Advanced Sustainable BIOfuels for Aviation

Deliverable D4.6:

KPIs monitoring report

Consortium:

Acronym	Legal entity	Role
RE-CORD	CONSORZIO PER LA RICERCA E LA DIMOSTRAZIONE SULLE ENERGIE RINNOVABILI	CO
ENI	ENI S.p.A.	BEN
SKYNRG	SKYENERGY BV	BEN
CENER	FUNDACION CENER-CIEMAT	BEN
ETA	ETA – Energia, Trasporti, Agricoltura Srl	BEN
CCE	CAMELINA COMPANY ESPANA S.L.	BEN
JRC	JOINT RESEARCH CENTRE – EUROPEAN COMMISSION	BEN

CO…Coordinator, BEN…Beneficiary

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Prepared by:	Giacomo Talluri (Lead), Tommaso Barsali, Calogero Schillaci, Luca Sassi, Enrique Medina Martos, Arwyn Jones, Paloma Leon, Yuri Herreras Yambanis, Javier Prieto, David Chiaramonti
Responsible Person:	Tommaso Barsali
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DEL	Technical reports identified as deliverables in the Description of Work	X
MoM	Minutes of Meeting	
MAN	Procedures and user manuals	
WOR	Working document, issued as preparatory documents to a Technical report	
INF	Information and Notes	

Dissemination Level		
PU	Public	
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	

CO	Confidential, only for members of the consortium (including the Commission Services)	**X**
CON	Confidential, only for members of the Consortium	

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1 Executive Summary

KPIs have been met at 87.5% (7 out of 8 completely achieved, 1 partially achieved).
The technological KPIs have all been met.
Namely, new installed capacity for biokerosene production has been met thanks also to the distillation column refurbishment operated by ENI in its Livorno refinery, specifically for BIO4A project.
SE2 and SE3 have been attained, namely the biofuels were compliant to sustainability biofuels standards, as shown also in deliverable D3.2.
Partial achievement is due to SE1 "Improvement of the economic viability of the biojet production". The economic viability of biojet production was severely affected, since 2021, by the rise in industrial utilities (from +300% to 600% for gas and electricity) and residual lipids feedstock prices, thus impairing the ability of process optimization to compensate for such production costs increases.
The environmental KPIs have all been met, in particular E1 largely outperforms the REDII 70% requirements on GHG emissions savings, not only for residual lipids, but also for lipids from Camelina cultivation, in particular when using biochar as a soil amendment (107%-128%).

Table I: Summary of KPI results

KPI - Description	Achieved	Results	Notes
T1: new installed annual production capacity of several hundreds thousands t/y of HEFA biojet	YES	60 kt/yr – 200 kt/yr	The lower value refers to actual HEFA projected capacity in Livorno; the upper value to max. HEFA projected capacity in Livorno and Gela (Gela in construction)
T2: Bio kerosene must comply with reference ASTM	YES	Compliance	Certification provided
T3: GIS mapping of potential feedstock production on marginal lands in EU MED area	YES	Maps realized	
SE1: Improvement of the economic viability of the the biojet production	PART.	2,800 €/t_{SAF} – 3,500 €/t_{SAF}	
SE2: Compliance to sustainability biofuels standards	YES	Compliance	Certification provided
SE3: Social and techno-economic sustainability of potential feedstock production on marginal land	YES	Sustainability assessed	
Change in income, Land tenure	*YES*	*8.75 / 10.00*	*From stakeholder interviews*
Jobs in the sector	*N.A.*	*6,500 – 19,500*	*FTE jobs, depending on scenario and assumptions*
Productivity	*N.A.*	*0.59 – 1.09 t/ha*	*Seeds production*

Net energy balance	*YES*	*2 – 2.5*	*From literature (should be >1)*
Gross value added	*YES*	*0.96 – 2.2*	*Profitability Index (should be >1)*
Infrastructure and logistics	*N.A.*	*0.34 – 3.18 tkm/MJ$_{SAF}$*	*Depending on the considered value chain*
E1: GHG emissions saving respect to fossil Jet A1 meeting the EU regulation in place at the moment of production.	YES	UCO:89% Tallow: 85% Camelina: 107% - 128%.	RED II target: 70%
E2: Environmental sustainability of feedstock potential production on marginal land	YES	Most of considered areas perform in the range from moderate to very good	

2 TECHNOLOGICAL KPIs

2.1 T1: new installed annual production capacity of several hundreds thousands t/y of HEFA biojet.

2.1.1 Brief description of context

The HEFA technology is currently the only pathway commercially exploited towards SAF on a significant scale. It is reported that most of these HEFA facilities mainly focus on the production of renewable diesel (also known as HVO) due to higher yields and market/policy circumstances; new market circumstances and increased demand and interest in SAF, are having an impact on the situation which is now rapidly changing.

Figure 1, taken from Deliverable 5.5, shows the total 2022 installed SAF capacity; most of it is from HEFA processes. It also shows total production capacity and therefore not per se SAF focused capacity. Beyond these current figures an important capacity development is ongoing in the EU: approximately 2.5 million tonnes of increase in SAF capacity is expected from announced facilities up till 2030.

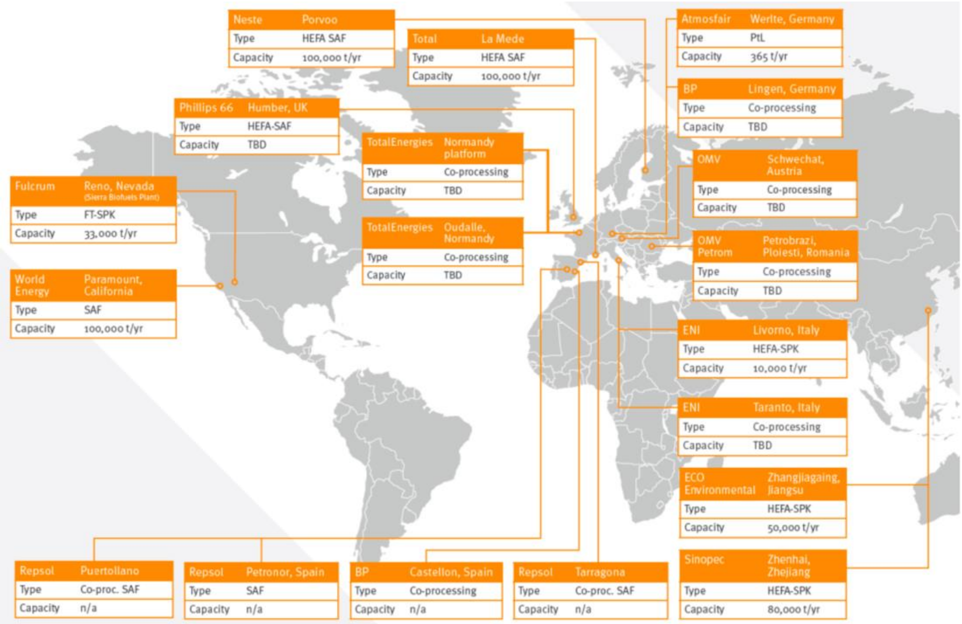

Figure 1:SAF operational capacity (source: Argus Media, 2022)

Deliverable 5.5 also presented a projection on SAF demand and supply; the basis for this assessment were the targets set by ReFuelEU, translated in Mt of jet fuel demand.

The proposed mandate results in a very steep SAF supply increase from 2.4 Mt in 2030 to 15.2 Mt in 2040 (in EU-27). The mandate for PtL SAF accelerates significantly after 2045 to 13.3 Mt in 2050. Total proposed mandated volumes finally are 1 Mt in 2025, 3.5 Mt in 2030 and 30 Mt in 2050. Based on these currently known ReFuelEU targets Deliverable 5.5 have identified the estimated market for advanced bio-based SAF in the EU to be approximately 15 Million tonnes in 2050, under very conservative market assumptions. Within this overall market outlook, approximately 3 Mt are expected to be potentially produced using HEFA technology. This result is based on a model considering competing use in other regions and for other products, such as Renewable Diesel, for the same waste oil feedstocks. Potential use of ‘cover crops’, as well as wider use of imported waste oils has not been considered.

On a worldwide basis, the WEF [1] reports a waste oils total potential of 40 Mt, together with 130 Mt of oils from cover crops and degraded land agriculture. Assuming an average 50% SAF share, taking into account yields and alternative fuel production like diesel, this could in total yield approximately 85 Mt of SAF worldwide from the HEFA pathway.

2.1.2 Methodology for KPI calculation

The possibility of producing HEFA from Livorno has been achieved thanks to the realization of minor investments on the site and allowed Eni to produce 1000 t of HEFA without using third party’s facilities and with product quality under the full guarantee and complete control of Eni. HVO-naphtha long cut on Gela had been produced from Annex IX, part b RED II, eligible feedstocks for the project aims.

The proposed configuration, integrating Gela bio-refinery and Livorno traditional refinery through the refurbishment of an idle naphtha fractionation column, has been an innovation by itself in Eni’s operations and it facilitates the potential industrial scalability of the solution. The proposed pathway is still relevant in its novelty for the research purposes of the project; it is an industrial choice in line with Eni's decarbonization strategy, transforming traditional sites into sites to produce new low-carbon footprint energy vectors/fuels such as HEFA/Biojet.

2.1.3 Results

The distillation column refurbished in Livorno (T-105) has a throughput capacity of about 25 tonnes per hour. It means that the nameplate throughput capacity on a yearly basis theoretically exceeds 200’000 tonnes. The potential HEFA biojet production is of about 60-70’000 tonnes per year considering a yield of HEFA-biojet 30-35%. Potential increase of the biojet content in HVO-naphtha long cut, still to be evaluated, could lead to a production close to 100’000 tonnes on a yearly basis. Including Gela biojet production capacity under construction the total production of HEFA biojet will reach 200’000 tonnes per year.

2.2 T2: Bio kerosene must comply with reference ASTM

2.2.1 Brief description of context

The conceptual scheme for the qualification of a new SAF is shown in Figure 2. The evaluation process refers to the FAA-approved operating limits based on ASTM fuel specifications; the evaluation of the specific new SAF then follows ASTM D4054 rules and definitions. The positive evaluation of the new SAF then leads to the drafting of a new specific ASTM D7566 annex, which will define the properties of the so-called "syntethic blend component" to be used in a blend with a conventional jet fuel to obtain a drop-in fuel compliant with ASTM D7566. Compliance with this evaluation process will allow the new SAF drop-in to be certified under the same standard applied for conventional jet fuel, i.e. ASTM D1655, thus ensuring its adoption in virtually all existing aircraft that can use conventional jet fuel.

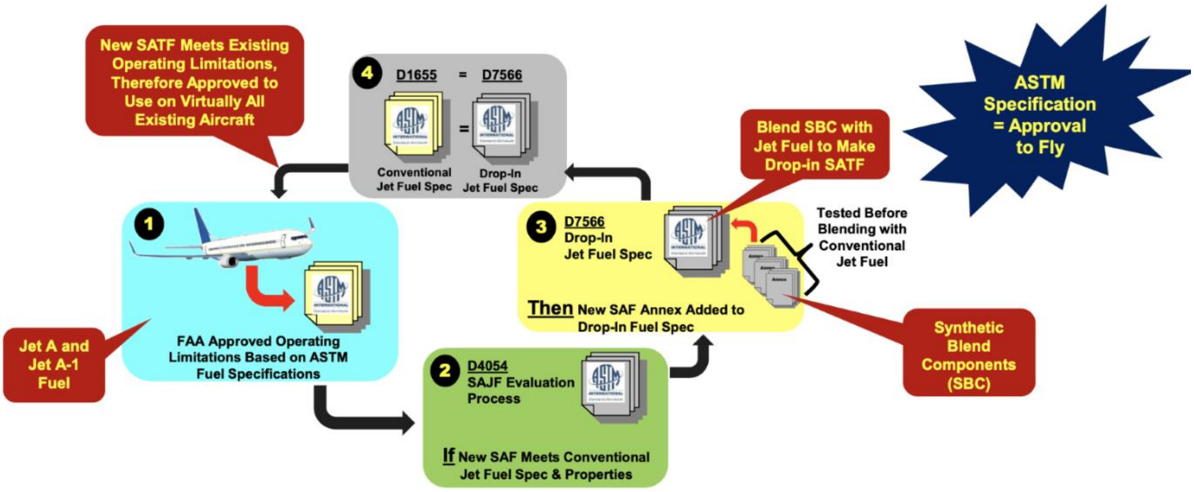

Figure 2: Conceptual scheme for the SAF approval process into ASTM certification

The procedure for the evaluation of the properties of a new SAF – which is a part of the more general procedure for the qualification of a new SAF - follows D4054 standard; the procedure is summarized in Figure 3.

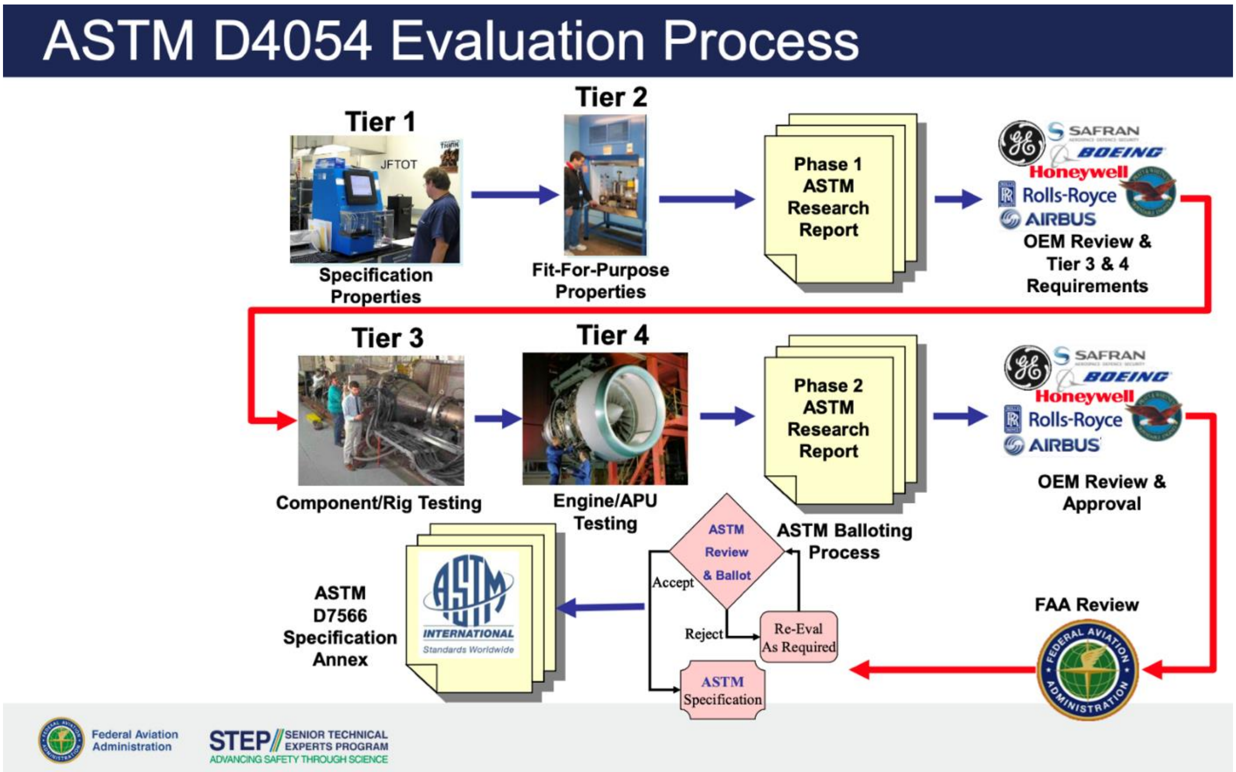

Figure 3: Evaluation process for SAF, as described in ASTM D4054

The candidate SAF goes through two initial test phases (called Tier 1 and Tier 2), the results of which are consolidated in a first document (research report) which is reviewed by a group of OEMs. After a positive evaluation two further test phases follow, involving the use of specific test rigs and real propulsion groups or GPUs, respectively called Tier 3 and Tier 4. Again, the test results are reported in a special document (research report) which is submitted to a group of OEMs for review; in the event of a positive outcome, it will be followed by the review by the American FAA. Finally, it undergoes a final review and ballot within the ASTM, with the consequent drafting of a dedicated annex to the ASTM D7566.

2.2.2 Results

As reported in Deliverable D1.3 "ASTM certified aviation biofuel production of at least 1000 tons", HEFA production was realized through a process configuration that involves:

- Eni's Gela biorefinery to produce HVO-naphtha long cut from Gela biorefinery instead of HVO-Diesel
- Eni's Livorno refinery for the distillation of HEFA from HVO through a dedicated and refurbished distillation column.

Eni reached the target production of 1000 t of HEFA, available for BIO4A project, during November 2022, thus **the KPI T2 can be considered 100% completed**.

Figure 4 below (as taken from Deliverable 1.3 "ASTM certified aviation biofuel production of at least 1000 tons") reports the laboratory analysis that certifies the compliance of the resulting HEFA product with the required ASTM aviation fuel standards.

Specification according to Standard ASTM D 7566-22A - Annex A.2

Analysis	Notes	U. of. M.	Limits	IP Method	ASTM Method	Result
Appearance						
Appearance	(1)	—	Pass		ASTM D4176	Pass
Colour Saybolt		—	Report		ASTM D6045	>30
Particolate, at point of manifacture, cumulative channel particle counts						
Channel counts >= 4 µm		Channel counts	Report	577		479.3
Iso Code >= 4 µm		ISO Code	Max. 19	577		16
Channel counts >= 6 µm		Channel counts	Report	577		93
Iso Code >= 6 µm		ISO Code	Max. 17	577		14
Channel counts >= 14 µm		Channel counts	Report	577		12.6
Iso Code >= 14 µm		ISO Code	Max. 14	577		11
Channel counts >= 21 µm		Channel counts	Report	577		5.8
Iso Code >= 21 µm		ISO Code	Report	577		10
Channel counts >= 25 µm		Channel counts	Report	577		3.0
Iso Code >= 25 µm		ISO Code	Report	577		9
Channel counts >= 30 µm		Channel counts	Report	577		1.3
Iso Code >= 30 µm		ISO Code	Max. 13	577		7
Composition						
Total acidity	#	mgKOH/g	Max. 0.015		ASTM D3242	0.004
Hydrocarbon composition						
Cycloparaffins	(5)#	% massa	Max.15		ASTM D2425	7.4
Aromatics	(5)#	% massa	Max. 0.5		ASTM D2425	0.2
Paraffins	(5)#	% massa	Report		ASTM D2425	92.6
Carbon and Hydrogen	(5)#	% massa	Min. 99.5		ASTM D5291	100.0
Non Hydrocarbon composition						
Nitrogen	#	mg/kg	Max. 2		ASTM D4629	0.34
Water	#	mg/kg	Max. 75		ASTM D6304	38
Total Sulphur	#	mg/kg	Max. 15		ASTM D5453	2.00
Al, Ca, Co, Cr, Cu, Fe, K, Mg, Mo	(4)#	mg/kg	<0.1 per singolo metallo		ASTM D7111	<0.1 per singolo metallo
Na, Ni, P, Pd, Pb, Pt, Sn, Sr, Ti, V, Zn	(4)#	mg/kg	<0.1 per singolo metallo		ASTM D7111	<0.1 per singolo metallo
Halogens	(4)#	mg/kg	Max. 1		ASTM D7359	<1
Incidental material						
Fatty Acid Methyl Ester (FAME)	(3)#	mg/kg	Max. 5	IP 585		<4.5
Volatility						
Initial boiling point		°C	Report		ASTM D 86	156.1
fuel recovered 10%	#	°C	Max. 205		ASTM D 86	166.8
fuel recovered 50%		°C	Report		ASTM D 86	189.1

Analysis	Notes	U. of. M.	Limits	IP Method	ASTM Method	Result
fuel recovered 90%	#	°C	Min.210		ASTM D 86	251.4
T90%-T10%		°C	Min. 22		ASTM D 86	84.6
evaporated at 250°C		%V	Min. 65		ASTM D 86	>65
end point	#	°C	Max. 300		ASTM D 86	267.6
residue	#	%V	Max. 1.5		ASTM D 86	1.0
loss	#	%V	Max. 1.5		ASTM D 86	0.1
IBP Simdist	#	°C	Report		ASTM D 2887	131.8
recovered 10% Simdist	#	°C	Report		ASTM D 2887	144.0
recovered 20% Simdist	#	°C	Report		ASTM D 2887	156.9
recovered 50% Simdist	#	°C	Report		ASTM D 2887	187.2
recovered 80% Simdist	#	°C	Report		ASTM D 2887	251.7
recovered 90% Simdist	#	°C	Report		ASTM D 2887	269.6
FBP Simdist	#	°C	Report		ASTM D 2887	327.3
Flash point	#	°C	Min. 38	IP 170		46
Density at 15°C	#	kg/m3	730.0 - 772.0	IP 160	ASTM D4052	754.7
Fluidity						
freezing point	#	°C	Max. -40.0	IP 529		-47
Viscosity at -20°C		mm2/s	Max. 8.000		ASTM D445	3.900
Corrosion						
Copper, classification (2h at 100°C)		—	Max. 1		ASTM D130	1B
Thermal stability JFTOT contr. temp. 325°C						
control temperature	#	°C	Min. 325	IP 323	ASTM D3241	325
filter pressure differential	#	mmHg	Max. 25.0	IP 323	ASTM D3241	0
tube deposit rating (visual)	#	—	Max. <3	IP 323	ASTM D3241	1
existing tires (not washed)	#	mg/100ml	Max. 7	IP 540	ASTM D381	2.2
Antioxidant:						
Antioxidant in Synthetic Fuels	(2)#	mg/l	17.0 - 24.0		FROM BLENDING	20.6
Seal n°		—	Report			086997
Quantity of fuel in the batch		m3	Report			2573.6

The product is 100% paraffinic kerosene synthesized from esters and hydroprocessed fatty acids (HEFA-SPK)
We certify that the samples have been analyzed using established test methods, and that the analyzed samples are representative of the batch that complies with ASTM D 7566-22A Annex A.2
(1) Clear, bright and visually free from solid matter and undissolved water at ambient fuel temperature.
(2) Antioxidant additive approved by both from ASTM D7566-22A Annex A.2 and DEF STAN 91-091/14 (Qualification reference RDE/A/609)
(3) Analysis performed by SGS Italia (doc. n° LIV22-00666.001 of 08.12.2022)
(4) Analysis performed by SGS Italia (doc. n° LIV22-00667.001 of 08.12.22)
(5) Analysis performed by Laboratorio di Ricerca ENI di San Donato Milanese (doc. n° 2705LB del 12.12.22)

(#) Characteristics foreseen by Annex A2 of ASTM D7566-22A

Figure 4: HEFA batch analysis certifying the compliance with specific ASTM standard for blending with jet fuel

2.3 T3: GIS mapping of potential feedstock production on marginal lands in EU MED area

2.3.1 Brief description of context

Bioenergy oil crops, and specifically Camelina, have the potential to be grown profitably on marginal lands and can therefore offer a source of income to local farmers and related industries while helping to achieving the targets of the Renewable Energy Directive II (EU) 2018/2001. Bioenergy can contribute to the energy resilience of a country. The geographic information systems (GIS) analysis has highlighted the more productive NUTS2 (Nomenclature of territorial units for statistics) which are considered the basic regions for the application of regional policies, under cropland land use, and the scenario analysis has found potential non-conflictual land where it is profitable to establish cereal-oil crop rotations for food and energy purposes.

2.3.2 Description of the KPI and Methodology for KPI calculation

The identification of potentially suitable lands for Camelina production was undertaken in Deliverable 4.4, on the basis of the integration and analysis of different spatially explicit factors, compiled in a GIS environment.

The spatial suitability analysis was derived from the crop modelling results from:

- the simulations values achieved by calibrating the ARMOSA crop model (obtained by real field experiments retrieved in published peer review papers);
- the meteorological daily data from the Gridded Agro-Meteorological Data in Europe;
- selected soil traits derived from LUCAS soil module (Soil organic carbon and soil texture) and environmental factors such as Slope and Aspect.

Marginality was recently framed as a dynamic concept in time and space [2]. The changing meaning of marginal land can be managed by choosing the right agronomic technique and conservation agriculture practices that can transform marginal land into an optimal soil condition or incorrect management can degrade prime land into marginal land.

Three Scenarios were developed in Deliverable 4.4:

- **Scenario CAMBAR 211**: based on land type CORINE 211 (croplands);
- **Scenario CAMBAR 241-243**: based on land types CORINE 241 (Annual crops associated with permanent crops), CORINE 242 (Complex cultivation patterns), CORINE 243 (Land principally occupied by agriculture, with significant areas of natural vegetation)
- **Scenario CAMBAR 211+241-243**: based on land types CORINE 211 (Cropland), CORINE 241 (Annual crops associated with permanent crops), CORINE 242 (Complex cultivation patterns), CORINE 243 (Land principally occupied by agriculture, with significant areas of natural vegetation).

The Camelina potential seed yields (average 2000-2022) were estimated for the various land types and regions in each scenario and divided in five different classes:

- Class 1: 0-250 kg/ha
- Class 2: 251-780 kg/ha
- Class 3: 781-1500 kg/ha
- Class 4: 1501-2000 kg/ha
- Class 5: 2001-3900 kg/ha

Productivity for each NUTS2 region was then divided across the five classes. Based on the potential yield obtained from the ARMOSA model at NUTS 2 level over the considered time period, marginal lands were defined; the threshold used - at NUTS 2 level – is the average yield found in the literature (1458 kg/ha). According to that, the above-defined Class 1 to 3 are the ones that identify marginal lands. Figure 5 below shows the connection between yield classes (on the left) and land marginality (on the right).

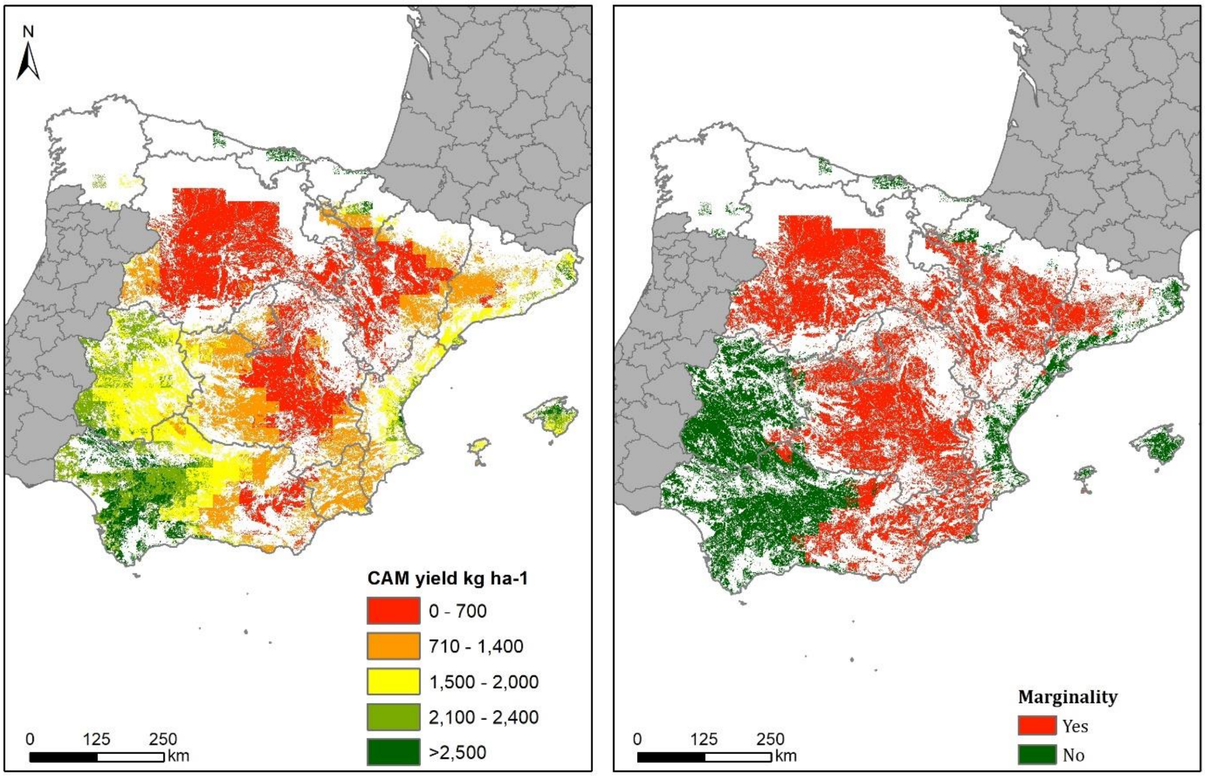

Figure 5: ARMOSA CAM model average yield 2000-2020 kg/ha for Spain, reporting the connection between yield classes (left) and land marginality (right)

2.3.3 Results

Output is provided at NUTS2 regions level. The complete tables are reported in Annex 1; this section presents the results for the three scenarios both at local level using color scales on map and at an aggregated level.

Figure 6 presents the results from the croplands-based scenario CAMBAR 211.

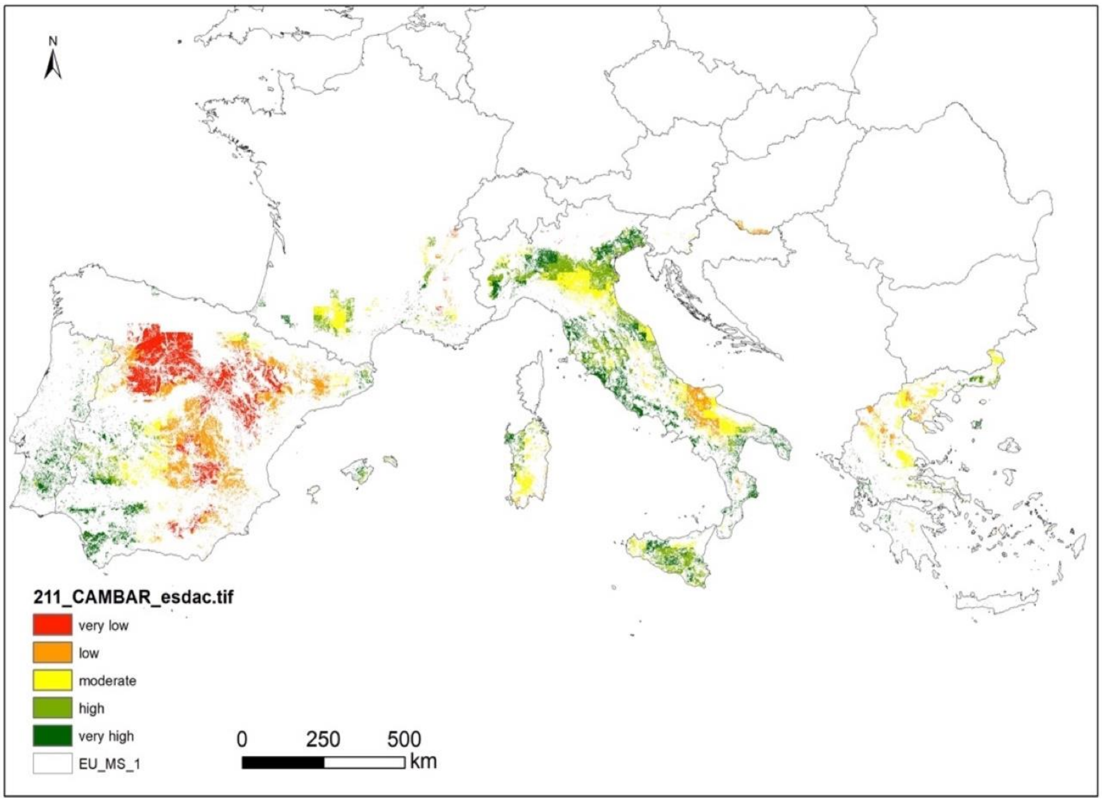

Figure 6: Scenario CAMBAR 211, based on land type CORINE 211 (croplands)

Figure 7 presents the results from the scenario CAMBAR 241-243, based on land types CORINE 241 (Annual crops associated with permanent crops), CORINE 242 (Complex cultivation patterns), CORINE 243 (Land principally occupied by agriculture, with significant areas of natural vegetation).

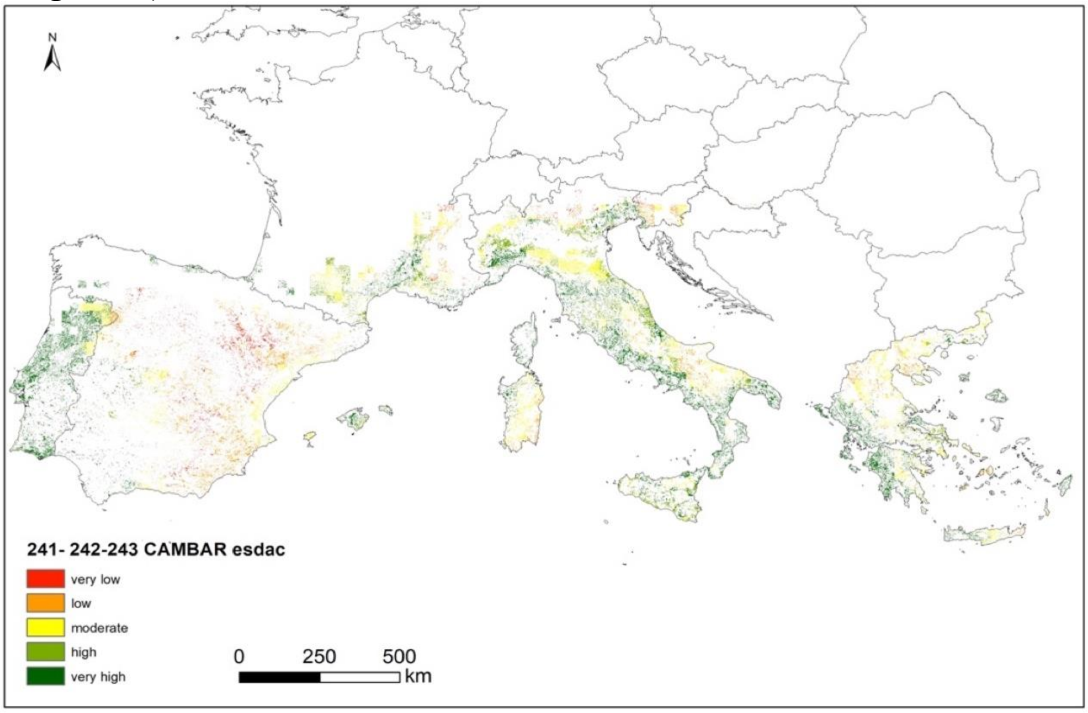

Figure 7: Scenario CAMBAR 241-243, based on land types CORINE 241 (Annual crops associated with permanent crops), CORINE 242 (Complex cultivation patterns), CORINE 243 (Land principally occupied by agriculture, with significant areas of natural vegetation)

Figure 8 presents the results from the scenario CAMBAR 211+241-243, which is the combination of the other two scenarios.

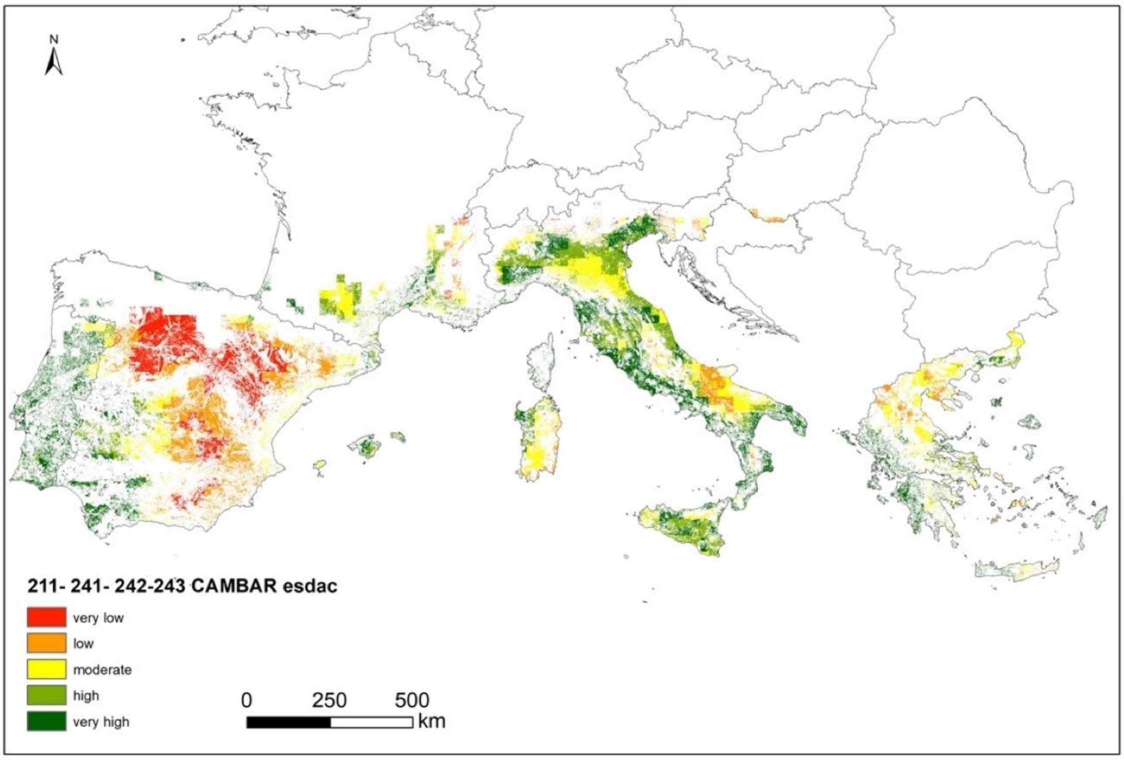

Figure 8: Scenario CAMBAR 211+241-243, based on land types CORINE 211 (Cropland), CORINE 241 (Annual crops associated with permanent crops), CORINE 242 (Complex cultivation patterns), CORINE 243 (Land principally occupied by agriculture, with significant areas of natural vegetation)

Finally, Figure 9 presents the aggregated results for total feedstock (seeds) production in the three scenarios. Since the yield data were available as classes (thus as ranges), total productivity in each scenario was calculated using both an *average yield* (central value) for each class and also using the *max yield* (upper extreme) of each class. The two sub-scenarios are named accordingly in the figure.

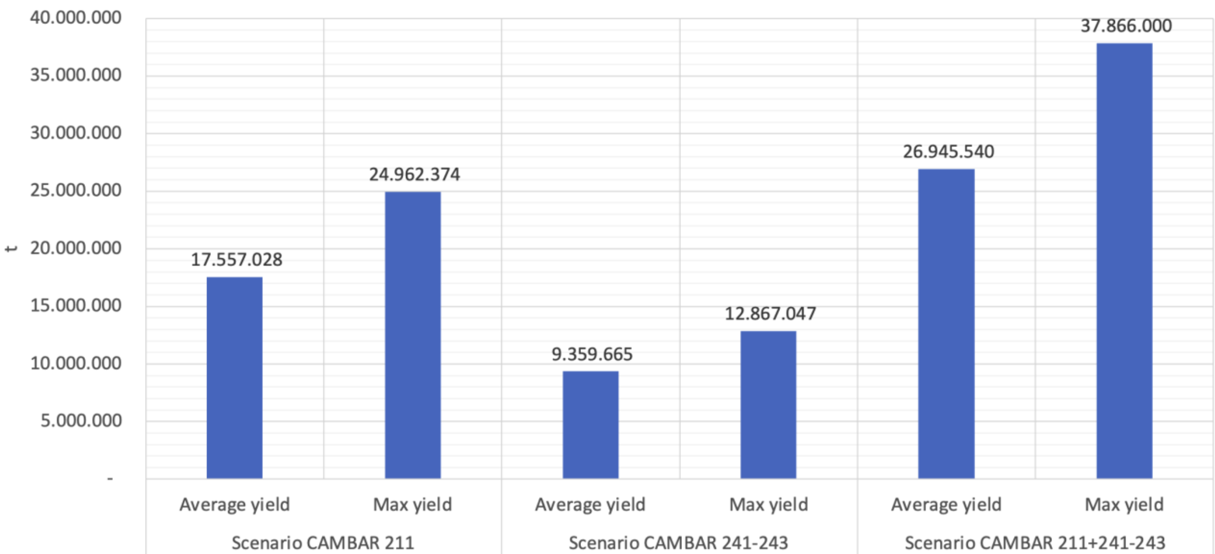

Figure 9: Aggregated results for total feedstock (seeds) production in the three scenarios

3 SOCIO-ECONOMIC KPIs

3.1 SE1: Improvement of the economic viability of the the biojet production: considering a reference price of 2000 €/t, biojet, achieve a reduction, under similar costs reduction for the feedstock, of 20%, with targeted price ≤1400 €/t.

3.1.1 Brief description of context

A significant increase in prices started before the Russian invasion of Ukraine but skyrocketed up to the second semester of 2022. In the second half of 2022, average household electricity prices in the EU continued to show a sharp increase compared with the same period in 2021; average gas prices also increased compared with the same period in 2021, reaching prices that are the highest on Eurostat's record.

In the first semester of 2023, electricity and natural gas prices have shown signs of stabilizing, partly due to policies and interventions by EU governments. EU countries opted for various measures, such as reducing taxes and fees, temporary tax waivers to consumers, price caps, providing lump sum support or allocating vouchers to final consumers, and some countries applied regulated prices.[1] The following Figure 10 and Figure 11 respectively show the trend of electricity and natural gas prices for non-household consumers.

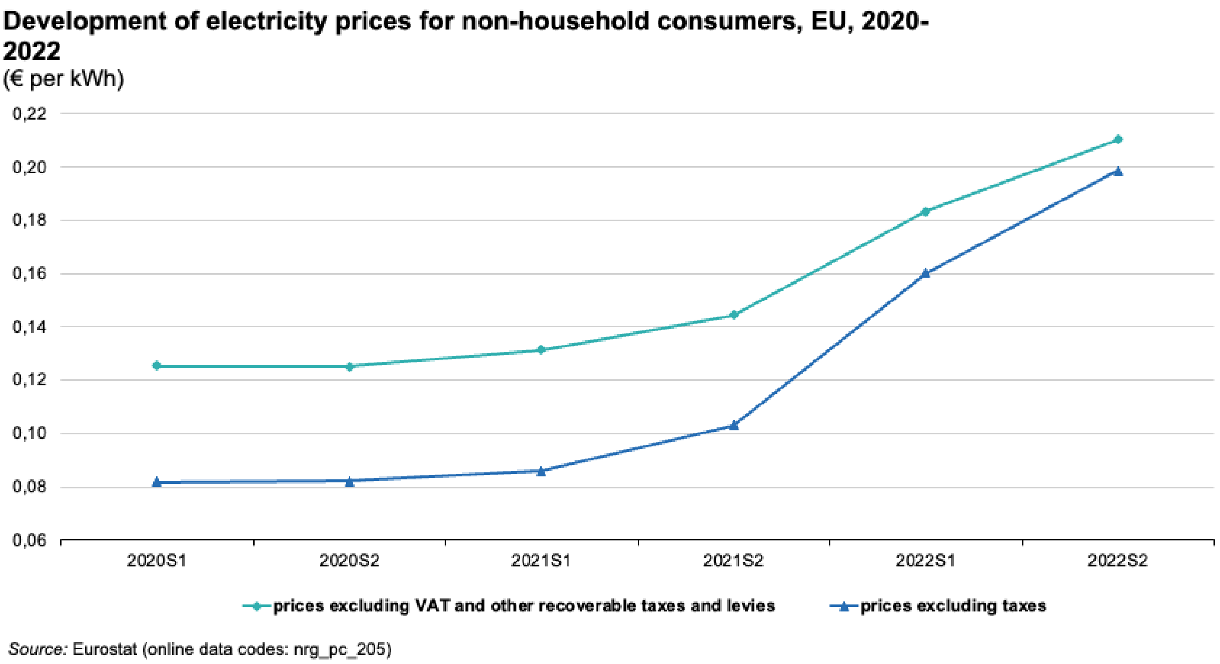

Figure 10: Price trend of electricity for non-household consumers (Source: Authors' elaboration on https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Electricity_price_statistics#Electricity_prices_for_non-household_consumers)

[1]Source: Eurostat (https://ec.europa.eu/eurostat/web/products-eurostat-news/w/DDN-20230426-2#:~:text=In%20the%20second%20half%20of,€28.4%20per%20100%20kWh.)

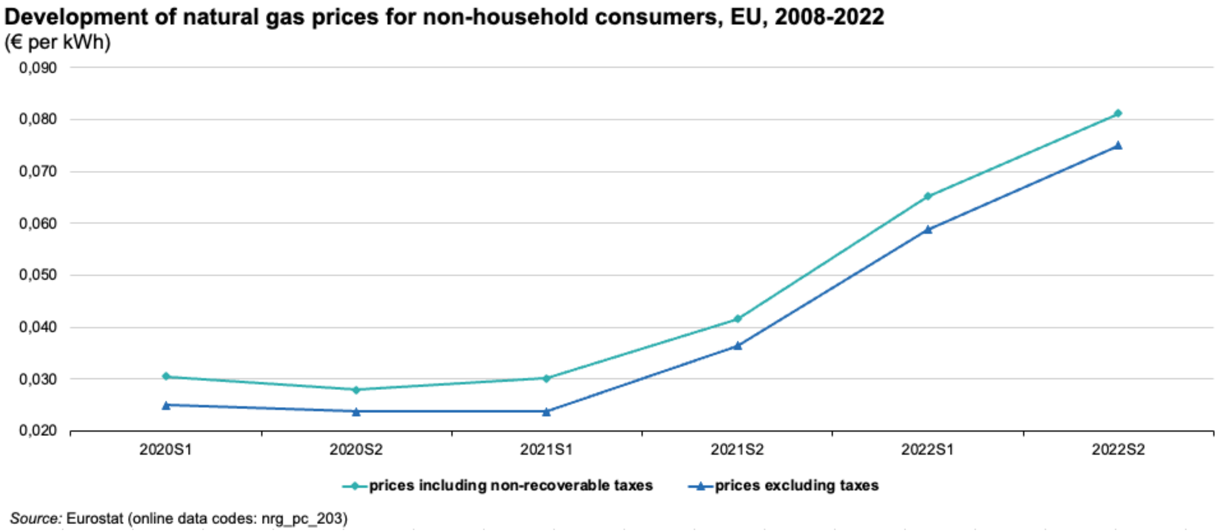

Figure 11: Price trend of natural gas for non-household consumers (Source: Authors' elaboration on https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Natural_gas_price_statistics#Natural_gas_prices_for_non-household_consumers)

3.1.2 Results

The reference production cost of about 2000 €/t had been set according to feedstock agreements for the residual period of 2021 and utilities (including natural gas and electricity) average price of first 5 months of 2021. Looking at the real prices during 2022 with focus on August and September months:

a. Regenerated feedstock price for the residual period of 2021 (according to existing agreements in place) of about 1200 €/t, while during 2022 the average price was 33% higher and even 50% higher during August/September 2022
b. Utilities: both natural gas and electricity showed, in comparison with first five months 2021 average price, an increase of about 3 times for 2022 average price (+300%) and even 6 times for august/September 2022 average price (+600%)

Both these effects dramatically affected the biojet production unit cost grown up to 2800 €/t according to 2022 average prices and 3500 €/t during August/September 2022.

Thus the targeted reduction price was not achievable given the market conditions under the HEFA-biojet production period.

3.2 SE2: Compliance to sustainability biofuels standards (RSB, ISCC, or similar).

3.2.1 Brief description of context

In order to avoid negative impacts related to SAF production, it is possible to adhere to the multi-stakeholder standards as set up by sustainability certification schemes. Certification under a scheme can happen on a voluntary basis to demonstrate sustainability; they can also be required to claim emission reductions under specific policy schemes or regulatory frameworks such as CORSIA and RED II.

The International Sustainability and Carbon Certification (ISCC+) and Roundtable on Sustainable Biomaterials (RSB) could be considered as the two main organizations relevant for SAF. RSB is commonly seen as a most ambitious standard, especially concerning feedstock, but it also involves more administration and in-person auditing.

In order to have a global overview of the status of different sustainability schemes a review of the most common standard or regulations used in the biofuel sector was provided in Deliverable 5.2; SAF eligibility in various schemes has been reviewed, and results summarized in Table II below (it also consider the Renewable Fuel Standard – RFS – program for USA and the Carbon Offsetting and Reduction Scheme for International Aviation – CORSIA – at global level).

Table II: Comparison of sustainability schemes and standards (Source: Deliverable 5.5)

Standard-Regulation		RED II	ISCC	RSB	RFS	CORSIA
Scope						
Geographical coverage of scheme		EU	EU	EU	USA	Global
Feedstock		Multiple agricultural feedstock, UCO, and agricultural residues	Multiple agricultural feedstock	Multiple agricultural feedstock	Multiple agricultural feedstock, MSW, UCO and agricultural/forestry residues	Multiple agricultural feedstock, MSW, UCO and agricultural/forestry residues
Sustainable criteria						
Environmental	GHG saving	✓	✓	✓	✓	✓
	Land criteria	✓	✓	✓	✓	✓
	Biodiversity protection (soil, water, ecosystems..)	✓	✓	✓	✓	✓
Social	Labour right and working conditions	X	✓	✓	X	X
	Land use right	X	✓	✓	X	X
	Food security	X	X	✓	X	X
Economic						
	Economic stability	X	X	X	X	X

3.2.2 Methodology for KPI calculation

Certification of compliance of Eni's biofuels produced within BIO4A was required.

In parallel, a set of indicators defined in the social impact study carried out in Task 4.4 were used to evaluate the compliance of the BIO4A value chain with different aviation fuel standards and certifications. Certification schemes related with biofuels, such as Roundtable on Sustainable Biomaterials (RSB), International Sustainability Et Carbon Certification (ISCC) and Certified sustainable Palm Oil, were reviewed to check the social indicators included. Different impact categories were analysed: Human and labour rights, rural and social development, local food security, land rights, working conditions, health and safety.

The survey carried out in task 4.4 has been conducted for each partner involved in the value chain to self-assess itself, according to the organisation's internal regulations and local laws, as each partner is aware of these aspects.

The indicators were originally analysed qualitatively; in order to comply with the reporting requirements of this deliverable, the indicators have been taken as a reference and adapted to present the results in a quantitative fashion.

The following list reports a brief description of each indicator, as described in Table III:
Workers:

- Health and safety: Assess the incidents and the status of prevention and management practices.
- Fair wages: Evaluate whether practices related to employee wages are in compliance with regulations and whether the wage offered complies with legal requirements, and whether it can be considered a living wage.
- Forced labour: Practices such as the use of compulsory prison labour by private commercial entities, debt bondage and human trafficking are discussed.
- Equal opportunities: The Company’s equal opportunity management practices and the presence of discrimination in the opportunities that organizations offer to workers and in working conditions are evaluated.
- Freedom of association and collective bargaining: The freedom of workers to form and join organizations of their own choosing, to promote and defend their interests, and to bargain collectively with other parties is assessed.
- Work-life balance: The number of hours actually worked is checked to ensure that it complies with International Labour Organization standards and, when overtime occurs, it is compensated in cash or time off.

Local Community:

- Health and safety: Assesses the general safety conditions of the organizations' operations and their impact on public health.
- Access to tangible resources: Assesses the general safety conditions of the organizations' operations and their impact on public health.
- Community engagement: Evaluates the extent to which organizations respect, provide or improve community access to local material resources and infrastructure
- Employment: The extent to which the company or facility creates new jobs in a manner which contributes to the economic development of the community.

Value chain actors:

- Land rights: Assess small-scale entrepreneur’s legal rights and tenure security.
- Fair trade relations: Analyze the quality of the business relationship between small entrepreneurs and value chain actors.
- Raw material: Follow up on the procurement of raw materials from the company and its suppliers
- Conflict zones: Knowing whether or not suppliers are in conflict zones

- Child labour: Ensure that all work is appropriate to the subject´s age and physical condition.

3.2.3 Results

All Eni's biofuels productions for export, including HEFA biojet, are compliant with both ISCC EU and 2BSVS while, as required by Italian law, production to satisfy Italian requirements are certified under the SNC (Sistema Nazionale di Certificazione – National Certification System).

Table III below reports the results from Task 4.4 activities. Equal weights have been assigned to calculate an overall value (last row of each group) for each target group (Workers, Local Community and Value Chain Actors). The first column contains the indicators. Compliance criteria are included in columns (2-5).

Table III[2]. Compliance of social standards in the Bio4A value chain. Equal weights were assigned to calculate an overall value (last row of each group) for each target group (Workers, Local Community and Value Chain Actors). The first column contains the indicators considered. The level of compliance is included in columns (2-5).

Indicator	Weighting			
	Non-compliant situation, improving 0%	**Compliance with local laws^{A} 50%**	**Progress beyond compliance 80%**	**Ideal performance 100%**
Workers				
1.1: Health and safety				1.6
1.2: Fair wages				1.6
1.3: Forced labour		0.8		
1.4: Equal opportunities			1.2	
1.5: Freedom of association and collective bargaining			1.2	
1.6: Work-life balance (WORKING HOURS)				1.6
Total			**8.0**	
Local community				
2.1: Health and Safety			2.0	
2.2: Access to tangible resources			2.0	
2.3: Community engagement		1.25		
2.4: Employment			2.0	
Total		**7.25**		
Value Chain Actors				
3.1: Land rights				2.0
3.2: Fair trade relation			1.6	

[2] For more information on the structure, scoring and explanation of the survey carried out for this assessment; please refer to deliverable 4.5.

3.3: Raw materials			1.6	
3.4: Conflict zones			1.6	
3.5: Child labor			1.6	
Total			**8.4**	

A: The local laws in accordance with The climate Community & Biodiversity Alliance, [3]: "include all legal norms given by organisms of government whose jurisdiction is less than the national level, such as departmental, municipal and customary norms".

The first group analysed was the workers, where the weight of the indicators was evenly distributed, and six indicators were evaluated. The result placed them within the third criterion, with a score of 8.0 out of 10.00 indicating that the analysed criteria go beyond local regulations and are related to the sections proposed by the certifiers.
In the second group the local community was analysed. For this section four indicators were define, and the score was 7.25 out of 10.00, placing them within the section on compliance with local standards, which is why they comply with the criteria analysed.
The last group analysed was related to the supply chain stakehoders, with five indicators analysed. This case obtained the highest score of the three groups: 8.4, placing them in compliance beyond what is required by local standards.
Finally, it should be noted that the value chain complies with the criteria analysed. In addition, one of the partners involved in the value chain has already been certified with ISCC CORSIA.

3.3 SE3: Social and techno-economic sustainability of potential feedstock production on marginal land is assessed through the measurement of a set of sustainability indicators (including but not limited to Land tenure, Change in income, Jobs in bioenergy sector, Modern energy access, Productivity, Net energy balance, Gross value added, Trainings, Infrastructures and logistics for bioenergy distribution, Capacity and flexibility of use of bioenergy).

This KPI is composed by a set of indicators, each one addressing social and techno-economic sustainability of feedstock production from different perspectives. For some indicators, no relevant data was available, either directly from project activities results or from literature, more specifically:

- **Modern energy access**: Spain and Italy locations where the field trials took place already have full access to modern energy; no granular data was available in literature on the topic regarding the Mediterranean region.
- **Trainings**: no information was available in literature on the topic regarding the Mediterranean region.
- **Capacity and flexibility of use of bioenergy**: while wide literature is available on the topic (i.e. IEA Task 44, among the others), quantifiable data from field trials was unavailable. The main product, camelina seeds were addressed toward SAF production; seed husk, considered as a co-product, could indeed be addressed toward different final uses, i.e. heat production, but this was not considered in project activities.

3.3.1 Methodology for KPI calculation and Results

3.3.1.1 Change in income and Land tenure

For the purpose of this KPI, two indicators related to feedstock production (Change in income and Land tenure) were evaluated. As these had not previously been assessed per se, certain indicators used in Task 4.4 were adapted and utilised. This evaluation was addressed in terms of self-perception of compliance by the stakeholders in the value chain, who were enquired on various social aspects in such task. Therefore, interpretation of the presented numerical results should only be taken as an indicative approach of actual compliance with local legislation.

The logics behind the construction and respective assessment of the indicators presented in this section were identical to those reported for SE2. This approach is based on the qualitative study carried out in Task 4.4. Please refer to deliverable 4.5 for precise information on the structure, scoring and explanation of the survey carried out for this assessment. Results are presented in Table IV below.

Table IV: Results from stakeholders interviews related to Change in Income and Land tenure indicators

Indicator	Weight %	Corresponding indicator of task 4.4	Perception of compliance by stakeholders: Non-compliant situation 0%	Compliance with local laws 50%	Progress beyond compliance 80%	Ideal performance 100%
Indicator 1: Change in income	50%	Fair wages: Indicator 1.2	-	-	3.75	-
Indicator 2: Land tenure	50%	Lands rights: Indicator 3.1	-	-	-	5
Total					**8.75**	

The result for this section in the three indicators grouped and evaluated gives a score of 8.75, resulting in a perception of compliance beyond local laws. Going one step ahead of only complying with local laws allows a change in income and gives land tenure security.

3.3.1.2 Jobs in the sector

A methodology has been prepared to link T3 "*Total feedstock production*" KPI as defined in Section 2.1 with the expected new jobs in the bioeconomy sector related to the turnover generated by the entire value chain. Figure 12 summarizes the main inputs and the overall structure of the methodology.

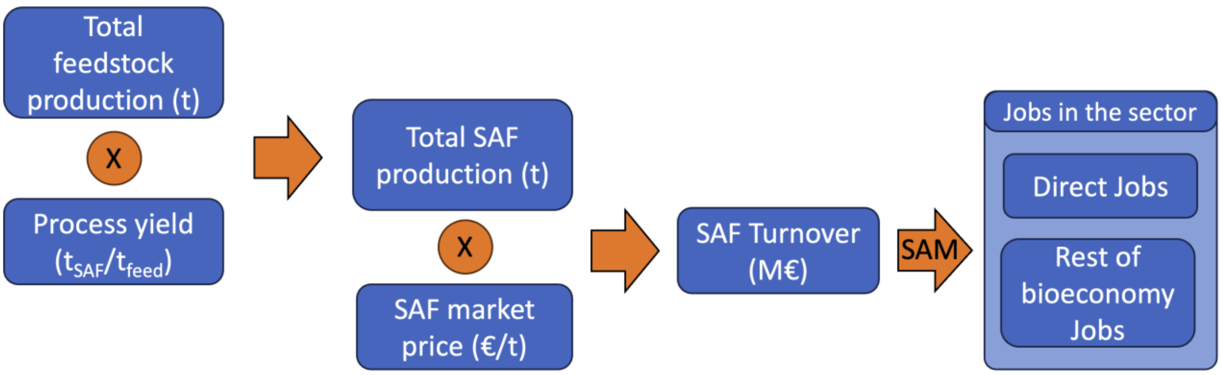

Figure 12: Methodology for the evaluation of the New Jobs in the bioeconomy sector related to expected feedstock production

Crucial is the use of a social accounting matrix (SAM), to convert the turnover related to SAF sales (M€) in Full-Time Equivalent Jobs (FTE). A social accounting matrix (SAM) is a database that includes all transactions between economic operators in the economy at a specific period together with organized economic and social data. For a specific period of time, this matrix offers a coherent and comprehensive account of all economic transactions involving institutions, production, and markets, as well as those involving markets, savings and investments, households, the government, and the rest of the world.

The multiplier used in this analysis is taken from [4] which defined a new set of SAMs specifically designed for studying the EU bioeconomy and natural resources, called BioSAMs

[5]; BioSAMs incorporated additional biomass sources, biotechnology applications, fuel, electricity, and chemical substances. The multiplier provided in [4] refers to a 2nd generation biofuel value chain and it is weighted at 15,37 FTE/M€.

Moreover, [4] provides also a further disaggregation of the results in Direct, Rest of bioeconomy, Indirect and Induced Jobs, as described in Figure 13.

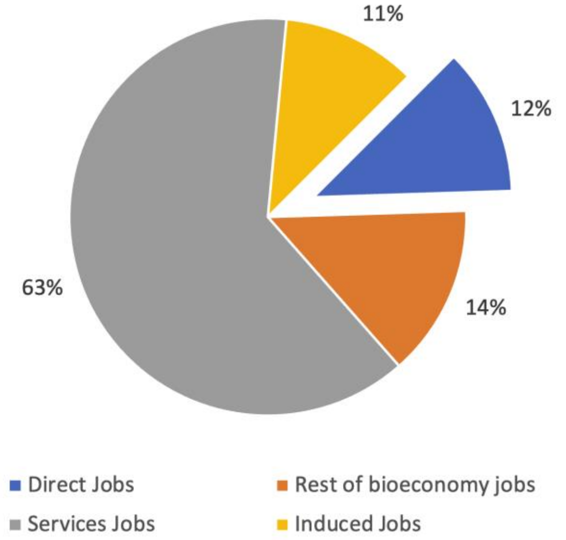

Figure 13: Direct, Rest of bioeconomy, Indirect and Induced Jobs shares, as described in [4]

All the information related to conversion and process yields are taken from Deliverable 4.3; two different levels of expected SAF prices are considered: 2.000 €/t as a baseline, and 2.800 €/t as defined in Section 3.1. The combinations of the various inputs were used to define a Low and High sub-scenario for each of the three feedstock production scenario defined in Section 2.3. Only Direct Jobs and Resto of bioeconomy Jobs were considered; the results are reported in Figure 14.

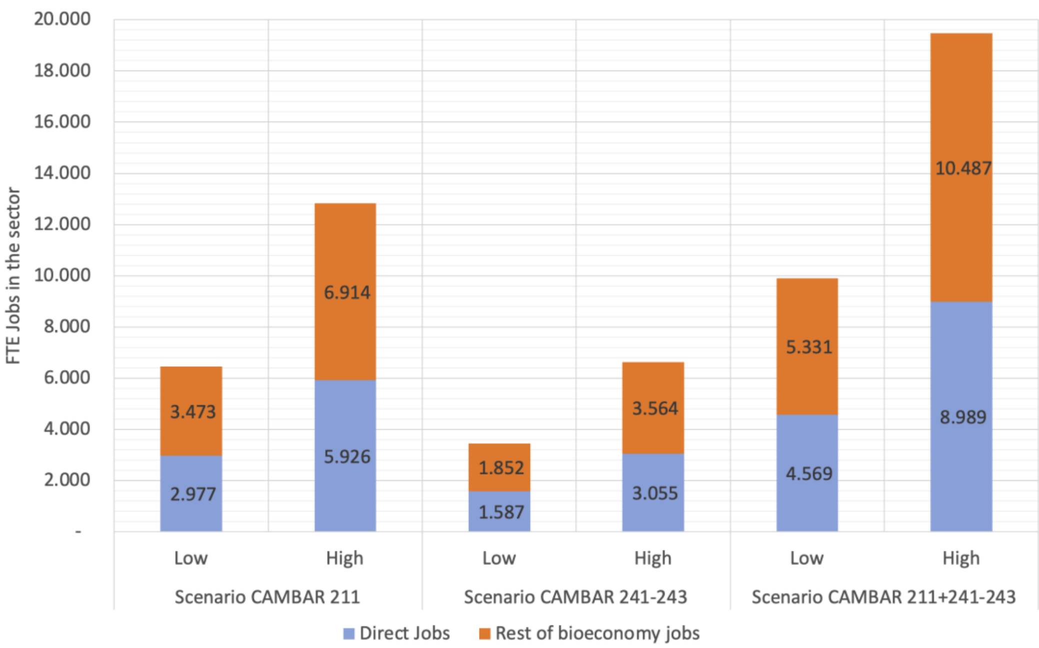

Figure 14: Summary of the results from Jobs in the sector evaluation

3.3.1.3 Productivity

The JRC GIS model provided data on productivity at NUTS 2 regions level; depending on the region and on the considered yield (see section 2.1.3 for further information on the methodology), average productivity in the entire region ranges between 0,59 t/ha and 1,09 t/ha of camelina seeds, as reported in Figure 15.

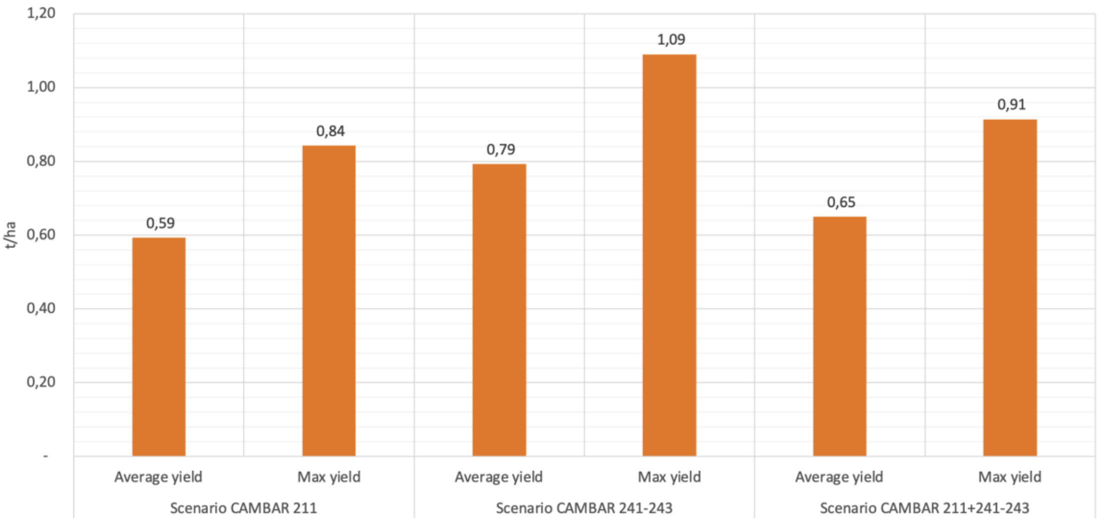

Figure 15: Aggregated results for total feedstock yields in the three scenarios

The productivity data obtained from the cultivation tests in Spain (conducted by CCE) and Italy (conducted by Re-Cord) are presented in Table V.

Table V: Seed yields obtained from the cultivation tests in Spain and Italy, conducted as part of BIO4A activities

	Harvest (t/ha)
Spain – Mineral Fertilizer	1,16
Spain – Biochar + Mineral Fertilizer	1,41
Spain – Compost	1,55
Spain – Combi (Compost (85%) + Biochar (15%))	1,99
Italy – Mineral Fertilizer	0,88
Italy – Biochar + Mineral Fertilizer	1,37
Italy – Compost	0,88
Italy – Combi (Compost (85%) + Biochar (15%))	1,49

3.3.1.4 Net Energy Balance

The *net energy balance* for Camelina cultivation phase is reported to be quite positive in literature. The energy output from the crop exceeds the energy input from the production process by a factor of 2 to 2.5, [6], [7] in US and Turkey. This is a very efficient energy balance, which is important for a sustainable agricultural system. This shows that Camelina is a highly efficient source of renewable energy. The calculation considered includes energy requirements for land preparation, sowing, fertilizing, weed control, and harvesting. Overall, Camelina cultivation in Europe can be assumed as net energy-positive activity.

The *net energy balance* has been calculated using the real data from BIO4A field activities as an energy return on investment, as follows:

$$Net\ Energy\ Balance = \frac{Diesel\ Consumption}{Seed\ Yield\ *\ LHV\ seed}$$

The following values have been considered in the calculation:

- LHV_{seed} = 25.42 MJ/kg
- LHV_{diesel} = 36 MJ/L

The overall findings from field activities are reported in Table VI,together with Net Energy Balance results.

Table VI: Seed yields, diesel consumption for agricultural activities and Net Energy Balance results

	Production	Diesel consumption		Net energy Balance
	Seed yield (kg/ha)	Diesel, L/ha	Diesel, MJ/ha	MJ_{Diesel} / MJ_{seed}
Spain – Mineral Fertilizer	1162	29	1044	0,035
Spain – Biochar + Mineral Fertilizer	1411	31,3	1126,8	0,031
Spain – Compost	1551	37,2	1339,2	0,034
Spain – Combi (Compost (85%) + Biochar (15%))	1987	37,2	1339,2	0,027
Italy – Mineral Fertilizer	877,3	29	1044	0,047
Italy – Biochar + Mineral Fertilizer	1368	36	1296	0,037
Italy – Compost	879,1	56,5	2034	0,091
Italy – Combi (Compost (85%) + Biochar (15%))	1493,1	56,5	2034	0,054
Average values	**1341,1**	**39,1**	**1407,2**	**0,044**

3.3.1.5 Gross Value Added

Data from Deliverable 4.7 has been used for the calculation of this indicator. In D4.7, production costs and profitability of selected oil crops have been analysed to estimate where and how cultivation has a positive socioeconomic impact in the EU. Total Production Costs (TPCs), obtained by summing the expenses for the depreciation of fixed assets including buildings and equipment, were compared with a range of selling prices in order to evaluate plausible Net Farm Profit (NFP) and profitability index (PI). Expected yields for different land qualities were also included in the analysis, The results are reported in Table VII below.

Table VII: Net Farm Profit (NFP) and profitability index (PI) for low quality and average farming land (in bold those with negative margins and profitability).

	Average market selling prices (€/t) Low quality land			Average market selling prices (€/t) Average farming land		
Crop	**NFP (€/ha)**	**NFP (€/t)**	**PI**	**NFP (€/ha)**	**NFP (€/t)**	**PI**
Rapeseed	99	66	1.23	577	192	2.2
Barley	−16	−5	0.96	224	45	1.46

3.3.1.6 Infrastructure and logistics

Data for the calculation of this indicator was taken from Deliverable 4.3, as reported in Table VIII; based on information related to each transportation step, the total transportation effort needed for each considered value chain was evaluated.

Table VIII: Life Cycle Inventory for transportation phase. Functional Unit: 1 MJ SAF produced, delivered and used.

Item	Value	Unit	Comments
UCO collection			Based on JRC (2019)
Truck	0.13	tkm	100 km (80% of UCO)
Ship	2.36	tkm	7,000 km (20% of UCO imported from Asia)
TOTAL	0,58	tkm	
Tallow collection			Based on JRC (2019).
Truck	0.27	tkm	162 km
Harvest (seed+husk), cultivation site – crushing facility			
Truck, ES	0.24	tkm	50 km Assumed
Truck, IT	0.24	tkm	50 km Assumed
Camelina oil, Central Spain – Valencia			
Truck	0.62	tkm	371 km. Toledo assumed as departing point
Camelina oil, Valencia – Gela			
Ship	2.18	tkm	1,296 km. Estimated with https://sea-distances.org/
Camelina oil, Inner Sicily – Gela			
Truck	0.17	tkm	100 km Assumed
Jet fuel/Naphtha mix, Gela – Livorno			
Ship	0.05	tkm	856 km. Estimated with https://sea-distances.org/
Neat SAF, Livorno – Amsterdam port			
Ship	0.09	tkm	4,171 km. Estimated with https://sea-distances.org/
Blended SAF, Amsterdam port – Schiphol airport			
Pipe	7.27E-04	tkm	16 km
Blended SAF, Livorno – Fiumicino airport			
Truck	0.02	tkm	387 km

The value chains considered are:

- **Tallow – Fiumicino airport:**
  1. delivery of Tallow to Gela refinery
  2. transportation of Jet fuel/Naphtha mix from Gela to Livorno
  3. transportation of blended SAF from Livorno to Fiumicino airport
- **Tallow – Schiphol airport:**
  1. delivery of Tallow to Gela refinery
  2. transportation of Jet fuel/Naphtha mix from Gela to Livorno
  3. transportation of neat SAF from Livorno to Amsterdam port
  4. transportation of blended SAF from Amsterdam port to Schiphol airport
- **Italy-based Camelina – Fiumicino airport:**
  1. Harvest (seed+husk) on cultivation site and transportation to crushing facility
  2. Camelina oil transportation from Inner Sicily to Gela

3. transportation of Jet fuel/Naphtha mix from Gela to Livorno
4. transportation of blended SAF from Livorno to Fiumicino airport

- **Italy-based Camelina – Schiphol airport:**
  1. Harvest (seed+husk) on cultivation site and transportation to crushing facility
  2. Camelina oil transportation from Inner Sicily to Gela
  3. transportation of Jet fuel/Naphtha mix from Gela to Livorno
  4. transportation of neat SAF from Livorno to Amsterdam port
  5. transportation of blended SAF from Amsterdam port to Schiphol airport
- **UCO – Fiumicino airport:**
  1. delivery of UCO to Gela refinery
  2. transportation of Jet fuel/Naphtha mix from Gela to Livorno
  3. transportation of blended SAF from Livorno to Fiumicino airport
- **UCO – Schiphol airport:**
  1. delivery of UCO to Gela refinery
  2. transportation of Jet fuel/Naphtha mix from Gela to Livorno
  3. transportation of neat SAF from Livorno to Amsterdam port
  4. transportation of blended SAF from Amsterdam port to Schiphol airport
- **Spain-based Camelina – Fiumicino airport:**
  1. Harvest (seed+husk) on cultivation site and transportation to crushing facility
  2. Camelina oil transportation from Central Spain to Valencia
  3. Camelina oil transportation from Valencia to Gela
  4. transportation of Jet fuel/Naphtha mix from Gela to Livorno
  5. transportation of blended SAF from Livorno to Fiumicino airport
- **Spain-based Camelina – Schiphol airport:**
  1. Harvest (seed+husk) on cultivation site and transportation to crushing facility
  2. Camelina oil transportation from Central Spain to Valencia
  3. Camelina oil transportation from Valencia to Gela
  4. transportation of Jet fuel/Naphtha mix from Gela to Livorno
  5. transportation of neat SAF from Livorno to Amsterdam port
  6. transportation of blended SAF from Amsterdam port to Schiphol airport

The resulting values for each considered value chain are reported in Table IX.

Table IX: Resulting values, in tkm/MJ_{SAF}, for each complete value chain evaluated

Tallow - Fiumicino	0,34	tkm/MJ_{SAF}
Tallow - Schiphol	0,41	tkm/MJ_{SAF}
Italy-based Camelina - Fiumicino	0,48	tkm/MJ_{SAF}
Italy-based Camelina - Schiphol	0,55	tkm/MJ_{SAF}
UCO - Fiumicino	0,65	tkm/MJ_{SAF}
UCO - Schiphol	0,72	tkm/MJ_{SAF}
Spain-based Camelina - Fiumicino	3,11	tkm/MJ_{SAF}
Spain-based Camelina - Schiphol	3,18	tkm/MJ_{SAF}

4 ENVIRONMENTAL KPIs

4.1 E1: GHG emissions saving respect to fossil Jet A1 meeting the EU regulation in place at the moment of production. Considering a reference of 83,3 gCO2eqMJ jet fuel, achieve GHG savings of at least 60%, targeting 70% (in line with the new targets proposed by the EC in the RED 2).

4.1.1 Background

The Renewable Energy Directive recast (REDII) targets 32% share of renewable sources to the gross final consumption of energy in the European Union by 2030. In the same terms, a specific goal of 14% share for the transport sector is also set. Besides, RED II further regulates how accounting to meeting these targets shall be performed. In particular, amongst other specifications, as of January 2021, biofuels are required to provide greenhouse gas emission savings of 65% when confronted to a fossil reference of 94 g CO_2 MJ^{-1} used fuel. This rule is applicable to aviation biofuels, which can particularly contribute to meeting the target, for aviation is left out of the calculation of the gross final energy consumption (denominator), while accountable and even fostered when calculating the consumption of renewables (numerator). Specifically, with the exception of those produced from food and feed crops, a multiplier of 1.2 is applied to the energy content of aviation biofuels. Further, certain feedstocks are indicated as eligible to contribute with twice their energy content. In the project, this is applicable to Used Cooking Oil (UCO) and tallow. In accordance to this background, compliance of emission savings has been analysed in the context of Bio4A.

4.1.2 Methodology for KPI calculation

As mentioned, RED II also indicates how emissions shall be calculated. The methodology follows a life cycle approach, which covers the complete value chain, from the extraction/production of raw materials to the usage of the produced biofuel. The following expression is utilised:

$$E = e_{ec} + e_l + e_p + e_{td} + e_u - e_{sca} - e_{ccs} - e_{cr}$$

E	Total emissions from the use of the fuel
e_{ec}	Emissions from the extraction or cultivation of raw materials
e_l	Annualised emissions from carbon stock changes caused by land-use change
e_p	Emissions from processing
e_{td}	Emissions from transport and distribution
e_u	Emissions from the fuel in use
e_{sca}	Emission savings from soil carbon accumulation via improved agricultural management
e_{ccs}	Emission savings from CO2 capture and geological storage
e_{cr}	Emission savings from CO2 capture and replacement

In particular, a term is included to account for carbon stock changes caused by land-use change in biofuels produced from crops (e_l). This in turn includes a sub-term, which is a bonus of 29 g MJ^{-1} biofuel which may be applied if the feedstock is obtained from restored degraded land. This aspect has been considered in Bio4A, as a dedicated effort to map suitable locations for camelina cultivation in the EU Mediterranean area has been made in the project.

Moreover, the e_{sca} factor defines the impact of improved agriculture management practices on soil carbon stock, and reports it in terms of biofuel emission savings; The agriculture management practices accepted for the purpose of e_{sca} calculation, beside from biochar use, also include: shifting to reduced or zero-tillage, improved crop/rotation, the use of cover crops and crop residue management, and the use of organic soil improver such as compost, manure fermentation, digestate, etc.

4.1.3 Results

An extensive set of cases was analysed by assuming different locations, logistic options and agricultural protocols (particularly the application of different soil amendments) for camelina cultivation.
The calculations introduced the above-mentioned e_{sca} term (emissions savings from improved agricultural management), included in REDII methodology, whose application has been limited up to now, via two different approaches to the quantification of the change in soil carbon stock:

1. one based on theoretical calculations, related to the content of fixed carbon in the soil amendments applied and
2. other based on experimental measurements from field trials carried out by Bio4A partners.

Encouraging results were observed for all the studied cases, for the calculated Greenhouse Gas (GHG) emission savings were always >65%, as required by REDII for biofuels to be quantified for national renewable energy objectives. In particular, 89% and 85% savings were respectively estimated for UCO and Tallow.

Camelina cases provided even better savings, in the range of 107% - 128%. If the e_{sca} factor and degraded land bonus (e_B) contributions are excluded from calculation, the camelina cases – based on the experimental data obtained from BIO4A field trials in Spain and Italy – provide reduced GHG emission savings ranging from 65% to 74%, depending on the country and cultivation scenario.

However, it should be emphasized that the e_{sca}-related calculations necessarily need to be considered as a pilot application of the term, since large uncertainty is involved in soil sampling and SOC measurements. Further experimental work in this sense should be performed to strengthen our results.

Finally, the 45 gCO_{2eq}/MJ biofuel cap (as indicated in RED II) was not reached, given that only moderate amounts of soil amendments were applied in this first pilot experiment on very degraded soils in Spain and Italy.

4.2 E2: Environmental sustainability of feedstock potential production on marginal land is assessed through the measurement of a set of environmental sustainability indicators (including but not limited to Soil quality, Non GHGs emissions, Water use and efficiency, Water quality, Biodiversity, and Land use change).

4.2.1 Brief description of context

According to the JRC and Mission Board Soil Health and Food evaluation reported in the "A soil for Europe" 2020 Implementation Plan, land management practices, pollution, intensive agriculture, urbanization, and the consequences of climate change are responsible for the fact that 60–70% of Europe's soils are in poor health conditions. Nearly 30% of the EU 28 region is classified as marginal agricultural land as a result of this situation and of other biophysical limitations that are reducing agricultural productivity. Marginal agricultural land has little agricultural value, because crops grown there are expected to generate economical returns lower than any rent that should be paid to access the area. These lands would likely continue to deteriorate if left neglected, causing further reduction in biodiversity and likely amplifying the effects of climate change, including desertification.

This description is particularly fitting for the Mediterranean region: there, climate change is having a strong impact with an average temperature increase of 1,54 °C above pre-industrial values – which is 20% higher than global average – as reported by the 2020 UNEP/MAP State of the Environment and Development in the Mediterranean. More than 510 million people live in the Mediterranean area, and already 8.5 Mha are reported to be marginal land, and desertification is quickly progressing, as documented by EC JRC, EC EEA. In addition to that, a 2-4°C average temperature increase is expected to lead to a 30% rainfall reduction; thus, fighting climate change and adapting to it to are becoming key needs.

Within this framework, biomass cultivation for the production of biofuels has the potential to ensure the use and return profitability on marginal lands, while enhancing biodiversity by cultivating non-food crops for industrial use, that are climate-resilient and biodiversity-friendly.

The use of low ILUC-risk biomass from abandoned or unused land can be seen as a clear opportunity to cover part of the RED II targets for energy use in transport sector, especially considering the new and more ambitious updates and of the ever-growing competition for residual biomass streams, e.g., waste oils or straws.

Moreover, under feedstock producers' perspective, the cultivation of low ILUC risk biomass crops can offer an outlet to diversify their production, improve agricultural practices, and restore soil. Crop diversification would in turn lead to income diversification as well, through new markets and business models. By ensuring that the crops and cropping systems are integrated in a complementary manner to their current activities, this would lead to a win-win situation.

Bringing back to production very arid/marginal or even deserted agricultural areas may bring to reverse ILUC effects, with additional positive impacts on the food/feed chains. In fact, new agronomic models, rather than being in conflict with the conventional food/feed sector, will support the shift to more sustainable agriculture and positively contribute to the achievement of several SDGs and EU Green Deal goals.
It becomes crucial to evaluate this complex scenario from a wider perspective, considering all the impacts and needs related to the many levels involved, i.e.: land restoration, biomass cultivation for biofuels production, socio-economic development, sustainable agriculture, life on

soil and water, sustainable communities and, finally, the contribution to the SDGs and the EU Green Deal goals.

4.2.2 Description of the KPI and Methodology for KPI calculation

The Environmental sustainability of feedstock production was assessed through the application of the Convergence of Evidences (CoE) applied to the main soil and plant threats. The CoE is a research strategy that involves collecting data from multiple sources and methods to address a research question or hypotheses. It involves collecting data from multiple research methods (e.g. surveys, interviews, experiments, archival analysis), multiple sources (e.g. primary and secondary sources), and multiple contexts (e.g. different countries, different times). A set of five indicators were evaluated. Following a brief description of each of them is reported, for the sake of clarity[3]:

- **The Aridity Index (AI)** is a measure of the dryness of a climate. It is calculated by dividing the potential evaporation (ET0) of a region by its annual precipitation. The AI measures how much moisture is in the air compared to the amount of moisture that could theoretically evaporate from the region. The aridity index is an essential measure of climate because it tells us how much water is available in a given area. The AI is used to classify climates into five general categories: hyperarid, arid, semi-arid, sub-humid, and humid.
- **Soil compaction (SC)** is a process that changes the soil's physical structure, making it denser. This process is important for many reasons, including decreasing crop yields, controlling erosion, and improving soil quality. Compaction affects soil permeability, fertility, drainage, and ability to hold water and air. It can also reduce the amount of organic matter and nutrients available to plants and animals. Mechanical, chemical, or biological processes can cause SC. Excessive SC can reduce soil fertility, water and air permeability, and water-holding capacity.
- **Soil biodiversity** plays a vital role in the functioning of ecosystems and is necessary for sustainable agriculture, food security, and ecosystem services. Soil biodiversity can be conserved through several approaches. One of the most essential and effective strategies is establishing protected areas; additionally, the implementation of agroecological practices, such as crop rotation and cover cropping, can help to promote soil fertility and conserve soil biodiversity.
- **Soil erosion** is a process that occurs when soil or sediment is removed from a particular area by several different forces, such as wind, water, and human activities. It is a significant cause of land degradation and soil loss and can have profound implications for agricultural productivity, food security, and the environment. A variety of factors, including overgrazing, over-cultivation, and deforestation, cause soil erosion. These activities can lead to soil destabilization, which releases large amounts of soil particles. The RUSLE, or Revised Universal Soil Loss Equation, is a tool used to predict the rate of soil erosion. It combines the effects of rainfall intensity, soil erodibility, slope length, slope gradient, land management practices, and cover or vegetative cover.
- **Soil nitrogen** is a vital nutrient for plant growth and productivity, and it is essential for a healthy and productive agricultural system. However, when there is an excessive input of nitrogen into the soil, it can lead to a range of environmental problems. Excess nitrogen inputs in the soil can lead to nutrient imbalances, resulting in poor plant growth and reduced yields. It can also lead to increased soil erosion and leaching of nutrients, resulting in water pollution and soil degradation. Excess nitrogen can also lead to

[3] for extended descriptions, please refer to Deliverable 4.4

increased atmospheric nitrogen, contributing to air pollution. Excessive nitrogen inputs can come from natural and human activities, such as agriculture and industrial processes.

To assess the Environmental sustainability (ES) of the feedstock production in the study area, we used the CoE approach, the indicators taken into account were derived from evidence synthesis literature. Through an additive model, this approach allowed us to preliminarily evaluate the spatial patterns of soil degradation and, as a result, the environmental sustainability that feedstock cultivation for energy production will exert. The land cover analyzed is CORINE agricultural soils (code 2) which are the most exposed to pressure. Additionally, as a measurement of environmental potential for crop cultivation, the aridity index (AI) provides insights into the study area's potential sustainability for the cultivation of drought-tolerant camelina variety and other similar crops. Each indicator is reclassified in potential risk classes of Environmental Sustainability (ES) (Figure 8).
To understand the significance of these results, modelled yield and environmental sustainability have been reclassified using the Likert scale (1=low, 2=moderate, 3=adequate, 4=high and 5=very high). Table X presents the thresholds for a score-based classification of the above-describes soil and environmental indicators.

Table X: Soil and environmental indicators and proposed thresholds

Scores for class	Soil Erosion	Soil compaction[A] [Mg m-3]	Nitrogen inputs [kg ha-1 yr-1]	Soil biodiversity[B]	Aridity index AI[C]
5	<0.5	<1.3	<50	High	>0.65
4	0.5-1	1.3-1.4	50-80	Moderate -High	0.5–0.65
3	1-3	1.4-1.5	80-120	Moderate	0.2–0.5
2	3-5	1.5-1.5	120-150	Low Moderate	0.03–0.2
1	5-10	>1.6	>150	Low	<0.03

A: taken as a proxy from Soil Bulk Density from SoilGrid 0-30 cm
B: Potential threat to biological functions
C: ET0Annual V3 Robert J. Zomer, Jianchu Xu & Antonio Trabucco 2022

For the calculation of the overall ES scores, obtained as the sum of the various soil and environmental indicators scores for each considered region, a new set of classes was defined; it is presented in Table XIbelow.

Table XI: Classes definition for the overall ES scores

Classes definition	Environmental sustainability (ES) Class-related scores
Very high	20-25
High	15-20
Moderate	10-15
Low	5-10
Very low	1-5

4.2.3 Results

Each indicator has been reclassified in potential risk classes of Environmental Sustainability (ES) using the Likert scale and the results are presented in Figure 16.

The higher the number of cases with a potential increased risk of degradation, the lower the environmental sustainability: very few spots with low ES are reported in northern Italy and southern Spain, the dominant class is the moderate condition which is almost the half of the entire area under study. Mountainous regions resulted in good ES status, but generally, they are not particularly suitable for cropping.
Figure 16 shows the overlay of the CAMBAR predicted yield reclassified in 5 classes and that of the total ES indicator.
The ES rating assessed using soil-related variables and aridity index as the climatic significance of the range of moisture availability conditions showed that the sea-facing areas are more vulnerable and need the adoption of conservation agricultural practices, improved organic carbon management to ensure environmental sustainability for agroenergy production. Additional ES measures, such as the use of organic fertilizers and organic mulch, should be put in place to rehabilitate land use types, especially arable land, to prevent further soil degradation under those land use types.

By linking the ES, and the potential yield of the CAMBAR average predicted yield (2000-2020) we can draw additional conclusions:

- The CoE approach is able to collect data from multiple sources and provide a comprehensive understanding of the land conditions.
- To avoid desertification[4], the adoption of crop diversification and the use of drought-resistant crops is strongly advisable.
- GIS land suitability analysis must be integrated in crop models to evaluate multiple factors, such as soil type, slope, elevation, land cover, climate, and other environmental considerations, to determine which areas of land are best suited for a given activity. This type of analysis can help decision makers identify areas that are most suitable for energy crop cultivation.

[4] Hereby intended as the process by which fertile land becomes increasingly arid and dry due to environmental changes (droughts) and anthropic pressures (deforestation, overgrazing); as a result, the land becomes more and more impervious and, generally, biodiversity decreases.

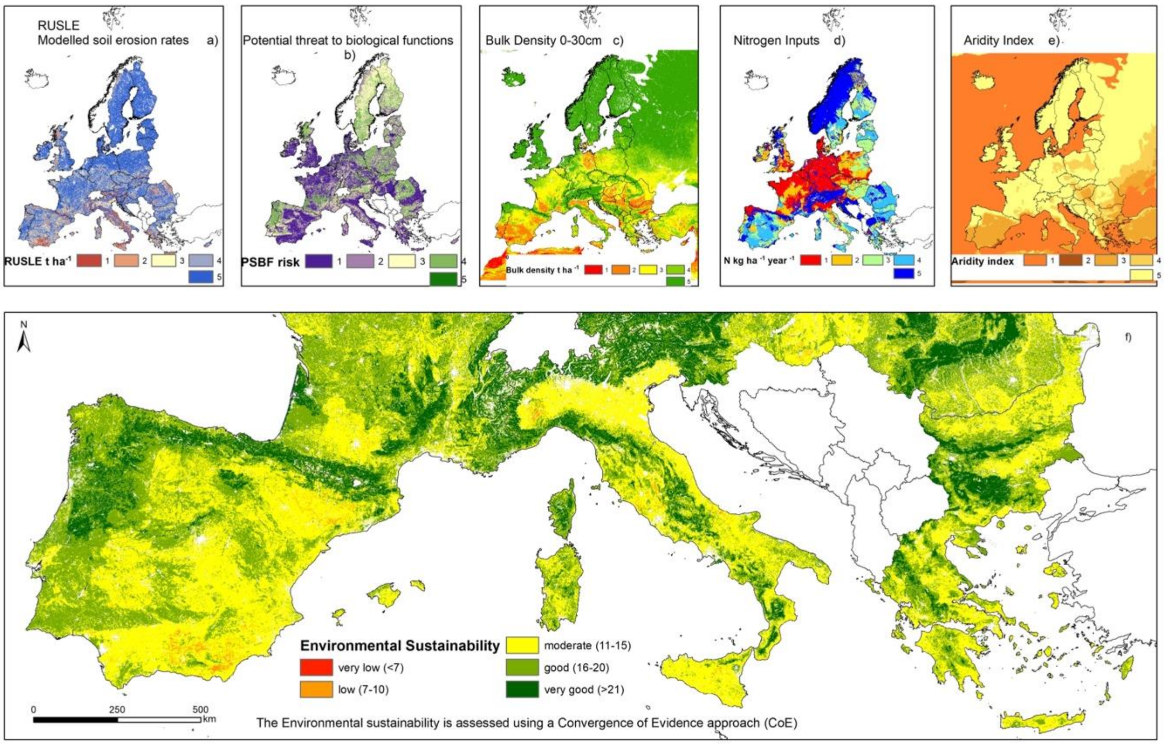

Figure 16: Summary of the five sustainability indicators overall maps and of the resulting ES map.

5 Conclusions

KPIs have been met at 87.5% (7 out of 8 completely achieved, 1 partially achieved).
The technological KPIs have all been met.
Namely, new installed capacity for biokerosene production has been met thanks also to the distillation column refurbishment operated by ENI in its Livorno refinery, specifically for BIO4A project.
SE2 and SE3 have been attained, namely the biofuels were compliant to sustainability biofuels standards, as shown also in deliverable D3.2.
Partial achievement is due to SE1 "Improvement of the economic viability of the biojet production". The economic viability of biojet production was severely affected, since 2021, by the rise in industrial utilities (from +300% to 600% for gas and electricity) and residual lipids feedstock prices, thus impairing the ability of process optimization to compensate for such production costs increases.
The environmental KPIs have all been met, in particular E1 largely outperforms the REDII 70% requirements on GHG emissions savings, not only for residual lipids, but also for lipids from Camelina cultivation, in particular when using biochar as a soil amendment (107%-128%).

Table XII: Summary of KPI results

KPI - Description	Achieved	Results	Notes
T1: new installed annual production capacity of several hundreds thousands t/y of HEFA biojet	YES	60 kt/yr – 200 kt/yr	The lower value refers to actual HEFA projected capacity in Livorno; the upper value to max. HEFA projected capacity in Livorno and Gela (Gela in construction)
T2: Bio kerosene must comply with reference ASTM	YES	Compliance	Certification provided
T3: GIS mapping of potential feedstock production on marginal lands in EU MED area	YES	Maps realized	
SE1: Improvement of the economic viability of the the biojet production	PART.	2,800 €/t_{SAF} – 3,500 €/t_{SAF}	
SE2: Compliance to sustainability biofuels standards	YES	Compliance	Certification provided
SE3: Social and techno-economic sustainability of potential feedstock production on marginal land	YES	Sustainability evaluated	
Change in income, Land tenure	*YES*	*8.75 / 10.00*	*From stakeholder interviews*
Jobs in the sector	*N.A.*	*6,500 – 19,500*	*FTE jobs, depending on scenario and assumptions*
Productivity	*N.A.*	*0.59 – 1.09 t/ha*	*Seeds production*
Net energy balance	*YES*	*2 – 2.5*	*From literature (should be >1)*

Gross value added	*YES*	*0.96 – 2.2*	*Profitability Index (should be >1)*
Infrastructure and logistics	*N.A.*	*0.34 – 3.18 tkm/*MJ_{SAF}	*Depending on the considered value chain*
E1: GHG emissions saving respect to fossil Jet A1 meeting the EU regulation in place at the moment of production.	YES	UCO:89% Tallow: 85% Camelina: 107% - 128%.	RED II target: 70%
E2: Environmental sustainability of feedstock potential production on marginal land	YES	Most of considered areas perform in the range from moderate to very good	

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Annex 1 – Projected feedstock production detailed results

		Scenario CAMBAR 211		Scenario CAMBAR 241-243		Scenario CAMBAR 211+241-243	
Region Name	**NUTS ID**	**Avg (t)**	**Max (t)**	**Avg (t)**	**Max (t)**	**Avg (t)**	**Max (t)**
Qender	AL03	97	146	-	-	97	147
Yugozapaden	BG41	1.869	2.502	3.172	4.318	5.046	6.825
Yuzhen tsentralen	BG42	5.370	7.114	2.267	3.052	7.660	10.202
Αττική	EL30	3.972	5.224	59.163	77.813	61.596	81.011
Βόρειο Αιγαίο	EL41	-	-	-	-	-	-
Νότιο Αιγαίο	EL42	11.842	17.421	64.891	92.736	75.432	108.269
Κρήτη	EL43	2.377	3.167	102.770	138.692	105.837	142.831
Ανατολική Μακεδονία, Θράκη	EL51	267.254	352.454	221.223	292.454	490.170	647.239
Κεντρική Μακεδονία	EL52	900.873	1.210.373	560.382	754.303	1.459.112	1.962.207
Δυτική Μακεδονία	EL53	348.011	484.848	221.886	306.651	568.679	790.096
Ήπειρος	EL54	-	-	22.277	30.240	18.698	24.967
Θεσσαλία	EL61	475.676	633.515	164.675	221.112	637.206	850.491
Ιόνια Νησιά	EL62	-	-	-	-	-	-
Δυτική Ελλάδα	EL63	-	-	6.637	8.729	8.083	10.630
Στερεά Ελλάδα	EL64	52.685	69.502	122.812	163.991	179.356	238.705
Πελοπόννησος	EL65	32.376	43.883	169.953	225.565	200.476	267.364
Galicia	ES11	-	-	-	-	-	-
Principado de Asturias	ES12	-	-	-	-	-	-
Cantabria	ES13	-	-	-	-	-	-
País Vasco	ES21	21.266	29.106	4.218	6.059	25.463	35.127
Comunidad Foral de Navarra	ES22	321.081	456.759	21.057	31.278	338.999	483.636
La Rioja	ES23	22.947	36.698	14.316	23.357	37.329	60.145
Aragón	ES24	787.717	1.280.538	393.205	611.816	1.182.399	1.895.010
Comunidad de Madrid	ES30	248.965	361.020	40.899	57.930	285.751	413.047

Castilla y León	ES41	1.387.736	2.449.832	203.621	312.860	1.631.970	2.814.579
Castilla-La Mancha	ES42	3.129.902	4.634.007	705.475	1.028.775	3.844.695	5.676.398
Extremadura	ES43	142.895	187.937	13.133	17.273	153.283	201.600
Cataluña	ES51	494.132	711.783	267.749	371.656	759.481	1.079.572
Comunitat Valenciana	ES52	76.618	111.447	472.244	643.653	545.913	751.397
Illes Balears	ES53	10.095	13.646	46.426	61.328	60.271	80.175
Andalucía	ES61	428.299	617.020	270.477	392.898	694.013	1.002.352
Región de Murcia	ES62	135.071	207.487	149.372	226.066	287.629	437.491
Aquitaine	FRI1	-	-	-	-	-	-
Languedoc-Roussillon	FRJ1	118.546	156.127	143.437	191.378	264.181	350.144
Midi-Pyrénées	FRJ2	943.665	1.242.642	351.685	464.823	1.287.613	1.695.767
Rhône-Alpes	FRK2	177.781	244.728	380.668	516.004	569.295	775.938
Provence-Alpes-Côte d'Azur	FRL0	161.128	218.266	171.485	233.776	333.681	454.003
Corse	FRM0	-	-	1.701	2.238	1.818	2.392
Panonska Hrvatska	HR02	4.032	5.506	10.154	13.547	14.151	19.013
Jadranska Hrvatska	HR03	-	-	1.388	2.000	1.388	2.000
Sjeverna Hrvatska	HR06	489	727	3.104	4.216	3.598	4.947
Dél-Dunántúl	HU23	101.569	149.291	7.191	10.776	107.080	157.597
Piemonte	ITC1	140.598	184.916	236.965	313.789	365.005	482.173
Valle d'Aosta/Vallée d'Aoste	ITC2	-	-	1.069	1.406	1.069	1.406
Liguria	ITC3	728	1.101	5.925	8.965	7.418	11.224
Lombardia	ITC4	408.446	538.886	113.198	155.004	531.092	705.238
Abruzzo	ITF1	188.954	251.786	126.614	169.653	317.452	423.450
Molise	ITF2	289.364	398.400	102.175	137.614	390.977	535.232
Campania	ITF3	195.296	285.872	106.944	149.893	296.781	429.208
Puglia	ITF4	1.131.195	1.540.912	325.984	438.087	1.458.095	1.980.045
Basilicata	ITF5	547.568	744.510	116.062	159.312	657.445	895.143
Calabria	ITF6	41.116	58.759	42.846	57.650	81.845	113.491
Sicilia	ITG1	344.179	452.668	152.815	200.984	472.409	621.319
Sardegna	ITG2	853.735	1.132.194	531.374	715.614	1.397.409	1.863.561

Provincia Autonoma di Bolzano/Bozen	ITH1	117	234	1.441	2.679	1.553	2.906
Provincia Autonoma di Trento	ITH2	449	725	24.810	39.067	25.422	40.068
Veneto	ITH3	111.678	146.880	96.552	131.747	204.696	275.706
Friuli-Venezia Giulia	ITH4	567	1.134	4.501	6.715	9.389	13.505
Emilia-Romagna	ITH5	1.838.748	2.418.345	1.057.861	1.393.873	2.900.175	3.818.082
Toscana	ITI1	59.303	77.996	35.042	46.088	94.345	124.084
Umbria	ITI2	61.812	82.538	53.271	71.859	113.496	152.213
Marche	ITI3	270.110	355.253	93.792	123.356	368.979	485.286
Lazio	ITI4	47.874	64.205	40.977	56.417	90.867	123.673
Severna Makedonija	MK00	1.520	2.147	940	1.280	2.460	3.427
Norte	PT11	122.523	165.524	323.149	433.382	446.009	599.252
Algarve	PT15	-	-	-	-	-	-
Centro (PT)	PT16	46.811	61.567	109.948	144.605	166.144	218.514
Área Metropolitana de Lisboa	PT17	-	-	-	-	-	-
Alentejo	PT18	-	-	-	-	-	-
Vzhodna Slovenija	SI03	27.275	36.818	148.606	207.359	176.296	244.632
Zahodna Slovenija	SI04	9.867	13.165	110.835	156.162	119.545	167.589
Tekirdağ, Edirne,Kırklareli	TR21	855	1.125	855	1.125	1.716	2.258