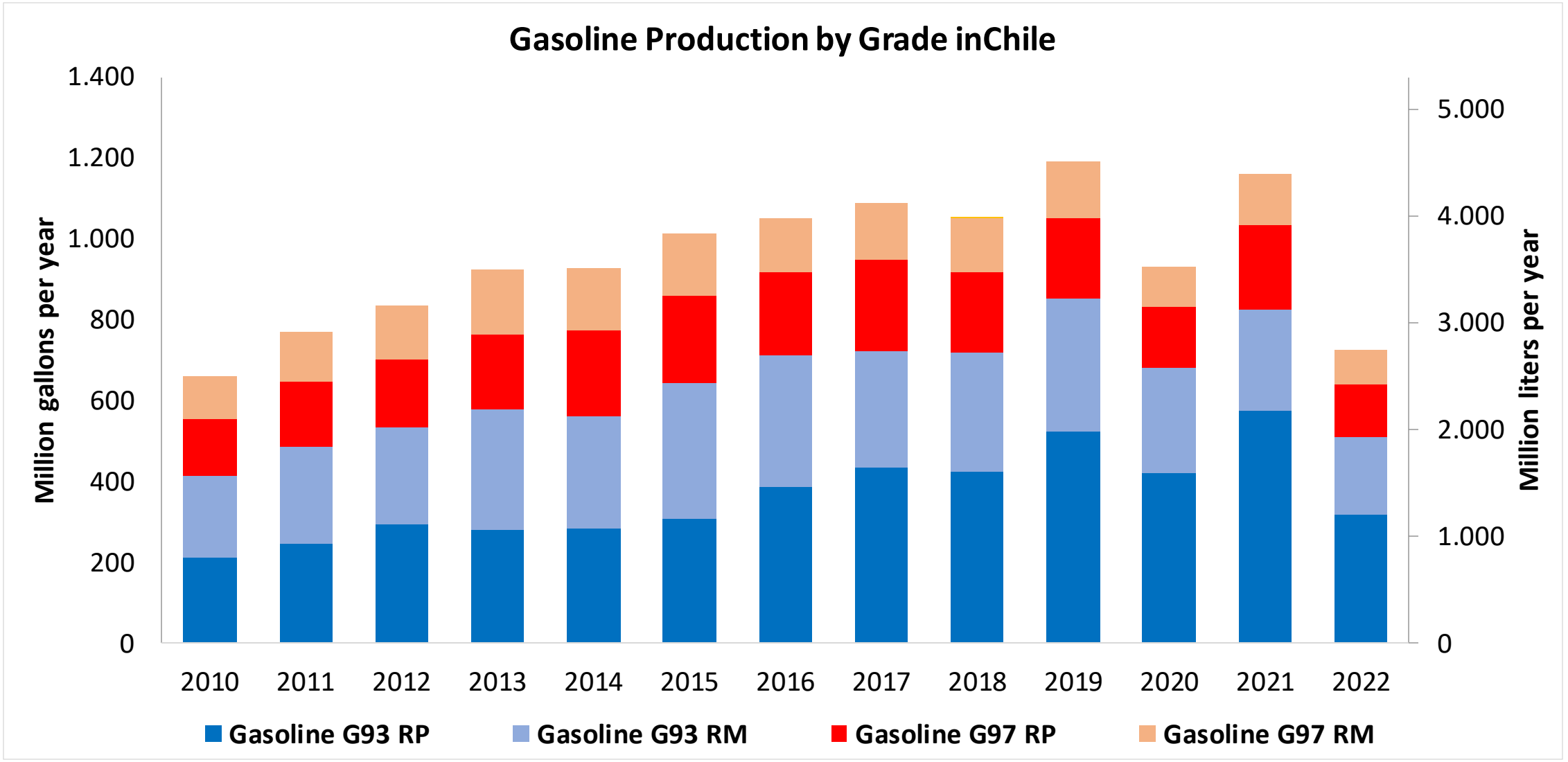
Source: SEC, 2023

Gasoline Demand in Chile



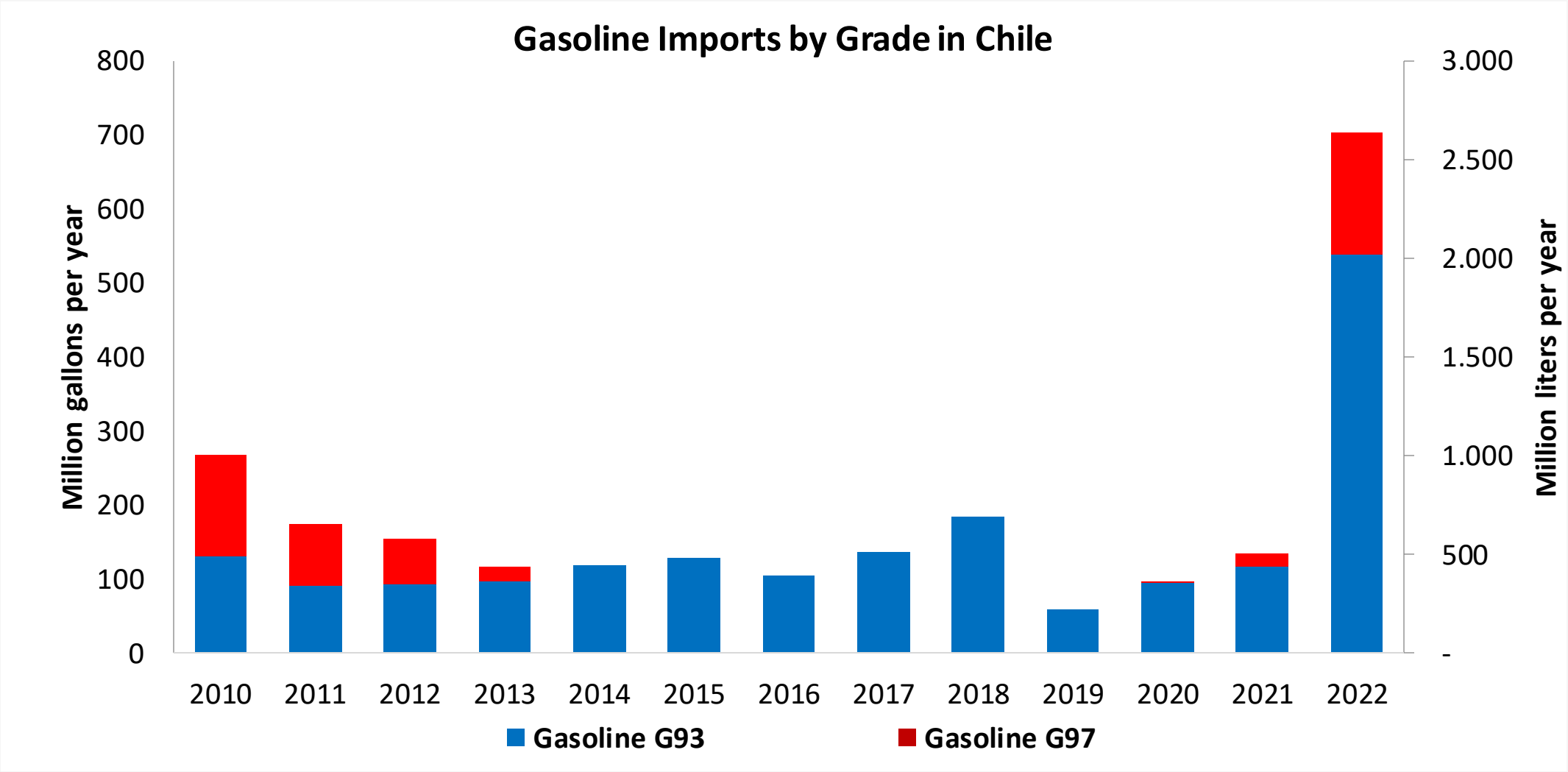
Source: SEC, 2023

Gasoline Production in Chile



Source: ENAP, 2022

Gasoline Imports in Chile



Fuente: SEC, 2023

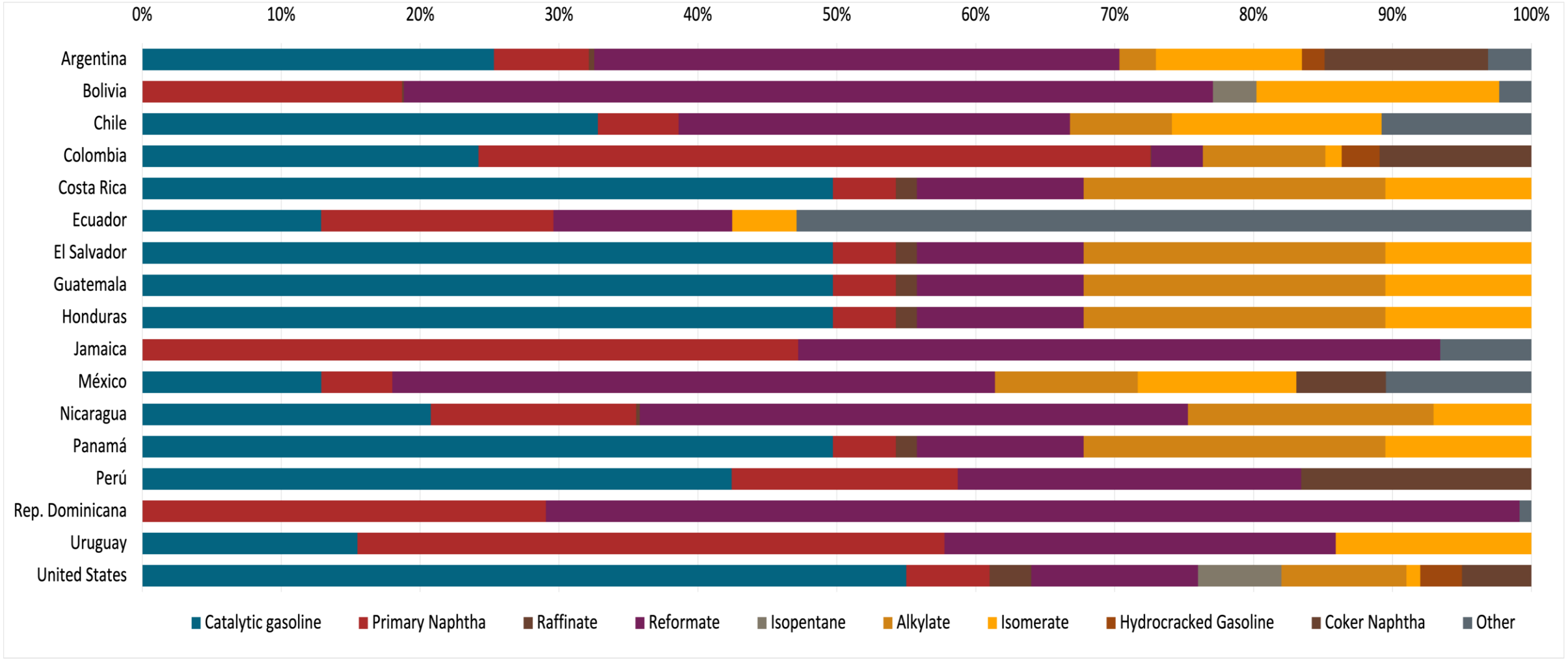
Gasoline Quality in Chile

Name	PPDA DS31	PPDA DS31	DS 60	DS 60	EN 228:2012 + A1:2017 (Euro 6 enabling)			
Implementation Date	2017	2017	2012	2012	2017			
Applicability	Metropolitan Region	Metropolitan Region	Rest of the country	Rest of the country	All countries			
Selected Grade	G93	G97	G93	G97	RON 95 E5	RON 95 E10	RON 98 E5	RON 98 E10
Benzene Content	< 1 %v/v	< 1 %v/v	< 1 %v/v	< 1 %v/v	< 1 %v/v	< 1 %v/v	< 1 %v/v	< 1 %v/v
Aromatics	< 38 %v/v	< 38 %v/v	< 38 %v/v	< 38 %v/v	< 35 %v/v	< 35 %v/v	< 35 %v/v	< 35 %v/v
Olefins	12 %v/v	12 %v/v	20 %v/v	20 %v/v	< 18 %v/v	< 18 %v/v	< 18 %v/v	< 18 %v/v
Lead Content	< 0,013 g/l	< 0,013 g/l	< 0,013 g/l	< 0,013 g/l	< 5 mg/l	< 5 mg/l	< 5 mg/l	< 5 mg/l
Manganese	Reportar	Reportar	Reportar	Reportar	< 2,0 mg/l	< 2,0 mg/l	< 2,0 mg/l	< 2,0 mg/l
RON	93	97	93	97	> 95	> 95	> 98	> 98
MON	Reportar	Reportar	Reportar	Reportar	> 85	> 88	> 85	> 88
AKI								
Sulfur Content	< 15 mg/kg	< 15 mg/kg	< 15 mg/kg	< 15 mg/kg	< 10 mg/kg	< 10 mg/kg	< 10 mg/kg	< 10 mg/kg
Oxygen Content	< 2 %m/m	< 2 %m/m	< 2 %m/m	< 2 %m/m	<2,7 % m/m	<3,7 % m/m	<2,7 % m/m	<3,7 % m/m
Ethanol (EtOH)	<5 %v/v	<5 %v/v	<5 %v/v	<5 %v/v	<5 %v/v	<10 %v/v	<5 %v/v	<10 %v/v
RVP 37.8°C (Summer)	<> 55 kPa	<> 55 kPa	<> 69 kPa, <> 83 kPa (Magallanes y región Antártica)	<> 69 kPa, <> 83 kPa (Magallanes y región Antártica)	<> 60 - 70 kPa *Depends on the country, RVP is regulated in the EU Fuel Quality Directive			
RVP 37.8 °C(Winter)	<> 69 kPa	<> 69 kPa	<> 45 - 80 kPa	<> 45 - 80 kPa				
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: ENAP, 2022

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:



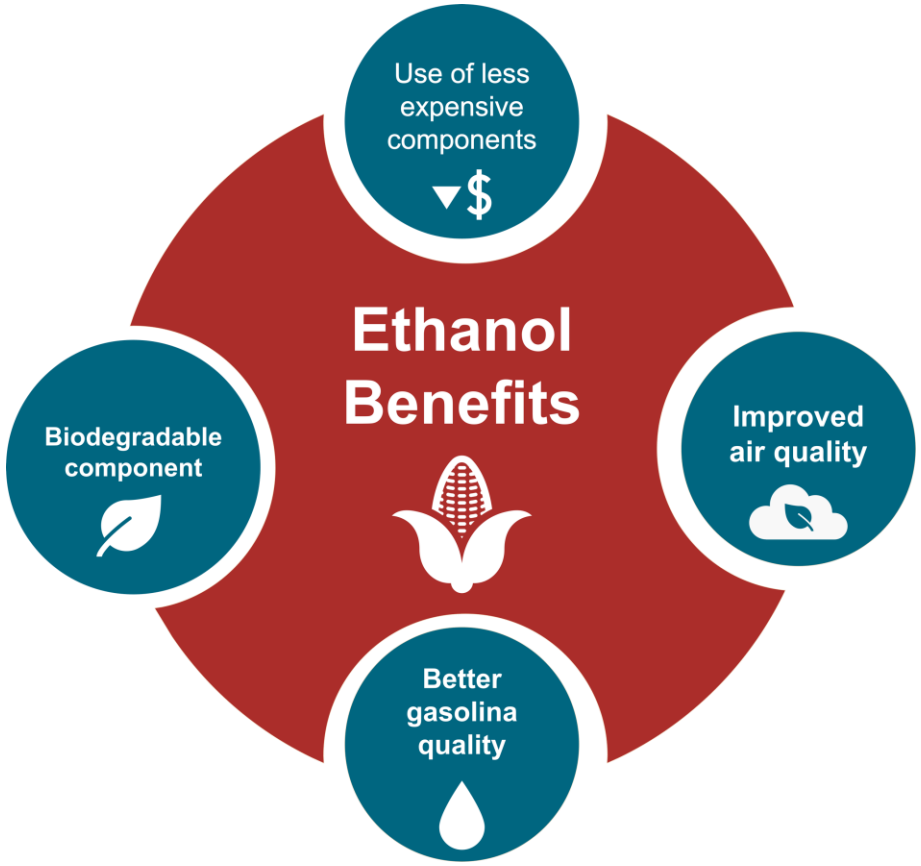
Gasoline Blending Optimization

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:

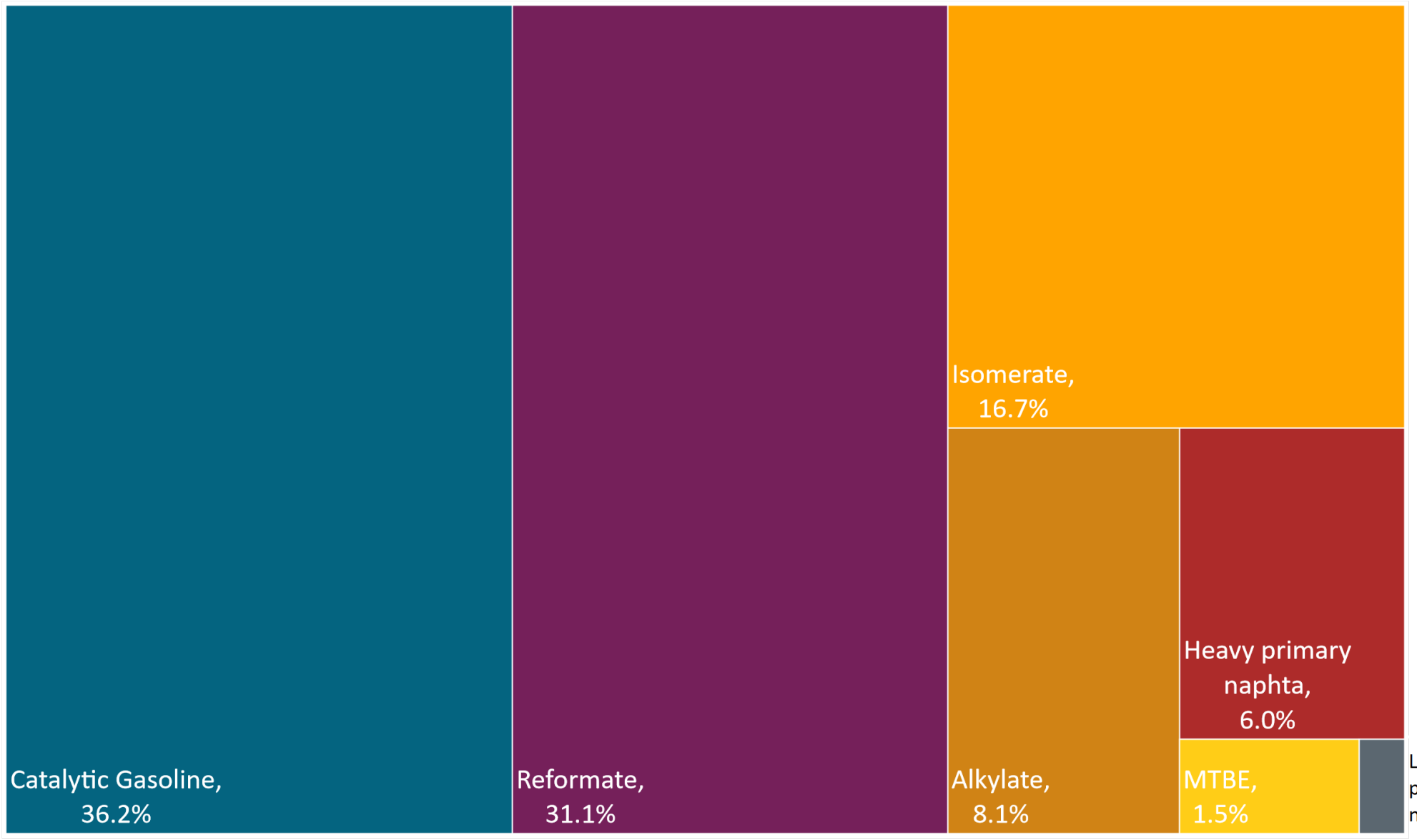
- Components prices,
- Properties each component affects,
- Quality parameters by country, and
- Component availability by country.

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.

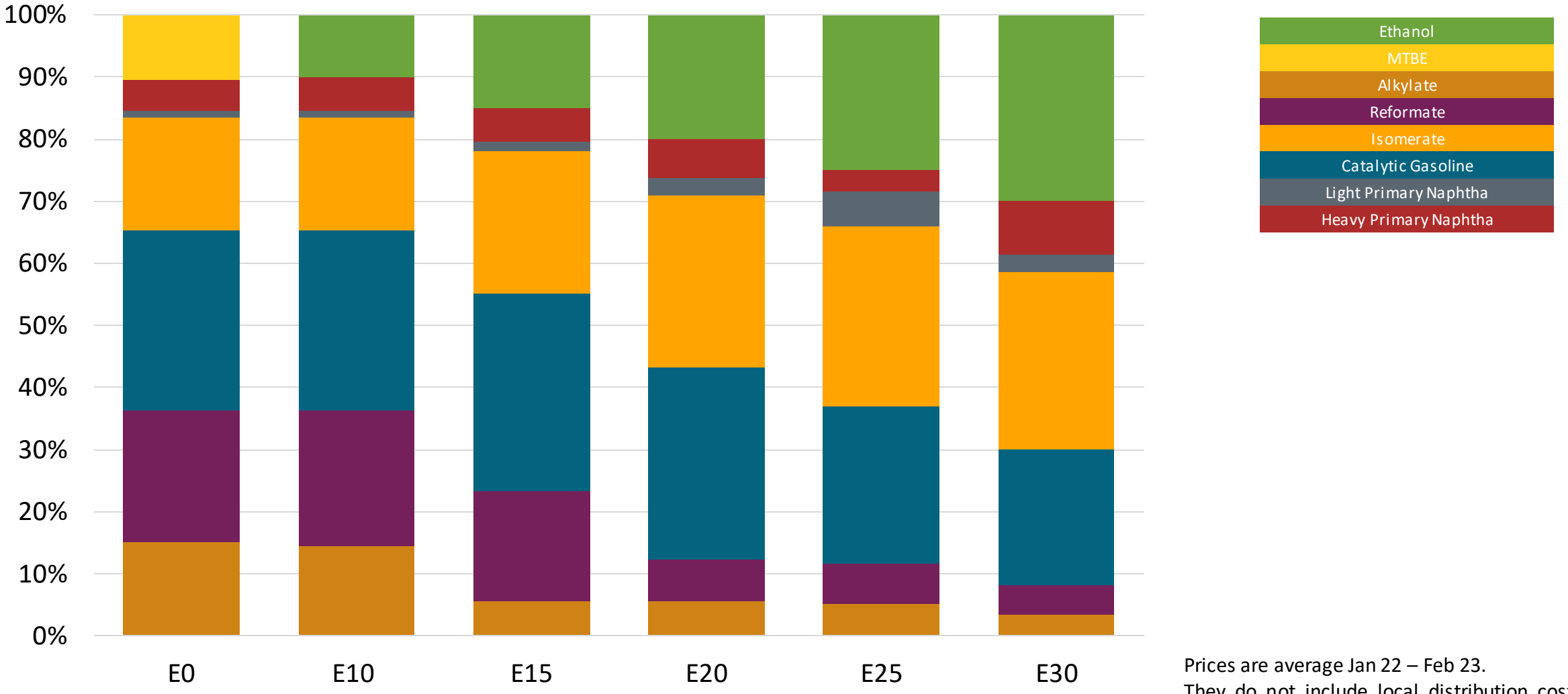


Available Blending Components



Source: ENAP, 2022

Chile – G93 RP Aconcagua – Constant Octane

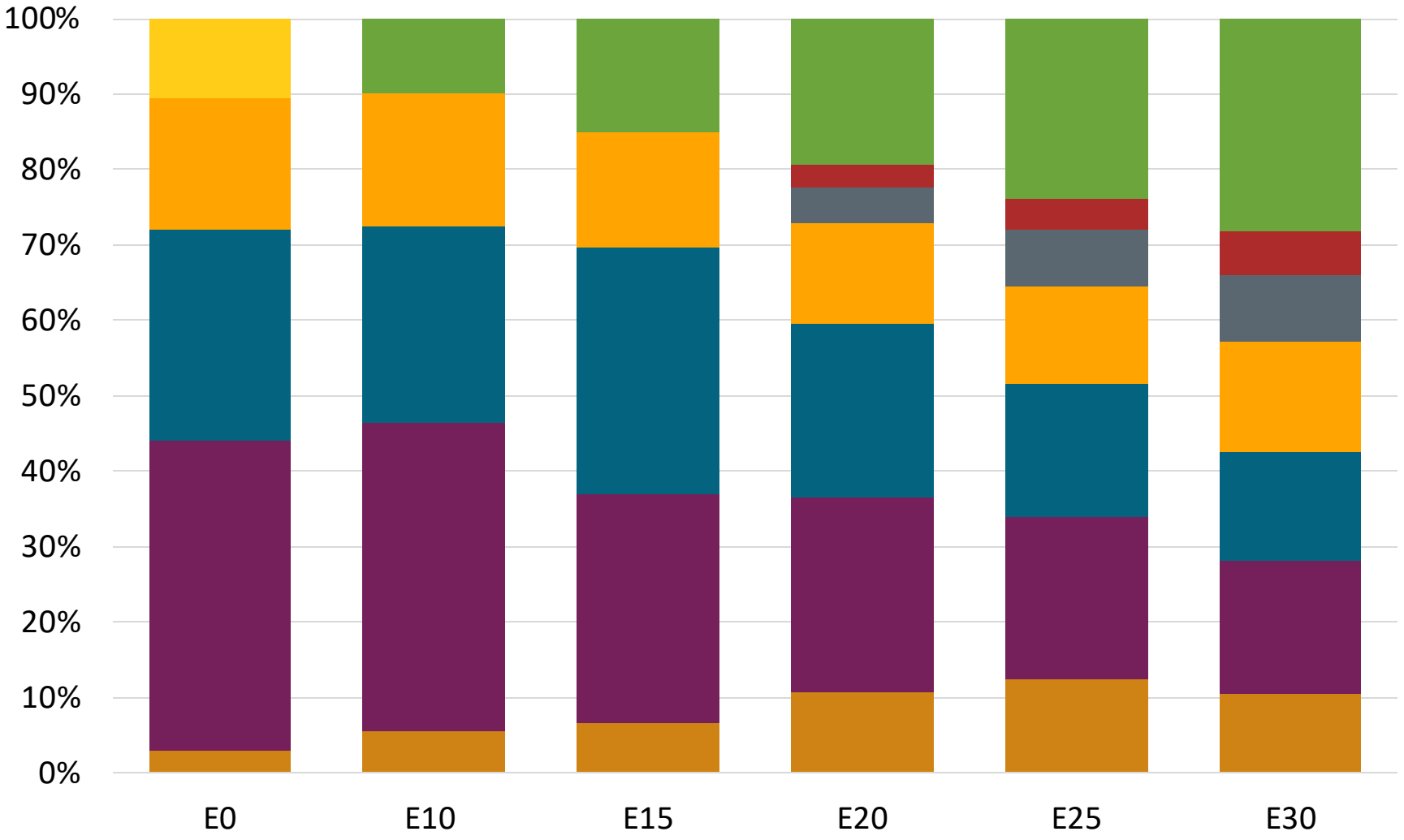


Octane (RON)	93.0	93.0	93.0	93.0	93.0	93.0
Price (USD/gal)	$ 2.566	$ 2.4851	$ 2.445	$ 2.404	$ 2.363	$ 2.323

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

Source: Faro90, 2023

Chile – G97 RP Aconcagua – Constant Octane

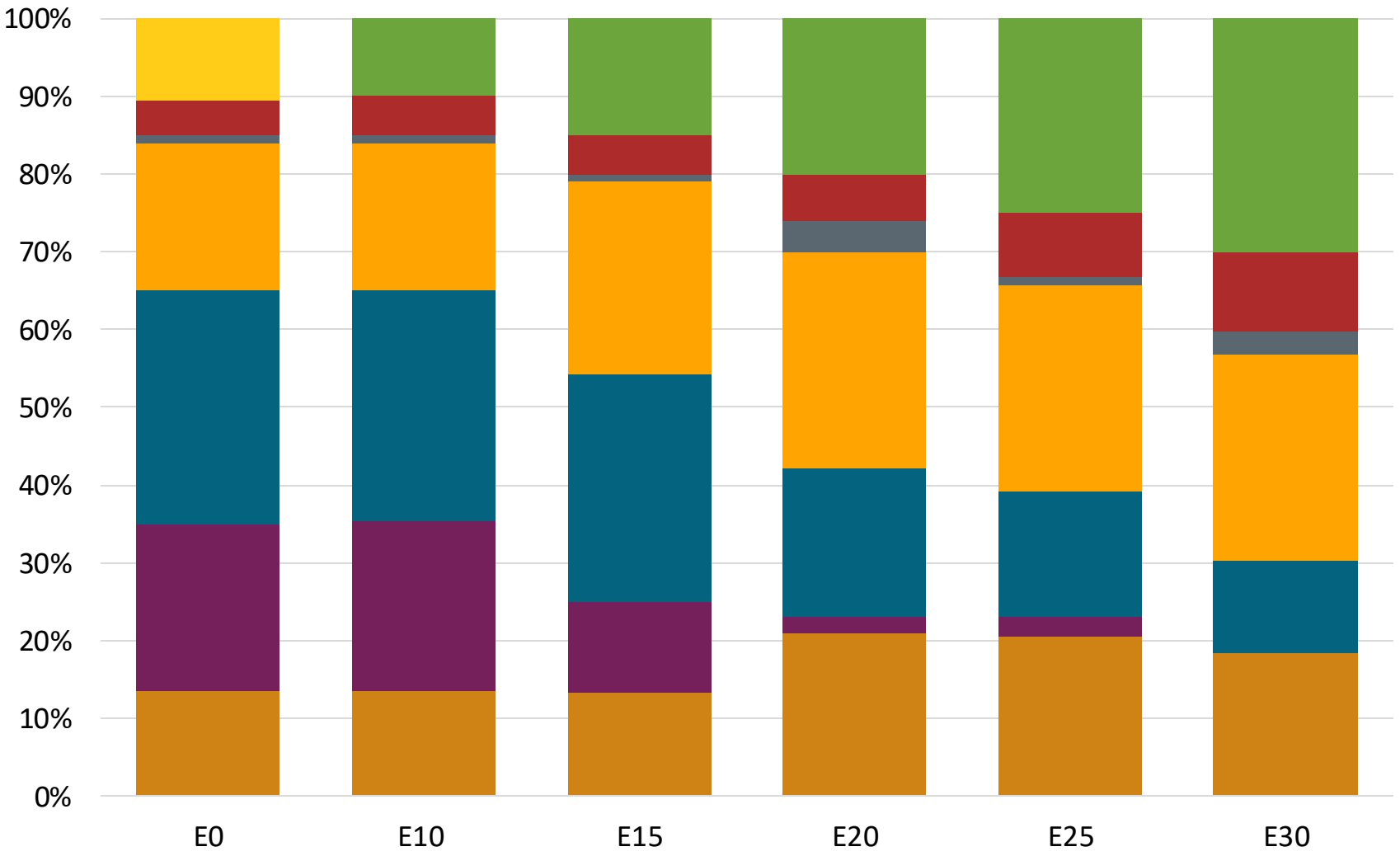


Octane (RON)	97.0	97.0	97.0	97.0	97.0	97.0
Price (USD/gal)	$ 2.622	$ 2.5582	$ 2.526	$ 2.495	$ 2.469	$ 2.431

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

Source: Faro90, 2023

Chile – G93 RM Aconcagua – Constant Octane

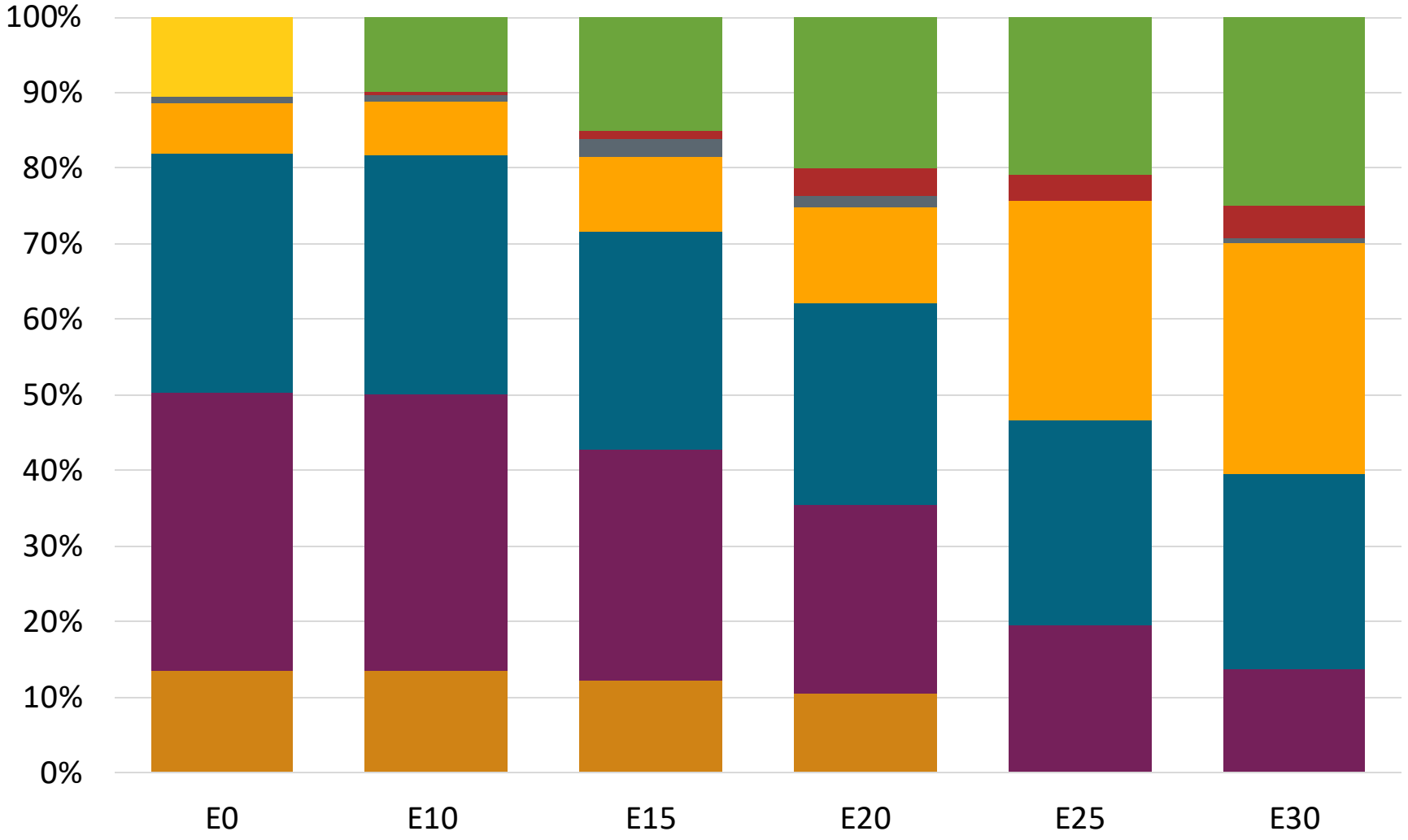


Octane (RON)	93.0	93.0	93.0	93.0	93.1	93.3
Price (USD/gal)	$ 2.564	$ 2.4867	$ 2.448	$ 2.409	$ 2.380	$ 2.332

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

Source: Faro90, 2023

Chile – G97 RM Aconcagua – Constant Octane

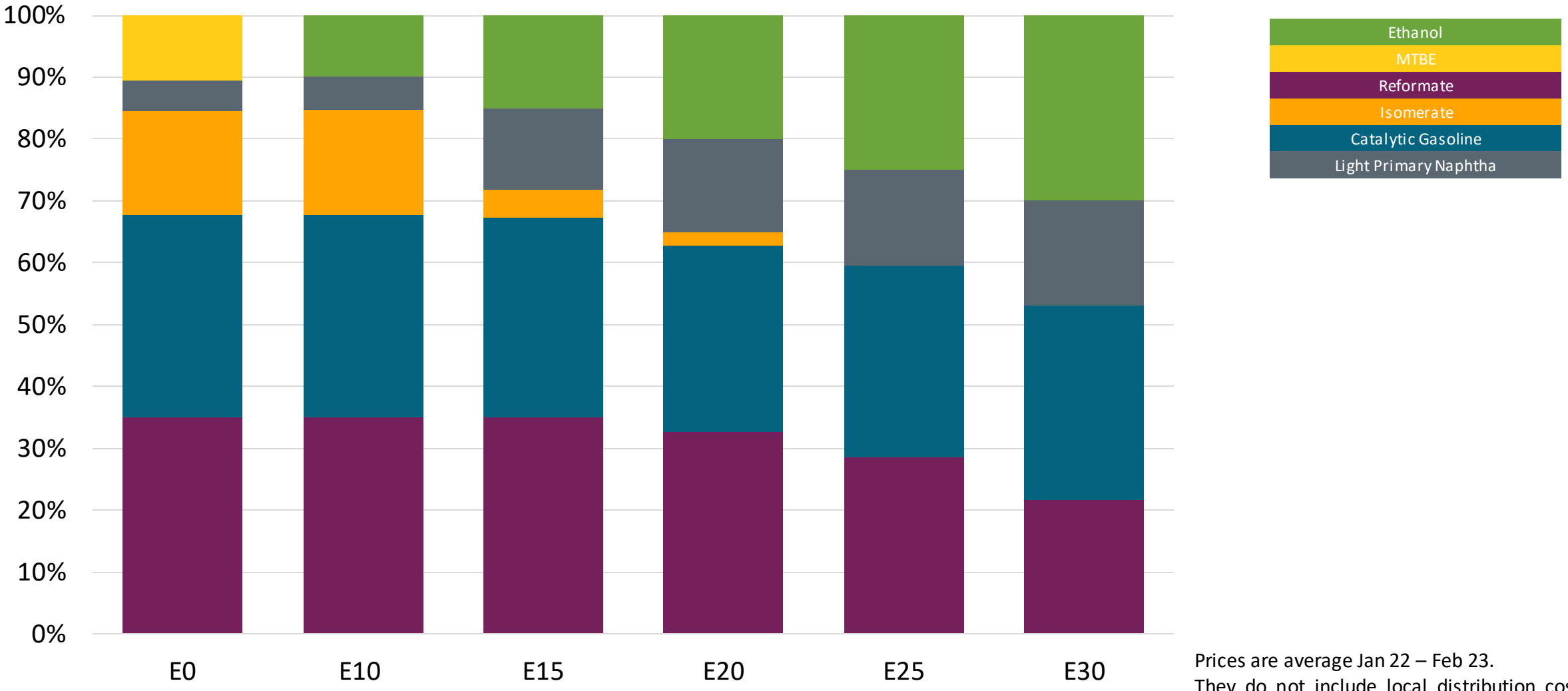


Octane (RON)	97.0	97.0	97.0	97.0	97.0	97.0
Price (USD/gal)	$ 2.674	$ 2.5826	$ 2.537	$ 2.491	$ 2.445	$ 2.399

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

Source: Faro90, 2023

Chile – G93 RP Biobío – Constant Octane

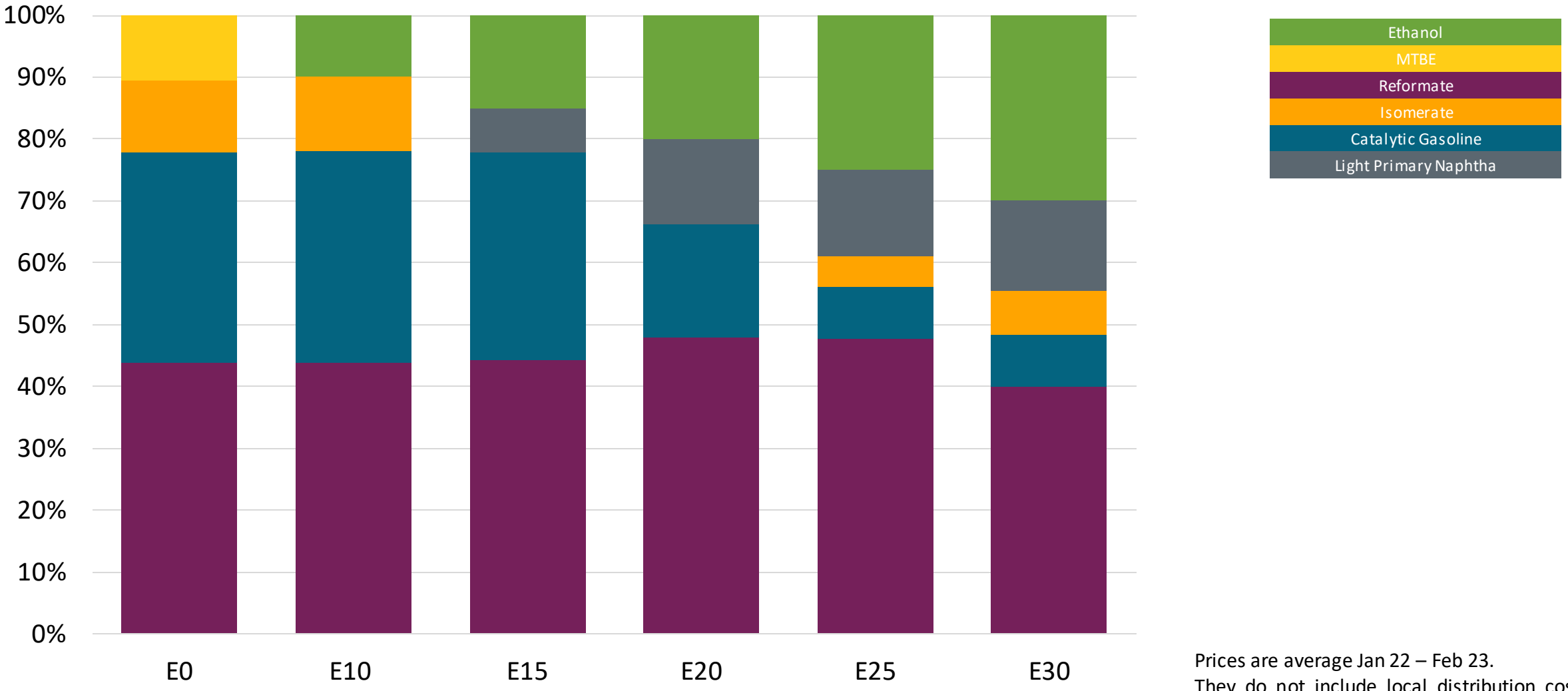


Octane (RON)	93.0	93.0	93.0	93.0	93.0	93.0
Price (USD/gal)	$ 2.513	$ 2.4485	$ 2.416	$ 2.384	$ 2.368	$ 2.320

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

Source: Faro90, 2023

Chile – G97 RP Biobío – Constant Octane

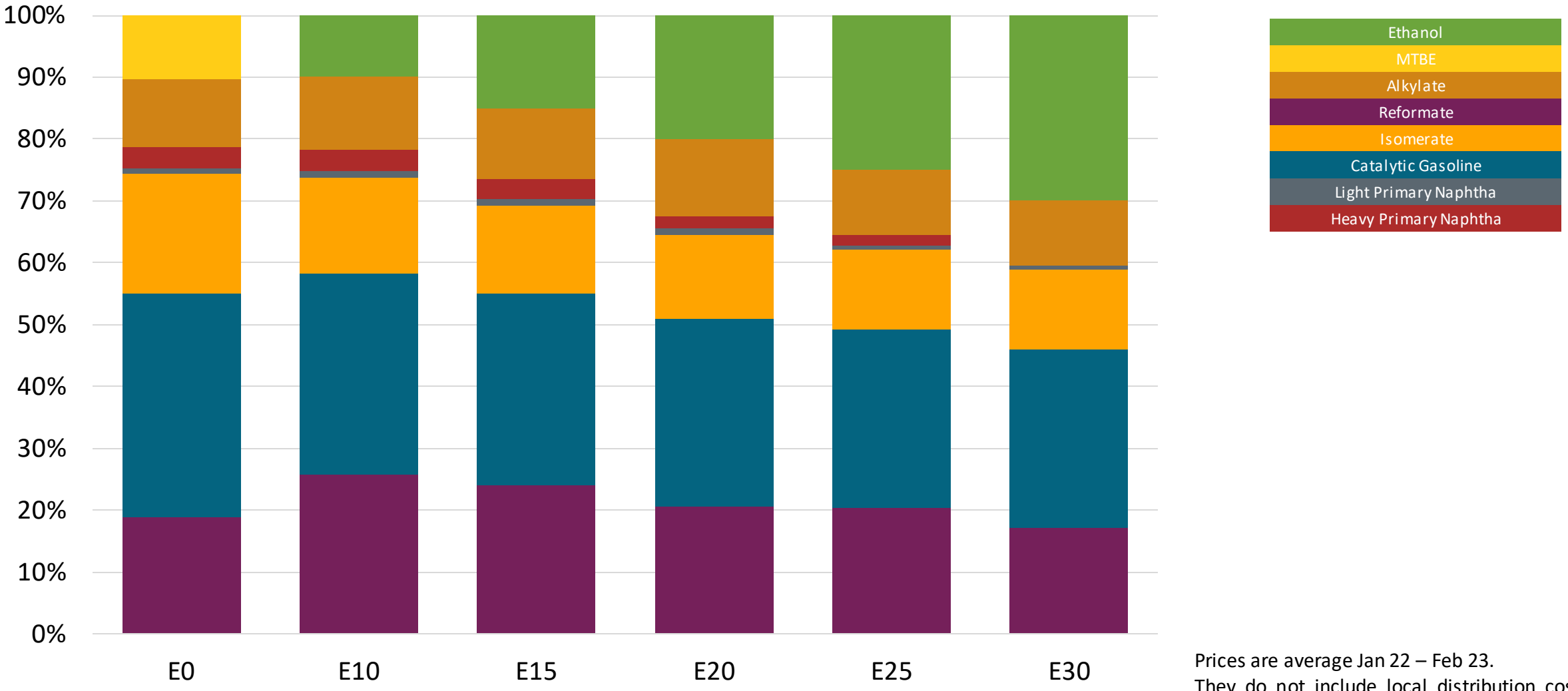


Octane (RON)	96.6	96.7	97.0	97.0	97.0	97.0
Price (USD/gal)	$ 2.588	$ 2.5235	$ 2.491	$ 2.459	$ 2.441	$ 2.394

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

Source: Faro90, 2023

Chile – G93 RP Aconcagua – Octane Increment

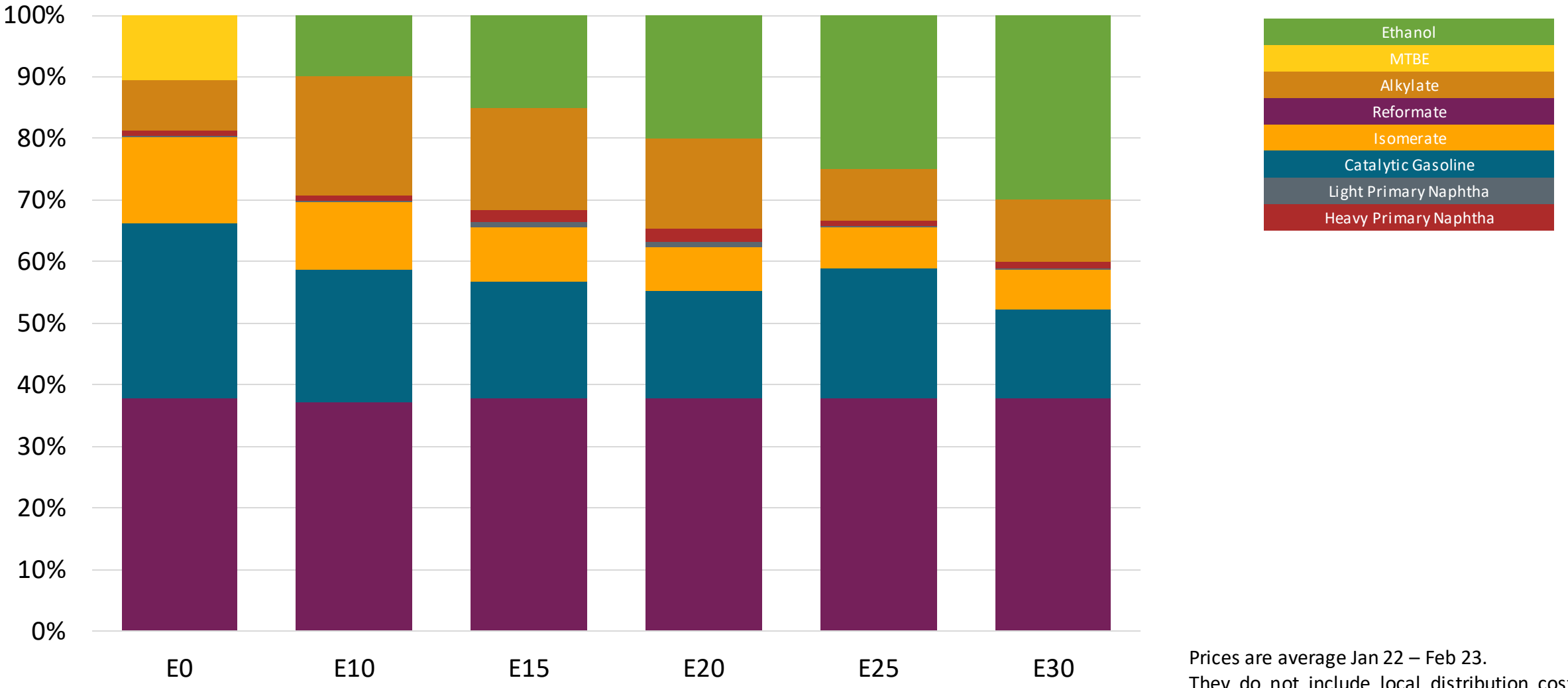


Octane (RON)	93.0	93.6	95.0	96.4	97.9	99.5
Price (USD/gal)	$ 2.315	$ 2.315	$ 2.315	$ 2.315	$ 2.315	$ 2.315

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

Source: Faro90, 2023

Chile – G97 RP Aconcagua – Octane Increment

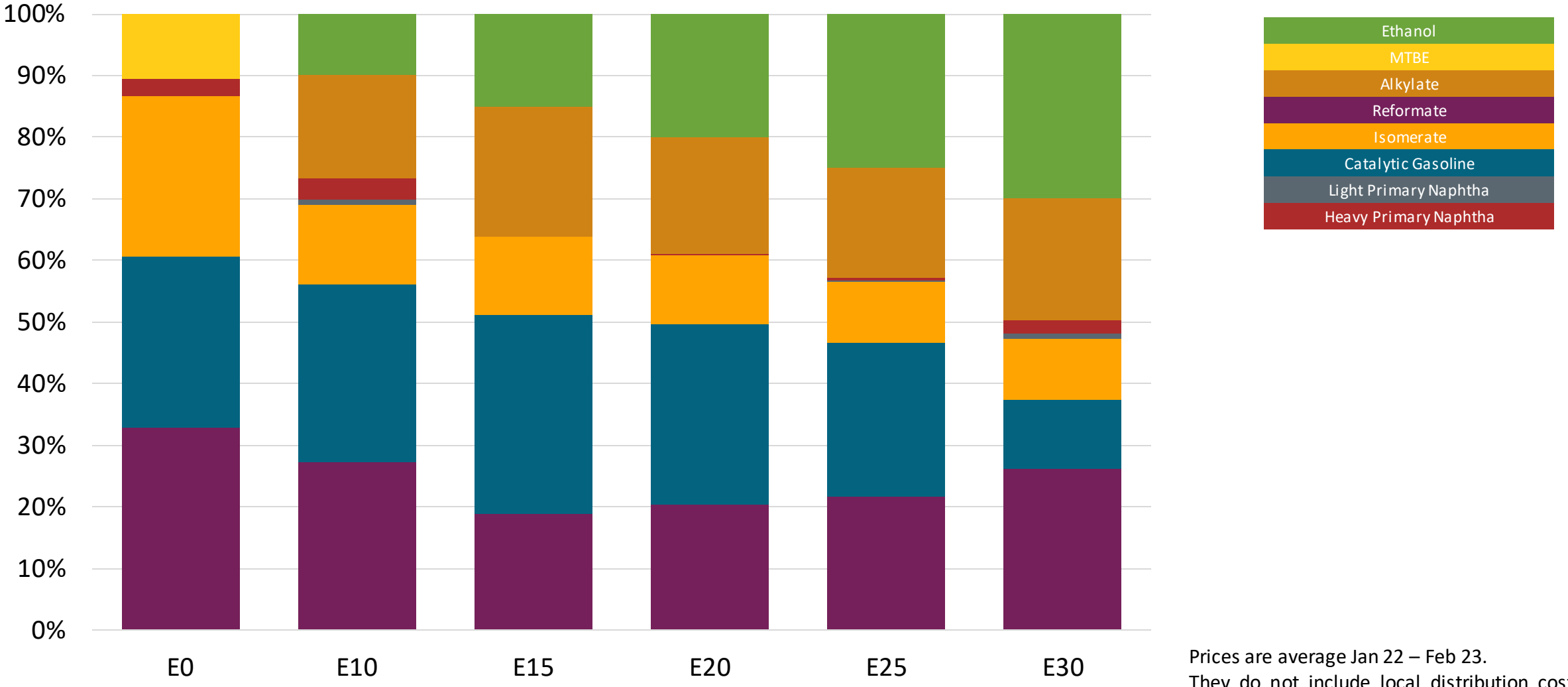


Octane (RON)	96.8	97.0	97.7	99.0	100.4	102.2
Price (USD/gal)	$ 2.393	$ 2.393	$ 2.393	$ 2.393	$ 2.393	$ 2.393

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

Source: Faro90, 2023

Chile – G93 RM Aconcagua – Octane Increment

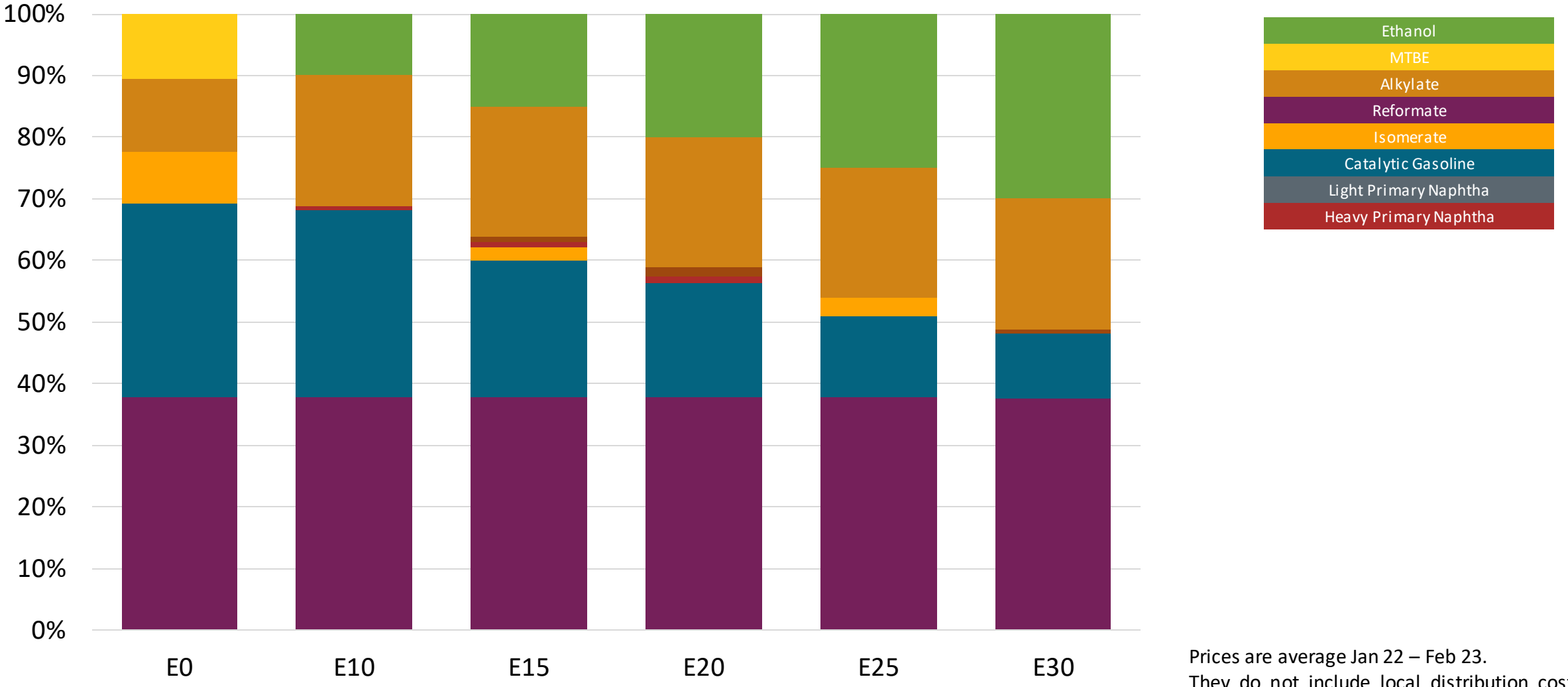


Octane (RON)	93.0	94.2	96.4	98.0	99.6	101.3
Price (USD/gal)	$ 2.345	$ 2.345	$ 2.345	$ 2.345	$ 2.345	$ 2.345

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

Source: Faro90, 2023

Chile – G97 RM Aconcagua – Octano Aumento

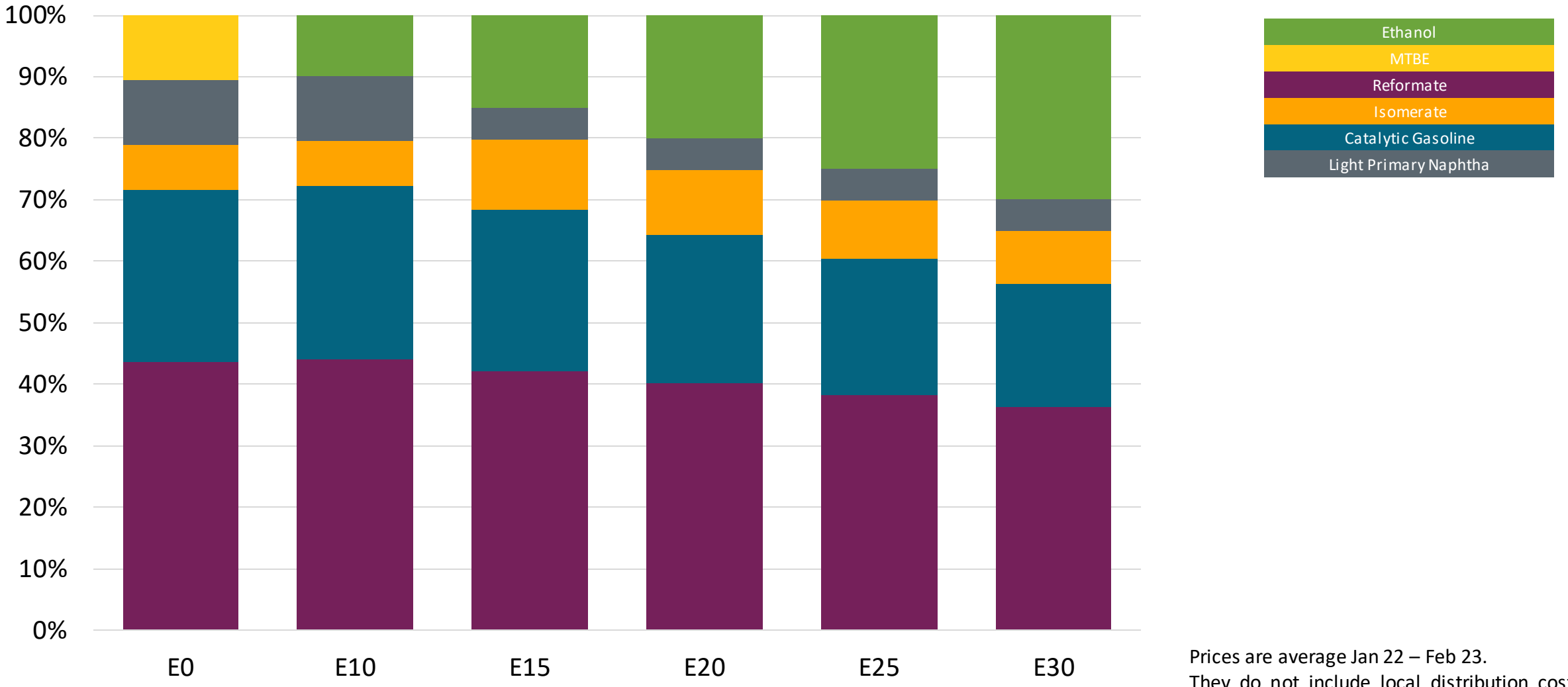


Octano (RON)	97.0	97.9	98.4	99.8	101.9	103.4
Precio (USD/gal)	$ 2.438	$ 2.438	$ 2.438	$ 2.438	$ 2.438	$ 2.438

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

Elaboración: Faro90, 2023

Chile – G93 RP Biobio – Octane Increment

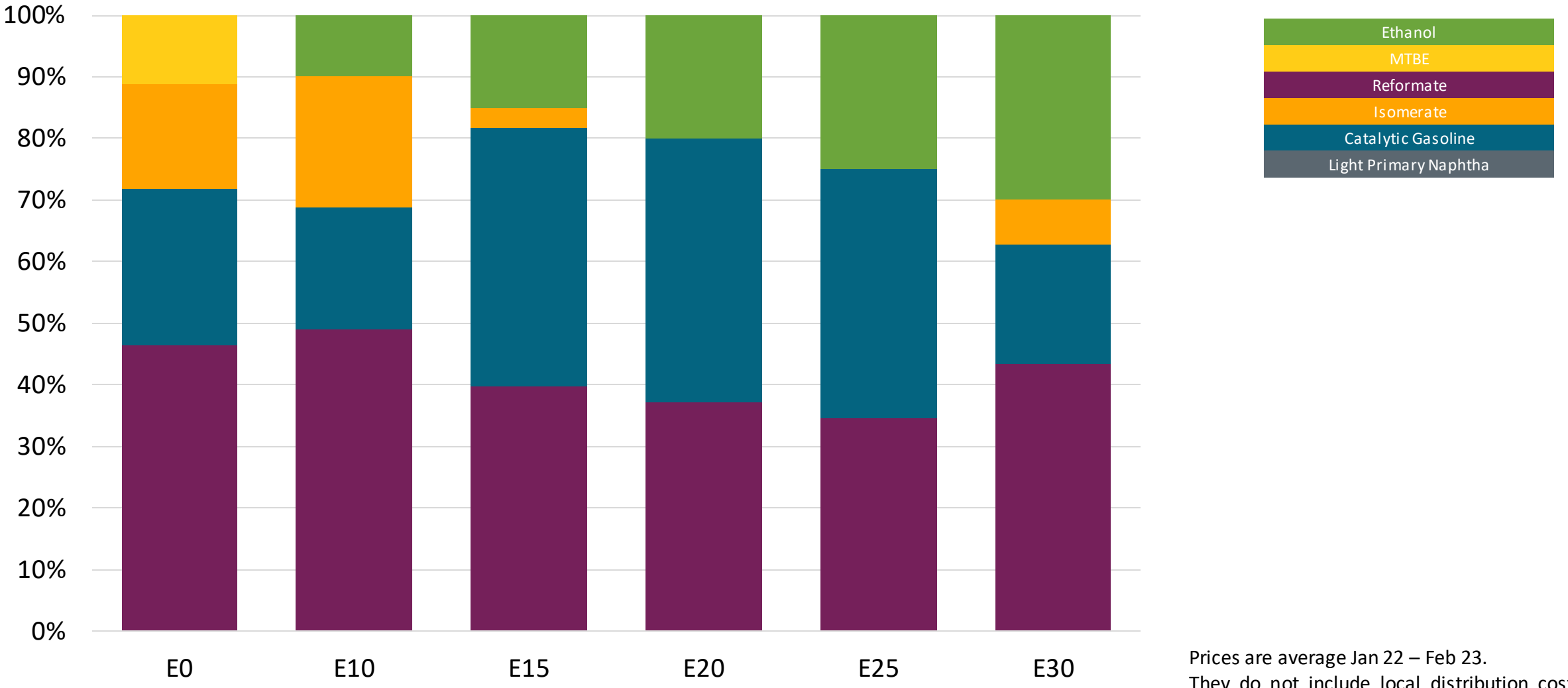


Octane (RON)	93.0	93.0	95.2	96.5	97.8	99.1
Price (USD/gal)	$ 2.293	$ 2.293	$ 2.293	$ 2.293	$ 2.293	$ 2.293

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

Source: Faro90, 2023

Chile – G97 RP Biobío – Octane Increment



Octane (RON)	97.0	97.0	97.6	98.4	98.8	102.4
Price (USD/gal)	$ 2.355	$ 2.308*	$ 2.325*	$ 2.338*	$ 2.352	$ 2.355

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

*E10 to E20 blends are at %Bnz, %Aro and %Sul limits.

Source: Faro90, 2023

Vehicle Emission Impact for Ethanol Gasoline Blending

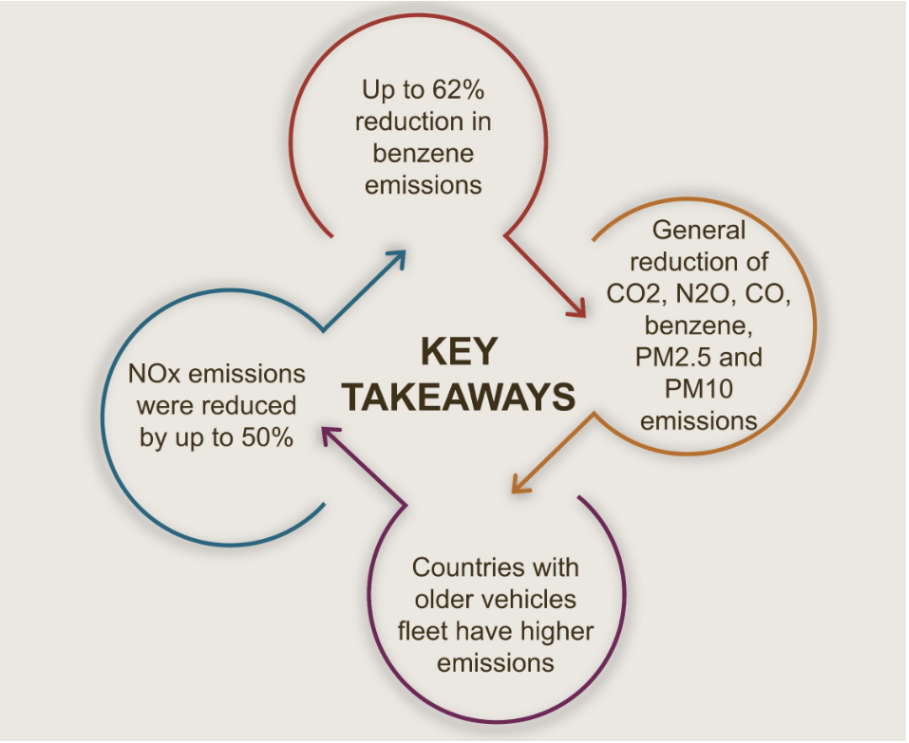
The model used in this analysis takes as a reference the **International Vehicle Emissions Model (IVE).**
The model uses the Base Emission Rates from IVE model, as well as its Adjustment Factors based on:

- 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*.

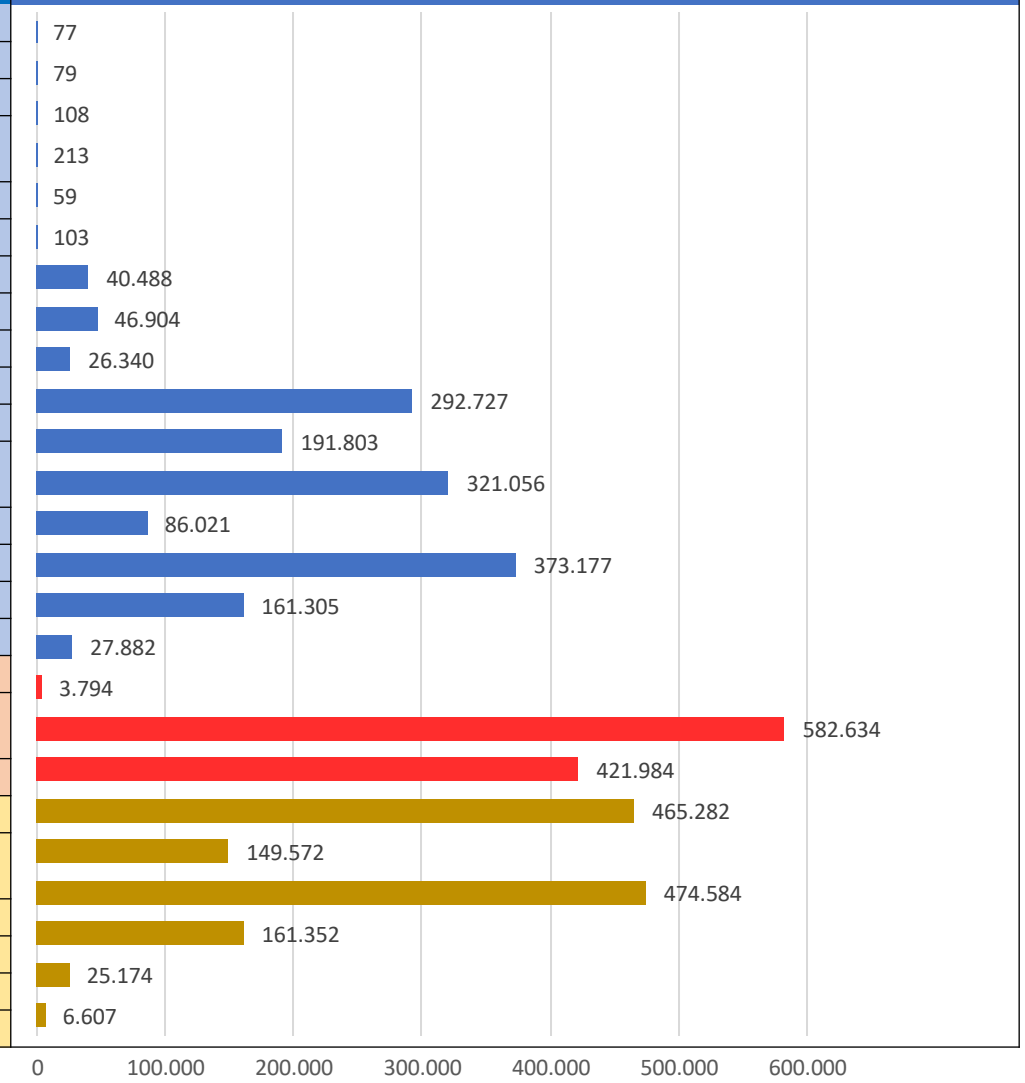
Main Results



Source: Bureau of transportation statistics.

Chile – Gasoline Vehicle Fleet

Type	Weight	Motor	Norm	Recuperator	Age	Number of vehicles
Auto/Sml Truck	Light	Carburetor	3-Way	PCV	≥161k Km (more than 8 years)	77
		Single Pt-FI	3-Way	PCV	≥161k Km (more than 8 years)	79
		Multi Pt-FI	Euro V	PCV/Tank	≥161k Km (more than 8 years)	108
					80-160k Km (between 4 - 8 years)	213
					≤79k Km (less than 4 years)	59
			3-Way	PCV	≥161k Km (more than 8 years)	103
			Euro III	PCV/Tank	≥161k Km (more than 8 years)	40.488
			Euro IV	PCV/Tank	≥161k Km (more than 8 years)	46.904
	Medium	Carburetor	3-Way	PCV	≥161k Km (more than 8 years)	26.340
		Single Pt-FI	3-Way	PCV	≥161k Km (more than 8 years)	292.727
		Multi Pt-FI	Euro V	PCV/Tank	≥161k Km (more than 8 years)	191.803
					80-160k Km (between 4 - 8 years)	321.056
					≤79k Km (less than 4 years)	86.021
			3-Way	PCV	≥161k Km (more than 8 years)	373.177
			Euro III	PCV/Tank	≥161k Km (more than 8 years)	161.305
			Euro IV	PCV/Tank	≥161k Km (more than 8 years)	27.882
Sml Engine	Light	4-Cycle, FI	Euro III	PCV	≤25k Km (less than 4 years)	3.794
			Euro II	PCV	25-50k Km (between 4 - 8 years)	582.634
					≥50k Km (more than 8 years)	421.984
Truck	Heavy	FI	Euro V	PCV	≤79k Km (less than 4 years)	465.282
					80-160k Km (between 4 - 8 years)	149.572
			3-Way	PCV	≥161k Km (more than 8 years)	474.584
			Euro III	PCV	≥161k Km (more than 8 years)	161.352
			Euro IV	PCV	≥161k Km (more than 8 years)	25.174
		Carburetor	3-Way	PCV	≥161k Km (more than 8 years)	6.607



Vehicular Fleet: **3,859,325**
Average Age: **12.8 years**

Main Technology: **Motor Multi-Fuel-Injection, Euro V, PCV Tank**

Source: INE, 3CV, Ministerio de Transporte, 2022

Chile – 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	3.42	3.27	3.15	3.05	2.98	2.87	-5%	-11%	-16%	1	3.5
VOC	0.25	0.25	0.25	0.25	0.25	0.25	-2%	-2%	-2%	95	255
VOCevap	0.29	0.29	0.29	0.30	0.31	0.31	0%	4%	7%	0.1	0.273
NOx	0.21	0.20	0.19	0.18	0.17	0.15	-6%	-17%	-28%	0.06	0.203
SOx	0.00	0.00	0.00	0.00	0.00	0.00	-8%	-21%	-36%		
NH3	0.07	0.07	0.07	0.07	0.07	0.07	-1%	1%	2%		
Butadiene	0.00	0.00	0.00	0.00	0.00	0.00	-1%	-1%	0%		
Acetaldehyde	0.01	0.01	0.02	0.02	0.03	0.04	68%	249%	440%		
Formaldehyde	0.02	0.02	0.03	0.03	0.03	0.03	13%	39%	78%		
Benzene	0.01	0.01	0.01	0.01	0.01	0.01	-5%	-7%	-14%		
CO2	218.53	196.67	199.86	198.12	196.13	195.35	-10%	-9%	-11%		
N2O	0.00	0.00	0.00	0.00	0.00	0.00	0%	2%	4%		
CH4	0.06	0.06	0.06	0.06	0.06	0.07	0%	4%	7%		
PM 2.5	0.01	0.01	0.01	0.01	0.01	0.00	-12%	-35%	-60%		
PM10	0.01	0.01	0.00	0.00	0.00	0.00	-12%	-35%	-60%	0.005	0.007
THC	0.10	0.10	0.12	0.12	0.14	0.15	7%	27%	50%		