New Annex 9:

Background information and discussion of feedstocks' potential

July 2024

A study by

SQUARECO

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SQUARECO

About SQUARECO

Based on the Leman Lake shores in Switzerland, SquareCo develops market intelligence solutions designed to help players active in renewable fuels markets to gain a deeper understanding of regulatory frameworks, market dynamics and industry developments.

SquareCo delivers high-quality expertise through the publication of articles, market reports and thematic studies displayed on our Web Platform. Our strong emphasis on data monitoring allows us to supply our clients with access to a comprehensively organized database.

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Summary

New Annex 9:

Background information and discussion of feedstocks' potential

1. Introduction and objectives of the study

Nine new feedstocks were added to Annex 9 in March 2024. We classified them into three categories:

1. Industrial wastes with clear streams and identified production: fusel oils (9A-r) and raw methanol from kraft pulping (9A-s).
2. Industrial waste streams with unclear streams and identified production: cyanobacteria (9A-v), and non-sludge municipal wastewater (9B-d).
3. Crop wastes or practices: intermediate crops (9A-t and 9B-e), energy crops grown on severely degraded lands (9A-u and 9B-f), and damaged crops (9B-c).

This classification determines our study's plan to display the definitions, production processes, and discussions of the potential under RED3.

Our review of the available scientific literature confirmed that established production chains exist only for the feedstocks listed under category 1. For those two feedstocks, we gathered enough information and data to estimate volumes potentially available if the pathways become economically attractive thanks to their inclusion in the new Annex 9.

The estimation of the potential availability for the seven others proved to be significantly more challenging. For both feedstocks listed under the category 2, industrial production processes are not established yet and their development depends on a great number of variables, including external ones, implying a high error margin for any modelling attempt. For the three feedstocks linked to agricultural practices, the absence of clear definitions, reliable data, and existing practice made our estimation work too uncertain to provide satisfying outcomes.

For all of them, the Assessment Report used by the European Commission (EC)[1] to base its decisions about the new Annex 9 stated that no potential estimate for 2030/2050 was available or possible at the time of writing (2022).

Our initial **ambition** to establish a clear methodology to calculate the potential for each feedstock had to be **downgraded significantly**, as the potential availability for only two out of nine feedstocks is provided in this study.

Feedstock	Process	Main Biofuel Production Pathways	Global availability	Market Readiness	Overall Risk of Fraud*
Annex 9 Part A					
Fusel oils from alcoholic distillation	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Raw methanol from kraft pulping	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Intermediate crops for aviation biofuel	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Crops on severely degraded land for aviation biofuel	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Cyanobacteria	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Annex 9 Part B					
Damaged crops	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Municipal wastewater non-sludge	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Crops on severely degraded land	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Intermediate crops for non-aviation biofuel	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

*EC report[1]

2. Fusel oil

Part A (r)
"Fusel oils from alcoholic distillation"

2.1 General definition

Fusel oil is a by-product of ethanol production: a yellow, oily liquid with a distinctive odour and some toxicity.

It is a mixture of fatty alcohols with more than two carbon atoms (higher alcohols), including n-propanol and isobutanol. It is considered as a waste under regulation 200/532/EC.

In the beverage industry, fusel oil is generally undesired because of its strong odour. However, in small amounts, it contributes to the complexity and character of certain spirits, such as rum, whisky, and bourbon. Due to its unique characteristics, fusel oil is used as an essence in the food, cosmetics, and pharmacy industries.

[redacted]

[redacted]

[redacted]

Meanwhile, the report[1] pointed out that **the biofuel conversion process and technology associated with fusel oils is still a topic of research, and the conversion technology is not well understood at this stage**.

[redacted]

[redacted]

2.2 Production process and yields

[redacted]

Below is a simplified flowchart describing the process of ethanol production, which results in the by-production of fusel oil.

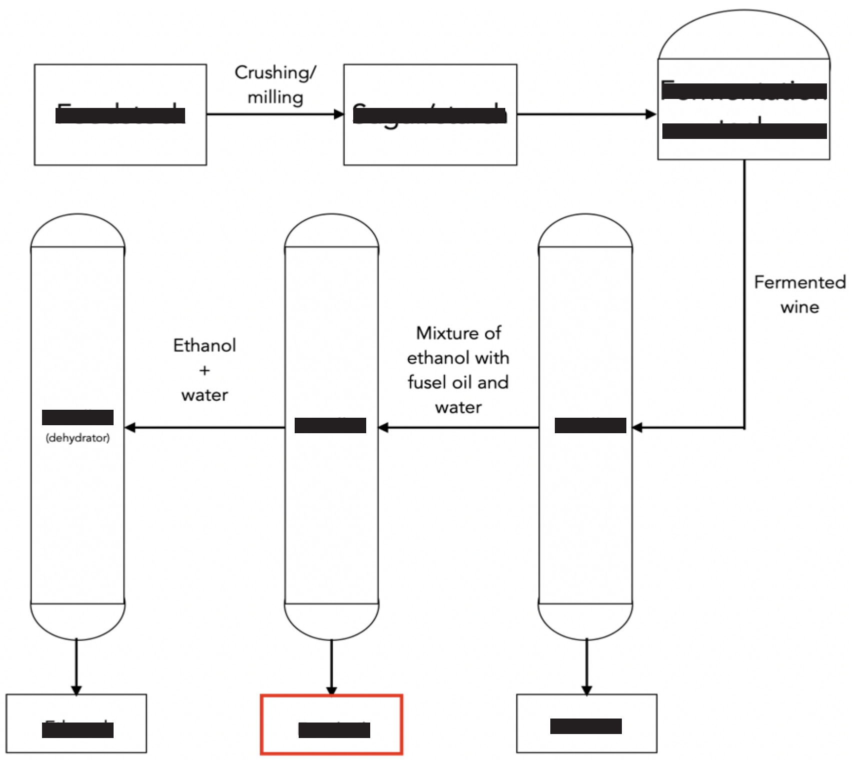

Chart 1: Simplified flowchart of ethanol production

The first step involves feedstock preparation, where sugar-rich feedstocks are milled or crushed, and then sugar and starch are extracted. This extraction is then sent to the fermentation tank, where it is fermented with yeast to produce fermented alcohol.

[redacted]

- [redacted]
- [redacted]
- [redacted]

[redacted]

[redacted] Below is a table showing the fusel oil yields from different feedstocks.

Table 1: Yields of fusel oil[7] from different feedstocks		
Feedstock	Yield range (%)	Average yield (%)
Molasses	0.26%	0.26%
Sugarcane	[redacted]	[redacted]
Corn	[redacted]	[redacted]
Wheat	[redacted]	[redacted]
Rye	[redacted]	[redacted]
Mixed grains	[redacted]	[redacted]
Sulphite liquor	[redacted]	[redacted]
Potatoes	[redacted]	[redacted]

[redacted]

[redacted]

2.3 Potential under RED3

2.3.1 Methodology

According to the Renewable Fuels Association[8] (RFA), eight countries/regions accounted for over 96% of global ethanol production in 2022: the US (54%), Brazil (26%), the EU (5%), India (4%), China (3%), Canada (2%), Thailand (1%), and Argentina (1%).

The methodology for the estimation is conducted using the feedstock split. Below is the calculation formula:

[redacted]

$$\textit{Fusel oil potential} = \sum_{i=1} \sum_{j=1}$$ [redacted]

Where:

C_i: total ethanol capacity in the country i
$r_{i,j}$: share of the feedstock j of the ethanol production in country i
y_j: yield of fusel oil from feedstock j

2.3.2 Ethanol production and feedstock use by country

All data presented below are derived from reliable sources, including the U.S. Energy Information Administration[9] (eia) for the United States, the European Renewable Ethanol Association[10] (ePURE) for the EU, and the latest annual report of the United States Department of Agriculture[11] (USDA) for the remaining countries, all based on the year 2022.

[redacted]

Brazil holds the second-largest ethanol production capacity in the world with 59 355 ML/y. Here, 97% of ethanol was derived from sugarcane and 3% from corn.

[redacted]

[redacted]

[redacted]

[redacted]

consisting of 46% molasses, 44% cassava, and 10% sugarcane.

[redacted]

Table 2: Ethanol capacity and the feedstock split in the selected countries/region									
Country/region	Ethanol capacity (million L/year)	Feedstock share							
		molasses	sugarcane	corn	wheat	rye	grains	cassava	Cellulose
US	64 929			99%		1%			
Brazil	[redacted]		[redacted]	[redacted]					
EU	[redacted]		[redacted]	[redacted]	[redacted]		[redacted]		[redacted]
India	[redacted]	[redacted]	[redacted]		[redacted]		[redacted]		
China	[redacted]			[redacted]	[redacted]			[redacted]	
Canada	[redacted]			[redacted]	[redacted]				
Thailand	[redacted]	[redacted]	[redacted]					[redacted]	
Argentina	[redacted]	[redacted]		[redacted]					

2.3.3 Global potential of fusel oil

The global potential for fusel oil production has been estimated at [redacted] **ML/y, or** [redacted] **m³**. The graph below illustrates the contribution to this potential from each specified country/region.

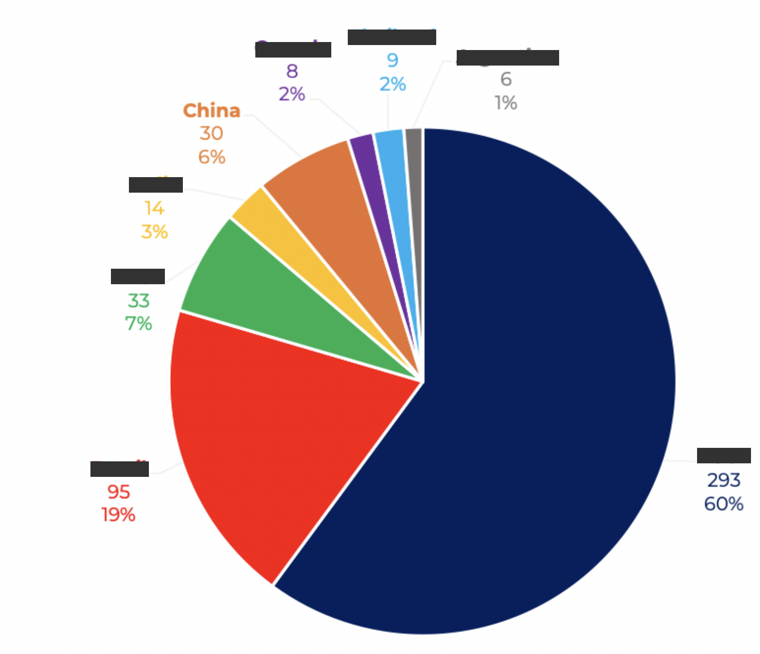

Chart 2: Fusel oil potential by country (million L)

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The top three countries/regions with the highest fusel oil potential are [redacted], with estimated potentials of 293 ML, 95 ML, and 33 ML, respectively.

These estimates assume maximized operating rates (100%) of the global ethanol's annual capacity. Official data suggest operating ratios of the selected countries for 2022 varied from 50% to 90%. Specifically, the operating ratios were as follows: the US ([redacted]%), Brazil ([redacted]%), the EU ([redacted]%), India ([redacted]%), China ([redacted]%), Canada ([redacted]%), Thailand ([redacted]%), and Argentina ([redacted]%).

Taking these operating ratios into account, the adjusted fusel oil potential for 2022 was estimated at [redacted], which is [redacted]% lower than the initial result.

3. Raw methanol from kraft pulping

Part A (s)
"Raw methanol from kraft pulping stemming from the production of wood pulp"

3.1 General definition

Methanol (MeOH) is a colourless, volatile liquid alcohol with chemical formula CH3OH. It can be used in several markets as a derivative, such as in the automotive, construction, electronics, fuel, paint, pharmacy, and marine industries. The chemical industry is the largest consumer of MeOH; more than 60% of MeOH produced in 2019 was used in the synthesis chemical industry[12].

[redacted]

[redacted]

3.2 Methanol production in the pulping process

[redacted]

The graph below presents a simplified flow chart of how raw methanol is produced during pulp production.

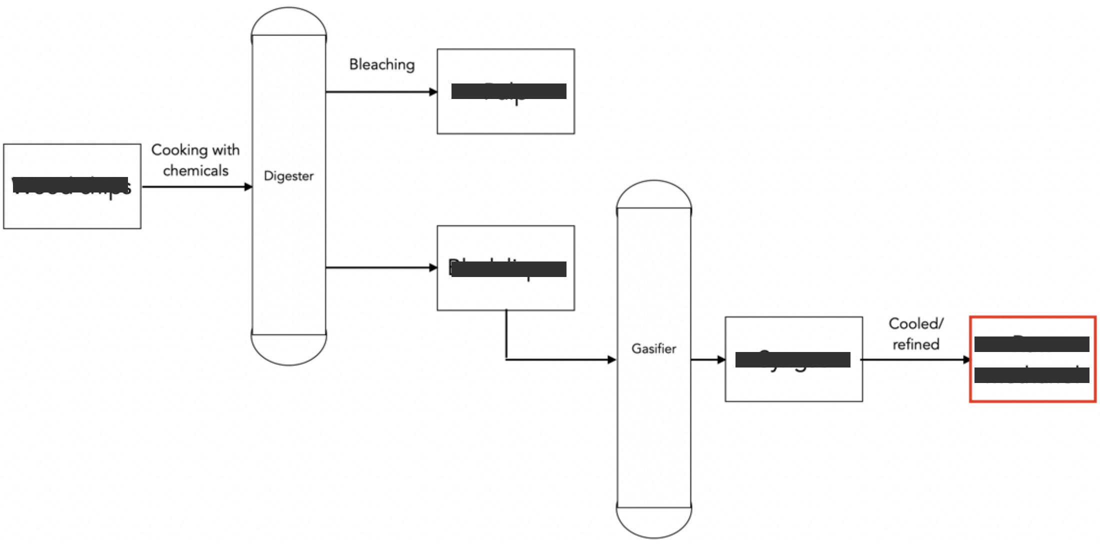


Chart 3: Formation of the raw methanol in the wood pulp industry

3.3 Methanol yield

The yield of methanol from wood pulp production can vary according to several factors, such as wood species, pulping time, temperature, hydroxide concentration, or alkalinity[16].

[redacted]

[redacted]

Chart 4: Broad leaf (left) and conifer (right)

[redacted]

[redacted]

[redacted]

- [redacted]
- [redacted]

3.4 Methodology

The potential of the raw methanol can be estimated from the wood pulp production/capacity, the share of hardwood or softwood used, and their respective yield.

The formula is presented as follows:

$$MeOH\ potential =$$ [redacted]

Where:

i: country (n=23)
j: type of wood (k=2)
P: production of wood pulp
S: share of the wood type
Y: yield of methanol of the wood type

3.5 Data selection and description

We retrieved the wood pulp production data from FAOSTAT[18] by selecting chemical wood pulp, as well as mechanical and semi-chemical wood pulp for all the available countries.

The reason we did not choose dissolving wood pulp is that this type of pulp is generally used to produce fibers in textiles, not for paper kraft, which is not within the scope of the new Annex 9.

[redacted]

[redacted]

[redacted]

Table 3: List of kraft pulp production, wood pulp capacity and the share of wood type

Country	Production (kt)	Capacity (kt)	Hardwood (%)	Softwood (%)
US	[redacted]	48 661	28%	72%
Brazil	24 969	[redacted]	92%	8%
China	[redacted]	[redacted]	[redacted]	[redacted]
Canada	[redacted]	[redacted]	[redacted]	[redacted]
Sweden	[redacted]	[redacted]	[redacted]	[redacted]
Finland	[redacted]	[redacted]	[redacted]	[redacted]
Indonesia	[redacted]	[redacted]	[redacted]	[redacted]
Russia	[redacted]	[redacted]	[redacted]	[redacted]
Japan	[redacted]	[redacted]	[redacted]	[redacted]
Chile	[redacted]	[redacted]	[redacted]	[redacted]
India	[redacted]	[redacted]	[redacted]	[redacted]
Portugal	[redacted]	[redacted]	[redacted]	[redacted]
Uruguay	[redacted]	[redacted]	[redacted]	[redacted]
Germany	[redacted]	[redacted]	[redacted]	[redacted]
Spain	[redacted]	[redacted]	[redacted]	[redacted]
Poland	[redacted]	[redacted]	[redacted]	[redacted]
Austria	[redacted]	[redacted]	[redacted]	[redacted]
France	[redacted]	[redacted]	[redacted]	[redacted]
Australia	[redacted]	[redacted]	[redacted]	[redacted]
New Zealand	[redacted]	[redacted]	[redacted]	[redacted]
Thailand	[redacted]	[redacted]	[redacted]	[redacted]
South Africa	[redacted]	[redacted]	[redacted]	[redacted]
Norway	[redacted]	[redacted]	[redacted]	[redacted]

[redacted]

[redacted]

3.6 Estimation of raw methanol potential

Based on the information above, we obtained the following results for raw methanol potential from kraft pulp production as shown in the following graph.

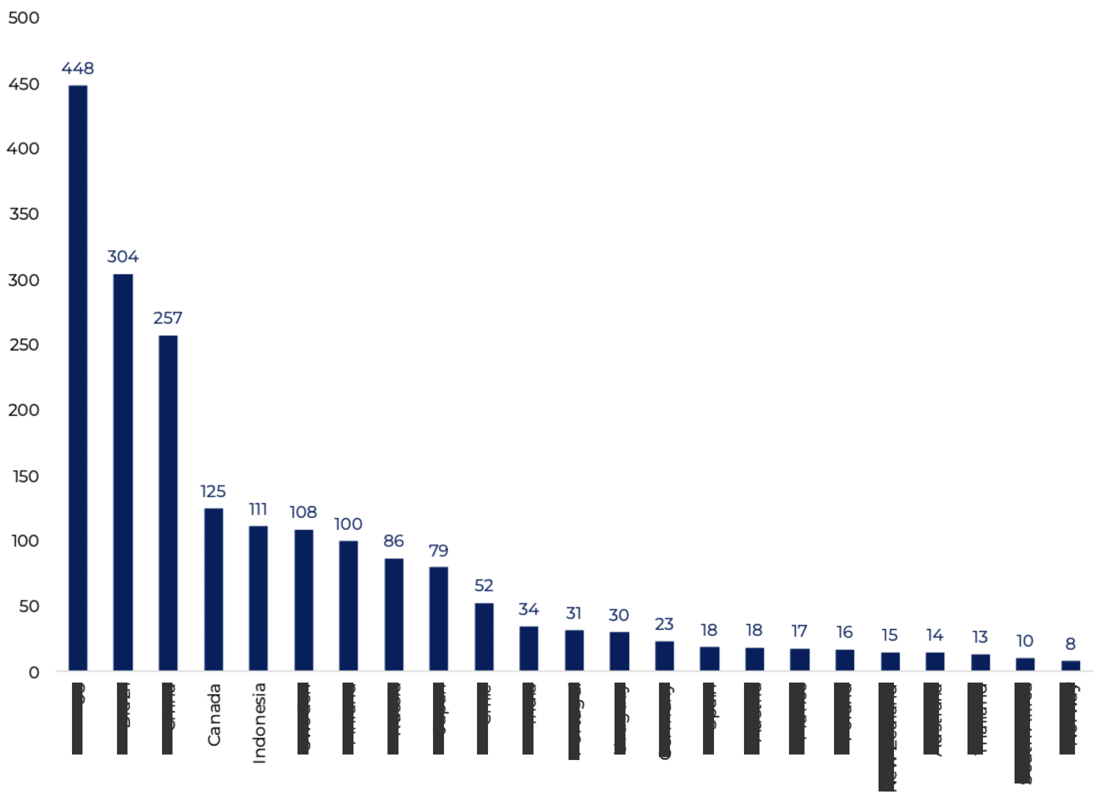


Chart 5: Raw methanol potential estimated from kraft pulp production (unit: kt)

[redacted]

[redacted]

[redacted]

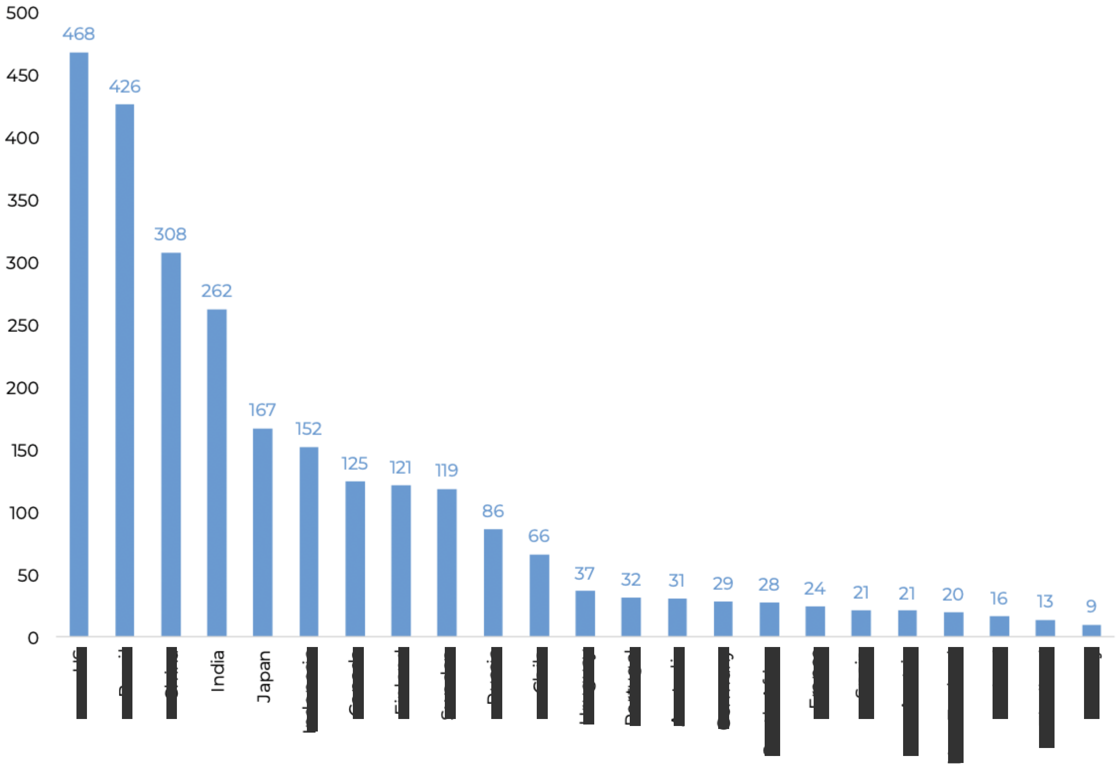


Chart 6: Raw methanol potential estimated from kraft pulp potential (unit: kt)

[redacted]

Case study: Sodras Monsteras raw MeOH purification

Purifying raw methanol involves several steps: initial fractional distillation to separate methanol from other components, chemical treatments to remove specific impurities, adsorption for trace contaminants, and advanced techniques such as membrane separation. Finally, further distillation into pure methanol would be required. The technology for methanol purification is mature, and some pulp mills are already equipped with it.

[redacted]

[redacted]

- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted]

From the Sodra case, we may conclude that the conversion ratio from raw MeOH to purified MeOH will range from [redacted]% to [redacted]%. Applying this to the estimated global potential of raw methanol ([redacted] Mt/y), we derive that the existing global availability of pure methanol derived from kraft pulping is [redacted] kt to [redacted] kt. The actual commercially viable pure methanol will be considerably lower, as most mills don't reach the size of Sodra's Monsteras. Further research into large-scale pulp operations will provide a more accurate range of future prospects for methanol derived from the kraft pulp industry.

4. Cyanobacteria

Part A (v)
"Cyanobacteria"

4.1 General Definition

Cyanobacteria are photosynthetic bacteria, often referred to as "blue-green algae" due to its colour and similarities with microalgae. They are widely found in nature but only commercially farmed for spirulina (a dietary/feed supplement,) for which the compounds extracted differ from those required for the production of biofuels.

[redacted]

[redacted]

[redacted]

[redacted]

4.2 Production Processes

4.2.1 Cultivation of cyanobacteria

It can be done in:

- Open systems: usually artificial raceway or circular-shaped shallow ponds; they rely on natural sunlight and air.
- Closed systems with natural sunlight or with artificial light.

Closed systems are more expensive to construct but are more efficient due to a lack of competition from natural strains of algae, exclusion of pests, and elimination of water evaporation. Artificial light further enhances productivity as it allows for 24h operation.

4.2.2 Harvesting cyanobacteria

- [redacted]
- [redacted]
- [redacted]
- [redacted]

[redacted]

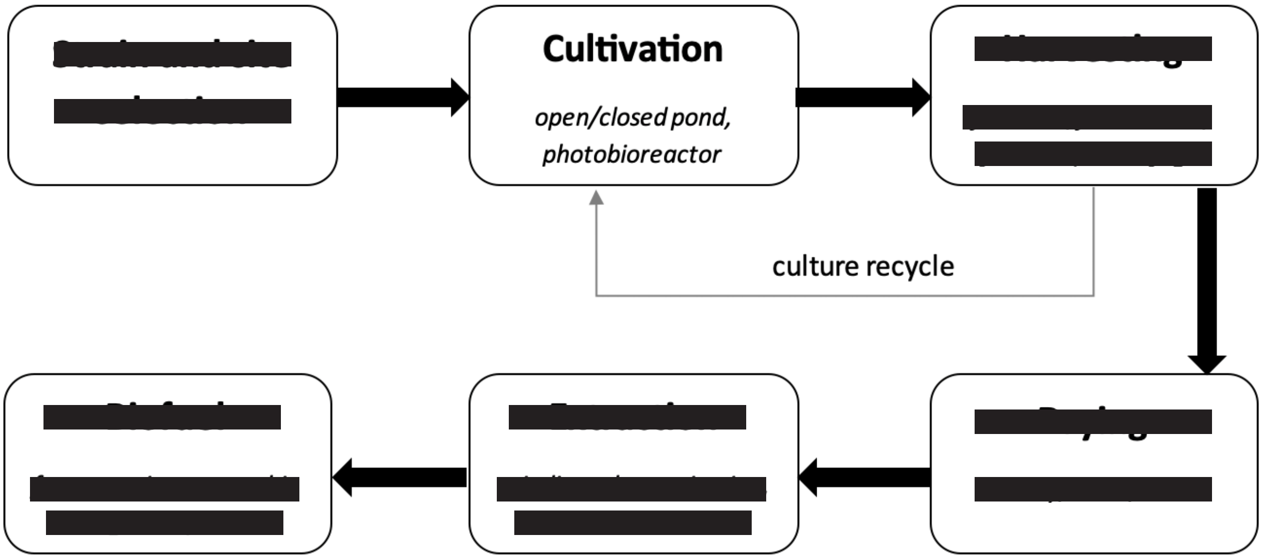


Chart 7: From cyanobacteria to biofuel

4.2.3 Potential fuel pathways

There are various routes for the production of biofuels using mature technologies. Cyanobacteria can be engineered to secrete glucose and sucrose for ethanol fermentation, converted to biomethane via anaerobic digestion, or used to produce biodiesel through lipid extraction and transesterification.

[redacted]

[redacted]

- [redacted]
- [redacted]
- [redacted]

4.3 Yield and Potential under RED3

[redacted]

[redacted]

5. Municipal wastewater

Part B (d)
"Municipal wastewater and derivatives other than sewage sludge"

5.1 General defintion

Municipal wastewater* and extracted non-sludge derivatives include fats, oils, and greases (FOGs) that are primarily derived from commercial food service establishments. It is sometimes referred to as black grease, which is different from brown grease typically collected in grease traps prior to discharge into sewers.

[redacted]

[redacted]

** Municipal wastewater is outside the scope of the Waste Framework Directive (WFD), which Annex 9A refer to for biowaste and mixed municipal waste.*

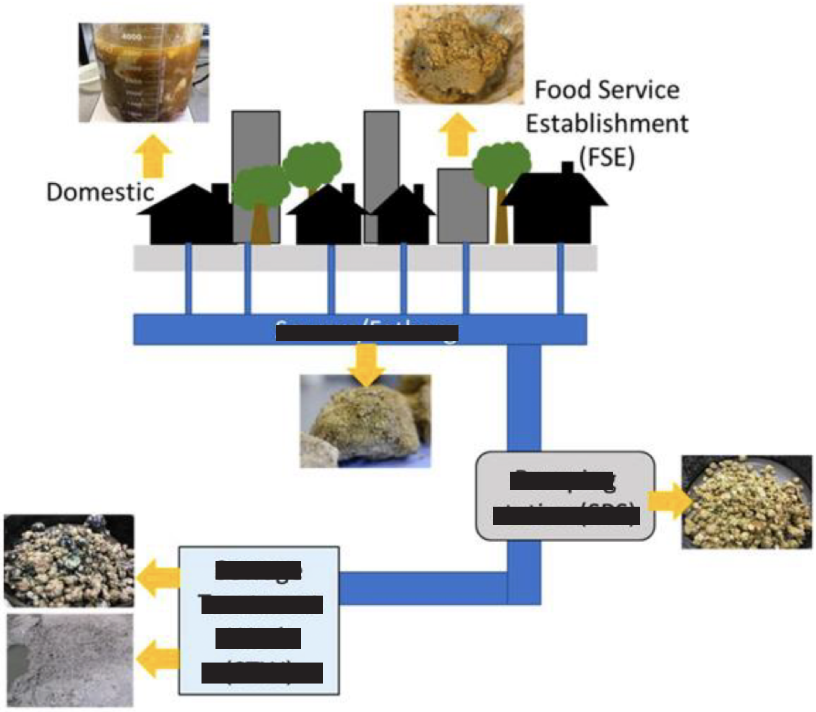


Chart 8: Waste FOGs collection

Waste FOGs from sewers are produced worldwide, primarily in large population centres and from commercial sources (restaurants, hotels, pubs, etc.). Industrial sources may also contribute but their effluent discharge is usually heavily controlled. They are traded in limited volumes, involving few parties and short distances. Global trade does not exist, with typical disposal being landfilling. FOGs extracted at sewer works may be used for on-site biogas production or landfilled.

[redacted]

[redacted]

5.2 Production processes

FOG blockages in the sewer system need to be removed to avoid overflows and contamination of water bodies. They are either dug out by hand or broken down into smaller pieces with high pressure water jets and:

- Continue through the sewer system and are separated at the wastewater treatment plant in skimming tanks. FOGs may further be removed using dissolved air flotation, centrifugation, filtration, biological removal, and ultrafiltration techniques. Or,
- They are removed from the pipe through manual excavation and/or powerful vacuumation tanker units. The process is extremely labor-intensive and has high health and safety risks.

[redacted]

[redacted]

[redacted]

1. [redacted]
2. [redacted]
3. [redacted]
4. [redacted]
5. [redacted]
6. [redacted]

[redacted]

5.3 Yield and potential under RED3

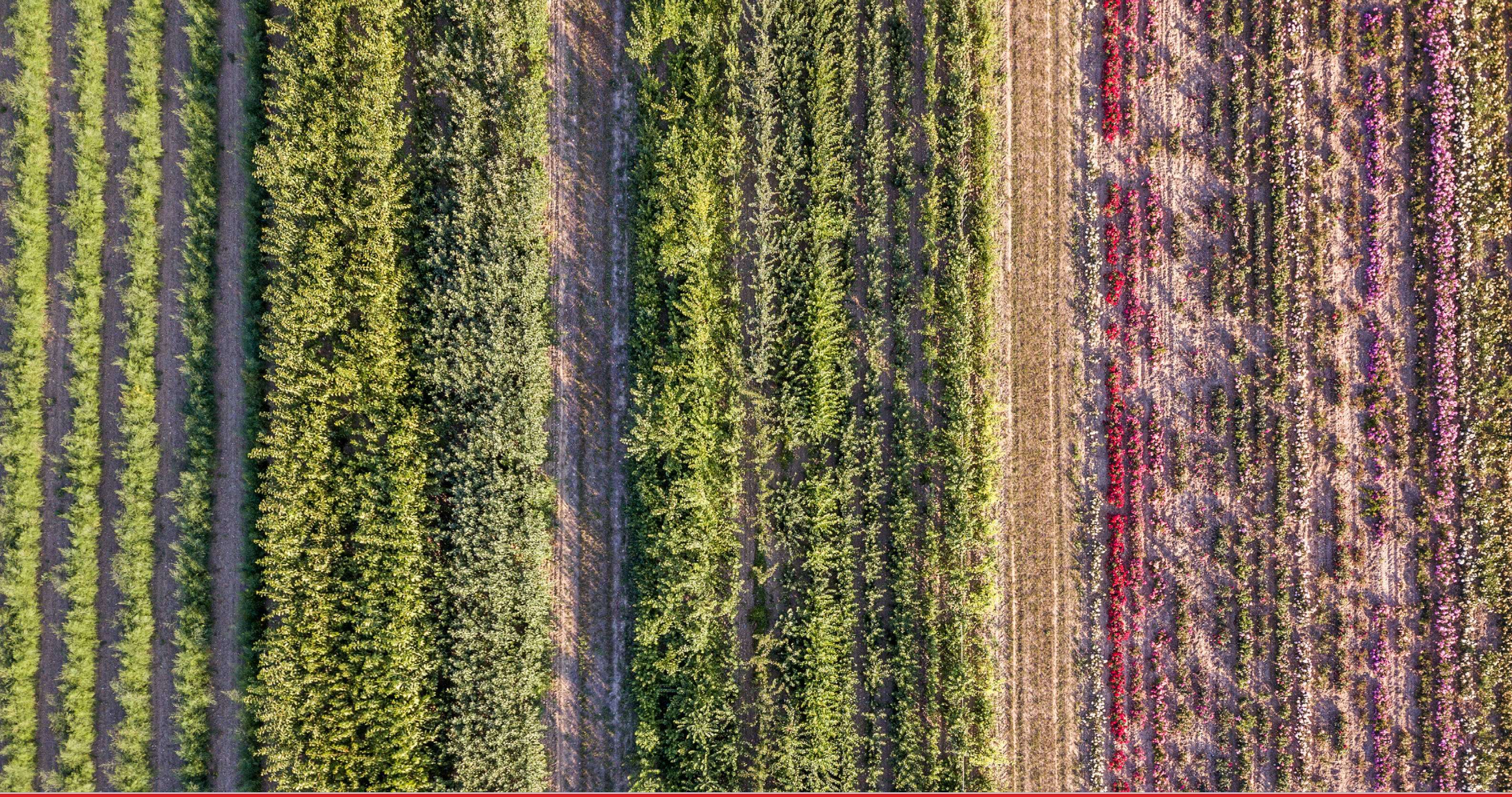
The EC assessment indicates that waste FOGs to FAME have a yield of 0.909 kg fuel/kg feedstock. Meanwhile, waste FOGs to HVO yield 0.852 kg fuel/kg feedstock. However, these conversion factors assume standard feedstock moisture content and composition. This is not the case for municipal wastewater and derivatives (other than sludge) which, as explained above, vary considerably in composition according to location, and even the specific sections along the sewer system where they concentrate.

[redacted]

[redacted]

[redacted]

[redacted]



6. Intermediate crops

Part A (t)
"Intermediate crops, such as catch crops and cover crops excluding feedstocks listed in part A of this Annex that are grown in areas where due to a short vegetation period the production of food and feed crops is limited to one harvest and provided their use does not trigger demand for additional land and provided the soil organic matter is maintained, where used for the production of biofuel for the aviation sector"

Part B (f)
"Intermediate crops, such as **catch crops and cover crops** excluding feedstocks listed in part A of this Annex that are grown in areas **where due to a short vegetation period the production of food and feed crops is limited to one harvest** and provided their use does not trigger demand for additional land and provided the soil organic matter is maintained, where not used for the production of biofuel for the aviation sector"

6.1 General definition

In the EC's "Assessment of New Advanced Biofuel Feedstocks" report[1], the term "cover and intermediate crops" refers to any crop that is:

- not the primary crop cultivated in a field in a given year
- grown at a different time than the primary crop, which is understood to be the crop harvested in that year associated with the highest expected revenue.

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[redacted]

[redacted]

[redacted]

- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted]

[redacted]

6.2 Wording of the new Annex 9

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

for additional land." This criterion is essential, as **it disqualifies all cover crops currently grown with an economic value in the food and feed sectors**. The example of safrinha corn grown in Brazil as a cover crop for soybeans, whose 2020 crop size was recorded at 76.7 Mt, is the most symbolic. If diverted for ethanol or SAF (ATJ), this cover crop would generate a massive indirect land use change, as the current crop would have to be grown elsewhere.

[redacted]

6.3 Current practices

Concordant sources confirmed that no crops are grown in Europe from which vegetable oil can be extracted. Although cover cropping is widely practiced on the western side of the continent, notably in Germany and France, it is only for protecting soil nutrients in the "multi-service" context described above. In most cases, CCCs are not harvested but instead left in the field to maximize yields of the main crop.

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

In France, Avril Group is leading a series of pilot projects for camelina grown as an intercrop, which would qualify for the definition of the new Annex 9. The group offers incentives to farmers, who are testing the cultivation of 2 000 t of seeds in 2024, with the aim to expand by a factor of 5 in 2025. No projected volumes for camelina oil were provided but the French company clearly targets the SAF market, a premium one, as the main outlet for its nascent output.

6.4 Potential under RED3

Estimating the potential of intermediary crop feedstocks as 9B for road/maritime and 9A for aviation is highly challenging.

As mentioned in the assessment report, "the data available do not allow an estimation of the amount of biomass that could currently be harvested from cover and intermediate crops globally, nor is this amount in 2030 and 2050 possible to accurately forecast".

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

7. Energy crops grown on severely degraded lands

Part A (U)
"Crops grown on severely degraded land excluding food and feed crops, where used for the production of biofuel for the aviation sector"

Part B (E)
"Crops grown on severely degraded land excluding food and feed crops and feedstocks listed in Annex 9 of this Annex, where not used for the production of biofuel for the aviation sector"

7.1 General definition

In the EC's "Assessment of New Advanced Biofuel Feedstocks" report, degraded lands are defined according to Annex V - 9C of Directive (EU) 2018/2001 (RED2) as "**lands that, for a significant period of time, have either been significantly salinated or presented significantly low organic matter content and/or have been severely eroded.**"

[redacted]

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7.2 Wording of the new Annex 9

The EC chose to stick to the basic definition of "severely degraded lands" in line with RED2 and to exclude all food and feed crops.

As RED2 (Directive + related regulations) defines also the three following marginal lands:
1. "unused": not cultivated for 5 years.
2. "abandoned": cultivation stopped due to biophysical or socioeconomic constraint.
3. "contaminated": where pollutants or hazardous substances are present in the soil, surface water, or groundwater at levels that pose a risk to human health or the environment.

[redacted]

[redacted]

[redacted]

7.3 Current practice

The scientific literature available on the topic focuses more on the potential of biomass cultivated on marginal lands, than on actual volumes of feedstocks grown. This is because the practice is not developed either in the EU or globally. We didn't find any study describing the specific potential for energy crops grown on severely degraded lands.

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

7.4 Potential under RED3

The EC's Impact Assessment clearly indicates that the 2030/2050 potential is "unknown" as a "**realistic estimate cannot be made.**"

The BIP-Task 3 study[38] mentions that during the last 10-15 years, several mapping exercises across EU attempted to calculate biomass potential out of marginal lands in the EU by 2030 and 2050, based on projected areas and yields. It compares results from three studies (Imperial College London, DGRTD and JRC Times) using various models.

Although the range for dry biomass potential (excluding forestry) is considerable — between 88 and 230 [redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

- [redacted]
- [redacted]
- [redacted]
- [redacted]

[redacted]

8. Damaged crops

Part B (c)
Damaged crops that are not fit for use in the food or feed chain, excluding substances that have been intentionally modified or contaminated in order to meet this definition

8.1 General definition and wording of the new Annex 9

The final definition encompasses all damaged crops that do not enter the food or feed chain, due to either pre-harvesting or post-harvesting degradation.

The EC did not retain the proposal of the Assessment Report's authors, who suggested: "to narrow the damaged crops group down to a sub-group which is crops that are damaged because they become affected pre- or post-harvest by pests and pathogens which make their consumption as food or feed a health threat."

[redacted]

[redacted]

[redacted]

8.2 Current practice

The amount of primary food not reaching the downstream chain is overwhelming. The FAO[44] estimates that about 13% does not reach the retail stage globally, including a significant share of vegetables and fruits. No data is available about the current use of biofuels feedstocks (oilseeds, cereals, and sugars) qualified as damaged.

[redacted]

[redacted]

8.3 Potential under RED3

EC's Assessment Report clearly states that "how large the availability of biomass for biofuels from damaged crops will be in 2030 and 2050 is impossible to predict and no studies are available that have tried to estimate this".

[redacted]

[redacted]

[redacted]

9. Fraud risks associated with new crop categories

Assessing the potential of the three feedstocks may come down to assessing the fraud risk created by the Annex 9 incentive.

The summary of risk assessment table displayed on page 145 of the EC assessment's final report clearly shows that the "Overall Fraud Risk" attributed to both cover crops and crops grown on severely degraded lands is "High"— the highest level of concern. The one for damaged crops is "Medium".

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

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[redacted]

[redacted]

[redacted]

[redacted]

New Annex 9:

Background information and discussion of feedstocks' potential

Appendix

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References

1: European Commission (2022), Assessment of new advanced biofuel feedstocks

2: B.Massa et al. (2023), Fusel Oil: Chemical Composition and an Overview of Its Potential Application, https://doi.org/10.21577/0103-5053.20220145

3: Simsek et al. (2018), Improvements to the Composition of Fusel Oil and Analysis of the Effects of Fusel Oil–Gasoline Blends on a Spark-Ignited (SI) Engine's Performance and Emissions, https://www.mdpi.com/1996-1073/11/3/625

[redacted]

[redacted]

[redacted]

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Annex 1: fusel oil potential estimation result

Country	By production* (ML)	By capacity (ML)
US	293	261
Brazil	[redacted]	[redacted]
EU	[redacted]	[redacted]
India	[redacted]	[redacted]
China	[redacted]	[redacted]
Canada	[redacted]	[redacted]
Thailand	[redacted]	[redacted]
Argentina	[redacted]	[redacted]
Total	[redacted]	[redacted]

**estimated by ethanol production in 2022*

Annex 2: fusel oil potential estimation result

Country	By production* (kt)	By capacity (kt)
US	448	468
Brazil	[redacted]	[redacted]
China	[redacted]	[redacted]
Canada	[redacted]	[redacted]
Indonesia	[redacted]	[redacted]
Sweden	[redacted]	[redacted]
Finland	[redacted]	[redacted]
Russia	[redacted]	[redacted]
Japan	[redacted]	[redacted]
Chile	[redacted]	[redacted]
India	[redacted]	[redacted]
Portugal	[redacted]	[redacted]
Uruguay	[redacted]	[redacted]
Germany	[redacted]	[redacted]
Spain	[redacted]	[redacted]
Austria	[redacted]	[redacted]
France	[redacted]	[redacted]
Poland	[redacted]	[redacted]
New Zealand	[redacted]	[redacted]
Australia	[redacted]	[redacted]
Thailand	[redacted]	[redacted]
South Africa	[redacted]	[redacted]
Norway	[redacted]	[redacted]
Total	[redacted]	[redacted]

**estimated by kraft pulp production in 2022*

Annex 3: Mapping data of degraded land and crop yields with natural constraints

Oil crop yields on land with natural constraints (t/ha seeds)[42]

	Atlantic	Continental	Mediterranean
rapeseed	2 (44%)	2.5 (63%)	1.5 (50%)
ethiopian mustard	[redacted]	[redacted]	[redacted]
crambe	[redacted]	[redacted]	[redacted]
camelina	[redacted]	[redacted]	[redacted]
cardoon	[redacted]	[redacted]	[redacted]
safflower	[redacted]	[redacted]	[redacted]
castor	[redacted]	[redacted]	[redacted]

Lignocellulosic yields on land with natural constraints (t/ha dry matters)[42]

	Atlantic	Continental	Mediterranean
willow	9 (75%)	9 (75%)	8 (62%)
poplar	[redacted]	[redacted]	[redacted]
sorghum	[redacted]	[redacted]	[redacted]
tall wheat grass	[redacted]	[redacted]	[redacted]
miscanthus	[redacted]	[redacted]	[redacted]
switchgrass	[redacted]	[redacted]	[redacted]
cardoon	[redacted]	[redacted]	[redacted]
giant reed	[redacted]	[redacted]	[redacted]
reed canary grass	[redacted]	[redacted]	[redacted]

** In (...) is the percentage relative to the yield that the crop is cultivated on lands with normal conditions.*

Mapping data of degraded agricultural land in Europe[41]

Country	Agricutural lands (km2)	High degr. (%)	Very high degr. (%)	high degr. Surface (km2)	very high degr. Surface (km2)
Norway	5 601	1.92	0.11	108	
Finland	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Sweden	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
UK	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Estonia	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Latvia	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Denmark	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Lithuania	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Ireland	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Poland	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Germany	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Netherlands	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Belgium	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
France	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Czechia	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Luxembourg	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Slovakia	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Romania	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Hungary	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Austria	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Switzerland	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Liechtenstein	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Italy	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Slovenia	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Croatia	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Serbia	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Bulgaria	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
BH	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Spain	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
San Marino	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Montenegro	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Kosovo	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Monaco					
Portugal	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Albania	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Macedonia	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Greece	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Andorra					
Cyprus	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Malta	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Mapping data of degraded arable land in Europe[41]

Country	Arable lands (km2)	High degr. (%)	Very high degr. (%)	high degr. Surface (km2)	very high degr. Surface (km2)
Norway	5 601	1.92	0.11	108	6
Finland	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Sweden	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
UK	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Estonia	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Latvia	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Denmark	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Lithuania	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Ireland	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Poland	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Germany	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Netherlands	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Belgium	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
France	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Czechia	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Luxembourg	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Slovakia	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Romania	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Hungary	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Austria	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Switzerland	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Liechtenstein	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Italy	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Slovenia	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Croatia	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Serbia	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Bulgaria	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
BH	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Spain	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
San Marino	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Montenegro	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Kosovo	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Monaco				[redacted]	[redacted]
Portugal	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Albania	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Macedonia	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Greece	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Andorra				[redacted]	[redacted]
Cyprus	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Malta	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Contact us

Square Commodities SARL
admin@squarecommodities.com

Editor in Chief
Olivier Pellegrinelli
olivier@squarecommodities.com
Tel: +41 79 676 88 87

Visit us on
www.squarecommodities.com

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New Annex 9:

Background information and discussion of feedstocks' potential

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