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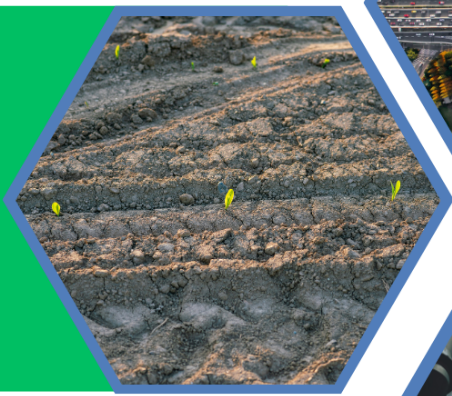


REPORT

ON THE STUDY OF COST-BENEFIT ANALYSIS FOR THE INCENTIVE POLICY IN THE DEVELOPMENT OF THE BIOFUEL INDUSTRY IN MOLDOVA.

Addressing the impacts of the
energy crisis in the Republic of Moldova Programme,
financed by European Union and implemented by
UNDP Moldova

CONTENTS

1. Executive Summary

The overall objective of the Programme is to assist the Government of Moldova in addressing the current energy crisis and energy poverty by targeting key systemic elements in the energy sector to mitigate the impact of potential future energy crises.

Notably, specific objectives of the programme include:

Implementing cost analysis within the regulatory framework for the decarbonization of the transport sector through the strengthening of the biofuel sector in accordance with EU requirements.

Enhancing the capacities of energy-related actors and improving institutional coordination mechanisms to address and mitigate risks associated with recent and potential future energy crises.

Increasing awareness and communication among strategic stakeholders to promote the adoption of best energy-saving practices and measures, and to encourage the use of renewable energy sources.

Operationalizing nationwide energy programmes and demonstrating solutions to improve the affordability of renewable energy sources in the transport sector.

In alignment with the 2030 mandates established by the Renewable Energy Directive (RED II), EU bioethanol and biodiesel supply and consumption are projected to increase in the coming years. On November 30, 2016, the European Commission published a new legislative proposal (RED II) for the period 2021-2030. This proposal outlined a stepwise increase in blending rates for advanced biofuels from 2020 to 2030, aimed at boosting the market for sustainable biofuels in the EU. The RED II also introduces additional harmonized sustainability criteria for biomass-to-biofuels processes (B. Flach et al., 2017). Based on agreements within the Energy Community, the Republic of Moldova has set a target to achieve 8,8% (with multipliers) or 7,6% (without multipliers) in term of energy consumption on RES-T by 2030. Indeed, current market trends suggest the potential for further integration of advanced biofuels, such as biodiesel from used cooking oil (UCO) and bioethanol from straw cereal, into the biofuels sector in the mid-term.

This Report provides information to the Government of the Republic of Moldova and relevant economic operators on the "Analysis of the Economic Market Model, Trends Forecasts, and Possible Strategies for First and Second-Generation Biofuels to be Adopted in the Republic of Moldova," based on the current state of the biofuels market at both the EU and national levels.

This Report includes the study/analysis for the state incentive policy in the development of the biofuel industry in Moldova (Del.4-6), including the results of the consultations carried out after the first analysis (Del.5) with aims to validate the strategies adopted for biofuels feedstock selected and the respective costs analysis.

2. Introduction

Eu and EnC background

The European Commission (EC) forecasts that the transportation sector, driven by sustainable biofuel growth, will continue to expand beyond 2030 due to the mandatory blending of biofuels at approximately 9% with conventional fuels in transport (Figure 1).

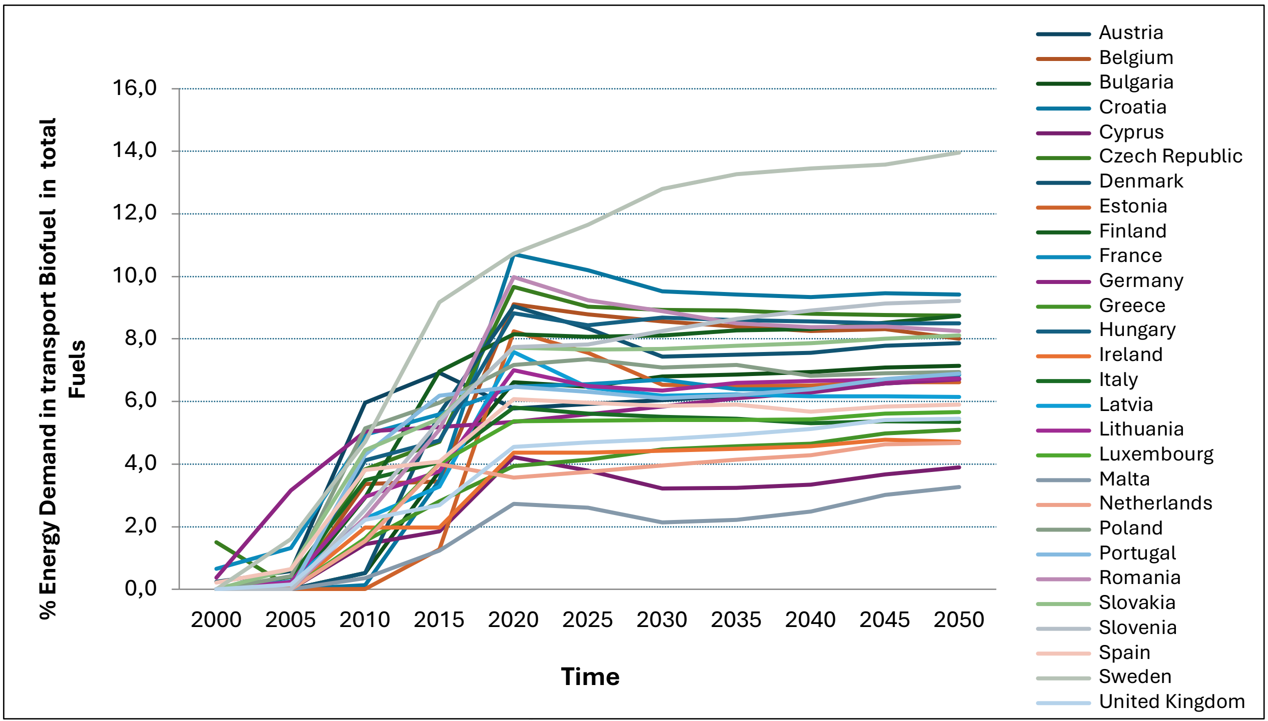


Figure 1. - Energy demand of biofuels in transport sector in EU, actual uses and forecasts, (EU Commission, 2018)

However, due to technical and technological limitations, the actual blending levels of traditional fuels with biofuels are unlikely to exceed 8–9%, with an emphasis on prioritizing EU-produced biofuels over those from outside the EU.

Over the past decade, the EU has imposed anti-dumping duties on bioethanol imports from non-EU countries, such as the US and Brazil (B. Flach et al., 2018). Since 2016, the European biofuel market has shifted further with the introduction of an additional import tariff of €102 per 1,000 liters for biofuels from non-EU countries. This tariff has significantly reduced bioethanol imports from outside the EU and boosted the production of conventional and advanced biofuels within the EU. Consequently, the biofuel market within the EU and EnC countries is expected to remain stable in the coming years, with reduced investment risks due to improved infrastructure.

Moreover, continued market development and investment in research and innovation (R&I) for the biofuels sector could enhance benefits and further reduce costs. Most analyses and policy efforts in the EU and EnC countries have so far focused on domestic production and the use of conventional biofuels. However, significant variations exist in feedstock availability and production costs between EU and non-EU countries.

These cost differences are likely to persist, as biofuel production facilities are typically located in countries where production is cheaper, provided the benefits in terms of oil usage and greenhouse gas emission reductions are greater than those achievable domestically.

Additionally, within carbon-trading frameworks, such as the Clean Development Mechanism under the Kyoto Protocol, biofuel production in non-EU countries has emerged as a valuable source of emissions reduction credits (IEA, 2004). Therefore, potential EU collaborations on investment projects could be considered. However, there is a need to address the challenge of minimizing environmental impacts while producing biofuels that meet sustainable criteria and comply with Directive 2018/2001 (RED II and the upcoming RED III). This entails increasing the cost-competitive self-production of sustainable biofuels and reducing imports where feasible (IEA, 2004).

The EU Directive 2018/2001 supports advanced biofuels by encouraging double-counting measures that promote the use of domestic residues and waste for biofuel production. This strategy aims to boost biofuel self-production across all EU countries.

In this context, the Republic of Moldova, along with other EnC countries, seeks to produce sustainable biofuels by leveraging available biomass feedstock, infrastructure, key stakeholder involvement, fiscal incentives, and legal frameworks.

Context on biofuels Market in the Republic of Moldova

Moldova is part of the EU's European Neighborhood Policy (ENP) and in the Eastern Partnership framework, which aims at strengthening individual and regional relationships between the EU and countries in its neighborhood.

Moldova is also part of the Energy Community Treaty since 2010 and signed the Association Agreement with the EU in June 2014, including the DCFTA which entered into force in 2016. Moldova was granted candidate status for the EU in June 2022. As a follow-up and as a result of Moldova's membership in the Energy Community it is required to ensure the transposition of the EU acquis Communautaire, with particular attention to EU Dir. 2018/2001 (RED II) which underpins the EU energy legislation on renewable energy and biofuels and the environment.

The energy sector, particularly the biofuels to support the decarbonization of the transport sector, is one of the priorities for the Republic of Moldova's Government. It is addressed in Government's plans and several policy documents, laws, and regulations. The most important are the following "Moldova Europeana" Development Strategy 2030, the National Energy Strategy 2030 (currently under review), the National Energy and Climate Plan (under development), the Law on Energy and Law on Promoting the use of energy from renewable sources, etc., as well as a list of secondary legislation, meant necessary to ensure the implementation of the primary legislation.

Currently, Moldova is revising its energy-related legislation considering the requirements of the Clean Energy Package that covers legislation in the areas of energy efficiency, renewables, governance, electricity market design, and electricity security of supply rules. Revised Renewable Energy Directive (RED II) with an implementation is also part of this process.

In depth, according to Law No. 10/2016 on promoting the use of energy from renewable sources, that transposed Directive 2009/28/EC (RED I) on the promotion of the use of energy from renewable sources, establish the following RES-related targets at the national level:

- achieving a share of energy from renewable sources of at least 17% in the final gross energy consumption in 2020;
- achieving a share of energy from renewable sources of at least 8,8% or 7,6 % in the final energy consumption in transport sector by 2030, with and without multipliers, respectively.

According to the Energy Community (ECS, 2022), Moldova exceeded its 2020 target of 17% by reaching 25,06% of renewable energy in 2020. However, only the sectoral target for heating and cooling was overreached, while contributions of renewable energy to electricity and transport are still meager.
According to the Moldova Annual Implementation Report 2022, despite transposing enabling provisions into its primary legislation, Moldova failed to implement a biofuels framework due to the missing pre-conditions able to incentivize biofuel uses nationally. Therefore, the only technology that counts towards the sectorial target is the use of renewable electricity by local electric public transport. For 2020, the Ministry of Energy reported a value of 0,18% as opposed to the objective of 8,8% (with multipliers) or 7,6% (without multipliers).

On a wider background, as per the Report “Modalities to foster the use of renewable energy sources in the transport sector by the Energy Community Contracting Parties” (Altmann M. et al., 2020), no one of the Contracting Parties of the Energy Community achieved the RES-T target.

According to the decision of the Ministerial Council no. 2022/02/MC-EnC, the target share of consumption of renewable energy in the gross final consumption of energy, in 2030, is at least 27%.

This target is also confirmed by the modelling results performed under the National Energy and Climate Plan development process. Under the same process, calculations were performed to establish the target share of renewables in the final energy consumption in transport and the target that should reach 8,8% (with multipliers) or 7,6% (without multipliers) of RES-T by 2030.

Moldova fully transposed the RED II provisions into national legislation, by amending Law No. 10/2016 on promoting the use of energy from renewable sources. The law defines the rules regarding support schemes, guarantees of origin, procedures applicable to administrative regulations, regional cooperation, and biofuel producers, as well as other necessary provisions to promote greater consumption of Biofuels in the transport sector of the national economy.

According to the RED II transposition package, the use of renewable energy in the transport sector practically does not take place. The use of RES by urban public transport (e.g. trolleybuses) is practically the only segment where this is taking place. This is confirmed by the value of 0.18% share of renewable energy consumption in the final energy consumption in the transport sector. At the same time, the use of biofuels by mixing with classical fossil fuels has not developed and must be promoted more categorically to reach the national target for 2030. The lack of this segment costs the Republic of Moldova economically, as this sector, which has potential for development, is stagnating.
Law No. 10/2016 on the promotion of RES aims to accelerate the use of renewable energy in transport and achieve a target of 9% by 2030, which was recently reduced to 8.8% with multipliers and 7.6% without multipliers, as follows:

- The share of biofuels and bioliquids, as well as biomass fuels consumed in transport, produced from food and fodder crops - shall be limited to 2%;

- The share of biofuels and biogas produced from used cooking oil and animal fats - is limited to 1.7%;

- The share of advanced biofuels and biogas produced from specific feedstock – is at least 1% in 2025 and 3.5% in 2030.

Currently, the share of transport in final energy consumption fluctuates around 26%. The vast majority of energy is consumed by road transport. There is only a small amount of Renewable energy (i.e. electricity) used for rail transport and non-specified transport. Almost all energy for transport is oil (Fig. 2), primally Diesel followed by motor gasoline and petroleum products (Fig.3), mostly imported by Romania, Russia, Belarus and Bulgaria, (Fig. 4). The only renewable energy source in transport is only consumed as electricity and is related to consumption by trolleybuses, which have been operated for many years in Moldova.

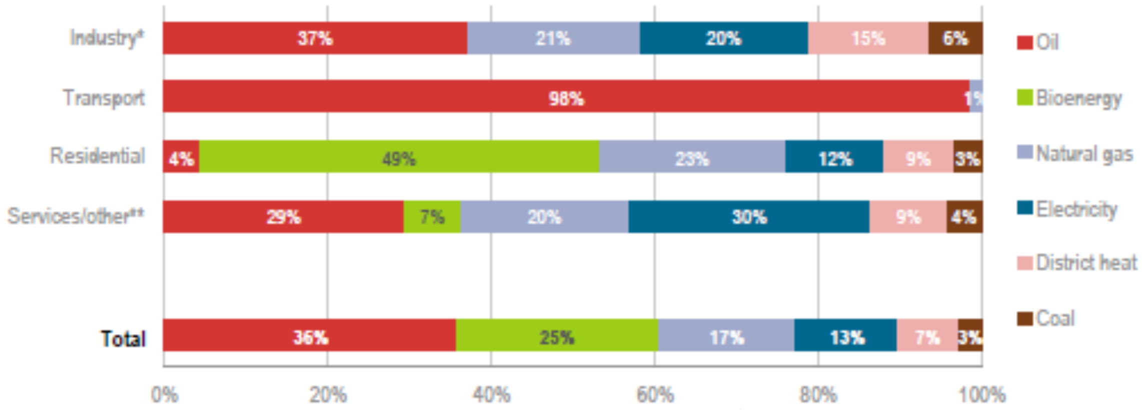


Figure 2. - Republic of Moldova - National final energy consumption by sector and sources, (IEA, 2022)

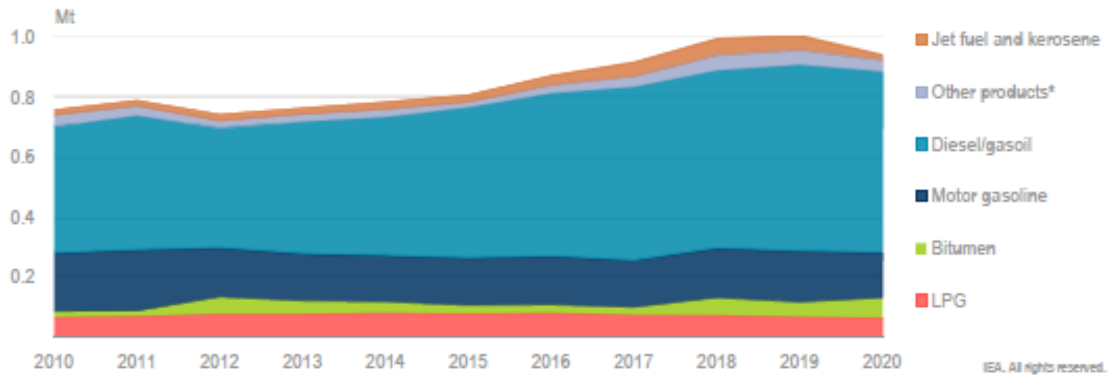


Figure 3. - **Moldova's oil consumption by products, (IEA, 2022)**

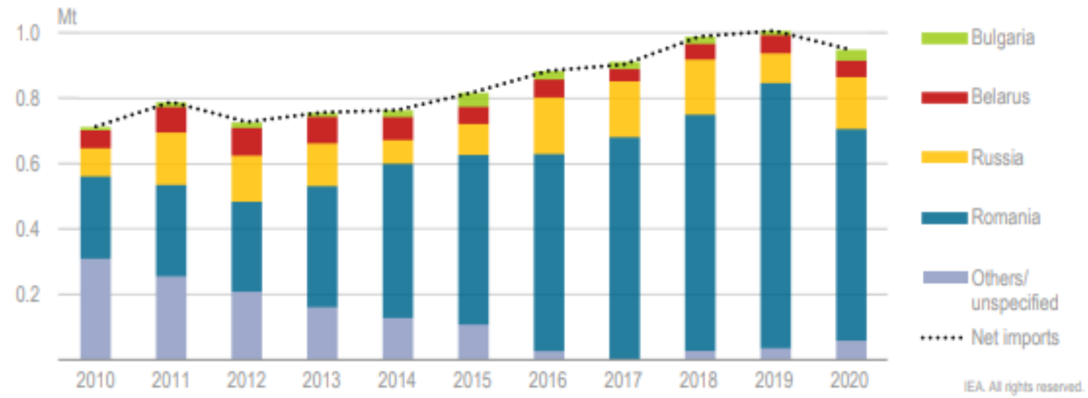


Figure 4. - Breakdown of oil imports from other countries (IEA, 2022)

In relation to fuel consumption in the transport sector, there has been a recovery starting from the post-COVID period, with an estimated stabilized consumption of over 980 million liters per year (Table 1).

To achieve the goals set by the national Energy from Renewable Sources Law (Law No. 10/2016 and subsequently updated in 2018), and in according with the latest decisions taken within EnC, the 8,8% (with multipliers) or 7,6% (without multipliers) in energy content from biofuels consumed in transport sector must be reached by 2030. At the same time, the reasonable blending with the respective fuels in term of volumes of blended biofuels should be considered, that are generally 7% on biodiesel and range of 8-10% for bioethanol. This translates to an initial estimated biofuel consumption of approximately 71 million liters per year(Vol./Vol.) (Table 1), on which around national biodiesel demand should be 46,640 tons/year and Bioethanol of 14,220 tons/year (including advanced biofuels admitted for double counting, and first-generation biofuels excluded for double counting).

Table 1. - Fuels Consumption and Biofuels Demand in the Republic of Moldova.

Petroleum products imported/consumed :		**Biofuels potential requested from 2024**		**Petroleum products imported/consumed**	
		(Biofuel blending):		**(Fuel blending):**	
FUELS	2022-2023	BIOFUELS	2024	FUELS	
	Liters/year		*Liters/year*		*Liters/year*
Diesel	757.145.280	Biodiesel[1]	53.000.169	Diesel	704.145.110
Gasoline	225.332.770	Bioethanol[2]	18.026.621	Gasoline	207.306.148

Considering the mentioned targets on share of RES-T and the complexity of the process to achieve it, this investigation aims to analyze the cost-benefit study for the state incentive policy in the development of the biofuel industry in Moldova, taking into consideration the current background of the potential biofuel cost in according with the concrete availability biomass feedstock as listed by the RED II, the national stakeholder interests and their involvement for the production, agricultural resources, technological infrastructure, and logistic aspects.

[1] *The adoption of B7 is most used in EU countries because it represents a good balance between environmental, cost-efficient benefits, and practical feasibility for everyday use in standard diesel vehicles.*

[2] *The adoption of E8 and E10 are most used in EU countries because it represents a good balance between environmental, cost-efficient benefits, and practical feasibility for everyday use in standard gasoline vehicles*

3. Cost Assessment of the Biofuels

This chapter examines the analysis covers economic factors influencing the costs of biodiesel and bioethanol to support the targets of biofuels to be reached by 2030 in compliance with Law No° 10/2016 and RED II.

It delves into biofuel market dynamics, production expenses, and comparative pricing with respective conventional fuels and final expected costs after blending and then the final costs.

Additionally, the analysis covers the impact of governmental policies on the national biofuel demand according to the fiscal strategies implemented in the Free Economic zones (FEZs) located in different areas of the Republic of Moldova. Key data on biodiesel and bioethanol production under the interests of national stakeholders will also include, providing a comprehensive overview of their economic viability within the country.

Introduction

Cost analysis of biofuels involves considering several aspects to evaluate their economic feasibility applied to the national context. The following key points need to be considered as follow:

Production Costs of Biofuels and EU legal framework
The production costs of biofuels (i.e. biodiesel and bioethanol) in the Republic of Moldova have been analyzed in alignment with the trends observed in the EU market and the directives outlined in the Renewable Energy Directive II (RED II), specifically Annex IX for advanced biofuels produced by feedstock mentioned in the respective lists A and B. Additionally, the National Renewable Energy Sources (RES) Law No. 10/2016 plays a pivotal role in shaping the framework for biofuel production, emphasizing the use of nationally sourced feedstock.

National Feedstock Prioritization
In according with the National RES Law No. 10/2016, priority is given to utilizing locally available biomass and agricultural residues for biofuel production. This includes suitable biomass crops such as corn and sunflower oil, as well as agricultural residues like straw and SSDG derived as co-products of the ethanol industry. These are considered promising feedstock for advanced biofuels and potentially admitted for double counting.
The selection of these biomasses a strategic, aiming to enhance the sustainability and economic viability of biofuel production within the country. Additionally, the stakeholder's interests have been also taken into account for real production concerning the available biomass feedstock.

In according with the above-mentioned premises , the cost of producing biofuels is influenced by a myriad of factors, that includes:

Type of Feedstock: Different feedstocks have varying costs associated with their cultivation, harvesting, and processing.

Harvesting and Processing: Technological efficiency and economies of scale in harvesting and processing can significantly affect costs.

Transport and Distribution: The logistics of transporting feedstocks and distributing the final biofuels contribute to the overall production cost.

Market Competition: Competition with other sectors, such as food and feed industries, particularly for commodities like cereals, can drive up prices and influence the cost structure of biofuels.

Impact of Feedstock Prices*:* The prices of agricultural commodities and fossil fuels on the international market have a substantial impact on the production costs of biofuels. Factors such as crop shortages or increased demand for specific feedstocks can lead to significant fluctuations in costs. For instance, volatility of the agricultural commodities prices of crops used as feedstock can affect biofuel production costs. Events like poor harvests or increased global demand can result in higher prices.
Fossil Fuel Prices: The cost of fossil fuels can influence biofuel production indirectly, as higher fossil fuel prices can increase the cost of agricultural inputs and transportation.

Subsidies and Incentives: Many EU countries offer subsidies and tax incentives to promote the use of biofuels, which can significantly reduce the net cost for producers and end consumers. These financial aids can take various forms, like direct subsidies are used by the governments to provide direct financial support to biofuel producers and to help offset production costs. Further financial support are represented by tax Incentives. Tax reductions or exemptions for biofuel producers and users can make biofuels more economically attractive compared to fossil fuels. Additionally, financial grants and low-interest loans for research, development, and expansion of biofuel facilities can lower capital costs and foster innovation. At last, systems like renewable energy credits (RECs) can provide additional revenue streams for biofuel producers. An overview of the policy incentives implemented by several EU and EnC-countries are summarized in the Deliverable 2.

Particular attention will be given to **FEZs - Free Economic Zones**, currently placed in the Republic of Moldova and which represent real financial opportunities that could encourage the growth of the biofuel industry, making it more competitive and aligned with the country's renewable energy goals**.**

In summary, the production costs of biodiesel and bioethanol in the Republic of Moldova are shaped by a combination of national policies, involvement of national stakeholders for national production, feedstock selection, agricultural practices, and global market trends. By prioritizing national feedstock in line with Renewable Energy Law No. 10/2016 and considering the guidelines of RED II, Moldova aims to develop a sustainable and economically viable biofuel industry.

The mentioned aspects will be outlined in the coming sections to fine-tune the best options. The implementation of subsidies and incentives can further reduce production costs and promote wider adoption of biofuels. Ongoing monitoring of international commodity prices and advancements in agricultural technologies will be crucial in managing production costs effectively.

Trends of Biofuel costs in relation to the biomass feedstock and readiness technology

The price of biofuels are also strongly dependent by two principal aspects mentioned in the previous section, that are: the price of respective feedstocks in relation to the efficiency of technology conversion (Figures 5, 6, 7).

Feedstocks for the production of transport biofuels include oil-seed crops, sugar and starch crops, lignocellulosic agricultural and forestry residues, and wastes such as straw, corn cobs, wood chips, wood extractives from pulping processes, and even water-based plants such as micro- and macroalgae. A wide range of mechanical, chemical, thermochemical, and biochemical processing steps are applied to convert these feedstocks into transport biofuels, (IEA Bioenergy, 2020).

In addition, several synthesis technologies used for the production of transport biofuels can also be applied using renewable, low carbon intensity hydrogen produced through electrolysis and recovered or captured CO_2 as feedstock; such fuels are called e-fuels (electro fuels) or power-to-x fuels. Examples of potential e-fuels include methane, methanol, and upgraded Fischer-Tropsch liquids.

In the case of transport biofuels, several production technologies have reached maturity, are already at TRL 9, and are widely deployed with a further reduction of the cost technology. These so-called established biofuels are principally named "First generation biofuels" and not supported by double counting of the EU Directive 2018/2001 (RED II) but included in the biofuel panel. They are represented:

- bioethanol from sugar and starch crops (i.e. corn, sugar beet).
- biodiesel from triglycerides and lipids (i.e. FAME from sunflower and rapeseed oil).
- hydrogenated triglycerides and lipids (HVO).
- biomethane and biogas from upgrading of anaerobic digestion biogas.

Other production technologies are not yet fully developed and need to be demonstrated at full scale with a technology cost not still ready to be stable nowadays. About half of the technologies that will decarbonize our energy system in 2030 are not yet fully developed with the respective cost of technologies still too high (IEA, 2024). Advanced biofuels are supported through double counting in the EU Directive 2018/2001 (RED II) with aim to encourage EU countries to support the investment on the advanced biofuels and accelerate the decarbonization of transport sector. TRLs for these technologies range from 3 to 8, (Fig.5).

These so-called emerging biofuel pathways include:

- Bioethanol from lignocellulosic feedstocks (i.e. links to the biomass feedstock to List A of Annex IX of EU Directive 2018/2001 - RED II)
- gasification-derived biofuels,
- pyrolysis-derived bio-oils,
- hydrothermal liquefaction-derived bio-crudes, lignin-derived biofuels, sugars to biofuels, and biofuels derived from non-lignocellulosic biomass such as microalgae.

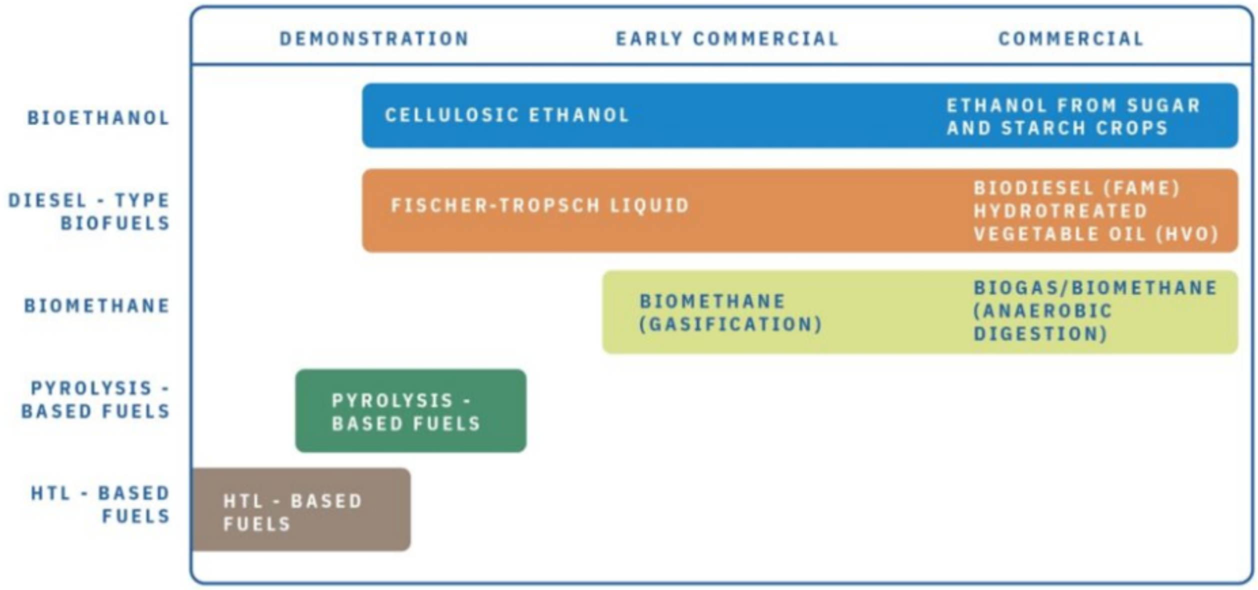


Figure 5. - Overview of technology pathways and their technology readiness level (TRL); Adapted from: The Role of Renewable Transport Fuels in Decarbonizing Road Transport – Production Technologies and Costs (IEA, 2024)

Effect of Feedstock and Technology Readiness on Biofuel Production Costs

The production costs of transport biofuels are typically higher than the prices of the fossil fuels they aim to replace, rendering their production unprofitable without supportive policy measures. However, there is potential to lower these costs by utilizing cheaper feedstocks and other inputs, such as residues or waste, which can enhance conversion efficiency or increase co-product profitability. Technology developers and biofuel producers worldwide are exploring these possibilities. For instance, the recent expansion in the production capacity of hydrotreated vegetable oil (HVO) fuels is being driven by regions like Sweden, where production costs are being reduced through a combination of low-cost feedstocks, production incentives, and carbon credit markets established by LCFS policies.

On the other hand, other production methods, particularly those that use lignocellulosic materials like wood or straw, which require collection and transport, remain economically unviable. According to a study by the IEA (IEA, 2020), developing and demonstrating these technological pathways is challenging, as the required investment is about 5-10 times higher than that for established biofuels like HVO or conventional ethanol, depending on the conversion process (Fig. 6).

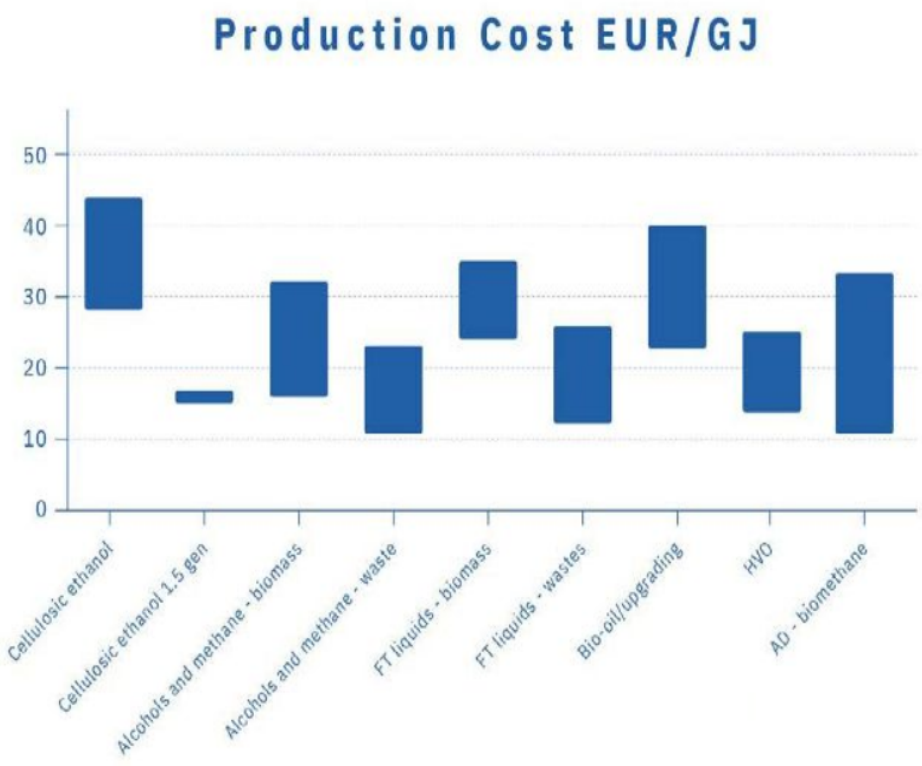


Figure 6. - Production costs for advanced biofuels assessed in 2019 are higher than the 8–14 EUR/GJ price range for fossil transport fuels in the years 2017–2019. Source (IEA, 2020)

The IEA study also highlights that feedstock and capital costs are the primary contributors to overall biofuel production expenses. The study indicates that production costs using biomass feedstocks that require collection and delivery range between 17–44 EUR/GJ but drop to 13–29 EUR/GJ when waste is used as feedstock. This contrasts with fossil fuel prices, which ranged from 8–14 EUR/GJ in 2019, when the assessment was conducted.

The IEA identifies early market opportunities for producing lower-cost advanced biofuels by using waste materials and integrating advanced biofuel production with existing biofuel processing plants.

It's important to note that fossil fuel prices have risen significantly since the assessment, from around 55 €/barrel in 2019, dipping below 18 €/barrel in early 2020, and spiking above 110 €/barrel in early 2022.

Further reductions in biofuel production costs can be achieved through technological advancements and demonstrations that lower investment costs, as well as cheaper access to capital as perceived investment risks decrease. Additionally, carbon pricing can help close the gap between biofuel production costs and fossil fuel prices.

Although these publications were written several years ago, most of the technology-specific challenges they describe remain relevant (IEA, 2024). A summary of R&D needs for key transport biofuel pathways is provided below (Fig. 7, Fig. 8).

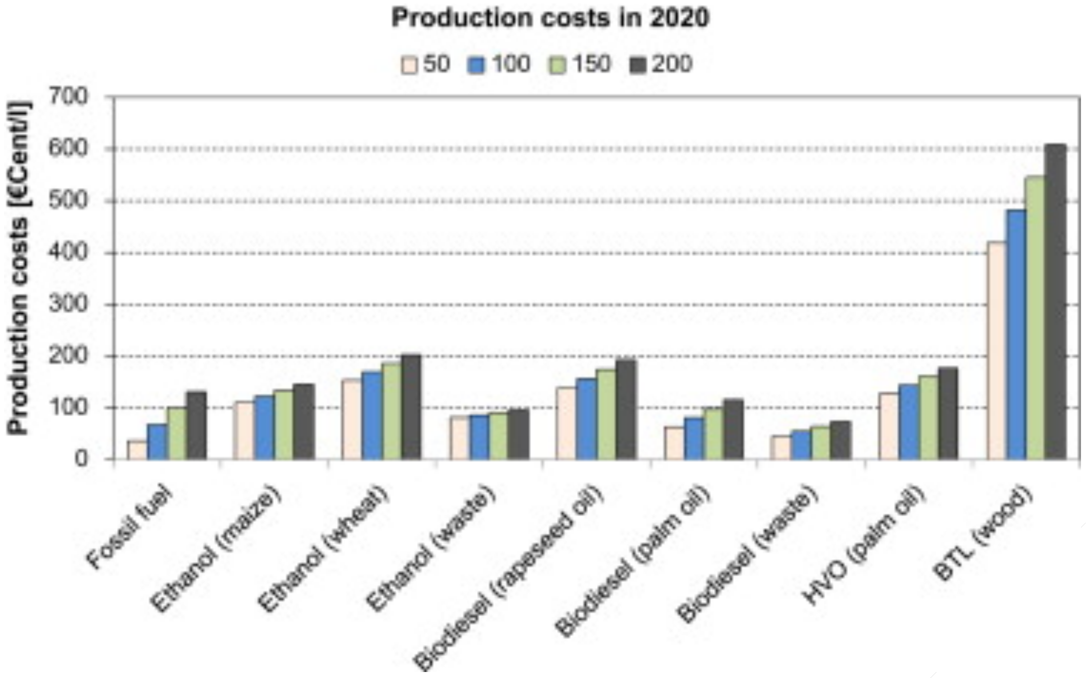


Figure 7. - Production Cost of Biofuels from different feedstocks, (G.Festel et al., 2014)

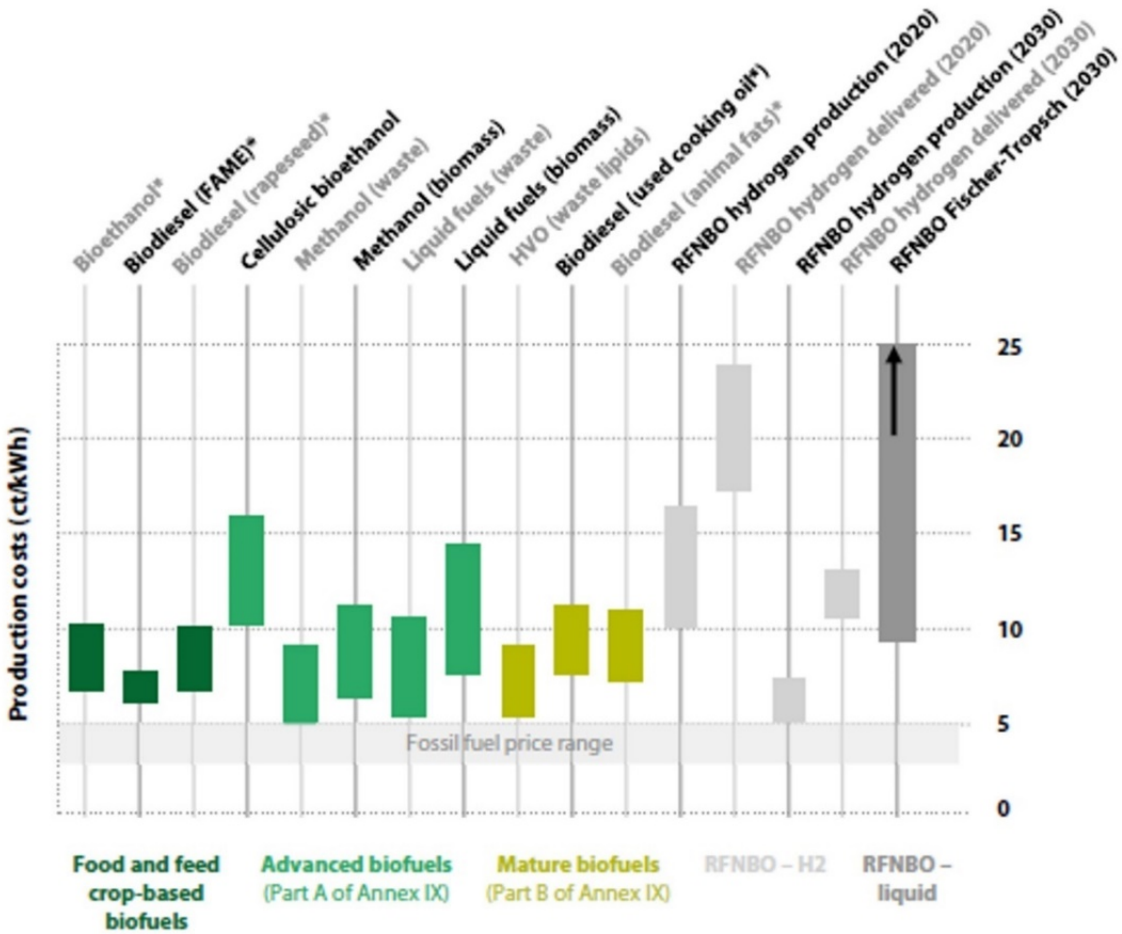


Figure 8. - Biofuel cost and technology pathways, (European Court of Auditor, 2023)

Despite the costs for advanced biofuels remain higher if compared with traditional biofuels, due to high cost of technology and their production, they represent opportunities for further biofuels market.

IEA points out the current research gaps to be implemented in the coming months as well as opportunities offered through implementation of novel pathways, that are different in relation to the feedstock and technologies used. In particular, regards Lignocellulosic ethanol, higher alcohols, hydrocarbons.

Their specific R&D needs should include:

- the development of improved feedstock pre-treatment and conversion processes (less intense use of water, energy, chemicals, and enzymes) to improve process efficiency and products;
- the development of novel strains to produce hydrocarbons or long-chain fatty alcohols from sugars;
- the development and demonstration of improved separation technologies (e.g., ethanol recovery from fermentation broth or avoidance of product inhibition through continuous removal of products);
- the development of lignin valorization towards energy/fuels and bio-based products.

Current production costs of biofuels in EU

The first generation of bioethanol, biodiesel (FAME), and hydrotreated vegetable oils (HVOs) are the most widely used biofuels in the road transport sector. Initially, some automakers permitted the use of pure biodiesel (FAME) in their vehicles, but this is no longer the case due to its poor performance in cold temperatures and compatibility issues with modern exhaust after-treatment systems. As a result, biodiesel (FAME) is typically blended with diesel fuel at ratios of around 7% to 8% (Tab. 7).

Bioethanol is most often blended with gasoline at low levels, typically around 5%, 8%, or 10% by volume (Tab. 2). It can also be used at higher concentrations, up to 85%, in specially adapted flex-fuel vehicles.

HVO, along with upgraded paraffinic fuel produced through Fischer-Tropsch synthesis, is considered a drop-in fuel, meaning it can fully replace fossil diesel. However, due to current diesel standards, HVO is most commonly used as a 30% blend with fossil diesel. Nonetheless, the use of pure HVO, particularly by freight companies aiming to reduce carbon emissions, is becoming increasingly common.

Trend production of Bioethanol in EU transport sector

Biofuel considered as Ethyl Alcohol made by fermenting of several carbohydrates of several crops. During last decade, the internal production of Bioethanol is increased from 4,789 during 2014 to 5,571 million of tons of Bioethanol during 2023, (Tab.2).

Table 2. - Bioethanol overview in EU Transport sector, (IEA, 2023), (IEA, 2024), (IEA, 2020), (USDA, 2023).

Calendar Year	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Fuel Beginning Stocks	219	358	317	356	5,542	366	341	423	147	341
Production	5,489	5,558	5,395	5,376	5,542	5,751	6,022	5,949	6,229	6,159
Fuel Production	4,789	4,772	4,728	4,785	4,994	5,181	5,061	5,352	5,633	5,571
-of which cellulosic (a)	40	40	40	40	5	5	20	50	70	80
Fuel Imports	424	292	315	110	189	665	832	1,125	1,257	1,392
-of which ETBE (b)	110	109	24	9	9	14	26	19	18	81
Fuel Exports	623	524	572	186	194	648	654	262	494	627
Fuel Consumption	4,451	4,530	4,432	4,677	5,010366	5,224	5,156	5,844	6,203	6,329
Fuel Ending Stocks	358	317	356	388		341	423	147	341	347
Production Capacity, First Generation (Millions of Liters)										
Number of Refineries	66	59	55	57	56	52	54	58	58	59
Capacity	8,089	7,949	7,621	7,418	7,278	7,266	7,456	8,051	8,392	8,519
Capacity Use (%)	59%	59%	62%	64%	69%	71%	68%	66%	66%	64%
Production Capacity, Cellulosic Ethanol (Millions of Liters)										
Number of Refineries	1	1	1	1	2	2	2	4	4	5
Capacity	50	50	50	50	10	10	40	120	140	200
Biomass feedstock used for bioethanol production (1,000 MT)										
DDG (Distillers Dried Grains)	3,122	3,158	3,219	3,293	3,504	3,51	3,699	3,745	4,034	4,129
Corn Oil	147	144	142	144	185	201	193	197	202	197
Wheat kernels	3,011	3,334	3,57	3,926	3,107	2,855	3,123	2,709	3,579	3,602
Corn kernels	5,084	4,956	4,884	4,962	6,392	6,929	6,647	6,798	6,971	6,804
Barley kernels	414	421	394	388	483	364	462	521	482	573
Rye kernels	805	724	662	514	484	231	441	585	421	507
Triticale Kernels	661	691	779	735	700	850	1,05	800	675	451
Sugar Beet	10,478	9,198	8,371	7,72	6,982	8,216	5,112	7,933	6,751	5,233
Cellulosic Biomass	160	160	161	160	20	20	80	200	281	321
Market Penetration (Millions of liters)										
Fuel Ethanol use	4,451	4,531	4,432	4,677	5,011	5,224	5,156	5,844	6,203	6,329
Gasoline Ethanol pool 1	91,144	89,789	90,186	91,127	96,142	98,272	86,025	93,503	98,409	98,854
Blend Rate (Vol. %)	**4,9%**	**5,0%**	**4,9%**	**5,1%**	**5,2%**	**5,3%**	**6,0%**	**6,3%**	**6,3%**	**6,4%**

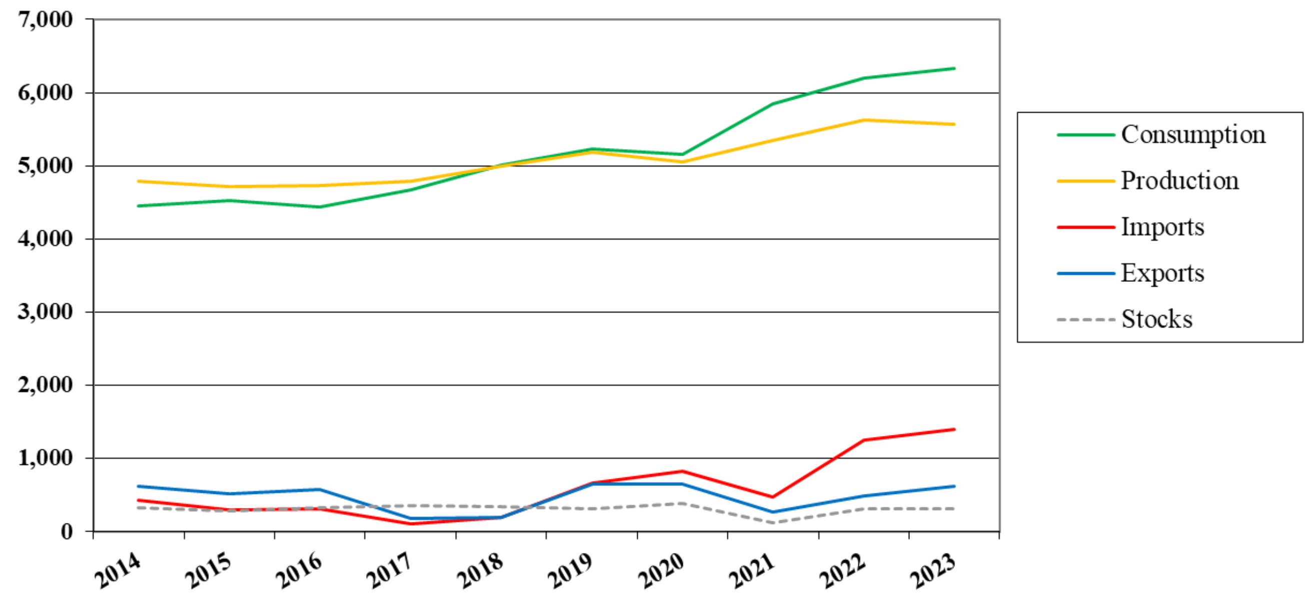


Figure 9. - Millions of Liter of Bioethanol-fuel market and trend in EU (USDA, 2023), data sources (EU FAS Posts).

In 2017 and 2018, domestic production and consumption are about in balance (Tab.2 and Fig.9). From 2018 forward (except the Covid Period), an upturned of bioethanol consumption to 5.9 billion liters in 2023, is reported. This recovery is mainly caused by the gradual increase of blending targets towards the 2030 mandate and the improved competitiveness of bioethanol versus gasoline. As of 2019, the EU became a net bioethanol importer as consumption outpaced production (Fig.9).

The Impact of the COVID-19 Outbreak and Recovery

One factor that contributed to increased bioethanol consumption in certain Member States was the blending rate achieved in 2020, which set the maximum allowable level for food-based biofuel blending through 2030. As COVID-19 lockdowns were gradually lifted in 2021, bioethanol consumption in the EU rose alongside higher gasoline use, even surpassing the levels seen in 2019 before the pandemic. This increase was further supported by policy measures introduced after 2020. However, due to domestic producers being unable to meet the higher demand from increased blending, several governments delayed the implementation of these measures (IEA, 2023), (IRENA, 2024), (B.Flach et al., 2018).

The Effect of Russia's War on Ukraine in 2022.

The anticipated recovery in bioethanol consumption was driven by increased blending in countries like France, the United Kingdom, Poland, the Netherlands, Spain, and Belgium, which continued through 2021 and 2022. In the first quarter of 2022, following Russia's invasion of Ukraine, prices for fossil fuels, feedstocks, and biofuels surged (see Fig.10 and 11).

While cereal and ethanol prices declined in the spring of 2022, crude oil and gasoline prices peaked during the summer, giving bioethanol a competitive edge in mid-2022 and boosting demand in key markets such as France and Germany.

As a result, EU bioethanol consumption increased by over six percent to 6.2 billion liters in 2022. This growth was also fueled by the introduction and increased sales of high blends like E10 and E85 in certain EU countries, particularly France.

The strong expansion of bioethanol use in 2022 and 2023 was driven by unique events that are unlikely to be repeated. While peak consumption is inevitable, the timing remains uncertain, influenced by factors such as the cap on conventional biofuels, the rising minimum use of advanced biofuels (including renewable diesel blending), and the longer-term shift toward e-mobility and the reduction of internal combustion engines (ICE).

In 2023, EU producers benefited from lower feedstock and energy prices, along with growing bioethanol demand in the EU. However, despite this increased demand, EU bioethanol production is expected to decline to around 5.57 billion liters, primarily due to a reduction in bioethanol production in France, where less agricultural land is being dedicated to sugar beet as a biomass feedstock for bioethanol production.

Outlook for the Forthcoming Period

Over time, the growth of first-generation bioethanol is anticipated to be restricted since the European Union's demand for crop-based bioethanol is projected to stabilize because of the limits imposed by the RED II regulations. The growth of cellulosic bioethanol production is now limited by the need for significant expenditures and the uncertainty surrounding the EU policy-making process.

The commercialization of cellulosic ethanol is significantly falling behind the advancement of sophisticated biodiesel. Operators are deterred from investing in cellulosic ethanol mostly because to the exorbitant costs associated with research and production, the lack of regulatory clarity, and the expansion of specialized supply chains.

In 2022, the European Union is projected to have a capacity to produce 125 million liters of cellulosic ethanol. It is important to mention that several ethanol factories recycle byproducts, often derived from their own production process, such as sludge, which might be classified as advanced biofuels. The predicted production of advanced ethanol from non-cellulosic waste materials, namely those included in Part A of Annex IX of the REDII, such as food waste, is projected to be 240 million liters in 2019, 440 million liters in 2020, and around 575 million liters in 2021, (ePURE, 2022).

Feedstock Use and Production of Co-products

In France, Germany, the United Kingdom, the Czech Republic, and Belgium, sugar beets and their byproducts are used to produce bioethanol. However, only a few sugar beet processing facilities in France have the capacity to distil ethanol on-site. Bioethanol derived from sugar beets has struggled against falling grain prices and rising sugar prices, leading to a decline in its production since 2017, with cereal feedstocks taking its place.

To achieve the production of 5.57 billion liters of bioethanol in the EU during 2023, an estimated 13.2 million metric tons (MMT) of cereal are required, an increase of about 300,000 MT from 2022. This amount represents approximately 4.6% of the EU’s total cereal production. Co-products from bioethanol production include dried distillers grains with soluble (DDGS), wheat gluten, and yeast concentrates. The theoretical maximum production of these co-products in 2023 was at 4.1 MMT, an increase of around 100,000 MT from 2022, making up 2.6% of the EU's total feed grain consumption. The increase in cereal use is offset by a decrease in sugar beet used for bioethanol production, with estimated amounts of 6.8 MMT in 2022 and 5.2 MMT in 2023, accounting for roughly 5.1% of total EU sugar beet production.

Looking ahead, EU bioethanol production is expected to continue relying heavily on cereals, primarily wheat, corn, barley, as well as sugar beet. Total production is anticipated to rise slightly, reaching around 6 billion liters, driven by policy support measures through 2030 (RED II and future revisions) and economic recovery post-COVID-19.

To support the mentioned production, approximately 18 million tons of biomass feedstock are required, with about 9.6 million tons coming from cereals. This indicates a continued reliance on a significant portion of the EU's cereal production for bioethanol. The primary feedstocks are expected to remain consistent, despite the decline in sugar beet, with corn, wheat, rye, barley, and cellulosic biomass contributing around 1% (Tab 3).

From 2024 onward, this trend is likely to persist with minor fluctuations based on agricultural yields and policy changes, particularly those influenced by the ongoing war in Ukraine. The estimated feedstock requirement for bioethanol production could be around 10.2 million tons of cereals, assuming a modest increase in production and consumption, (USDA, 2023), (IEA, 2023), (EU Commission, 2023) (Oeko-Institute, 2017), Tab. 4.

Table 3. - Feedstock base for Bioethanol production in the EU.

Bioethanol production feedstock imported (2014)	Mass (1,000 Mt)	Input (%)
Wheat	2,798	15%
Corn	5,174	27%
Barley	0,541	3%
Sugar Beet	9,364	49%
Rye	0,846	4%
Cellulosic Biomass	0,270	1%
Total	**18,993**	**100%**

Corn Imports from US and Ukraine

The US and Ukraine remain the main sources for corn imports into the EU. Despite facing logistical challenges and geopolitical tensions, Ukraine continues to be a favored supplier for bioethanol producers due to its ability to provide non-GMO corn that is suitable for both bioethanol production and animal feed **(Chemanalyst, 2024)**, (Table 4).

Logistical and Export Challenges in Ukraine

Ukraine's export capacity has been severely affected by the ongoing conflict with Russia. The collapse of the Black Sea Grain Initiative and ongoing attacks on infrastructure have forced the country to seek alternative export routes, such as those through the Danube and other EU transit corridors. Although these new routes have enabled Ukraine to maintain its exports, logistical bottlenecks and regulatory shifts are likely to cause delays in 2024 **(Chemanalyst, 2024)**, (Table 4).

Moldova's Role in Barley Exports

Moldova remains a key trading partner for the EU, particularly for barley used in bioethanol production. This relationship has become increasingly important as the EU looks to diversify its sources of bioethanol feedstock in light of supply chain disruptions from other regions **(Mordor Int., 2024)**[3], (Table 4).

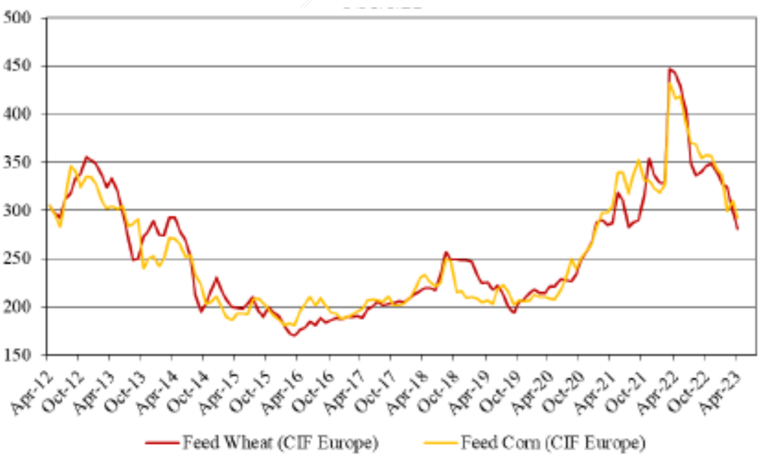
Table 4. – Biomass imported for bioethanol production in EU Countries: partner traders for feedstock[4] .

Bioethanol Feedstock	Partners trader	%
Barley	**Republic of Moldova**	**29**
	Russia	25
	Serbia	8
	Ukraine	37
Corn	Brazil	5
	Canada	10
	Russia	7
	Serbia	6
	Ukraine	59
	USA	7
Sugar Beet	Serbia	100
Rye	Russia	43
	Ukraine	56
Wheat	Canada	49
	Russia	7
	Ukraine	20
	USA	13

During the first quarter of 2022, during the conflict between Russia and Ukraine, prices for fossil fuels, feedstocks, and related biofuels continued to rise (see Fig. 10 and 11), (USDA, 2023).

Following the first quarter of 2022, cereal and ethanol prices declined, while crude oil and gasoline prices reached their peak in the summer of 2022. This shift gave bioethanol a competitive edge, driving up demand in key markets such as France and Germany, (USDA, 2023), (B. Flach et al., 2018), (Teseo, 2024).

In terms of production costs relative to the volume of bioethanol produced, the trend mirrored the increase in feedstock prices, (Tab. 5).



[3] (http://comtrade.un.org/).

[4] (Oeko-Institute, 2017), (Chemanalyst, 2024), (Mordor Int., 2024)

Figure 10. - Feedstock prices (USD/MT) used for bioethanol production, (USDA, 2023).

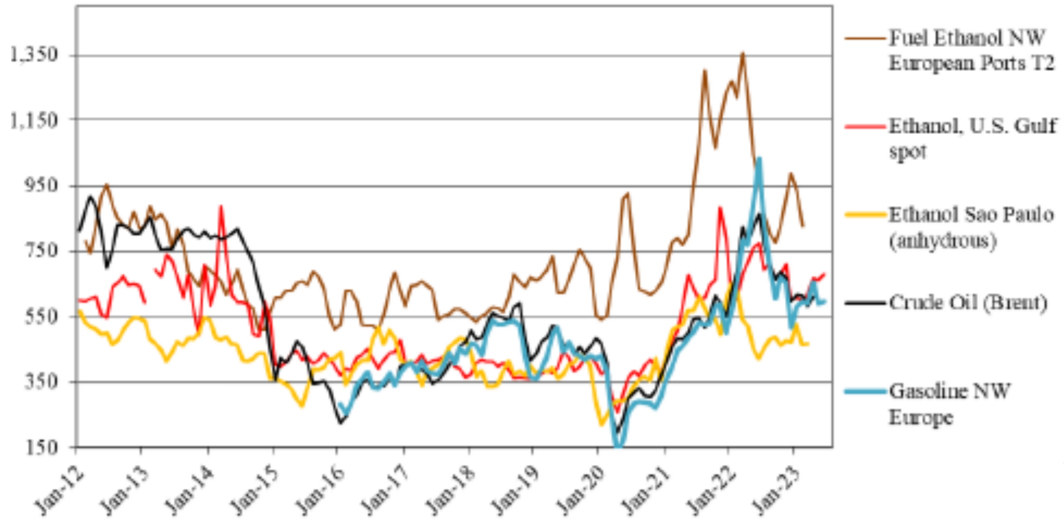


Figure 11. – Biofuels Prices (USD/MT), (USDA, 2023).

In terms of production cost referred to the volume of bioethanol produced, trend is similar and in line with increasing price of feedstock, (Tab. 5).

Table 5. – Average production cost of bioethanol in relation to several feedstocks[5].

Year	Wheat (€/liter)	Corn (€/liter)	Barley (€/liter)	Sugar Beet (€/liter)
2023	0.90	0.84	0.86	0.68
2024	0.97	0.90	0.88	0.70

These trends highlight the growing cost of feedstocks used for bioethanol production, reflecting broader market dynamics, including supply chain disruptions, increased demand, and geopolitical factors.

For this reason, the choice of bioethanol feedstock should consider a national and cheapest feedstock as much as possible integrated with existing technology and plants able to convert into biofuels. this assumption will be the key option selected for bioethanol production analyzed in the Republic of Moldova.

Trend production cost of Biodiesel in EU transport sector

Biodiesel production is anticipated to keep expanding worldwide as governments introduce policies to boost the use of renewable energy in the transport sector and lower greenhouse gas emissions.

In 2022-2023, global biodiesel production reached nearly 52 million tons, with the European Union contributing the largest share—about 25% of the global total, or roughly 14 million tons annually. Biodiesel production in Europe has been steadily rising, driven by the EU's targets for member states to increase their reliance on renewable energy sources, including biofuels.

[5] Data elaborated considering (EU Commission, 2023), (IEA, 2023), (B.Flach et al., 2018), (Teseo, 2024); (Oeko-Institute, 2017), (Chemanalyst, 2024), (Mordor Int., 2024).

After peaking in 2019, EU biodiesel production gradually declined, reaching 13.7 million tons per year (or approximately 16,000 million liters per year) in 2022, largely due to the impact of the COVID-19 pandemic, (EBB, 2023), (USDA, 2023).

However, production remained relatively high, especially for biodiesel from advanced feedstocks, due to the EU's RED II mandate. Within Europe, Germany is the largest biodiesel producer, followed by France, Italy, and Spain, with Poland, Belgium, and the Netherlands also being significant producers (Tab. 6).

Table 6. – Biodiesel production in EU countries, (EBB, 2023).

EU Countries	**Biodiesel Production** *(mil. Tons)*
Germany	3,428
France	2,158
Italy	1,261
Spain	1,607
Poland	1,030
Belgium	0,506
The Netherlands	2,096
Portugal	0,040
Sweden	0,226
Finland	0,364

At the EU level, biodiesel is produced from oil crops (traditional biodiesel), fatty acid methyl ester (FAME), and hydrogenated vegetable oil (HVO).

The EU biofuels targets outlined in Directive 2018/2001/EC (RED II) have recently encouraged greater use of advanced biodiesel derived from non-conventional feedstocks like used cooking oils (UCO) and animal fats (classified as waste and residues).

These feedstocks are listed in Annex IX, Part B of RED II, (B.Flach et al., 2018), (Official Journal of EU, 2018).

The following table (Tab. 7) presents the trends in EU production, supply, and demand from 2014 to 2023.

Table 7. - Biodiesel overview in EU Transport sector[6].

Calendar Year	2014	2015	2016	2017	2018[f]	2019	2020	2021	2022	2023
Production Biodiesel (FAME+HVO) (Millions of liters)										
Beginning Stocks	500	550	540	530	590	900	670	680	715	720
Production	13,944	13,555	13,058	14,464	15,200	16,280	15,600	16,044	16,110	16,200
>HVO Production	2,151	2,310	2,029	2,421	2,702	2,842	3,629	4,12	3,96	4,200
Imports	820	817	958	1,699	4,148	4,286	3,539	3,217	3,159	3,600
Exports	1.139	863	841	1,364	2,530	4,062	2,007	1,371	1,304	1,490
Consumption	13,575	13,519	13,185	14,709	16,508	16,734	17,122	17,855	17,96	18,300
Production capacity, Biodiesel (FAME+HVO) (Million of liters)										
N° Biorefineries	212	193	186	179	180	174	175	172	171	171
Nameplate Capacity	21,860	21,160	20,700	20,050	20,450	19,83	17,79	19,91	20,08	20,115
Capacity Use (%)	56,90%	53,10%	53,30%	60,10%	61,10%	67,80%	60,50%	59,90%	60,50%	59,70%
Production Capacity, Renewable Diesel (HVO) (Million Liters)										
Number of Biorefineries	10	11	11	13	14	15	15	16	16	17
Nameplate Capacity	2,830	3,395	3,395	3,600	3,600	5,450	5,450	6,060	6,24	6,265
Capacity Use (%)	76,00%	68,00%	59,80%	67,30%	75,10%	52,10%	66,60%	68,00%	63,50%	67,00%
Feedstock Use for Biodiesel (FAME+ HVO) (1,000 MT)										
Rapeseed oil	6,300	6,300	5,850	6,300	6,000	5,950	5,800	6,075	6,200	6,375
UCO	1,570	1,950	2,200	2,600	2,700	3,375	3,500	4,000	4,300	4,350
Palm oil	2,060	2,000	2,020	2,300	2,250	2,600	2,500	2,000	1,500	1,400
Soybean oil	860	500	550	700	1,200	1,070	900	780	750	740
Animal fats	950	1,200	1,000	860	1,050	1,190	1,200	1,150	950	1,000
Sunflower oil	320	210	250	230	1,000	260	225	210	290	265
Other (pine oil/tall oil/fatty acids)	310	415	304	280	510	580	450	820	900	950
Market Penetration, Biodiesel + Renewable Diesel (HVO) (Million Liters)										
Biodiesel+HVO	13,575	13,519	13,185	14,709	16,508	16,734	17,122	17,855	17,960	18,300
Diesel, total use (on the road)	210,852	215,207	220,274	237,56	245,122	246,25	219,783	235,778	236,771	229,059
Blend Rate (Vol. %)	6,40%	6,30%	6,00%	6,20%	6,70%	6,80%	7,80%	7,60%	7,60%	8,00%

The new policy support for advanced biodiesel is impacting biodiesel production and potentially influencing the import and export of suitable feedstocks, following the double counting system established by the EU Directive 2018/2001. Biodiesel consumption, including FAME and HVO, is primarily driven by mandates set by member states (MS) and, to a lesser extent, by tax incentives, which vary from country to country.

Between 2014 and 2016, biodiesel usage fluctuated due to several factors. While some MSs increased mandates and overall diesel use, others saw reduced biodiesel consumption because of the extensive use of double-counting feedstocks, particularly in countries like the Netherlands and Portugal.

Additionally, Germany's shift in 2015 from an energy-based usage mandate to a minimum greenhouse gas (GHG) reduction mandate led companies to calculate actual GHG values rather than relying on the default values of the RED Directive. This change prompted fuel companies to prefer biofuels with higher GHG

[6] Data elaborated and compared by checking references (B.Flach et al., 2018) , (IEA, 2023), (IEA, 2024), (IEA, 2020), (IRENA, 2023), (EBB, 2023), (EBB, 2023), (USDA, 2023).

reduction values, which in turn reduced the physical quantity of fuel required to meet the mandate. Moreover, in the Czech Republic, an increase in the excise tax on biofuels made biodiesel more expensive compared to fossil diesel.

By 2017, France, Germany, Italy, Spain, and Sweden had become the largest biodiesel consumers in the EU, collectively accounting for 62 percent of the region's total biodiesel consumption. In 2018, EU biodiesel consumption grew by 2 percent due to mandate increases in several MSs, including Croatia, Finland, Italy, the Netherlands, Poland, Portugal, Spain, and the United Kingdom. Projections suggest that these mandate increases will not significantly alter the consumption rankings among the MSs., (B.Flach et al., 2018).

The EU biodiesel sector is currently characterized by a wide range of plant sizes, from small facilities with an annual capacity of 2.3 million liters, typically owned by groups of farmers, to large-scale operations producing up to 680 million liters annually, owned by multinational corporations. Biodiesel (FAME) production facilities are present in every EU member state except for Finland, Luxembourg, and Malta. In contrast, HVO production is concentrated in only six countries, with most HVO capacity coming from dedicated plants. Notably, in Spain, HVO is co-processed with conventional fuel in oil refineries.

Despite the widespread presence of biodiesel plants across EU countries, FAME production capacity declined by 5 percent in 2018, reaching 20.3 billion liters. This decline is due to strong competition leading to the permanent closure of some plants, while many others are operating below capacity or temporarily shut down.

EU FAME producers have not benefited from increased domestic consumption because of high import levels and elevated stockpiles. EU-produced FAME faces intense competition, particularly from domestically produced HVO and even more so from low-cost FAME imports from Argentina (primarily soybean oil methyl ester, SME) and Indonesia (mainly palm oil methyl ester, PME). Consequently, EU FAME production is projected to decrease by 7 percent. On the other hand, EU HVO production is expected to grow, driven by the addition of new HVO production facilities, (B.Flach et al., 2018), (USDA, 2023).

In 2017, the majority of biodiesel imports into the EU, totaling around 1.3 billion liters, were classified under the HS/CN code 3826.00.10, indicating a biodiesel content of at least 96.5 percent. Additionally, approximately 1 million liters and 4.9 million liters were imported as blends under HS/CN codes 3826.00.90 (containing 30 to 96 percent biodiesel) and 2710.20.11 (containing up to 30 percent biodiesel), respectively. It is assumed that most products traded under the latter code are B5 blends. The bulk of biodiesel imports entered through the Netherlands and Spain.

As of now, the EU does not have a distinct customs code for HVO, which means HVO can be imported under various CN codes, likely leading to an underestimation of import volumes. In 2018, the export tax on biodiesel ranged from 8 to 15 percent, which contributed to a reduction in imports starting from June 2018.

In 2018, EU HVO production capacity increased to 5.3 million liters due to the launch of two new facilities in Italy and France. Exports of EU biodiesel to countries outside the EU remained minimal, typically accounting for only about one percent of production.

By 2019, EU biodiesel consumption continued to rise due to increased mandates, particularly in countries like Spain and Poland. However, FAME production capacity saw a slight decrease as some plants were shut down in response to intense competition, rising imports, and high stock levels. Conversely, HVO production capacity grew with the establishment of new plants, driven by the demand for biofuels with superior GHG reduction performance.

The COVID-19 pandemic in 2020 had a substantial impact on the biodiesel market, with lockdowns and reduced transportation leading to a decline in overall diesel consumption, which in turn affected biodiesel demand. Despite these challenges, the EU biodiesel industry demonstrated resilience, with some countries increasing their mandates to meet renewable energy targets. By the end of 2020, biodiesel consumption began to recover as economies reopened.

From 2021 to 2022, the EU biodiesel market experienced further fluctuations. Mandates in countries like France, Germany, and Italy continued to drive consumption, but rising feedstock costs, especially for vegetable oils, posed significant challenges. The Ukraine crisis in 2022 further disrupted the supply of key feedstocks like sunflower and rapeseed oils, leading to increased prices and market volatility. Producers were forced to seek alternative sources or adjust their production strategies.

The impact of the Ukraine crisis persisted into 2023, with the EU biodiesel industry continuing to face high feedstock prices. Despite these challenges, the EU remained committed to its renewable energy targets. Biodiesel production in the EU saw modest growth, supported by the introduction of new HVO plants and technological advancements that improved production efficiency. The increased use of alternative feedstocks, such as used cooking oil (UCO) and animal fats, helped mitigate some of the supply chain disruptions caused by the crisis.

Preliminary data for 2022 suggests that EU biodiesel production increased slightly by 0.4 percent compared to 2021, largely due to lower domestic consumption in some member states, reduced exports, and rising imports from China in the last quarter of the year. Projected production decreases in countries like France, Spain, Italy, Greece, the Czech Republic, Portugal, and Belgium were too significant to be fully offset by small increases in Poland, Germany, Sweden, Finland, Hungary, the Netherlands, the Slovak Republic, Bulgaria, Austria, and Romania. Both FAME and HVO production were affected by this trend. The decline in HVO production was partly due to the beginning phase-out of palm oil as a feedstock in France and operational issues at the Gela HVO biorefinery in Italy.

For 2023, biodiesel production increased by only 0.6 percent to 16.2 billion liters, with high imports, particularly from China, leaving less room for domestic production. However, this overall growth conceals differing trends for FAME and HVO. HVO production is expected to grow by 6.3 percent due to its higher GHG reduction values and the lack of a need for a separate dedicated supply chain. In contrast, FAME production is projected to decline by 1.2 percent, especially in Germany, Hungary, and Spain. Increases in FAME production in Greece, Poland, and Italy are insufficient to compensate for declines elsewhere. However, the actual development of imports in the coming years will significantly influence EU domestic biodiesel production.

In 2024, the EU biodiesel market is adapting to new global feedstock supply chain realities. The industry saw a gradual stabilization in feedstock prices, although they remained higher than pre-crisis levels. Biodiesel consumption continued to grow, driven by stringent renewable energy mandates and increased blending rates. The EU's focus on reducing greenhouse gas emissions further incentivized the use of biodiesel and HVO in the transport sector.

During this period, the EU also adjusted its biodiesel import patterns. While Argentina and Indonesia remained key suppliers, the EU increased imports from other regions, including the United States and Brazil, to diversify its supply base and reduce reliance on any single country, particularly China. The competition from imported biodiesel, especially from countries with lower production costs, remained a challenge for EU producers.

In summary, the period from 2018 to 2024 saw significant developments in the EU biodiesel market. The industry faced challenges from fluctuating feedstock prices, geopolitical crises, and competition from imports but also demonstrated resilience and adaptability. This resilience was supported by strong policy frameworks, technological advancements, and a commitment to renewable energy goals. The future of biodiesel in the EU appears promising, with continued growth anticipated as the region strives to meet its climate targets and reduce dependence on fossil fuels.

Feedstock in Europe's biodiesel production

The choice of feedstock for biodiesel production varies by country, but globally, vegetable oils are the most commonly used. Palm oil makes up 36% of the global feedstock, soybean oil accounts for 23%, and rapeseed oil represents 14%. Waste oils (including used cooking oil, or UCO) also contribute 14%, while animal fats make up 5%.

In the EU, agricultural crops are the predominant feedstock for biodiesel, comprising 76% of the total. Rapeseed oil is the leading feedstock, contributing about 40% to biodiesel production. This is despite a reduction in imports from Russia due to the Ukraine conflict, which has been somewhat offset by increased imports of palm oil from Asia and a rise in the use of advanced feedstocks as detailed in Annex IX of RED II.

The role of sunflower oil has diminished further, as much of it has been redirected to the food market because of the Ukrainian crisis and a significant drop in its exports. The EU oilseed crushing industry has swiftly shifted sunflower oil to the food sector, demonstrating the close relationship between biodiesel production and the food and feed industries.

Looking ahead, the use of palm oil is expected to decline due to the anticipated phase-out mandated by the EU Delegated Act on High ILUC. Conversely, the proportion of Annex IX feedstocks, such as UCO, animal fats, and other oils, is growing and now makes up 24% of the total. Soybean oil use remains low and is mainly concentrated in a few EU countries like Spain, which has not imposed a ban on its use for biodiesel production, (Tab. 8).

Table 8. – Domestic and imported Feedstock for Biodiesel production in the EU, (Oeko-Institute, 2017), (EBB, 2023), (GlobalData, 2023).

Biodiesel Feedstock	Tons in 2023 *(1,000Mt)*	Input in 2023 *(%)*
Rapeseed oil	6.375	42%
UCO	4.350	29%
Palm Oil	1.400	9%
Soybean oil	740	5%
Animal Fats	1.000	7%
Sunflower Oil	265	2%
Other (pine oil, fatty acids)	950	6%
Total	**15.080**	**100%**

Notably, agricultural products from key trading partners include the Republic of Moldova, which typically exports around 9% of its sunflower oil as feedstock for biodiesel to EU countries.

The cost of production is significantly influenced by the type of feedstock used (see Fig. 12).

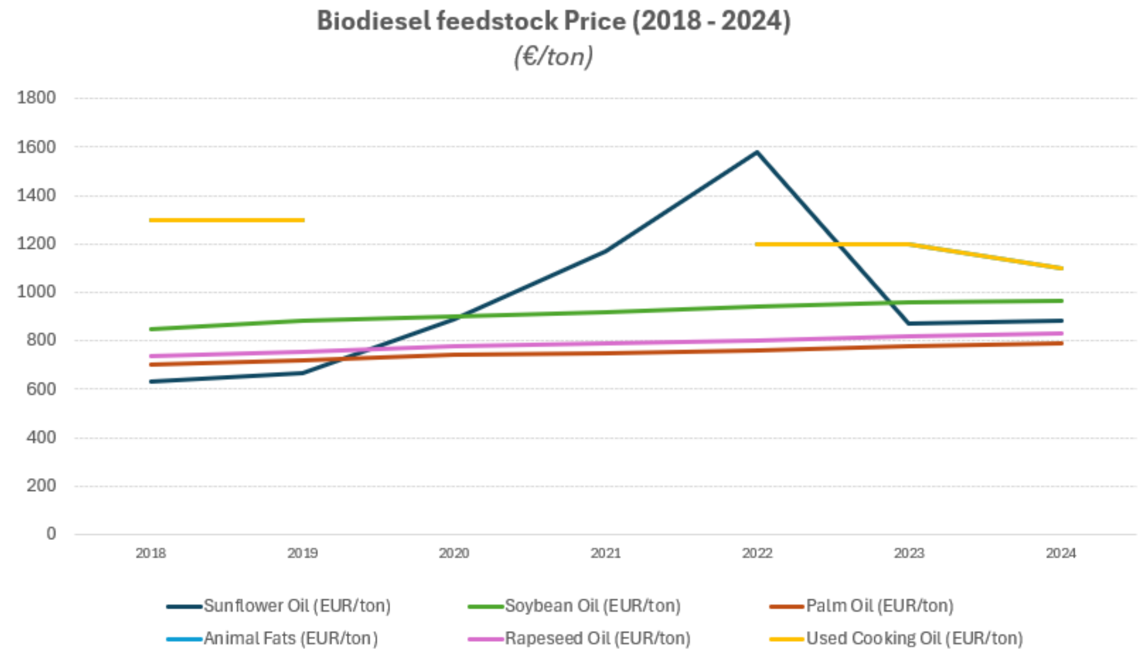


Figure 12. – Biodiesel feedstock price (2018 – 2024). Data elaborated [7]

Rapeseed oil and palm oil are the primary vegetable oils used as feedstocks for biodiesel. The invasion of Ukraine by Russia has exacerbated the already rising prices of these vegetable oils, creating further difficulties for biofuel producers.

This price increase is attributed to high fuel and energy costs, as well as Ukraine's historical role as a major supplier of rapeseed, soybeans, and sunflower seeds and oils. Recently, palm oil has experienced significant growth due to its lower price, leading to increased imports of palm oil feedstock from Asian countries.

The table 9 details the trading partners outside the EU-28 for these commodities, (Oeko-Institute, 2017). (USDA, 2023).

Table 9. - Biodiesel production in no-EU Countries: partner traders for feedstock, (Oeko-Institute, 2017).

Bioethanol Feedstock	Partners trader	%
Rapeseed oil	Russian Federation	39
	Belarus	27
	United Arab Emirates	23
	Canada	6
	Serbia	4
Sunflower oil	Ukraine	73
	Republic of Moldova	**9**
	Argentina	8
	Serbia	5

[7] https://www.indexmundi.com; https://www.investing.com/commodities, Business Insider, 2024; https://www.neste.com/palm-and-rapeseed-oil-prices; https://www.iisd.org; (S&P Global Commodity Insights, 2024); https://markets.businessinsider.com/commodities;

	Russian Federation	3
Palm oil	Indonesia	54
	Malaysia	27
	Papa New Guinea	8
	Guatemala	2
	Honduras	2
	Colombia	2
	Togo	1
Soybean oil	Ukraine	49
	Paraguay	7
	Russian Federation	20
	Norway	13
	Serbia	10

According to the most recent market trend data, the price of biodiesel, especially that derived from used cooking oil (UCO), has been notably stable despite sluggish buying activity. As of March 23, Platts reported the price of UCO at €1,020 per metric ton, a figure that has remained largely unchanged.

This stability contrasts with the situation for FAME (Fatty Acid Methyl Ester), which has experienced weak demand since the start of the year. This weak demand is attributed to market volatility in European biodiesel, which is associated with a decrease in diesel consumption (Fig.13).

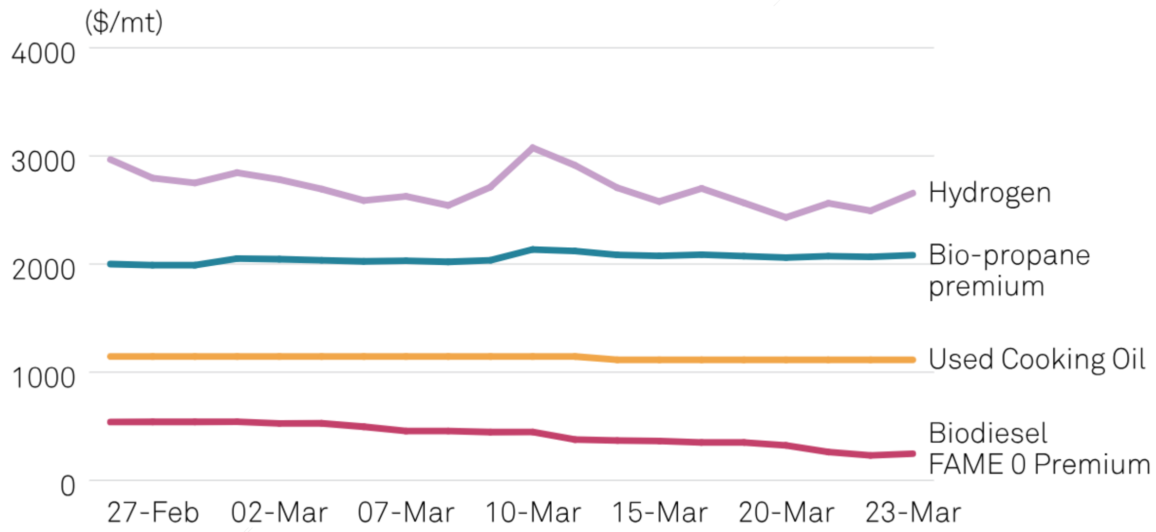


Figure 13. – Current cost for biodiesel by FAME and advanced feedstocks, (S&P Global Commodity Insights, 2024).

Although there is a slight decline in biodiesel demand, particularly for FAME, the prices for used cooking oil (UCO) remain steady. This stability is largely due to the double counting mechanism established under the Renewable Energy Directive II (RED II).

This policy promotes the use of waste-based biodiesel like UCO by allowing it to count double towards renewable energy goals, thereby cushioning it against variations in demand.

4. Cost Analysis of Biofuels in the Transportation Sector of the Republic of Moldova

The market analysis for biofuel implementation in Moldova is primarily based on the following key points:

- **Targets for 2030 Decarbonization**: Objectives to be achieved by 2030 for the decarbonization of the transport sector at the national level, in compliance with the Renewable Energy Directive II (RED II) and the national Law No. 10/2016 promoting Renewable Energy Sources, in according with the latest revision indicated withing EnC.

- **Current Market Assessment**: Evaluation of the current status of the national biofuels market and the availability of respective feedstock for biofuel production.

- **Existing Infrastructure**: Analysis of the existing plants and operational infrastructures at the national level.

- **Stakeholder Interests**: Interests of stakeholders in supporting national biofuel production according to sustainability criteria as required by the European directive.

- **Production Services**: Existing services needed for the production, certification of sustainable production, storage, refinery, and blending of biofuels.

- **Opportunities from Free Economic Zones (FEZ)**: Opportunities provided by the FEZs present in Moldova to support the development of the biofuels market.

Additionally, the analysis includes strategies achievable in line with the biofuels target by 2030 and in the coming years, as well as Identification of barriers to the biofuels market at the national level and corresponding recommendations.

Current State and Future Prospects of the Biofuels demand in the Republic of Moldova

As highlighted in Tables 4 and 10, the Republic of Moldova is a candidate country for the production of biomass feedstocks (such as cereals and sunflower oil), exporting them to European countries for the production of biofuels. However, no imports or exports of biofuels are officially registered by the Customs Agency, despite the demand and internal consumption expected to develop in the coming years due to the full transposition of the European Directive 2018/2001 (RED II) and the corresponding national The Law No. 10/2016 on the promotion of the RES.

Nowadays, the biofuel market in the Republic of Moldova is not yet developed. The present situation shows that domestic biofuel production remains stagnant. This stagnation is due to the lack of incentive measures for biofuel producers and the absence of mandatory requirements for fuel producers to use biofuel blends to achieve an 8,8% (with multipliers) or at last 7,6% (without multipliers) for decarbonization of the transport sector by 2030.

Fiscal measures to support biofuel production can facilitate the commencement of national consumption. In this regard, free economic zones should be considered to strengthen the development of new supply chains.

The latest data on fuel consumption in the transport sector indicates a total of 982,5 million liters per year, of which 757 million liters per year are diesel and 225 million liters per year are gasoline (as of 2022-2023). The national target is to achieve 8,8% (with multipliers) or at last 7,6% (without multipliers) in terms of energy consumption in the transport sector through the introduction of biofuels in the mix, therefore approximately a range withing 51 – 88 million of liters per year of biofuels should be required in relation to the nature of biofuels (I° and II° generation biofuels).

This includes a range of 35 – 62 million liters per year of biodiesel and the range of 15 - 26 million of liters per year of bioethanol, (Tab.10a and Tab. 10b).

Table 10a. - Fuel demand[8] in transport sector and forecast of biofuels to be blended considering target 8,8% (with multipliers) (Stars Project, 2019. Data revised to 2024).

Advanced Biofuels - Target 8,8% RES - T (with multipliers)								
Fossil fuel Demand (2022 - 2023)			Biofuel Demand (8,8% energy content, with multipliers x2)			Biofuels Demand Biofuel blending *(in volume)*		
FUELS	*(Liters/year)*	*(MJ/year)*	**BIOFUELS**	*(MJ/year)*	*(% MJ)*	**BIOFUELS**	*(Liter/year)*	*(% Vol.)*
Diesel	757.145.280	27.257.230.080	Biodiesel	2.398.636.247	8,80	Biodiesel[1]	35.800.541	4,73
Gasoline	225.332.770	7.210.648.640	Bioethanol	634.537.080	8,80	Bioethanol[2]	15.108.026	6,70
Total	**982.478.050**	**34.467.878.720**	**Total Biofuels**	**3.033.173.327**	8,80	**Total Biofuels**	**50.908.567**	5,72

Table 10b. - Fuel demand[8] in transport sector and forecast of biofuels to be blended considering target 7,6% (without multipliers) (Stars Project, 2019. Data revised to 2024).

I° Generation Biofuels - Target 7,6 % RES - T (without multipliers)								
Fossil fuel Demand (2022 - 2023)			Biofuel Demand (8,8% energy content, with multipliers x2)			Biofuels Demand Biofuel blending *(in volume)*		
FUELS	*(Liters/year)*	*(MJ/year)*	**BIOFUELS**	*(MJ/year)*	*(% MJ)*	**BIOFUELS**	*(Liters/year)*	*(% Vol)*
Diesel	757.145.280	27.257.230.080	Biodiesel	2.071.549.486	7,60	Biodiesel[1]	61.837.298	8,17
Gasoline	225.332.770	7.210.648.640	Bioethanol	548.009.297	7,60	Bioethanol[2]	26.095.681	11,58
Total	**982.478.050**	**34.467.878.720**	**Total Biofuels**	**2.619.558.783**	7,60	**Total Biofuels**	**87.932.979**	9,87

[1] The adoption of B7 is most used in EU countries because it represents a good balance between environmental, cost-efficient benefits, and practical feasibility for everyday use in standard diesel vehicles

[2] The adoption of E8 up to E10 blending is mostly used in EU countries because it represents a good balance between environmental, cost-efficient benefits, and practical feasibility for everyday use in standard gasoline vehicles

[8] Data source Fuel consumption: statistical national data.

On the other hand, national regulations on biofuels include prerequisites designed to support the implementation of biofuels at the national level. One of the key requirements is the presence of adequate refineries capable of mixing potential biofuels according to technical standards and sustainability criteria in compliance with EU directives (RES and FQD).

According to the latest direct investigations, one of the key barriers hindering the development of the biofuels market in Moldova is the lack of petroleum refineries, despite the existence of terminals in port zones that could be utilized for further blending of biofuels.

Furthermore, other barriers obstructing the development of a national biofuels supply chain by 2030 include:

- Lack of biofuel plants and technologies for both traditional and advanced biofuels (e.g., biodiesel plants, UCO treatment plants for advanced biodiesel).
- Limited knowledge of biomass feedstock, biofuel production processes, and potential uses (from suppliers to end users).

However, the strategy to achieve the targets of 8.8% (with multipliers) or 7.6% (without multipliers) in RES-energy consumption could be feasible by 2030 if certain strategies will be implemented in close cooperation with stakeholders in the transport and fuels/biofuels sectors (including biomass operators), as outlined in the following section.

Cost analysis of biofuels production to be adopted by 2030

The Republic of Moldova imports fuel for the transport sector, as there are no petrol refineries in the country. This significantly influences the strategy to be adopted by 2030.

At the same time, the country has facilities for the production of bioethanol, primarily used in the food sector (Zernoff company), with the potential to blend it with petrol in strategic areas (Port of Constanța, free economic zones).

The establishment of a stakeholder table within the project has identified potential collaboration among key stakeholders:

- *Zernoff Company*: Designated for the production of bioethanol from cereals (corn) and possibly biodiesel from DDGS, a byproduct of the bioethanol production chain.
- *ROMPETROL Company*: Oil company operating in Moldova, is open to collaborating on the use of national biofuels in petroleum blends.

The petrol company and project stakeholders are prepared to blend biofuels (both self-produced nationally and imported) with respective fuels in compliance with the technical regulations and sustainability criteria adopted by EU Directives RED II, FQD, and DAFI. They are already applying these standards in other EU countries where they operate, such as Romania.

The lack of refineries suggests the possibility of biofuel blending in other compatible areas, such as the port terminals of *Giurgiulești* and *Constanța* ports that are also considered FEZ areas. The choice of feedstock and the designated areas for production, process efficiency, blending, and storage of biofuels can significantly impact biofuel costs.

The meetings held with stakeholders throughout the project have facilitated the development of the most effective strategies to contain costs and make the development of national supply chains feasible. The strategies concerning biofuels supply chains to meet national demand are outlined below, with Figure 14 illustrating bioethanol production and Figure 15 depicting biodiesel production.

For each supply chain, three potential options are identified:

1. **Option 1**: Domestic production of biofuels, transportation, storage, and blending conducted within the Republic of Moldova, utilizing suitable port areas for blending, for example "*Giurgiulesti Port*", and/or Free Economic Zones (FEZ).

2. **Option 2**: Domestic production of biofuels, export to refining or terminal facilities outside the Republic of Moldova, and subsequent importation back into the country. This option may include the potential use of the "*Constanta terminal port*" terminal located on the Romanian coast. Although this option is less economical compared to the first, it may be necessary if oil companies require blending facilities according to internal company regulations.

3. **Option 3**: International production and blending of biofuels, with direct importation of pre-blended biofuel. Oil companies would directly import the pre-blended biofuel. According to information provided by project stakeholders, this option would increase the final pump price by approximately 30% compared to the current cost. This option is deemed inevitable due to the lack of companies and facilities dedicated to the production of biodiesel from both traditional biomass and UCO residues eligible for double counting.

Although bioethanol from cereals is considered a 1st-generation biofuel and thus not eligible for double counting under RED II provisions, the implementation of Law No. 10/2016 on the promotion of the RES prioritizes domestic biofuel production by incentivizing national feedstocks (Options 1 and 2).

Currently, 1stgeneration bioethanol produced domestically amounts to 20,000 tons/year (25.4 million liters/year), which could cover 97.34% of the 7.6% as target in terms of national energy demand without considering multipliers, while the remaining portion could be potentially imported from other countries, that corresponds approximately to 695.681 liters/year (2.66 %), (Figure 14).

Conversely, the biodiesel supply chain from national residues (DDGS from bioethanol plants) can cover less than 1% of the national biodiesel demand (Table 11), (Fig. 15), but could contribute to achieving double counting, as it is a processing residue rather than a primary product (e.g., sunflower oil). The biodiesel supply chain, both 1st-generation (e.g., sunflower biodiesel) and 2nd generation (e.g., UCO biodiesel), must necessarily be supplemented by foreign imports until there are domestic infrastructure (facilities) and companies willing to produce it internally (Option 3, Figure 15).

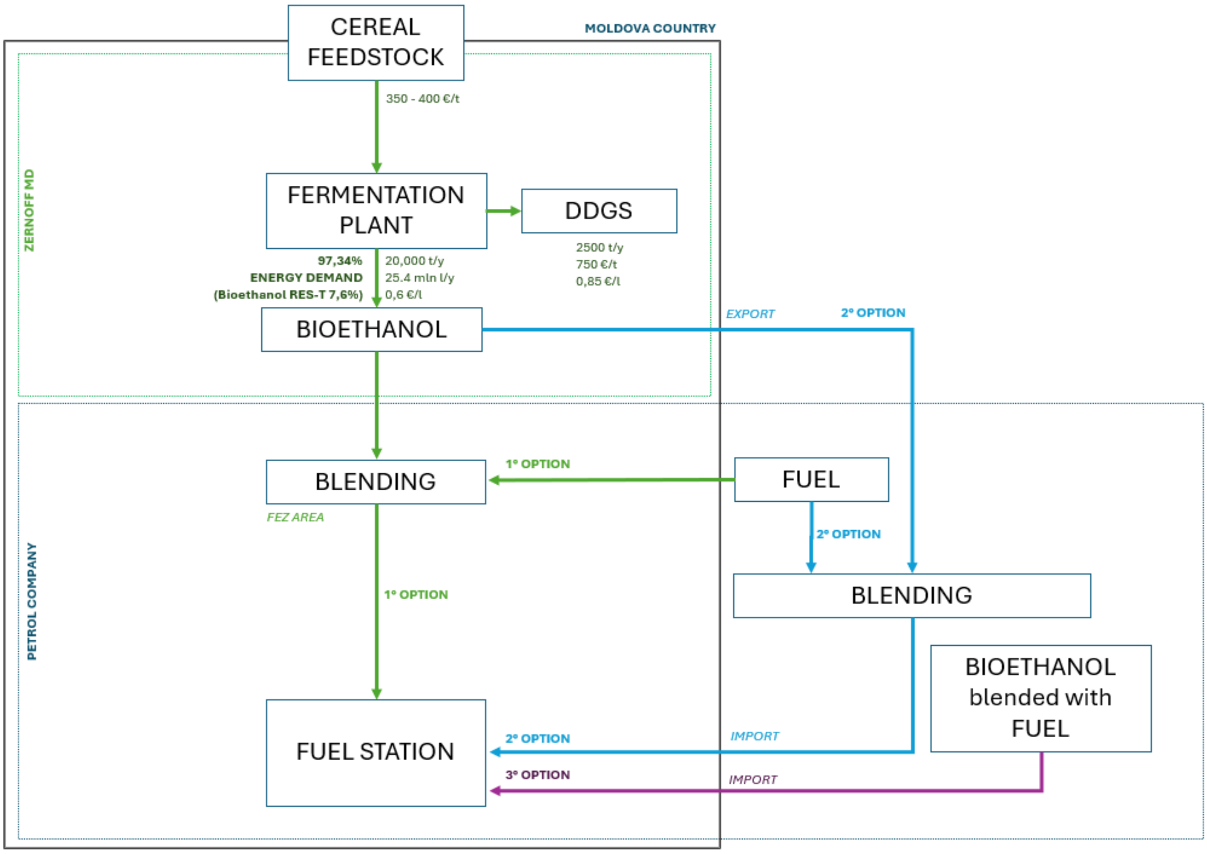


Figure 14. – Bioethanol supply chain in the Republic of Moldova and strategies for national production (data elaborated, 2024).

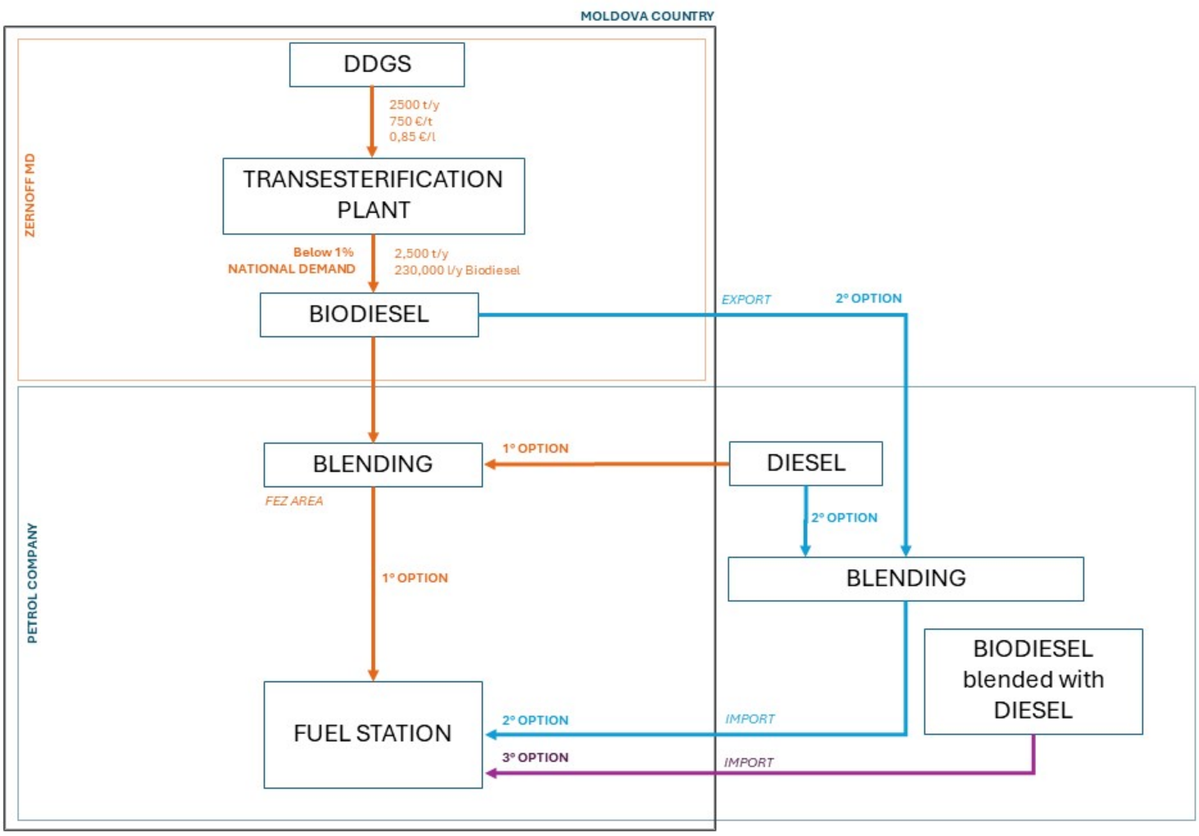


Figure 15. - Biodiesel supply chain by local feedstock and strategies for national production (data elaborated, 2024).

The stakeholders confirmed their willingness to collaborate with the Government of the Republic of Moldova for the development of biofuel supply chains (both self-produced nationally and imported), in compliance with the technical regulations and sustainability criteria established by national Law No. 10/2016 on the promotion of the RES, as well as EU Directives (RED II, FQD, and DAFI).

The oil companies involved are already applying these standards in other EU countries where they operate, such as Romania.

According to their projections, adapting new blends to comply with the new national regulations will require a short timeframe of approximately 4 to 6 months.

Specific actions will include:

- Readapting the correct blends of fuel/biofuels according to technical specifications in accordance with EU Directives.
- Prioritizing the purchase of biofuels produced domestically (I.e.: Bioethanol produced by Zernoff Company) under specific agreements in compliance with the Law No. 10/2016 on the promotion of the RES
- Purchasing imported biofuels to cover the shortfall in national biofuel production, in compliance with the sustainability criteria adopted by RED II.

According to recent assessments, the oil companies anticipate needing to increase the final blended fuel price by approximately 30% compared to the current price.

Particularly:

- An increase of 0.20c€/liter fuel for a blend with respective biofuels: Gasoline E5 (DAFI Directive) with 5% certified bioethanol, and Diesel B7 blend (DAFI Directive) with 7% certified biodiesel

Detailed cost analyses are presented in the further tables , prioritizing the first options according to the biomass feedstocks used by national companies:

- Bioethanol from cereals (1st generation bioethanol, not eligible for double counting)
- Biodiesel from DDGS (2nd generation biodiesel, eligible for double counting)

Furthermore, additional options have been analyzed for both supply chains, related to various feedstocks present in the national territory but still untapped:

- Bioethanol from straw (advanced bioethanol, eligible for double counting),
- Bioethanol from sugar beets (1st generation bioethanol, not eligible for double counting),
- Biodiesel from sunflower oil (1st generation biodiesel, not eligible for double counting),

At last, the final prices of blended fuels are calculated and presented in the next tables considering:

- Different costs of biomass feedstocks for bioethanol and biodiesel (in compliance with RED II),
- Costs of processes applied through different technology readiness levels (TRL 9) according to suitable biomass feedstocks to produce bioethanol and biodiesel,
- Potential duty rates based on the latest EU decisions for biofuel imports from non-EU countries,
- National taxes/VAT,
- Blending costs,
- Logistics and distribution costs to petrol stations,

Cost Analysis of the Biofuel Supply Chain in the Republic of Moldova

Cost Analysis of the Cereal-Based Bioethanol Supply Chain in the Republic of Moldova

The cost analysis refers to the supply chain presented in Fig. 14 and referred to 1st generation biofuel.

Table 11. - Cost Analysis of Cereal-based Bioethanol produced internally to the Republic of Moldova.

Average Bioethanol Production Cost (1) (I° Generation Biofuel)			
	Bioethanol from Cereals (Corn)		
	€/L	*€/Gl*	*€/toe*
Net Feedstock cost	na	na	na
Feedstock	0,6	28,44	1.190,56
Co-product credit	0,0	0,00	0,00
Subtotal feedstock cost	0,60	28,44	1.190,56
Conversion Cost (Bioethanol process)	0,28	13,27	555,59
Duty Rate Bioethanol (range 10,2 - 19,2 €/hl Ethanol)	**0,19**	9,10	380,98
Blending Cost (incl. Adaptation of gasoline)	0,05	2,37	99,21
Distribution Cost	0,10	4,74	198,43
National taxes (20% VAT and excises in Moldova)	**0,22**	10,33	432,37
Total Cost of Bioethanol	**1,44**	68,24	2.857,14
Total Cost of mix Bioethanol/Gasoline at petrol station (5% blending)	**1,31**	37,29	2.601,75
Cost of Gasoline at petrol station (2023-2024)	**1,30**		

Assumption: Priority to the national biofuels production, imports and blending from EU Countries (i.e.: Romania)

*** Source:** International Monetary Fund; www.indexmundi.com; https://www.globalpetrolprices.com/gasoline_prices/#hl209

Cost Analysis of the Cellulosic-Based Bioethanol Supply Chain

The cost analysis refers to the supply chain of bioethanol production from cellulosic residues. The chain is still not developed in the Republic of Moldova, but strongly supported by EU Directive 2018/2001 (Annex IX, List A of biomass feedstock) for implementation of advanced biofuels by exploitation of rural residues. The fuel companies can furthermore plan to blend the mentioned bioethanol with aim to increase the sustainability and decarbonization of transport sector reaching (with multipliers) 8,8% of target as foreseen by the latest revisions of national action plan (Tab.10a)

Assumption: Priority to the national biofuels production, imports and blending from EU Countries (i.e.: Romania)

Current situation: No advanced bioethanol is produced in Rep. of Moldova admitted to the double-counting.

Possible option: to import already blended by other EU countries, if any.

Table 12. - Cost Analysis of Blending Gasoline/Bioethanol (II° generation) imported by EU Countries by using woody and cereals straw as biomass feedstock.

Average Bioethanol Production Cost (1) (Advanced biofuel)			
	Bioethanol from Straw based		
	€/L	€/Gl	€/toe
Net Feedstock cost (before the process)	na	na	na
Feedstock (after the process)	0,92	43,47	1.819,97
Co-product credit	0,00	0,00	0,00
Subtotal feedstock cost (Bioethanol produced)	0,92	43,47	1.819,97
Conversion Cost	0,28	13,27	555,59
Duty Rate Biodiesel EU (3,5 % on FAME at 96,5%-100%) and Duty Rate Bioethanol (range 10,2 - 19,2 €/hl Ethanol)	0,19	9,10	380,98
Blending Cost (incl. Adaptation of gasoline)	0,05	2,37	99,21
Distribution Cost	0,10	4,74	198,43
National taxes (20% VAT and excises in Moldova)	0,31	14,59	610,84
Total Cost of Bioethanol	**1,85**	87,54	3.665,02
Total Cost of mix Bioethanol/Gasoline at petrol station (blending 5%)	**1,34**	63,69	2.666,38
Cost of Gasoline at petrol station (2023 - 2024) (€/l)	**1,30**		

*** Source:** International Monetary Fund; www.indexmundi.com; https://www.globalpetrolprices.com/gasoline_prices/#hl209

Cost Analysis of the Sugar Beet-Based Bioethanol Supply Chain

Despite the decline in the use of sugar beet as a feedstock due to internal EU problem, it is worth considering this biomass as a candidate for bioethanol production due to its cost-effectiveness compared to other biomass sources, Tab.16).

I° Assumption: No bioethanol from sugar beet is produced in Rep. of Moldova.

II° Assumption: Priority to the national biofuels production, imports and blending from EU Countries (i.e.: Romania)**.**

Possible option: to import already blended by other EU countries, if any.

Table 13. - Cost Analysis of Blending Gasoline/Bioethanol imported by EU Countries by using Sugarbeet as biomass feedstock.

Average Bioethanol Production Cost (I° Generation Biofuel)			
	Bioethanol from Sugarbeet		
	€/L	*€/Gl*	*€/toe*
Net Feedstock cost	na	na	na
Feedstock	0,26	12,46	521,86
Co-product credit	0,00	0,00	0,00
Subtotal feedstock cost	0,26	12,46	521,86
Conversion Cost	0,51	24,17	1.011,98
Duty Rate Biodiesel EU (3,5 % on FAME at 96,5%-100%) and Duty Rate Bioethanol (range 10,2 - 19,2 €/hl Ethanol)	0,19	9,10	380,98
Blending Cost (incl. Adaptation of gasoline)	0,05	2,37	99,21
Distribution Cost	0,10	4,74	198,43
National taxes (20% VAT and excises in Moldova)	0,22	10,33	432,37
Total Cost of Bioethanol	**1,33**	63,17	2.644,83
Total Cost of mix Bioethanol/Gasoline at petrol station (blending 8%)	**1,30**		
Cost of Gasoline at petrol station (2023-2024)	**1,30**		

* **Source:** International Monetary Fund; www.indexmundi.com; https://www.globalpetrolprices.com/gasoline_prices/#hl209; https://www.researchgate.net/publication/330571317_Economic_and_legal_aspects_of_the_direct_processing_of_sugar_beet_to_ethanol

Cost Analysis of the SSDG-Based biodiesel Supply Chain in the Republic of Moldova

SSDG is a by-product from the bioethanol production process and is generally used in the feed sector. The oil contained in it, approximately 10% of the by-product, can be further processed into biodiesel. The Moldovan bioethanol-producing company is actively engaged in the valorization process of this oil for potential biodiesel production from this waste.

A detailed cost analysis of biodiesel production under specific national conditions of this by-product's production is provided. As mentioned at the beginning of the chapter, the national production of biodiesel from SSDG covers only 1% of the national demand (230,000 liters/year biodiesel by 2,500 t/y from DDGS) (Fig. 15). Therefore, importing biodiesel from third countries is strategic for achieving the decarbonization target in the transport sector, especially in the short term.

Assumption: Priority to the national biofuels production, imports and blending from EU Countries for the remain part.

Table 14. - Cost Analysis of DDGS – Based Biodiesel supply chain in the republic of Moldova.

Average mix Diesel/Biodiesel Cost (II° Generation/ADVANCED Biofuel)			
	Biodiesel from DDGS Oil		
	€/L	*€/Gl*	*€/toe*
Net Feedstock cost	na	na	na
Feedstock	0,85	22,49	941,48
Co-product credit	0	0,00	0,00
Subtotal feedstock cost	0,85	22,49	941,48
Conversion Cost	0,07	1,85	77,53
Duty Rate Biodiesel EU and Duty Rate Bioethanol	0,19	5,03	210,45
Blending Cost (incl. Adaptation of gasoline)	0,05	1,32	55,38

Distribution Cost	0,1	2,65	110,76
National taxes (20% VAT and excises in Rep. of Moldova)	0,21	5,56	232,60
Total Cost of Biofuels (Biodiesel)	**1,47**	38,89	1.628,20
Total Cost of mix Biofuels/Fuels at petrol station (7% blending)	**1,12**	29,54	1.236,77
Cost of Diesel at petrol station (2023-2024) (€/l)	**1,09**		

Source: International Monetary Fund; www.indexmundi.com; https://www.globalpetrolprices.com/gasoline_prices/#hl209;

Cost Analysis of the sunflower oil-Based biodiesel Supply Chain

Further cost analysis concerns the biodiesel supply chain from sunflower oil. This feedstock is very common in Moldova, although its primary use is oriented towards the food market. Data provided by the European STAR project indicate that a partial production of approximately 20% of sunflower oil could be allocated to national biodiesel production without causing distortions in the food and feed markets.
Alternatively, biodiesel from this type of feedstock could be supplied by neighboring countries, which are major producers of sunflower oil. The cost analysis is provided in the following table (Tab.12).

Assumption: Priority to the national biofuels production, imports and blending from EU Countries (i.e.: Romania).

Table 15. - Cost Analysis of Sunflower Oil – Based Biodiesel supply chain.

Average mix Diesel/Biodiesel Cost (1) (I° Generation Biofuel)			
	Biodiesel from Sunflower oil		
	€/L	*€/GJ*	*€/toe*
Net Feedstock cost	na	na	na
Feedstock	0,60	16,10	674,02
Co-product credit	0,00	0,00	0,00
Subtotal feedstock cost	0,60	16,10	674,02
Conversion Cost	0,07	1,88	78,64
Duty Rate Biodiesel EU and Duty Rate Bioethanol	0,19	5,15	215,69
Blending Cost (incl. Adaptation of gasoline)	0,05	1,34	56,17
Distribution Cost	0,20	5,37	224,67
National taxes (20% VAT and excises in Rep. of Moldova)	0,18	4,83	202,21
Total Cost of Biofuels (Biodiesel)	**1,29**	34,67	1.451,39
Total Cost of mix Biofuels/Fuels at petrol station (7% blending)	**1,104**	29,63	1.240,36
Cost of Diesel at petrol station (2023-2024) (€/l)	**1,09**		

Source: International Monetary Fund; www.indexmundi.com; https://www.globalpetrolprices.com/gasoline_prices/#hl209.

Strategies for further reduction of biofuels costs

From this perspective, the analysis of logistical infrastructure is crucial for further enhancing the efficiency of supply chain costs, particularly regarding the availability of ports for the maritime transport of fuels produced domestically and those that need to be imported from neighboring countries. The Giurgiulesti Port (Moldova) warrants attention due to its capacity and its status as a free port area (FEZ).

Giurgiulesti Port is equipped with an oil terminal as well as rail and road terminals. The port is managed by the Giurgiulesti International Free Port (GIFP) Operator. The Giurgiulesti cargo terminal has the following features:

- channel depth of 7 meters,
- trimodal transport infrastructure,
- access to the road network and rail network with both European and Russian gauges,
- specialized equipment for loading and unloading grains to/from ships and for transhipment of bulk or containerized cargo,
- storage capacity for bulk goods, containers, and warehousing of 5,600, 2,700, and 2,000 square meters respectively.

Since 2009, a logistics base for the storage and loading-unloading of agricultural goods has been managed by Trans Cargo Terminal (TGT). The port's characteristics (river depth and docks) allow it to accommodate ships capable of transporting up to 7,000 tons of cargo. The silos at TGT enable daily loading and unloading of up to 3,000 tons of feedstock, with a storage capacity of 50,000 tons.

There are 12 silos of varying capacities. The agricultural terminal is equipped with a laboratory for product quality analysis.

To date, "In-Out" shipments have involved the following European and non-European countries: Greece, Netherlands, Tunisia, Morocco, Panama, Syria, USA.

The port area hosts a free zone "*FEZ Giurgiulesti*" covering 120 hectares. There is interest in establishing agro-industrial activities such as soybean processing plants and initiatives related to agro-energy, including biofuel production plants and blending facilities.

Regarding investment and production facility measures, recent Moldovan legislation has identified several areas with free economic zone (FEZ) status, including the aforementioned Giurgiulesti area and others such as Balti. Despite 40 per cent of the Balti FEZ being already assigned to German companies, the remaining portion is still available.

The main advantages of allocating investments and activities settling in a free zone include:

- exemption from taxes on products manufactured in the FEZ destined for export,
- the ability to choose the most favorable legal conditions for FEZ treatment from past or future regulations,
- FEZ status for 25 years,
- exemptions from VAT, excise taxes, and import duties,

- no export duties for shipments to CIS countries, Russia, and the EU. In the FEZ, the production of arms, alcohol, and tobacco is prohibited.

It is important to note that bioethanol is considered a fuel rather than alcohol, and therefore, its production can be considered for establishment in the mentioned free zones. The inclusion of free zones in the cost analysis of biofuels could potentially reduce the final cost by up to 20 cents per liter, making thus domestic bioethanol production more attractive and sustainable.

5. Conclusion

Despite the country's current significant reliance on fuel imports, strategic measures can be adopted to enhance domestic biofuel production in the short and medium term, aligning with the overarching policy goals of the national government. The Government of the Republic of Moldova aims to maximize the energy potential of biomass as a partial and gradual substitute for fossil fuels, emphasizing the processing of local biomass feedstocks into biofuels to ensure sustainability, efficiency, and competitiveness.

Demonstration projects that promote the use of biomass and address technical barriers are crucial for fostering a more sustainable agricultural sector in Moldova. This strategy is consistent with the Renewable Energy Law (No. 10/2016) and EU Directive 2018/2001.

Although the use of local biomass feedstocks for biofuel production is promising, the most significant challenge remains the lack of petrol refineries necessary for fuel blending. Consequently, petrol companies operating in Moldova may need to source national biofuels and process them in refineries located in EU countries, such as Romania.

However, achieving this by 2030 is unfeasible due to the substantial capital and technical investments required. Nevertheless, the resolution of this technical barrier seems achievable through the utilization of port terminals (*Constanța and Giurgiulești*) and Free Economic Zones (FEZ) located in various national areas.

Investing in national biofuel production through the available FEZ and port terminals could unlock innovative pathways, potentially generating new jobs in rural areas and enhancing farm revenues through the added value of biomass conversion technologies in the short term. This would contribute to maintaining a competitive fuel mix price.

Final Recommendations

Based on extensive consultations, the following two distinct strategies are recommended:

b. Short-Term Strategy by 2030

Biofuel Imports and Compliance: Biofuel Imports and Compliance: This strategy should involve local stakeholders and blending biofuels produced nationally, subsequently, importing pre-blended biofuels from refineries in EU countries, managed by petrol companies operating in Moldova. Immediate actions required include:

- Mandating that economic operators blend imported fuels in compliance with EU technical standards and biofuel sustainability criteria (EU Directives: REDII, FQD, ILUC).
- Implementing monitoring and quality checks of biofuel blends through certified organizations and laboratories to ensure adherence to EU technical standards and national targets.
- Requiring certificates from economic operators (petrol companies) related to fuel quality and sustainability criteria for biofuels, in accordance with EU Directives.

b. Long-Term Strategy post-2030

Local Biofuel Production: The feasibility of local biofuel production depends on:

- The competitive cost of biomass feedstock.
- Investments in decentralized biofuel plants to support farmer incomes and local job growth.

Furthermore, potential risks such as the market expansion of electric vehicles, rising commodity prices, and emerging technologies in the biofuel sector must be considered, as they will significantly influence the biofuel market in the future. It is crucial to plan investments that also focus on training local stakeholders involved in the advanced biofuel sector, including farmers' associations, technicians, engineers, chemists, petrol companies, standardization bodies, policymakers, customs agencies, and consumer associations.

Abbreviations

ACEA = European Automobile Manufacturer´s Association

ASTM = American Society for Testing and Materials

Biodiesel = Fatty acid methyl ester produced from agricultural feedstock (vegetable oils, animal fat, recycled cooking oils) used as transport fuel to substitute for petroleum diesel

B5, B7 = Diesel blends with % FAME. Blend of mineral diesel and biodiesel with the number indicating the percentage of biodiesel in the blend, e.g. B100 equals 100% biodiesel, while B5 equals 5% biodiesel and 95% conventional diesel.

Bioethanol = Ethanol produced from agricultural feedstock used as transport fuel

BtL = Biomass to Liquid

CCP = Climate Change Package

CEN = European Committee for Standardization (Comité Européen de Normalisation)

DDGS = Dry distillers grains and solids, by-product of ethanol production

DME = Di-methyl ether

Diesel Fuel = it is any liquid fuel used in diesel engines, whose fuel ignition takes place, without any spark, as a result of compression of the inlet air mixture and then injection of fuel

EBB = European Biodiesel Board

EC = European Commission

EnC = Energy Community

EnC - CPs = Energy Community Contracting Parties

E5-E8-E10 = Blend of mineral gasoline and bioethanol with the number indicating the percentage of bioethanol in the blend, e.g. E10 equals 10% bioethanol and 90% conventional gasoline.

FAME/FAMAE = fatty acid methyl ester/fatty-acid mono-alkyl esters

FQD = Fuel Quality Directive 2009/30/EC

FT = Fischer Tropsch

GASOLINE Fuel = *Gasoline* (American English), or *Petrol* (British English), is a transparent, petroleum-derived liquid that is used primarily as a fuel in spark-ignited internal combustion engines.

GHG = Greenhouse Gas

GJ = Gigajoule = 1,000,000,000 Joule or 1 million KJ

Ha = Hectares, 1 hectare = 2.471 acres

HVO = Hydrogenated Vegetable Oil

KTOE = 1000 MT of oil equivalent = 41,868 GJ = 11.63 GWh

ICCT = International Council of Clean Transportation

IEA = International Energy Agency

ILUC = Indirect Land Use Change

IRENA = International Renewable Energy Agency

ISO = International Organization for Standardization

LCA = Life-cycle assessment

MJ = Megajoule

MMT = Million metric tons

MON = Motor Octane number

MS = Member State(s) of the EU

MT = Metric ton (1,000 kg)

MTOE = Million tons of oil equivalent

MW = Mega Watt = 1,000 Kilo Watt (KW)

MWh = Mega Watt hours= 1,000 Kilo Watt hours (KWh)

MY = Marketing Year

NREAPs = National Renewable Energy Action Plans

OJUE = Official Journal of European Union

PVO = Pure vegetable oil used as transport fuel

RED = EU Renewable Energy Directive (2009/28/EC) , which will expire at the end of 2020.

RED II = EU Renewable Energy Directive 2009/28 which will succeed the existing regulation 2009/28/CE and enter into effect on January 1, 2021.

RES - T = Renewable Energy Sources in Transport Sector

RON = Research Octane number

RME = Rapeseed Methyl Ester

SME = Soybean Methyl Ester

TME = Tallow Methyl Ester, biodiesel made from animal fat

TOE = Tons of oil equivalent = 41,868 MJ = 11.63 MWh

UCO = Used cooking oil/ recycled vegetable oil

UCOME = UCO based methyl ester biodiesel

VSS = Voluntary Scheme-based System

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