European Commission

# Development of outlook for the necessary means to build industrial capacity for drop-in advanced biofuels

Annex 2 Report on Task 2

Research and Innovation

**Development of outlook for the necessary means to build industrial capacity for drop-in advanced biofuels**

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EUROPEAN COMMISSION

# Development of outlook for the necessary means to build industrial capacity for drop-in advanced biofuels

## *Annex 2 Report on Task 2*


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# 1. Introduction

Here the work under Task 2 is reported. This chapter is accompanied by an excel with all cost and supply data of the biomass assessed. Task 2 reported here includes at least the analyses of the potential of feedstock for drop-in advanced biofuels at regional level for 2030 and 2050 in the EU, UK, and the Associated countries.

The definition of ‘Advanced biofuels’ means biofuels that are produced from the feedstock listed in Part A of Annex IX in Renewable Energy Directive II such as lignocellulosic feedstocks (i.e., agricultural and forestry residues, e.g., wheat straw/corn stover/bagasse, wood-based biomass), non-food crops (i.e., grasses, miscanthus, algae), or industrial waste and residue streams. The advanced biofuels must have low CO2 emission or high GHG reduction and reach zero or low ILUC impact. (Adapted from https://www.etipbioenergy.eu/everyone/advanced-boifuels).

Beside the advanced fuels biomass categories also some more feedstock potentials were analysed such as REDII Anne IX Part B categories that are not in the Advanced Fuels category but may be considered in the future. For a detailed list of the Annex A and B biomass types see Table A2 - 1.

The overall approach to task 2 is implemented in 10 sub-tasks which are interrelated (see Figure A2 - 1). What is reported here are the outcomes of all these sub-tasks.

In the following chapter 2 an overview is given of all biomass types involved in the assessment. It covers all biomass feedstock that complies with Low indirect land use risk because it is produced according to additionality principles as specified in the Delegated Act of the REDII. In chapter 3 the overall approach to the assessment of biomass potentials and of cost is explained which is supported by a more detailed description per biomass potential type. In addition, this report is also accompanied by a separate excel file including all cost-supply data generated in this task. In chapter 4 an overview is presented of the cost-supply assessment results for 2030 and 2050. This cost-supply has been worked out for three different scenarios: low, medium, and high mobilization scenarios in order to provide results that range according to the main factors that determine the order of magnitude of biomass potential for drop-in fuels in the near 2030 and further 2050 futures. The application of the three scenarios enable to make a sensitivity analysis for the most uncertain factors such as competing use levels, different cropping, and management strategies for biomass from agriculture, forestry and waste sectors and other most influential factors such as changes is supporting policies, climate change effects and the application of stricter sustainability considerations. In chapter 5th biomass potentials are presented in relation to cost levels, the cost-supply relation.

In Chapter 6 the comparison is presented of the Biomass demands simulated with the PRIMES model in the high and a low bioenergy demand context across the scenarios developed and modelled in Task 1. Chapter 7 presents the results from the sensitivity analysis which is addressed through a comparison of biomass potentials against current uses of biomass for energy. It also discusses the most influential factors driving the biomass potentials in the different scenarios. The last chapter summarizes the results and describes the first main conclusions and explains about further steps in this task 2.


Figure A2 - 1 Overview of subtasks in Task 2

## 2. Overview of biomass potentials assessed

The cost-supply assessment in this task focusses on biomass feedstock types listed in Part A and B of Annex IX of the RED II and biomass feedstock that complies with Low indirect land use risk because it is produced according to additionality principles as specified in the Delegated Act of the REDII.

For the final selection of the feedstock addressed in this study the following documents were consulted:

- The S2BIOM project categorization of lignocellulosic feedstock from forest, agriculture, and waste sectors (Dees et al., 2017)
- The classification of biomass categories followed in the Biomass Policies project covering cellulosic and non-cellulosic biomass categories (Elbersen et al., 2016) .
- The biomass categories covered in the CONCAWE study (Panoutsou, 2021)
- All biomass types listed in parts A and B of the Annex IX of Directive 2018/2001 and low indirect land use risk biomass (Article 26 and article 5 of the Delegated Act) complying with 'additionality' principles. The latter refer to either feedstock derived from : i) yield increases from improved agronomic practices, or ii) cultivation of areas that are unused, abandoned, or severely degraded.
- All biomass types listed in the draft Annex to the Commission Delegated Directive amending Annex IX to Directive (EU) 2018/2001 of the European Parliament and of the Council, as regards adding feedstocks for the production of biofuels and biogas.

The total overview of biomass categories selected is presented in Appendix 2 Table A2 - 1. In the first two columns of this table a code and a short name is presented that is unique to the biomass category. This code and short name is also used in the excel files with the final cost supply results to refer to every biomass type. In the third and fourth column the biomass is further characterized according to primary, secondary, and waste types and classified according to sector. The fourth column provides and additional description of the biomass. The last column indicates whether the feedstock type is referred to in REDII in Annex IXA or B or under additionality principle or whether it is a new feedstock presented in the draft Annex to the Commission Delegated Directive amending Annex IX. The latter is indicated with REDII- Annex IX-A_new.

In total 61 biomass types were included in the first selection. However, a few biomass categories indicated with * and ** have not been included in the assessment for the reasons explained under the Table A2 - 12 in Appendix 2-1 which implies that 48 types of biomass were also quantified

In the Table A2 - 1, the assessed biomass categories are ordered according to the Annex IX of RED II (Part A and B) and according to sectors.

| Annex IX Part A | DI codes | PRIMES groups | Agricultural feedstocks (virgin, primary and secondary biomass) | Forest feedstocks (primary secondary biomass) | Biowastes (tertiairy biomass) |
|---|---|---|---|---|---|
| (b) Biomass fraction of mixed municipal waste, but not separated household waste subject to recycling targets under point (a) of Article 11(2) of Directive 2008/98/EC | 5102 | Solid waste (incl. secondary forestry residues) | | | Organic fraction in municipal solid waste (MSW), |
| (c) Biowaste as defined in point (4) of Article 3 of Directive 2008/98/EC from private households subject to separate collection as defined in point (11) of Article 3 of that Directive; | 5211; 5212; 5101; 5104 | Solid waste (incl. secondary forestry residues); | | | Post consumer wood waste, separately collected organic waste Animal & mixed food waste, waste fruit and vegetable |
| (d) Biomass fraction of industrial waste not fit for use in the food or feed chain, including material from retail and wholesale and the agro-food and fish and aquaculture industry, and excluding feedstocks listed in part B of this report | 4206; 4207; 4208; 4209; 4210; 4211; 4214 | Solid waste (incl. secondary forestry residues); | Bagasse from sugarbeet; Olive stones; deoiled olive pommace; Brewers spent grain; liquid whey; alcoholic distellerie products; bakery residues and waste; Dextrose ultrafiltration retentate | | |
| (e) Straw | 2201; 2202; 2203 | Agricultural residues | Cereal straw (from barley, wheat, rye and oats), maize stover, stro from oil crops, sugarbeet leaves | | |
| (f) Animal manure and sewage sludge | 2301; 2302; 5108; | Gaseous biomass (incl. manure) | Solid and liquid manure from poultry, pigs, cattle, shep & goats | | Organic fraction in sewage sludge |
| (k) Grape marcs and wine lees | 4202 | Solid waste (incl. secondary forestry residues); | Grape marcs and wine lees | | |
| (m) Husks | 4201; 4203 | Solid waste (incl. secondary forestry residues); | Rice husk; | | |
| (n) Cobs cleaned of kernels of corn | 4204 | Solid waste (incl. secondary forestry residues); | Cob cleaned from grain | | |
| (o) Biomass fraction of wastes and residues from forestry and forest-based industries, namely, bark, branches, pre- commercial thinnings, leaves, needles, treetops, saw dust, cutter shavings, black liquor, brown liquor, fibre sludge, lignin and tall oil; | 1200; 1220; 4111; 4112; 4121; 4122; 4131; 4132 | Solid waste (incl. secondary forestry residues); | | Primary forestry residues; Secondary forest residues; Primary forest stumps; sawdus, other sawmill residues, residue from industries producing semi-finished wood based panels; residues from further wood processing, bark, black liquor | |
| (p) Other non-food cellulosic material | 2204; 2205; 4205; | Solid waste (incl. secondary forestry residues); | Agricultural prunnings from permanent crops; damaged crops; | | |
| (q) Other lignocellulosic material except saw logs and veneer logs | 1100; | Solid waste (incl. secondary forestry residues); | | Stemwood (fuelwood) | |

| Annex IX Part A | DI codes | PRIMES groups | Agricultural feedstocks (virgin, primary and secondary biomass) | Forest feedstocks (primary secondary biomass) | Biowastes (tertiairy biomass) |
|---|---|---|---|---|---|
| (a) Algae if cultivated on land in ponds or photobioreactors | See Annex 7 | - | | | |
| **Annex IX Part B** | | | | | |
| (a) Used cooking oil | 5106; 5107 | Non-agricultural oils | | | Used Cooking oil; Brown grease |
| (b) Animal fats classified as categories 1 and 2 in accordance with Regulation (EC) No 1069/2009 | 4216 | Non-agricultural oils | | | Animal fats (cat 1&2) |
| **Dedicated crops – Annex IX part A** | | | | | |
| Lignocellulosic crops from unused & abandoned lands | 2101 | Perennial lignocellulosic crops | Biomass sorghum, miscanthus, switchgrass, giant reed, RCG, cardoon | | |
| Oil crops from unused & abandoned lands | 2102 | Oil crops | Cardoon, Camelina, Castor | | |
| Woody crops from unused & abandoned lands | 2103 | Perennial lignocellulosic crops | SRC Poplar, willow | | |
| Lignocellulosic crops from severely degraded lands | 2104 | Perennial lignocellulosic crops | Biomass sorghum, miscanthus, switchgrass, giant reed, RCG, cardoon | | |
| Oil crops from severely degraded lands | 2105 | Oil crops | Cardoon, Camelina, Castor | | |
| Woody crops from severely degraded lands | 2106 | Perennial lignocellulosic crops | SRC Poplar, willow | | |
| Intermediate crop lignocellulose (biomass sorghum) | 2107 | Annual lignocellulosic crops | Biomass sorghum | | |
| Intermediate oil crop | 2108 | OIl crops | Camelina | | |
| Cover crop - harvested | 2109 | Annual lignocellulosic crops | Assumes mix of cover crops that in average produce 4 ton dm/ha/yr | | |

*Not considered: (h) tall oil pitch; (i) Crude glycerine; (j) Bagasse, (L) Nut shells; crude methanol, Vinasse, DDGS; secondary residues of drinking products. It should be also noted that the above-mentioned unexploited biomass types, eligible under RED criteria, are expected to be significant in size, even if not yet available by 2050. Therefore, these types of biomasses will make no difference on the final potentials estimated for the 2030 and 2050 horizon in this work.

Table A2 - 1 The overview of biomass categories selected for this study, ordered according to Annex IX (Part A and B), according to sector (agriculture, forest and biowastes) and according to PRIMES[1] classification

[1] Relevant for the comparison between PRIMES demands and biomass potential assessment

# 3. Overall approach to quantification of biomass potentials and costs

## 3.1. Quantification of biomass

A systematic review was first done of existing studies, data, and approaches to assessing cost and supply levels of the biomass types in Table A2 - 1. This review ensured that per biomass type existing work and data were consulted and more updated and improved data and methodologies were applied where necessary and possible.

The most relevant former studies consulted were:

- Biomass Policies: Elbersen, B., Staritsky, I., Hengeveld, G., Jeurissen, L., Lesschen, J.P. & C.Panoutsou (2016) Outlook of spatial biomass value chains in EU28. Deliverable 2.3 of the Biomass Policies project
- S2BIOM: Dees, M., Elbersen, B., Fitzgerald, J., Vis, M., Anttila, P., Forsell, N., Ramirez-Almeyda, J., Glavonjic, B., Staritsky, I., Verkerk, H., Prinz, R., Leduc, S., Datta, P., Lindner, M., Zudin, S., Höhl, M., 2017. Atlas with regional cost supply biomass potentials for EU 28, Western Balkan Countries, Moldavia, Turkey and Ukraine. Project Report. S2BIOM – a project funded under the European Union 7th Framework Programme for Research.
- https://www.s2biom.eu/images/Publications/D1.8_S2Biom_Atlas_of_regional_cost_supply_biomass_potential_Final.pdf
- JRC. 2015 (2019). ENSPRESO - an open data, EU-28 wide, transparent, and coherent database of wind, solar and biomass energy potentials[2].
- CONCAWE: Panoutsou, C. (2021). Sustainable biomass availability in the EU, to 2050[3]
- BIKE project: Panoutsou et al. (2022) and Elbersen et al. (2022).

Overall, all these studies and their data were consulted and used where relevant, but for most of the biomass potentials assessed in this study new more up-to-date base data, methodologies and scenario assumptions were used and developed as follows:

- The biomass assessments in S2BIOM, Biomass Policies, ENPRESO and CONCAWE take 2015 base data from where future biomass potentials were generated. In this study the newest CAPRI baseline run data for 2030 and 2050 published in 2022 report (CAPRI, 2022[4]) were used. So, all new baseline scenario runs for agricultural land use in 2030 and 2050 are used here.
- For waste the assessments for 2030 and 2050 projections take the most recent regional EUROSTAT waste statistics as a starting point.
- For primary and secondary biomass potentials rom forest sector the S2BIOM data were used here, since there are no other more up to date EFISCEN model runs available. However, for this study specific scenarios from S2BIOM were selected to fit the drop-in low, medium, and high mobilisation scenarios ensuring a diversity in competing use levels and sustainability requirements over these scenarios.
- For all the new proposed Annex IXA and B biomass types, not yet assessed in other studies, new quantification approaches were developed, and data collection was done.
- All data were generated at Nuts2 regional level which involved several disaggregation and data processing steps. This also enabled the presentation of all final biomass cost supply data for one uniform regional classification.
- Cost assessments were updated for all biomass types. New data were identified. Cost levels from former studies were updated according to 2020 cost levels by taking account of inflation development levels to 2020. For cost developments towards 2030 and 2050 future inflation development expectations were applied in the three mobilisation scenarios.

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[2] https://ec.europa.eu/jrc/en/publication/enspreso-open-data-eu-28-wide-transparent-and-coherent-database-wind-solar-and-biomass-energy

[3] Sustainable biomass availability in the EU, to 2050 - Concawe

[4] CAPRI model documentation version 18/01/2022. https://www.capri-model.org/dokuwiki_help/

- Novel biomass resources, e.g., algae, DAC were not considered.

The overall assessment of the biomass potentials is based on the following formula:

**Availability = Presence – (T1 + T2 + T3)**

*Where:*

**Availability** = Availability under certain minimum sustainability requirements and competing use assumptions (depending on the scenario situation) and within a certain time period (2030 & 2050).

- Presence = Presence of biomass now and in future (2030 & 2050) and this will differ per scenario
- **T1** = part of biomass has to be left behind for soil conservation/biodiversity/erosion control
- **T2** = known conventional competitive uses (food, feed, bedding, fiber, etc.)
- **T3** = new competitive uses (particularly for (non-energy) more circular material and biochemical uses)

**T1, T2 and T3** will be influenced by specific factors in the scenario assumptions and will result in different supply and cost levels by 2030 and 2050 which are also further assessed in the sensitivity analysis (task 2.8).

Overall, the competing uses as referred to in T3 have been addressed carefully in this study through the use of scenario assumptions. In the three mobilization scenarios the demands for biomass from competing uses outside the energy sectors were addressed in two ways:

- By already selecting low-ILUC risk biomass types, so biomass that has no or low competition with food production
- Assuming different levels of competing demands for biomass from both feed and material and chemical sectors in the three mobilization scenarios. The low mobilization scenario has the highest competing use levels and the highest effect of other constraining factors on the supply. This implies that it leaves little biomass available for the energy demands from electricity, heat and transport fuels. In the high mobilization scenario, the competing uses and other constraining factors are assumed to be much lower and in the Technical potential no competing uses are assumed.

**Assessment of costs**

As for the cost assessment a more pragmatic approach is followed. A distinction has been made between types of cost and price estimates specific per biomass type (see Appendix 2 assessment of Cost assessment):

- Market prices for already traded biomass types (but these are very few)
- Road-side-costs for biomass for which markets are (practically) not developed yet. This applies to most of the biomass types.
- At-gate-costs have then been generated for all biomass types which cover the cost at roadside + transport and handling costs until the biomass reaches the conversion plant gate. This is the biomass cost level that can best be linked to the biomass supply levels to generate the cost supply curves at regional levels for the different types of drop-in fuel options. For the at-gate-costs different transport distances have been assumed.

For biomass streams that are already traded on a market in large quantity and can be regarded as (near to) a commodity, the cost level will be similar to a price level. However, it is practically impossible to obtain price levels for most of the biomass types, particularly because these can fluctuate very strongly in time and place and here there is a need for future cost levels for 2030 and 2050. Therefore, for most biomass categories cost estimates are made taking account of production and/or harvesting costs up to roadside, where possible taking account of national and regional specific cost levels, such as labour and fuel cost (averages over several years). For future cost developments, expectations regarding inflation development rates are not applied, so the price/cost levels are kept stable over time. For further detailed explanation see also Appendix 2-5.

## 3.2. Approach to assessing primary biomass potentials 2030 and 2050 from agriculture

The most logical model and dataset used as a basis for the estimation of future residual and dedicated biomass supply from crops and livestock (manure) is *the CAPRI model and related COCO database.* The CAPRI model predicts the future market and production responses at the regional level for the whole EU-28, western Balkans, Turkey, and Norway (not Ukraine). It is therefore the only source of information available that gives a plausible overview taking account of the specific diverse regional circumstances in the EU planned policy and of what land-use changes can be expected by 2030 and 2050. It was also used in Biomass Policies (Elbersen et al., 2016), S2BIOM (Dees et al., 2017) and Concawe (Panoutsou, 2022) as the basis for estimating the future primary residual biomass sources and land. In this study, however the more up to date CAPRI data generated for the most recent Business As Usual (BAU) scenario which became available in January 2022 were used.

CAPRI forecasts future land use and livestock production changes in the EU-27, UK, most Balkan countries (except Moldova) and Turkey including land demand for domestic biofuels (although NOT for bioenergy crop demand for bio- electricity and heat). Ukraine is not covered in CAPRI (except as part of the rest of the world for import and export relations with the EU).

For the assessment in Drop-in fuels (like for S2BIOM, Biomass Policies) land-use, crop and livestock production levels are used based on the most recent CAPRI baseline run 2008-2050, providing intermediate results for 2010, 2020, 2030 and 2050. This baseline run is seen as the most probable future simulating the European agricultural sector under status-quo policy and including all future changes in policy already foreseen in the current legislation. It also assumes all policy regarding bioenergy targets as agreed until now and further specified in the Trends to 2050 report (CAPRI, 2022[5]) for as far as affecting agriculture. For the assessment of residues, the CAPRI land use patterns for 2020, 2030 and 2050 area and livestock numbers were taken.

Yields and changes in yield levels per region and country in CAPRI for the conventional crops delivering residues are already included in the baseline scenario of CAPRI. These values are based on country specific modelling baselines, expert consultations, historic projections. The national input is then recovered in Aglink-Cosimo by adapting the behavioural equations in the model while at the same time adapting these to joint worldwide future development expectations regarding import/and export relations, worldwide price, and technological developments. CAPRI then takes Aglink-Cosimo output as an input. These developments are then further incorporated into CAPRI but tuned where necessary with internal constraints set on yields for both vegetable and animal products. These internal constraints are needed to maintain a consistent and stable relationship between the very influential CAPRI specific yield increase parameters and other factors such as technology development, seed use and losses, land use ratio factors, etc. Further details on this aspect see (CAPRI, 2022[6]) .

For the assessment of the several agricultural biomass potentials the CAPRI output was used and further processed into biomass potentials for 2030 and 2050. This CAPRI output consists of regional specific data for 2030 and 2050 on land use, agricultural crops (area, yields, production levels) and on animals (animal types, heads, production) at regional level (Nuts II).

CAPRI output results were used as a basis for assessing the agricultural biomass categories presented in Table A2 -2. For further details on the exact assessment of these biomass potentials consult Appendix 2-4 and the SWOT fact sheets in Appendix 2-7.

| DI codes | Description of biomass category | Input data used |
|---|---|---|
| 2101, 2102, 2103, 2104, 2105, 2106, | All dedicated crop potentials from unused and degraded lands | CAPRI baseline 2022<br>S2BIOM & BIKE – crop yields & costs<br>MAGIC & CAPRI & additional modelling: Unused, abandoned and degraded lands |
| 2107, 2108, 2109, | All dedicated crop potentials from intermediate and cover crop practices | CAPRI baseline 2022<br>S2BIOM & BIKE – crop yields & costs<br>CAPRI & Eurostat data for land availability |
| 2201, 2202, 2203, 2204, 2205 | Primary residues from arable and permanent crops and damaged crops | CAPRI baseline 2022: yields, area crops, production<br>Garcia Condado et al. (2019): residue to product relations |

[5] CAPRI model documentation version 18/01/2022. https://www.capri-model.org/dokuwiki_help/
[6] CAPRI model documentation version 18/01/2022. https://www.capri-model.org/dokuwiki_help/

| DI codes | Description of biomass category | Input data used |
|---|---|---|
| 2301, 2302 | Liquid and solid manure | CAPRI baseline 2022: animal heads<br>Biomass Policies – for manure production and type |
| 4201, 4202, 4203, 4204, 4205, 4207; 4208, 4209, 4210, 4211, 4214 | Food processing residues | CAPRI baseline 2022: crop production and processing levels<br>S2BIOM and other literature for: Residue factors |

Table A2 -2 The overview of biomass categories from agriculture

## 3.3. Approach to assessing primary and secondary biomass from forestry

The biomass potential types covered in this study from the forest sector are presented in Table A2 -3.

| DI codes | Description of biomass category | Input data used |
|---|---|---|
| 1100 | All stemwood from final fellings & thnnings | S2BIOM – EFISCEN |
| 1200; 1220; 4111; 4112; 4121; 4122; 4131; 4132 | Primary forestry residues; Secondary forest residues; Primary forest stumps; sawdust, other sawmill residues, residue from industries producing semi-finished wood-based panels; residues from further wood processing, bark, black liquor | S2BIOM – EFISCEN<br>And S2BIOM post model assessment using additional UNECE-FAO and national statistics |

Table A2 -3 The overview of biomass categories from forest

The main source used in the S2BIOM data was also used as the core input in the CONCAWE study (Panoutsou). In S2BIOM the central model to assess biomass potential was the European Forest Information SCENario model (EFISCEN) (Sallnäs, 1990). It was first used to assess the theoretical potential of forest biomass at regional to national level. Versions 3.1.3 (Schelhaas et al. 2007) and 4.1 (Verkerk et al. 2016a) were used. IN S2BIOM these two versions were used, because the former version is included in a script to estimated biomass potentials Verkerk et al. (2011), while the latter version has the ability to directly store results in a database, which is used to run the EFISCEN disaggregation tool (Verkerk et al. 2016b). EFISCEN describes the state of the forest as an area distribution over age- and volume-classes in matrices, based on data on the forest area available for wood supply (FAWS), average growing stock and net annual increment collected from NFIs. Forest development is determined by different natural processes (e.g., increment) and is influenced by human actions (e.g. management). National forest inventory data on area, growing stock and net annual increment are used to initialize the EFISCEN model. In S2BIOM the NFI input data were updated as much as possible.

In the model, the forest area was scaled to match the forest area available for wood supply (FAWS) as reported by Forest Europe (2015). FAWS are defined as “forests where any legal, economic, or specific environmental restrictions do not have a significant impact on the supply of wood” (MCPFE 2007). In this study the FAWS remains static until 2030 and effects of changes in forest area are not estimated. The amount of wood that can be felled in a time-step is controlled by a basic management regime that defines the period during which thinnings can take place and a minimum age for final harvest. Age-limits for thinnings and final fellings were based on conventional forest management according to handbooks at regional to national level (Nabuurs et al. 2007) and by consulting national correspondents (UNECE-FAO 2011). The amount of stemwood potential removed as logs was estimated by subtracting harvest losses from the stemwood felling potential. Harvest losses were estimated using the ratio between fellings and removals as reported by UNECE-FAO (2000) for coniferous and broadleaved species separately.

Branches together with harvest losses represent logging residues that can be potentially extracted as well. In addition, stumps could potentially be extracted, separately from logging residues. The volume of branches, stumps and coarse roots was estimated from stemwood volume (incl. harvest losses) using age-dependent, species-specific biomass distribution functions (Vilén et al., 2005; Romano et al., 2009; Mokany et al., 2006; Anderl et al. 2009). No difference in basic wood density between stems and other tree compartments was assumed, due to lack of information.

Climate change is accounted using results from LPJmL (Sitch et al. 2003, Bondeau et al. 2007). Data are an average for several climate models for the A1b SRES scenario. Annual tree Net Primary Production (NPP) in gC/m2 for 3 individual years (2010, 2020, 2030) was calculated with LPJmL and used to scale the increment functions used in EFISCEN.

The EFISCEN disaggregation tool was used to disaggregate the estimated biomass potentials to the 1km grid level using tree species distribution maps (Brus et al. 2011). The disaggregated woody biomass potentials were then multiplied with the respective constraint maps to address sustainability limitations covering:

- site productivity, soil surface texture, soil depth and soil bearing capacity (EC 2006b)
- Slope: terrain ruggedness index (Riley et al 1999)
- natural soil susceptibility to compaction (Houšková 2008)
- Natura 2000 sites (EC 2009b)
- fire weather index (average for summer months June, July, August over the period 1975-2005; Marco Moriondo, pers. comm.)

Eventually the resulting maps give the constrained biomass potential at grid level. The rasters were then re-aggregated to NUTS 3 regions, as used in S2BIOM. IN drop in fuels the results are allocated to the uniform region classification.

EFISCEN could not be applied to all countries within S2BIOM, due to absence of the required forest inventory data. Instead, woody biomass potentials for Cyprus, Greece, Montenegro, FYROM, Bosnia and Herzegovina, Kosovo and Serbia were estimated following the methodology from BEE (Vis and Dees, 2011). This approach assumes that the theoretical stemwood harvest potential was based on the net annual increment corrected for harvesting losses. Aggregated data on forest area and net annual increment from Forest Europe (2015) or – in case of missing data – on Forest Europe (2011) were used. For Greece net annual increment as reported by Meliadis et al. 2010 was used. Net annual increment was scaled to account for climate change, as done for all other countries (Sitch et al. 2003, Bondeau et al. 2007). Biomass allocation functions from Teobaldelli et al. (2009) and estimated stump biomass based on data by Asikainen et al. (2008) was also followed. No data were available for Malta.

In this Drop-in Fuels project also 2050 biomass potentials from forests were needed which were not assessed in S2BIOM. Therefore, an extrapolation of the forest production trends was made using the trends between 2010 and 2030 from S2BIOM and continuation of this trend towards 2050.

Beside the stemwood from final fellings and thinning and the primary residues and stumps from forests secondary biomass residues from sawmills and wood industries need to be assessed. Also, these were already quantified in S2BIOM. These data are also used here, but further adaptations were made regarding extrapolation to 2050, but also in relation to the selection of user defined S2BIOM scenarios results chosen.

Sawmill residues consist of sawdust and other residues, comprising chips, slabs and shavings. To determine the technical and base potential the statistics on production volumes provided by FAOSTAT per country are the starting point used in combination with product recovery rates and the quantitative relation of residues to products.

The amounts of saw dust and other residues from sawmills are estimated using:

- SD-Q = P-Q * SD-P-Ratio
- OR-Q = P-Q * OR-P-Ratio

*Where:*

- SD-Q is saw dust quantity,
- P-Q is product quantity,
- SD-P-Ratio is sawdust to product ratio
- OR-Q is non-saw dust residues quantity
- OR-P-Ratio for the other residues to product ratio.

These ratios were determined using the recovery rate of the product and the share of saw dust and other residues that are provided by UNCECE/FAO (2010) and by Saal (2010a) .

The analysis of residues in S2BIOM from semi-finished wood-based panels and from further wood processing (in sectors construction, Packaging, Furniture and Other) followed the categories established by FAOSTAT and also Eurostat industrial activity business statistics. Again, through assuming a product to residue ratio (also derived from UNCECE/FAO (2010) and by Saal (2010a)) the residues could be quantified.

Finally, the residue from pulp and paper industry, black liquor, and bark, was also assessed in S2BIOM. For black liquor the FAOSTAT production data from 2010 to 2014 were used to determine an average value. Then the round wood input per pulp technology was estimated using conversion factors published by UNECE /FAO (2010). To estimate the amount of black liquor from the chemical pulping process a factor of 0.5 is thus adequate to determine the amount of round wood input that is included in the pulp that contains in addition chemicals that are used to separate cellulose from lignin (Saal 2010a).

To estimate the amount of bark a 10% ratio was considered leading to an average over bark/ under bark ratio of 0.88 (UNECE/FAO 2010) and certain bark losses. This was then applied to country share of pulpwood going to pulp and paper in order to calculate bark residues from this sector.

All S2BIOM forest residue data were also disaggregated to regional levels (Nuts 3) using several spatial data, such as in the case of residues of pulp and paper industry the locations of pulp and paper mills in Europe.

Projections of forest potentials to 2030 were made using a combination of population development data, expectations on GDP development and a forests consumption index.

More details about the forest biomass potential assessment can be read in the S2BIOM Deliverable 1.6 (Dees et al., 2017).

## 3.4. Approach to assessing primary and secondary biomass from waste

The biomass potential types covered in this study from the biowaste sector are presented in Table A2 - 4.

| DI codes | Description of biomass category | Input data used |
|---|---|---|
| 5101, 5102 | Organic fraction of municipal solid waste separately collected; Organic fraction of municipal solid waste un-separately collected | Eurostat waste statistics & Population projections[7] |
| 5111, 5212 | Post-consumer wood waste hazardous and non-hazardous | S2BIOM, EFSOS, Eurostat waste data |
| 5104 | Fruit and vegetable residues and waste not fit for use in the food and feed chain, excluding tails, leaves, stalks and husks | CAPRI baseline 2022<br>S2BIOM – crop yields |
| 5106 | Used cooking oil (UCO) | Panoutsou (2022) |
| 5107 | Waste Brown_Grease | Literature and Eurostat population projections |
| 5108 | Organic fraction in sewage sludge | Eurostat waste statistics & Population projections[8] |

Table A2 - 4 The overview of biomass categories from organic waste

**Organic waste**

Organic waste consists of fractions that are separately collected and as part of mixed waste in the municipal solid waste (MSW) category. Eurostat reports the amount of waste produced per country on a yearly basis in waste production per head. The separately organic waste categories used are 'Animal and mixed food waste' and 'Vegetal waste'. In principle the organic waste amounts develop according to population development figures which were derived from Eurostat 2030 and 2050 population projections at regional level. However, differences in development of organic waste (separated and un-separated) are applied according to the mobilisation scenarios (see next).

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[7] Population on 1st January by age, sex, type of projection and NUTS 3 region [PROJ_19RP3__custom_5802835]
[8] Population on 1st January by age, sex, type of projection and NUTS 3 region [PROJ_19RP3__custom_5802835]

**Post-consumer wood**

Post-consumer wood (PCW) data was derived from S2BIOM. It comprises packaging materials, demolition wood, and timber from building sites and fractions of used wood from residential (municipal waste), industrial and commercial activities. The c*alculation method:*

$PCW_{\text{technical potential}} = PCW_{\text{material}} + PCW_{\text{energy}} + PCW_{\text{disposed}}$
$PCW_{\text{base potential}} = PCW_{\text{energy}} + PCW_{\text{disposed}}$

*in which:*

$PCW_{\text{recovered}}$ = PCW used for materials like panels and chipboards
$PCW_{\text{energy}}$ = PCW used for energy production
$PCW_{\text{disposed}}$ = landfilled and/or incinerated with MSW.

Eurostat data could not be used because this statistical data on “wood waste” includes not only post-consumer wood but processing wastes from agriculture forestry and fishing sectors. For S2BIOM and also this study, data on recovered wood were used from a forest biomass resource assessment done for the EUwood and EFSOS II studies (Mantau et al. 2010; UN-ECE/FAO 2011[9]). EUwood combines among others Eurostat and COST Action E31 data. The EFSOS II data on demolition wood is based on EU wood but covers Europe as a whole instead of EU28. In order to determine the base potential PCW available for energy, it was necessary to estimate how much is used for material applications. In the Methodology report of the EUwood project[10], a table is given on the availability of *PCW recovered* [for material recycling] and *PCW energy* for 2007, page 119-120, which have been used in this study as well. In addition, EFFSOS II data have been used to estimate the availability of PCW in other non-EU European countries. Since the S2BIOM data were only provided until 2030 for 2050 the historic trend of this resource between 2012 to 2030 was further continued towards 2050. In the scenarios assumptions (see next) stricter competing use levels were applied then in S2BIOM because new additional bioeconomy uses can be expected particularly towards 2050.

**Fruit and vegetable residues and waste not fit for use in the food and feed chain**

To estimate their potential, Mason D’Croz et al. (2019) was followed, who expected the amount of fruit and vegetable waste to be:

0.01378 kg/day/person by 2030 (assuming 8% dry mass)

0.01416 kg/day/person by 2050 (assuming 8% dry mass)

These figures were multiplied by the number of inhabitants as projected by Eurostat for European regions by 2030 and 2050 to generate the technical potential. For the additional assumptions made per mobilisation scenario, see next section on scenarios.

**Used Cooking Oil (UCO)**

Used cooking oil can come from households and companies (professional use). The current amount of UCO per country were derived from Panoutsou (2021). These were converted to UCO production per head to enable the prediction of UCO production towards 2030 and 2050. However, not all countries in Europe were covered by Panoutsou (2021). So for missing countries UCO production per head had to be used from neighboring countries to fill gaps (see also Appendix 2).

**Brown grease**

Brown grease is the oily material collected from grease traps that are used to segregate insoluble and gelatinous grease present in kitchen wastewater streams. Brown grease is quantified based on the population size per NUTS-2 region and the brown grease production in Germany from 2019 (Umweltbundesamt, 2019):

Brown grease (tonnes/capita/year) lower limit: 0.000015

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[9] UNECE (United Nations Economic Commission for Europe), FAO (Food and Agricultural Organization of the United Nations) 2011: The European Forest Sector Outlook Study II; Geneva

[10] EU Wood (2010) Methodology report, real potential for changes in growth and use of EU forests EUwood. Call for tenders No. TREN/D2/491-2008.

Brown grease (tonnes/capita/year) upper limit: 0.0051

For the future production the population projections towards 2030 and 2050 from Eurostat[11] were used.

**Organic fraction in sewage sludge**

Eurostat reports the amount of sewage sludge produced per country on a yearly basis in production per head. To determine what the organic fraction is, Sharma et al., (2022) was followed, who indicate that the dewatered sludge is composed of organic matter (50–70 %). So, for the assessment of the potential in this study, 60% organic matter content was considered.

Like with the organic waste, sludge is also assumed to develop according to population development figures which were derived from Eurostat 2030 and 2050 population projections at regional level. However, differences in development of sewage sludge are applied according to the mobilisation scenarios (see next).

## 3.5. Scenarios

In this study one technical potential is developed for every type of biomass and this is further elaborated into three potential levels for 2030 and 2050 according to three mobilisation scenarios: Low, Medium, and High mobilization. The technical potential refers to the maximum biomass availability assuming current technological possibilities (such as harvesting techniques, infrastructure, and accessibility) and minimal sustainability considerations such as exclusion of dedicated food crops (excluding of course their residues which are included in the technical potential) and spatial confinements due to other land uses and ecological reserves.

In the Low bioenergy scenario biomass use in the energy sector is not a key priority, but resource efficient use of biomass is. This implies that there are less stimulation measures in place for mobilisation of domestic biomass supply and sustainability criteria are strict putting limits to the removal of residues from forests and agriculture and the production of dedicated cropping potential for biofuels from woody and ligno-cellulosic crops. Competing uses for material conversion of biomass have higher priority than the use of biomass residues and waste in energy because of stricter policy guided strongly by overall resource efficiency. There are also less stimulation measures in place for agriculture and forestry to increase production of biomass for non-food uses. Finally, the effects of climate change will become more influential.

The medium scenario corresponds most to a reference or business as usual case and specifies the most likely future development of bioenergy leading to a continuation of current trends. There is stimulation of bioenergy production and of improvements in cropping and forest management practices but taking account of sustainable and resource efficient use of biomass. This implies that bioenergy use of types of biomass with high sustainability risks are avoided and that enough room is left for competing uses of biomass outside the energy sector. The mobilisation of biomass production and harvesting is enhanced through innovation and support measures, but not as strongly in the high scenario. Stimulation and policy measures can be assumed to be in strong line with currently agreed policies and targets.

The High bioenergy scenario is compatible with a situation where stimulation measures are in place for rapid technology development both for agricultural and forestry practices and for uptake of new drop-in biofuels technologies. Demand for biomass is high and there is a willingness to pay a (higher) price for it. This enhances the mobilisation of biomass production and harvesting opportunities and stimulates the use of biomass above alternative uses.

For every biomass type these scenario storylines are translated in specific mobilization factors as will become clear from the following. For all scenarios the baseline (2020 situation) is the current conventional uses of biomass. This is ensured for agricultural biomass by addressing land for food demand first as is the starting point of the CAPRI output data for baseline run 2030 and 2050, used here. Also, in the forest sector this is addressed through the EFISCEN model output used and the post-model assessments of biomass potentials for primary and secondary forestry biomass. Material uses obtain priority, certainly in relation to known conventional uses in our assessments. For future competing biomass demands and effects of stricter circularity uses assumptions will need to be made that will become part of the scenarios. This is necessary because no studies are available that provide good insights on future biomass demands for other non-food biomass applications. JRC does address the monitoring of biomass uses in different sectors (e.g., Gurria et al., 2020) but only addresses current uses.

[11] Population on 1st January by age, sex, type of projection and NUTS 3 region [PROJ_19RP3__custom_5802835]

### 3.5.1. Scenario assumptions for biomass types from agriculture

For the biomass types from agriculture an overview of scenario assumptions is summarized in Table A2 - 5.

For dedicated crops scenario assumptions are specified for 3 different issues: 1) % of abandoned and degraded lands and agricultural lands (in case of inter or cover crops) taken into use for cropping availability of land, 2) crop mix and expectations on yield change and 3) effects of climate change on yield. The latter is applied per environmental zone following expectation for climate change impacts on agriculture (EEA, 2019). For dedicated crops yield levels were higher in the IC study because part of the dedicated cropping can take place on abandoned lands with good quality lands, but in this study it was assumed that all dedicated crops would grow on low quality lands, so the yields were more modest, but yield increases were assumed to be larger then what was assumed in the IC study. Also, the land availability in IC, based on S2BIOM, is different from the land availability estimates in this study. In IC only the abandoned lands were taken into account which were estimated to be around 20 million hectares in 2030 and 2050. In this study the land availability for dedicated crops was assessed with new models and data and distinguishes between land abandoned and degraded land. This resulted in a total technical land availability of 8.3 million hectares in 2030 (3.3 abandoned and 5 million ha degraded) and almost 40 million in 2050 (7.6 million abandoned and 32 million degraded). Of this technical land available, the assumptions on the land share that would also be used for dedicated cropping, were more modest in this study, then the IC also because 2030 is close and see very little, large progress in dedicated cropping until now. On the other hand, the technical potential is very large. For further details on how the dedicated crop potential is assessed see Appendix 2-4 in this report.

For primary crop residues from arable and permanent crops 5 issues are addressed: future cropping area and yield levels, changes in yields and climate change effect on yield changes, sustainable removal rates and competing uses. Indirectly the assumptions per scenario on how yields develop, how yields respond to climate change address the technological improvements and innovations expectations. Generally, these innovations and technology developments are expected to be more supported in the medium and the high mobilization scenarios hance leading to higher yield increases in these scenarios. These technological and innovation development are crucial for yield increases and introduction of new crops. Innovations need to focus on provision of new plant varieties that can better cope with climate change, that provide new options for non-food biomass needs and mechanization improvement that decrease harvest losses and that enable the introduction on new crops in existing cropping systems.

For manure potentials the available manure is calculated according to number of animals in 2030 and 2050 based on CAPRI BAU, but also on the number of animals held in stables and the assumed removal rates.

Finally, residues produced in the food processing industries depend on the amount of processed agricultural commodities which are either derived from CAPRI BAU output or other sources. This is further explained in Appendix 2-4 of this report. The availability per scenario is determined by the level of competing uses assumed.

### 3.5.2. Scenario assumptions for biomass types from forestry

As explained in the former the biomass potentials in the forest sector are mostly derived from the S2BIOM project (Dees et al., 2017). In S2BIOM different mobilisation scenarios were generated. In this study the following mobilisation scenarios from S2BIOM were matched for the low, medium, and high mobilisation scenarios as is presented in Table A2 - 6.

For the stem wood and primary forestry residues different assumptions were made for forest area available for wood production, developments in growth and yield of forests, technical and environmental constraints and competing use levels. The latter relate to uses for wood-based materials and pulp and paper.

For the secondary residues the assumptions in the scenarios range according to competing uses.

| DI codes | Description of biomass category | Issue | Technical potential | Low mobilisation | Medium mobilisation | High mobilisation |
|---|---|---|---|---|---|---|
| 2101, 2102, 2103, 2104, 2105, 2106, | All dedicated crop potentials from unused and degraded lands | Land availability:<br>-Abandoned land<br>-Degraded land | 100% abandoned used<br>100% degraded used | Only NECR* from CAPRI baseline in 2030 & 2050 | NECR* from CAPRI baseline + 10 % of abandoned and 5% of degraded land in 2030. In 2050 this is 15% of abandoned and 10% of degraded land | NECR* from CAPRI baseline + 20 % of abandoned and 10% of degraded land in 2030. In 2050 this is 30% of abandoned and 20% of degraded land |
| | | Yield increases | 1% per year | 0.2% per year | 0.5% per year | 1% per year |
| | | Climate change effect on yields | No effect on yields | In Mediterranean zone: up to 2030 10% total yield decrease and up to 2050 20% yield **de**crease<br>In Boreal & Nemoral zone:<br>2030: 5%/2050: 10% yield **in**crease in all crops | In Mediterranean zone: up to 2030 5% total yield decrease and up to 2050 10% yield **de**crease<br>In Boreal & Nemoral zone:<br>2030: 5%/2050: 15% yield **in**crease in all crops | In Mediterranean zone: NO yield decrease expected<br>In Boreal & Nemoral zone:<br>2030: 15%/2050: 25% yield **in**crease in all crops |
| | | Competing use | No competing use | No competing use | No competing use | No competing use |
| 2107, 2108 | Intermediate crops in combination with winter crops: grown in fallow summer period following land availability per region of area under pure winter sequences from LUCAS (Ballot et al., 2022) | How much | (50% Oil crop (camelina) and 50% biomass sorghum) | 50% Oil crop (camelina) and 50% biomass sorghum | 50% Oil crop (camelina) and 50% biomass sorghum | 50% Oil crop (camelina) and 50% biomass sorghum |
| | | ENZ | Intercrops in MDN, MDS, CON, PAN, LUS** | Where: in MDN, MDS, CON, PAN, LUS** | Where: in MDN, MDS, CON, PAN, LUS** | Where: in MDN, MDS, CON, PAN, LUS** |
| | | Available land? | 100% of available arable land with only winter crops | In 2030 0.5% and 1% in 2050 of available arable land with only winter crops | In 2030 2% and 4% in 2050 of available arable land with only winter crops | In 2030 5% and 10% in 2050 of available arable land with only winter crops |
| | | Yield increase assumed | 1% per year | 0.2% per year | 0.5% per year | 1% per year |
| | | Climate change effect on yields (based on EEA, 2019) | No effect on yields | In Mediterranean zone: up to 2030 10% total yield decrease and up to 2050 20% yield **de**crease<br>In Boreal & Nemoral zone:<br>2030: 5%/2050: 10% yield **in**crease in all crops | In Mediterranean zone: up to 2030 5% total yield decrease and up to 2050 10% yield **de**crease<br>In Boreal & Nemoral zone:<br>2030: 5%/2050: 15% yield **in**crease in all crops | In Mediterranean zone: NO yield decrease expected<br>In Boreal & Nemoral zone:<br>2030: 15%/2050: 25% yield **in**crease in all crops |
| | | Competing use | No competing use | No competing use | No competing use | No competing use |
| 2109 | Cover crops | ENZ | ATN, ATC, CON, LUS, PAN | ATN, ATC, CON, LUS, PAN | ATN, ATC, CON, LUS, PAN | ATN, ATC, CON, LUS, PAN |

| DI codes | Description of biomass category | Issue | Technical potential | Low mobilisation | Medium mobilisation | High mobilisation |
|---|---|---|---|---|---|---|
| | | Available land? | All arable land with rotational crops | 0.5% in 2030 and 1% in 2050 of available arable land | 2% in 2030 and 4% in 2050 of available arable land | 5% in 2030 and 10% in 2050 of available arable land |
| | | Yield increase assumed | 1% per year | 0.2% per year | 0.5% per year | 1% per year |
| | | Climate change effect on yields (based on EEA, 2019) | No effect on yields | In Mediterranean zone: up to 2030 10% total yield decrease and up to 2050 20% yield **de**crease<br>In Boreal & Nemoral zone:<br>2030: 5%/2050: 10% yield **in**crease in all crops | In Mediterranean zone: up to 2030 5% total yield decrease and up to 2050 10% yield **de**crease<br>In Boreal & Nemoral zone:<br>2030: 5%/2050: 15% yield **in**crease in all crops | In Mediterranean zone: NO yield decrease expected<br>In Boreal & Nemoral zone:<br>2030: 15%/2050: 25% yield **in**crease in all crops |
| | | Competing use | No competing use | No competing use | No competing use | No competing use |
| 2201, 2202, 2203, | Primary residues from arable crops | *Area change 2030 & 2050* | According to CAPRI 2.7 BAU: crop area, yield & production levels 2030 & 2050 | According to CAPRI 2.7 BAU: crop area, yield & production levels 2030 & 2050 | According to CAPRI 2.7 BAU: crop area, yield & production levels 2030 & 2050 | According to CAPRI 2.7 BAU: crop area, yield & production levels 2030 & 2050 |
| | | *Yield change* | As in CAPRI BAU + 1% yield increase per year | As in CAPRI BAU, NO additional yield increase | As in CAPRI BAU + 0.5% yield increase per year | As in CAPRI BAU + 1% yield increase per year |
| | | *Removal rate in field* | 100% for all crops | Cereals: 35%<br>Oil crops: 40%<br>Rice: 30%<br>Stover: 50%<br>Sugarbeet leaves: 50% | Cereals: 40%<br>Oil crops: 50%<br>Rice: 40%<br>Stover: 60%<br>Sugarbeet leaves: 60% | Cereals: 45%<br>Oil crops: 60%<br>Rice: 50%<br>Stover: 70%<br>Sugarbeet leaves: 70% |
| | | *Competing use* | 0% competing use | For animals (bedding, feed) and other biobased uses (building, biochemicals, paper) 2030 (2050)<br>Cereals: 100% (100%)/ Oil crops: 10% (20%)/ Rice: 10% (20%) Stover: 30% (50%)/ Sugarbeet leaves: 50% (70%) | For animals (bedding, feed) and other biobased uses (building, biochemicals, paper) 2030 (2050) Cereals: 50% (50%)/<br>Oil crops: 5% (10%)/<br>Rice: 5% (10%)/<br>Stover: 20% (40%)/ Sugarbeet leaves: 30% (50%) | For animals (bedding, feed) and other biobased uses (building, biochemicals, paper) 2030 (2050)<br>Cereals: 25% (25%)/<br>Oil crops: 0% (0%)/<br>Rice: 0% (0%)/<br>Stover: 10% (20%)/<br>Sugarbeet leaves: 15% (25%) |
| | | *Climate change* | No effect on residue yields | In Mediterranean zone: up to 2030 10% total yield decrease and up to 2050 20% yield **de**crease<br>In Boreal & Nemoral zone: | In Mediterranean zone: up to 2030 5% total yield decrease and up to 2050 10% yield **de**crease<br>In Boreal & Nemoral zone: | In Mediterranean zone: NO yield decrease expected<br>In Boreal & Nemoral zone:<br>2030: 15%/2050: 25% yield **in**crease in all crops |

| DI codes | Description of biomass category | Issue | Technical potential | Low mobilisation | Medium mobilisation | High mobilisation |
|---|---|---|---|---|---|---|
| | | | | 2030: 5%/2050: 10% yield **in**crease in all crops | 2030: 5%/2050: 15% yield **in**crease in all crops | |
| 2204 | Primary residues from permanent crops | *Area change 2030 & 2050* | According to CAPRI 2.7 BAU: crop area, yield & production levels 2030 & 2050 | According to CAPRI 2.7 BAU: crop area, yield & production levels 2030 & 2050 | According to CAPRI 2.7 BAU: crop area, yield & production levels 2030 & 2050 | According to CAPRI 2.7 BAU: crop area, yield & production levels 2030 & 2050 |
| | | *Yield change* | As in CAPRI BAU | As in CAPRI BAU | As in CAPRI BAU | As in CAPRI BAU |
| | | *Removal rate in field* | 100% for all crops | Apple& pear: 50%<br>Soft fruit: 50%<br>Vineyards: 50%<br>Olives: 50%<br>Citrus: 50% | Apple& pear: 60%<br>Soft fruit: 60%<br>Vineyards: 60%<br>Olives: 60%<br>Citrus: 60% | Apple& pear: 70%<br>Soft fruit: 70%<br>Vineyards: 70%<br>Olives: 70%<br>Citrus: 70% |
| | | *Competing use* | 0% competing use | For other biobased uses (building, biochemicals, paper) 2030 & 2050)<br>Apple& pear: 50%/<br>Soft fruit: 50%/<br>Vineyards: 50%/<br>Olives: 50%/<br>Citrus: 50% | For other biobased uses (building, biochemicals, paper) 2030 (2050)<br>Apple& pear: 25%/<br>Soft fruit: 25%/<br>Vineyards: 25%/<br>Olives: 25%/<br>Citrus: 25% | For other biobased uses (building, biochemicals, paper) 2030 (2050)<br>Apple& pear: 10%/<br>Soft fruit: 10%/<br>Vineyards: 10%/<br>Olives: 10%/<br>Citrus: 10% |
| | | *Climate change* | No effect on residue yields | No effect on residue yields | No effect on residue yields | No effect on residue yields |
| 2205 | Damaged crops | Production and yield | According to CAPRI 2.7 BAU: crop area, yield (+0.5% a year) & production levels 2030 & 2050 | According to CAPRI 2.7 BAU: crop area, yield & production levels 2030 & 2050 | According to CAPRI 2.7 BAU: crop area, yield (+ 0.2% a year) (& production levels 2030 & 2050 | According to CAPRI 2.7 BAU: crop area, yield (+0.5% a year) & production levels 2030 & 2050 |
| | | *Competing use* | 0% competing use | 50% in 2030 & 75% in 2050 | 30% in 2030 & 40% in 2050 | 10% in 2030 & 20% in 2050 |
| 2301, 2302 | Liquid and solid manure from stables | Amount of animals | According to CAPRI 2.7 BAU: type of animals and heads in 2030 & 2050 | According to CAPRI 2.7 BAU: type of animals and heads in 2030 & 2050 | According to CAPRI 2.7 BAU: type of animals and heads in 2030 & 2050 | According to CAPRI 2.7 BAU: type of animals and heads in 2030 & 2050 |

| DI codes | Description of biomass category | Issue | Technical potential | Low mobilisation | Medium mobilisation | High mobilisation |
|---|---|---|---|---|---|---|
| | | Manure produced in stables | For cattle, pig, sheep & goat, poultry: 100% of **solid and liquid manure** available. | For cattle, pig, sheep & goat, poultry: 50% of **solid and liquid manure** available. | For cattle, pig, sheep & goat, poultry: 60% of **solid and liquid manure** available. | For cattle, pig, sheep & goat, poultry: 80% of **solid and liquid manure** available. |
| | | Competing use | No competing use | No competing use | No competing use | No competing use |
| 4201, 44202, 4203, 4204, 4205, 4207, 4208, 4209, 4210, 4211, 4214 | Food processing residues | Amount of processed agricultural products | According to CAPRI 2.7 BAU 2030, 2050: or other published sources (see Appendix 2) | According to CAPRI 2.7 BAU 2030, 2050: or other published sources (see Appendix 2) | According to CAPRI 2.7 BAU 2030, 2050: or other published sources (see Appendix 2) | According to CAPRI 2.7 BAU 2030, 2050: or other published sources (see Appendix 2) |
| | | Competing uses | 0% competing use | 75% to competing uses | 50% to competing uses | 25% to competing uses |
| 4216 | Animals fats cat. 1 & 2 | Meat production | According to CAPRI 2.7 BAU: type of animals and heads in 2030 & 2050 | According to CAPRI 2.7 BAU: type of animals and heads in 2030 & 2050 | According to CAPRI 2.7 BAU: type of animals and heads in 2030 & 2050 | According to CAPRI 2.7 BAU: type of animals and heads in 2030 & 2050 |
| | | Competing uses | 0% competing use | 30% in 2030<br>40% in 2050 | 20% in 2030<br>30% in 2050 | 10% in 2030<br>20% in 2050 |

*CAPRI baseline run allocates in post-model assessment some area no longer needed for food and feed production to the production of New Energy Crops (NECR). It assumes that exogenous demand (from PRIMES) for 2nd Generation biofuels can partly but not fully be satisfied by primary residues. The rest is to be satified by NECR. However, as the production of new energy crops require agricultural land the available agricultural land for the production of other agricultural products is reduced accordingly with the yield information collected for NECR (from IIASA GLOBIOM). The land demand comes on top of the land demand for food and feed production.
** Mediterranean North (MDN), Mediterranean South (MDS), Continental (CON), Pannionian (PAN), Lusitanian (LUS), Atlantic North (ATN), Atlantic Central (ATC) (for map see Appendix -2-2)

Table A2 - 5 Overview of scenario assumptions for dedicated crops, primary and secondary biomass potentials from agriculture

| DI codes | Description of biomass category | Issue | Technical potential | Low mobilisation | Medium mobilisation | High mobilisation |
|---|---|---|---|---|---|---|
| 1100, 1200, 1220 | Stemwood, primary harvesting residues and stumps | Area | Forest area available for wood supply. Excluding protected and protective areas. | Forest area available for wood supply minus 5%. Excluding protected and protective areas. | Forest area available for wood supply. Excluding protected and protective areas. | Forest area available for wood supply. Excluding protected and protective areas. |
| | | Growth | Growth based on regional/ national conditions (incl. climate change effect). | Growth based on regional/ national conditions (incl. climate change effect). | Growth based on regional/ national conditions (incl. climate change effect). | Growth based on regional/ national conditions (incl. climate change effect). |
| | | **Yield** | Yield according to regional management guidelines for age limits for thinnings and final fellings. | Yield according to regional management guidelines for age limits for thinnings and final fellings. | Yield according to regional management guidelines for age limits for thinnings and final fellings. | Yield according to regional management guidelines for age limits for thinnings and final fellings. |
| | | Technical & environmental constraints | Max volume of stemwood that could be harvested annually during 50-year periods.<br>Technical constraints on residue and stump extraction (recovery rate) | Max volume of stemwood that could be harvested annually during 50-year periods.<br>Local extraction constraints according to site productivity, slope, soil and water protection, biodiversity, soil bearing capacity.<br>Increase in protected forest by 5% plus increase in retained trees by 5% plus no stump extraction. | Max volume of stemwood that could be harvested annually during 50-year periods.<br>Local extraction constraints according to site productivity, slope, soil and water protection, biodiversity, soil bearing capacity.<br>Increase in protected forest by 5% plus increase in retained trees by 5% plus no stump extraction. | Max volume of stemwood that could be harvested annually during 50-year periods.<br>Local extraction constraints according to site productivity, slope, soil and water protection, biodiversity, soil bearing capacity.<br>Increase in protected forest by 5% plus increase in retained trees by 5% plus no stump extraction. |
| | | Competing use | No competing use | Roundwood production for material use subtracted from BP. | Roundwood production for material use excluding production of pulp and paper and board industry subtracted. | No competing use |
| | | Mobilisation | No constraints in mobilisation | Reduction in potentials by 5% | Reduction in potentials by 5% | No constraints in mobilisation |
| 4111; 4112; 4121 | Sawdust, other sawmill residues and residue from industries producing semi-finished wood based panels | Competing use | No competing use | 75% to competing use (material) | 50% to competing use (material) | 25% to competing use (material) |
| 4122; 4131; 4132 | Residues from further wood processing, bark, black liquor | Competing use | No competing use | 50% to competing use (material) | 25% to competing use (material) | No competing use |

Table A2 - 6 Scenario assumptions for stemwood, primary and secondary forestry residues

### 3.5.3. Scenario assumptions for biomass types from biowaste

The biomass types from the waste sector are mostly assessed with new data taking waste statistics from Eurostat as a starting point.

For the different mobilisation scenarios, the assumptions for low, medium and high mobilisation scenarios were chosen, as is presented in Table A2 - 7.

For the secondary residues the assumptions in the scenarios range according to competing uses.

*For organic waste:* the expectation for future development follows the Circular Economy Package[12] that 60% of municipal waste needs to be re-used and recycled by 2030, and 65% by 2035. These shares are reflected in the mobilisation scenarios where in the low mobilisation scenario the separation rates are reached in 2050, but has higher recycling levels, while in the medium and especially the high mobilisation scenario higher separation shares are reached with lower recycling and circular use rates.

For UCO 2030 and 2050 the developments in the share of UCO to be collected from household is ranging. The initial shares of collection levels were obtained from Greenea (2016) (quoted from Panoutsou et al., 2021):

- 2030: Household rate 15%, Professional rate 90%
- 2050: Household rate 45%, Professional rate 90%

For this study these shares are ranging in the three mobilization scenarios.

*For brown grease:* The future potentials of brown grease production are based on the lower and upper limit estimates from Umweltbundesamt (2019) in tonnes/capita/year. For the low mobilization scenario, the lower limit of 0.000015 tonnes/capita/year was taken. For the high mobilization scenario, the upper limit of 0.0051 tonnes/capta /year were taken and for the medium the figure in-between lower and upper limit. There are limited competing uses of brown grease, therefore they were not taken into consideration for the scenarios.

The organic fraction in sewage sludge will develop in the future in the three mobilization scenarios according to assumptions on the amount of sewage sludge produced and competing use level. In the low mobilization scenario, it is assumed that water use by households and industries will go down strongly, leading to lower sludge amounts. The competing use levels for organic fraction in sludge will also be higher in the low mobilization scenario then in the medium and high.

[12] https://ec.europa.eu/commission/presscorner/detail/en/IP_15_6203

| DI codes | Description of biomass category | Issue | Technical potential | Low mobilisation | Medium mobilisation | High mobilisation |
|---|---|---|---|---|---|---|
| 5101, 5102 | Organic fraction of municipal solid waste separately collected; Organic fraction of municipal solid waste un-separately collected | Collection & Separation level organic waste | All separately collected waste + all organic waste in un-separated MSW | All separately collected waste + 2030: already separated fraction in 2020 + extra up to 50% separated fraction<br>2050: already separated fraction in 2020 + extra up to 65% separated fraction | All separately collected waste + 2030: already separated fraction in 2020 + extra up to 60% separated fraction<br>2050: already separated fraction in 2020 + extra up to 70% separated fraction | All separately collected waste + 2030: already separated fraction in 2020 + extra up to 65% separated fraction<br>2050: already separated fraction in 2020 + extra up to 75% separated fraction |
| | | Recycling & other uses | No recycling & other uses | In 2030: 60% and in 2050: 70% recycling & other uses | In 2030: 45% and in 2050: 55% recycling & other uses | In 2030: 30% and in 2050: 40% recycling & other uses |
| 5111, 5212 | Post-consumer wood waste hazardous and non-hazardous | Competing use | No competing use | 50% to competing use (material) | 25% to competing use (material) | No competing use |
| 5104 | Fruit and vegetable residues and waste not fit for use in the food and feed chain, excluding tails, leaves, stalks and husks | Consumption levels fruit and vegetables | As in 2020 | 2030: 10% less<br>2050: 15% less<br>(compared to 2020) | As in 2020 | 2030: 10% more<br>2050: 15% more<br>(compared to 2020) |
| | | Wasted | | 2030: 20% less<br>2050: 25% less<br>(compared to 2020) | As in 2020 | 2030: 10% more<br>2050: 15% more<br>(compared to 2020) |
| | | Competing use | No competing use | 2030: 60%<br>2050: 70% to competing use (material) | 2030: 40%<br>2050: 45% to competing use (material) | 2030: 20%<br>2050: 25% to competing use (material) |
| 5106 | Used cooking oil (UCO) | Collection rate | 2030: & 2050: 100% from households; 2030 and 2050: 90% professional | 2030: 10% & 2050: 30% from households;<br>2030 and 2050: 90% professional | 2030: 15% & 2050: 45% from households;<br>2030 and 2050: 90% professional | 2030: 20% & 2050: 60% from households;<br>2030 and 2050: 90% professional |
| | | Competing use | No competing use | 2030: 60%<br>2050: 70% to competing use (material) | 2030: 40%<br>2050: 45% to competing use (material) | 2030: 20%<br>2050: 25% to competing use (material) |
| 5107 | Waste Brown_Grease | Amount per capita | Upper limit: 0.0051 tonnes/capita /year | Lower limit: 0.0015 tonnes/capita /year | Lower limit: 0.0033 tonnes/capita /year | Upper limit: 0.0051 tonnes/capita /year |
| | | Competing use | No competing use | In 2030 30% and in 2050 40% competing use | In 2030 20% and in 2050 30% competing use | In 2030 5% and in 2050 10% competing use |
| 5108 | Organic fraction in sewage sludge | Change towards 2030 & 2050 | Growth according to population projection | Growth according to population projection, but in 2030 20% and in 2050 40% less water consumption | Growth according to population projection | Growth according to population projection |
| | | Competing use | No competing use | In 2030 30% and in 2050 40% competing use | In 2030 30% and in 2050 40% competing use | In 2030 5% and in 2050 10% competing use |

Table A2 - 7 Scenario assumptions for stemwood, primary and secondary forestry residues

### 3.5.4. Type of competing uses expected for non-energy uses

For all residual biomass types competing use levels have been applied. In the three mobilization scenarios the demands for biomass from competing uses outside the energy sectors range from high to low. By already focusing on selecting low-ILUC risk biomass types, so biomass that has no or low competition with food production, the remaining competing use levels used only apply to potential future demands for biomass for biomaterials and biochemicals.

The low mobilization scenario has the highest competing use levels which implies that it leaves little biomass available for the energy demands from electricity, heat and transport fuels. In the high mobilization scenario these competing uses are assumed to be much lower and in the technical potential no competing uses are assumed.

In Table A2 - 8 an overview is given of the type of biochemical and biomaterial product groups for which demands for biomass will start to increasingly compete with bioenergy demand for biomass towards 2030 and 2050. The level of competing uses per scenario is also included (million tonnes biomass) beside the total technical potential. The latter is also presented in Figure A2 - 1.

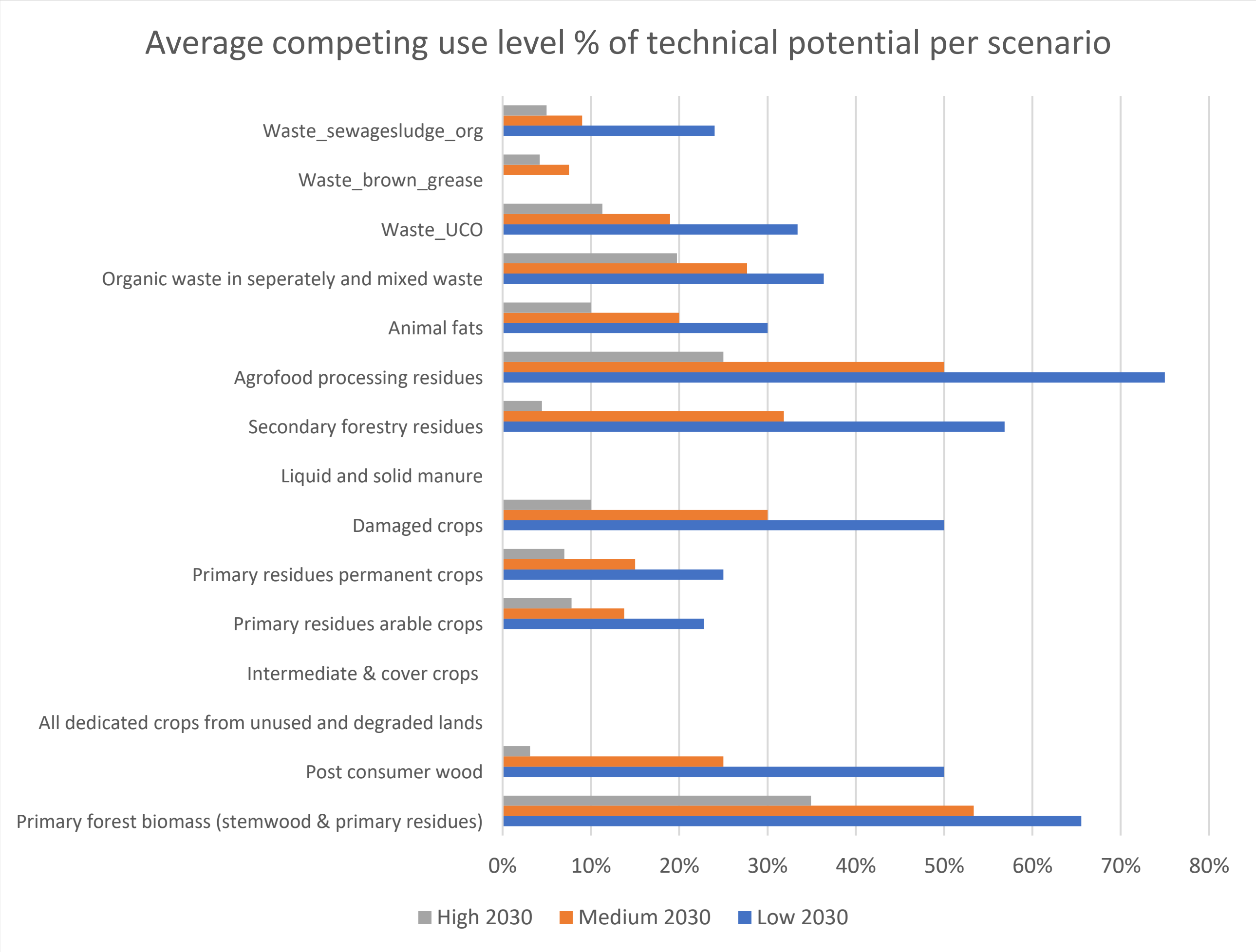


Figure A2 - 1 Competing use levels per scenario (expressed as %/TP) in 2030

No competing uses were applied to dedicated crops and manure. Agro-food residues and primary biomass from forests have the highest relative shares of competing uses. However, since the agro-food residues are so small the competing use levels are displayed in table A2-8 as zero.

Overall, the constraining influence of competing uses is larger in 2030 than in 2050 where other factors in the scenarios are clearly becoming more dominant. In the Tables on the scenario assumptions (Table A2-5 to A2-7), it can be identified per type of biomass what these constraining factors are.

| | | TP2030 | Kton/y going to competing uses | | | TP2050 | Kton/y going to competing uses | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Biomass DI codes** | **Short name** | | **Low 2030** | **Medium 2030** | **High 2030** | | **Low 2050** | **Medium 2050** | **High 2050** | **Possible competing uses for biochemicals and biomaterials applications** |
| **1100** | **Stemwood** | 311.7 | 263.4 | 204.0 | 109.1 | 302.8 | 262.3 | 210.7 | 106.0 | • Textiles- man made cellulosic fibres (e.g. viscose, lyocell)<br>• Woodworking (timber-based products used in construction, carpentry, furniture making)<br>• Particle & fibre based building materials<br>• Fibre composites<br>• Pulp & paper<br>• Board<br>• Chemical intermediates (Succinic acid, luvelinic acid, methanol, etc.)<br>• Resins, bioaromatics |
| **1200** | **Prim_forest_residues** | 98.7 | 56.4 | 56.4 | 61.3 | 95.8 | 54.2 | 54.2 | 59.0 | |
| **1220** | **Prim_forest_stumps** | 77.5 | 0.0 | 0.0 | 0.0 | 77.3 | 0.0 | 0.0 | 0.0 | |
| **5211** | **Post_cons_wood_hazard** | 4.9 | 2.5 | 1.2 | 0 | 5.6 | 2.8 | 1.4 | 0 | |
| **5212** | **Post_cons_wood_non_hazard** | 27.2 | 13.6 | 6.8 | 0 | 30.8 | 15.4 | 7.7 | 0 | |
| **2101** | **Ligno_crops_unused_land** | 16.6 | 0 | 0 | 0 | 49.5 | 0 | 0 | 0 | No competing use assumed here |
| **2102** | **Oil_crops_unused_land** | 0.7 | 0 | 0 | 0 | 2.2 | 0 | 0 | 0 | No competing use assumed here |
| **2103** | **Woody_crops_unused_land** | 17.2 | 0 | 0 | 0 | 29.2 | 0 | 0 | 0 | No competing use assumed here |
| **2104** | **Ligno_crops_degraded_land** | 10.1 | 0 | 0 | 0 | 133.2 | 0 | 0 | 0 | No competing use assumed here |
| **2105** | **Oil_crops_degraded_land** | 0.8 | 0 | 0 | 0 | 5.8 | 0 | 0 | 0 | No competing use assumed here |
| **2106** | **Woody_crops_degraded_land** | 9.4 | 0 | 0 | 0 | 72.9 | 0 | 0 | 0 | No competing use assumed here |
| **2107** | **Intermediate_crop_Sorg** | 116.4 | 0 | 0 | 0 | 138.6 | 0 | 0 | 0 | No competing use assumed here |
| **2108** | **Intermediate_crop_oil** | 26.9 | 0 | 0 | 0 | 32.2 | 0 | 0 | 0 | No competing use assumed here |
| **2109** | **Cover_crop_ligno** | 42.8 | 0 | 0 | 0 | 50.9 | 0 | 0 | 0 | No competing use assumed here |
| **2201** | **Prim_res_cereal_straw** | 265.8 | 93.0 | 53.2 | 29.9 | 266.6 | 93.3 | 53.3 | 30.0 | • Animal bedding<br>• Feed<br>• Horticulture protection of flower bulbs and strawberries<br>• Particle & fibre based building materials<br>• Fibre composites<br>• Textiles- man made cellulosic fibres (e.g. viscose, lyocell)<br>• Chemical intermediates (Succinic acid, luvelinic acid, methanol, etc.)<br>• Resins, bioaromatics |
| **2202** | **Prim_res_other_straw** | 202.5 | 13.7 | 11.1 | 6.6 | 201.8 | 27.2 | 16.6 | 13.1 | |
| **2203** | **Prim_res_sugar_leaves** | 5.7 | 1.4 | 1.0 | 0.6 | 6.0 | 2.1 | 1.8 | 1.0 | |

| | | TP2030 | Kton/y going to competing uses | | | TP2050 | Kton/y going to competing uses | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Biomass DI codes** | **Short name** | | **Low 2030** | **Medium 2030** | **High 2030** | | **Low 2050** | **Medium 2050** | **High 2050** | **Possible competing uses for biochemicals and biomaterials applications** |
| **2204** | **Prim_res_perm_crops** | 16.2 | 4.1 | 2.4 | 1.1 | 16.3 | 4.1 | 2.4 | 1.1 | • Woodworking (timber-based products used in construction, carpentry, furniture making)<br>• Particle & fibre based building materials<br>• Fibre composites |
| **2205** | **Prim_res_damaged_crops** | 3.7 | 1.9 | 1.1 | 0.4 | 3.9 | 2.9 | 1.6 | 0.8 | • Feed<br>• Textiles- man made cellulosic fibres (e.g. viscose, lyocell)<br>• Chemical intermediates (Succinic acid, luvelinic acid, methanol, etc.)<br>• Resins, bioaromatics intermediates (Succinic acid, luvelinic acid, methanol, etc.) |
| **2301** | **Animal_solid_manure** | 166.2 | 0 | 0 | 0 | 156.7 | 0 | 0.0 | 0 | • On farm use as soil improver |
| **2302** | **Animal_liquid_manure** | 36.9 | 0 | 0 | 0 | 33.9 | 0 | 0.0 | 0 | |
| **4111** | **Sec_res_sawdust** | 12.2 | 9.2 | 6.1 | 3.1 | 12.7 | 9.5 | 6.4 | 3.2 | • Textiles- man made cellulosic fibres (e.g. viscose, lyocell)<br>• Woodworking (timber-based products used in construction, carpentry, furniture making)<br>• Particle & fibre based building materials<br>• Fibre composites<br>• Pulp & paper<br>• Board<br>• Animal bedding<br>• Chemical intermediates (Succinic acid, luvelinic acid, methanol, etc.)<br>• Resins, bioaromatics<br>• Biopolymers |
| **4112** | **Sec_res_other_sawmill** | 2.3 | 1.7 | 1.1 | 0.0 | 2.7 | 2.0 | 1.4 | 0 | |
| **4121** | **Sec_res_semi_woodbp** | 4.3 | 3.2 | 2.1 | 0 | 5.1 | 3.8 | 2.5 | 0 | |
| **4122** | **Sec_res_other_wood** | 18.5 | 9.2 | 4.6 | 0 | 21.1 | 10.5 | 5.3 | 0 | |
| **4131** | **Sec_res_bark** | 5.5 | 2.7 | 1.4 | 0 | 6.3 | 3.1 | 1.6 | 0 | |
| **4132** | **Sec_res_black_liquor** | 25.7 | 12.9 | 6.4 | 0 | 25.7 | 12.9 | 6.4 | 0 | |
| **4201** | **Sec_res_rice_husk** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | • Feed<br>• Fibre composites<br>• Chemical intermediates (Succinic acid, luvelinic acid, methanol, lectic acid, xylitoletc.)<br>• Biopolymers |
| **4202** | **Sec_res_grapes** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| **4203** | **Sec_res_cereal_bran** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| **4204** | **Sec_res_maize_cobs** | 7.4 | 5.6 | 3.7 | 1.9 | 6.5 | 4.8 | 3.2 | 1.6 | |
| **4205** | **Sec_res_olive_stones** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| **4206** | **Sec_res_sgb_bagasse** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| **4207** | **Sec_res_olive_pommace** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| **4208** | **Sec_res_BSG** | 1.6 | 1.2 | 0.8 | 0.4 | 1.6 | 1.2 | 0.8 | 0.4 | • Pulp & paper<br>• Chemical intermediates (Succinic acid, luvelinic acid, methanol, lectic acid, xylitoletc.) |
| **4209** | **Sec_res_LWP** | 0.3 | 0.2 | 0.1 | 0.1 | 0.3 | 0.2 | 0.1 | 0.1 | • Casein textile fibres |

| | | TP2030 | Kton/y going to competing uses | | | TP2050 | Kton/y going to competing uses | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Biomass DI codes** | **Short name** | | **Low 2030** | **Medium 2030** | **High 2030** | | **Low 2050** | **Medium 2050** | **High 2050** | **Possible competing uses for biochemicals and biomaterials applications** |
| | | | | | | | | | | • Fertilisers<br>• Chemical intermediates (Succinic acid, luvelinic acid, methanol, lectic acid, xylitoletc.) |
| **4210** | **Sec_res_ADRW** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | • None, only fusel oils |
| **4211** | **Sec_res_Bakery** | 0.9 | 0.7 | 0.5 | 0.2 | 0.9 | 0.7 | 0.5 | 0.2 | • Feed |
| **4214** | **Sec_res_DUR** | 1.0 | 0.7 | 0.5 | 0.2 | 2.8 | 2.1 | 1.4 | 0.7 | • Feed |
| **4216** | **Sec_res_ani_fats12** | 1.7 | 0.5 | 0.3 | 0.2 | 1.7 | 0.7 | 0.5 | 0.2 | • Oleochemicals |
| **5101** | **Organic_waste_sepa** | 30.9 | 11.1 | 8.4 | 6.0 | 31.6 | 14.4 | 12.1 | 9.5 | • Chemical intermediates (Succinic acid, luvelinic acid, methanol, lectic acid, xylitoletc.) |
| **5102** | **Organic_waste_mixed** | 5.9 | 2.1 | 1.6 | 1.2 | 5.2 | 2.4 | 2.0 | 1.6 | |
| **5104** | **Waste_fruit_vegetable** | 2.1 | 0.9 | 0.8 | 0.5 | 2.1 | 0.9 | 1.0 | 0.7 | • Biofertilisers<br>• Bioplastics |
| **5106** | **Waste_UCO** | 2.2 | 0.7 | 0.4 | 0.2 | 2.2 | 1.2 | 0.6 | 0.4 | • Oleochemicals<br>• Biofertilisers |
| **5107** | **Waste_brown_grease** | 3.1 | 0.0 | 0.2 | 0.1 | 3.1 | 0.0 | 0.4 | 0.3 | • Oleochemicals<br>• Biofertilisers |
| **5108** | **Waste_sewagesludge_org** | 12.7 | 3.0 | 1.1 | 0.6 | 12.6 | 3.0 | 1.5 | 1.3 | • Chemical intermediates (Succinic acid, luvelinic acid, methanol, lectic acid, xylitoletc.) |

Table A2 - 8 Overview of biomass types, typical non-energy competing uses, and technical potential (million tons/y) and competing use levels per scenario (million tons/y)

# 4. Biomass potential assessment results

Here an overview is given of the total biomass potentials in 2030 and 2050 in the different scenarios for biomass potentials from agriculture, forestry and biowastes. The technical potential provides the amount available for all markets (energy and non-energy ones) and in the low, medium and high potentials lower biomass potentials are available due to competitions, stricter sustainability measures and other factors that influence mobilisation of biomass.

## 4.1. Results for total potentials in all scenarios

The total biomass potentials available for the energy markets in the three mobilisation scenarios for 2030 range from 310 in Low, 524 in Medium and 836 million dry tonnes (132, 221, 353 Mtoe) in High scenario. For 2050 this range is from 294, 520, 892 million tonnes (128, 222, 382 Mtoe).

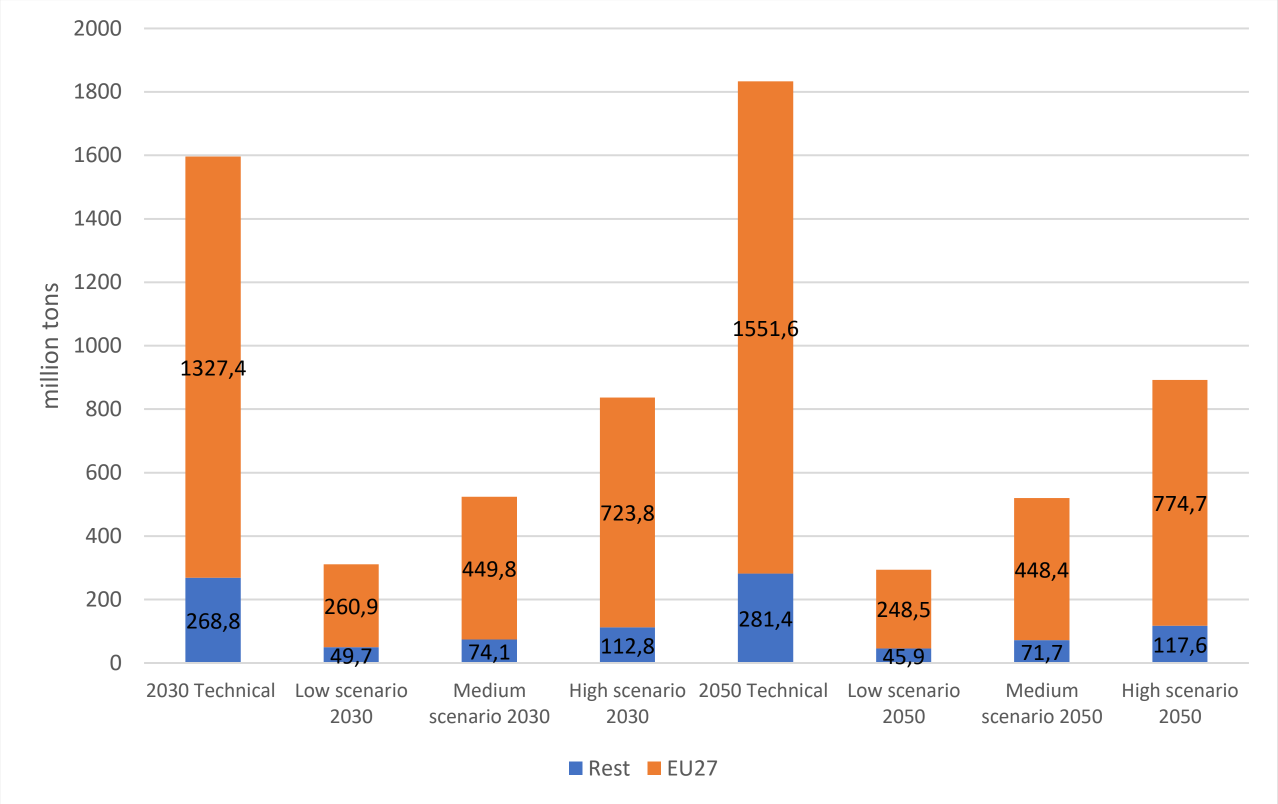


Figure A2 - 2 Total biomass potentials in Technical, low, medium, and high mobilization scenarios in 2030 and 2050 in million dry tonnes

In the low mobilization scenario only 20% and 16% of the technical potential in 2030 and 2050 will be available for energy uses for heat, electricity, and biofuels. In the medium mobilization scenario this share amounts to 34% and 33% in 2030 and 2050 respectively. In the high mobilization scenario this is 55% and 54% respectively in 2030 and 2050.

Countries with the largest biomass potentials are of course the largest (EU) countries[13]. France, the leader with a total technical potential of 218 million tonnes in 2030 and 249 million tonnes in 2050 is followed by Germany (195 and 222 million tonnes), Turkey (155 and 154 million tonnes), Poland (126 and 139 million tons), Spain (85 and 116 million tonnes) and Italy (78 and 102 million tonnes).

[13] It should be mentioned that potentials for several accession countries have not been finalised or were not assessed because of data limitations. In June an update of the potentials will be made in which the data gaps for these countries will be filled as much as possible.

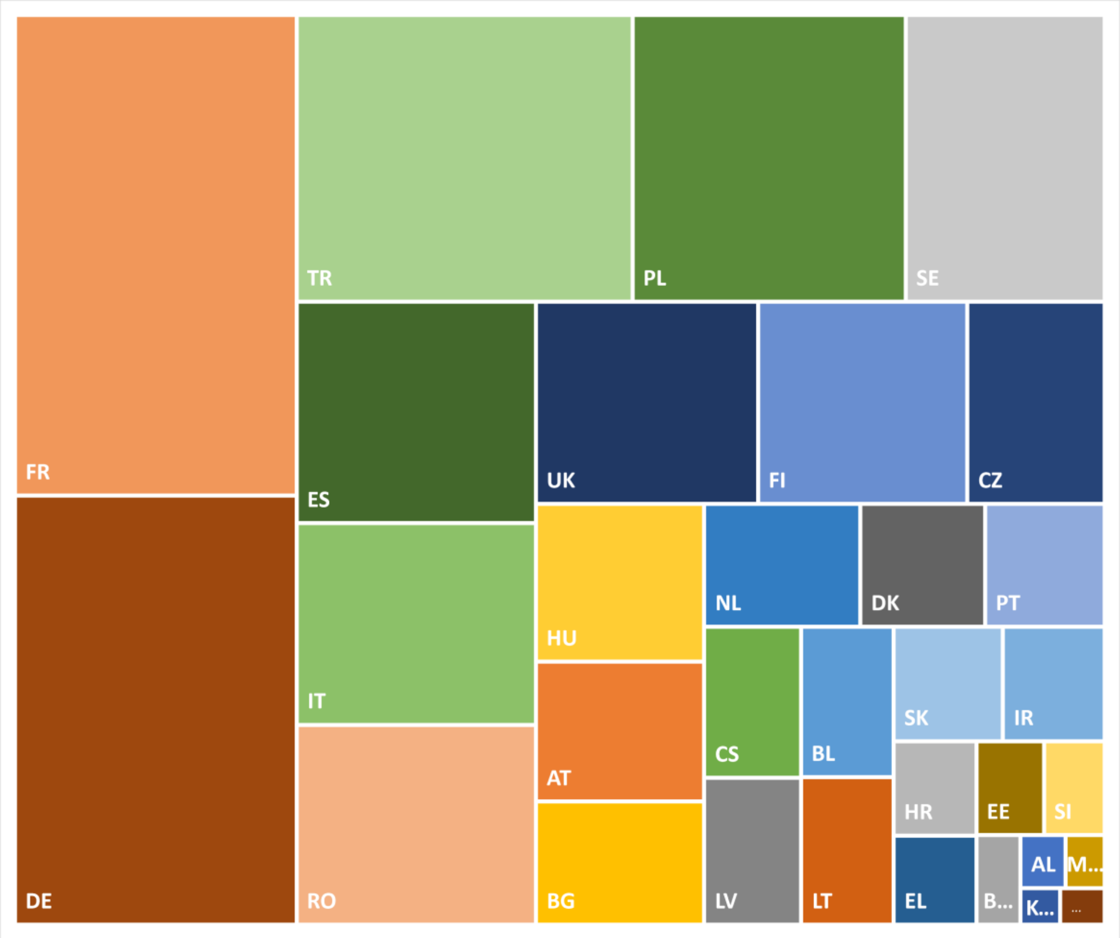


Figure A2 - 3 Distribution of technical biomass potential over countries in 2030 (see Appendix 2-5 for country names)

In Figure A2 - 4 the total biomass potential distributed over the EU regions are presented in total biomass per region per year. This is presented for the medium mobilisation scenario. Unfortunately, not all regions have the same size, so this influences the biomass distribution information in the map. Generally larger regions colour darker, then smaller regions. However, there are also similar size larger regions that still have low and high biomass potential. IN Spain for example the Castilla -Leon region has a large biomass potential, while the similar size region Castilla la Mancha  has much less biomass potential. Also, in Italy the region Emilia Romagna has the largest biomass potential concentration in Italy. On the other hand, Denmark for example is coloured very dark green in the potential because it is mapped as one region (no subdivision for the regional classification in CAPRI exists) and all-important biomass potentials occur in this country like manure, primary agricultural residues, and cover crops. In the Netherlands the same large amounts of biomass are expected, but the Netherlands is subdivided into 12 regions showing smaller totals per region.

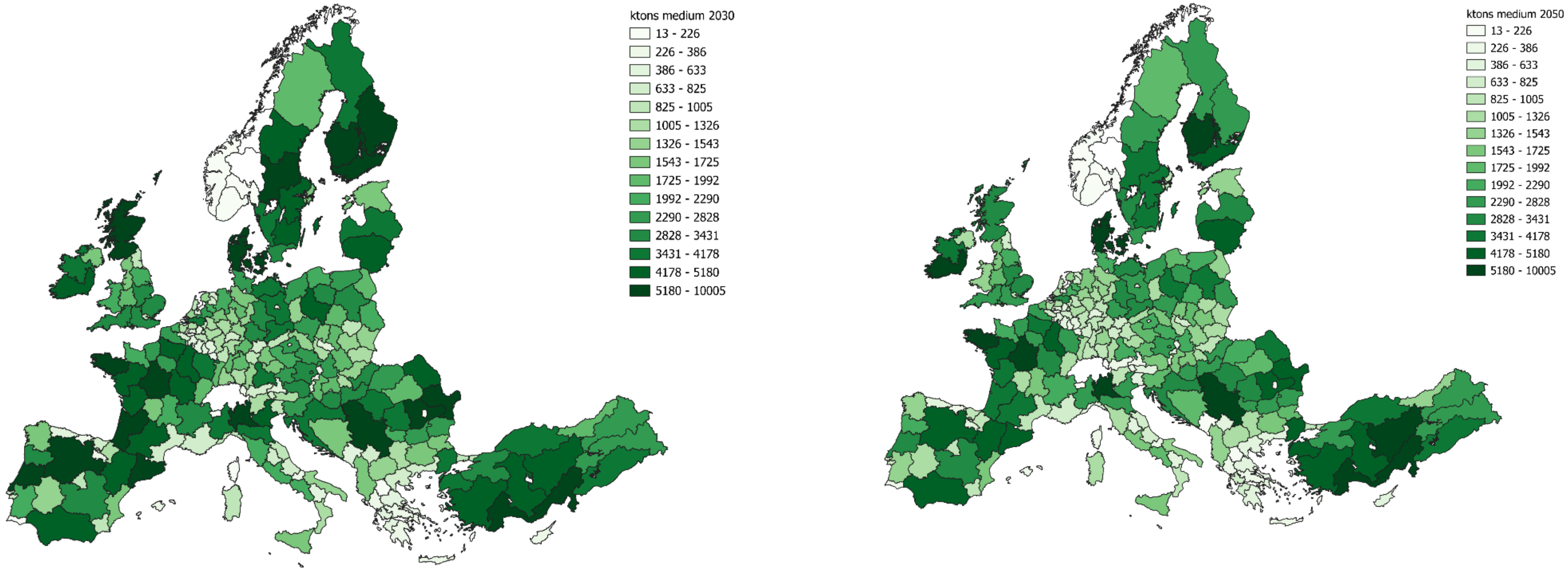


Figure A2 - 4 Distribution of total biomass potential (Medium mobilization scenario) over regions in Europe in 2030 and 2050 (Map)

As to the composition of the total potential it can be concluded that the agricultural sector is contributing the largest potential. In 2030 in the technical, low, medium and high scenarios the agricultural sector contributed 59%, 57%, 55% and 55% respectively. Towards 2050 this share increased even a little to 64%, 58%, 57% and 57% respectively (see Figure A2 - 5). The contribution of the agrofood industry residues is the smallest with a contribution ranging between 1% to 2% in the different scenarios and years. The biowaste sector has the largest contribution with 11% in the low scenario in 2030 and 2050 and only 6% and 5% in the technical scenario in 2030 and 2050 respectively.

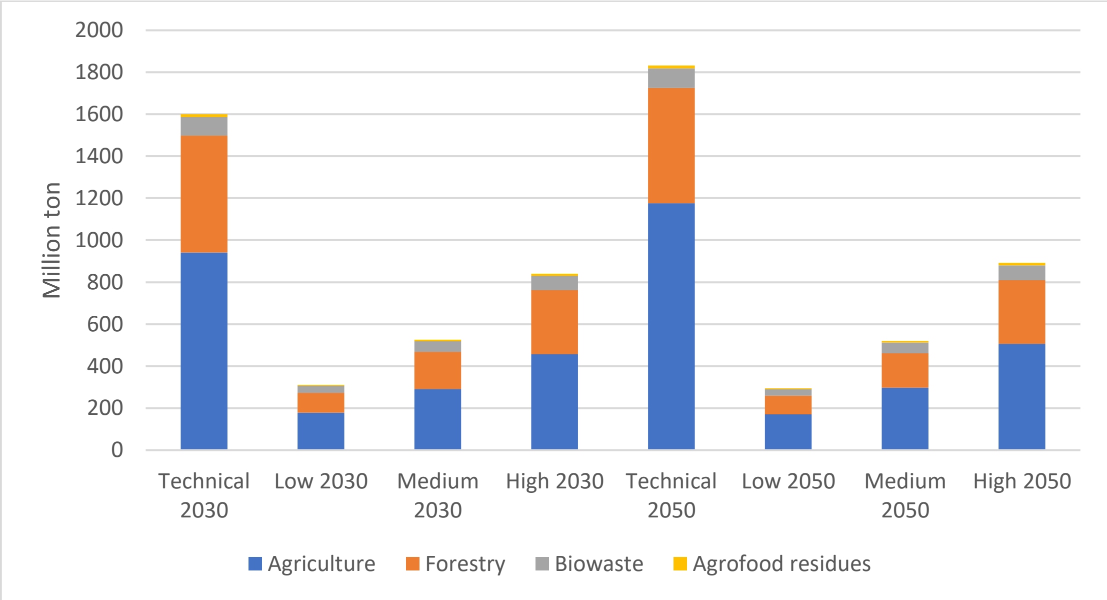


Figure A2 - 5 Biomass potentials in technical, low, medium, and high potentials in 2030 and 2050 and distribution over sectors delivering biomass.

The importance of the agricultural sector for biomass provision also applies to most European countries (see Figure A2 - 6). In some countries over 70% of the biomass potential is from the agricultural sector such as in Ireland, Serbia, Denmark, Romania, Hungary, Bulgaria, Netherlands, and Cyprus. There are also a few countries where forest biomass dominates, above agriculture and that's in Sweden, Finland, Moldova, Portugal, Kosovo, Slovenia, Latvia, and Austria. Malta is the only country where biowaste dominates with biowaste taking 74% of the potential.

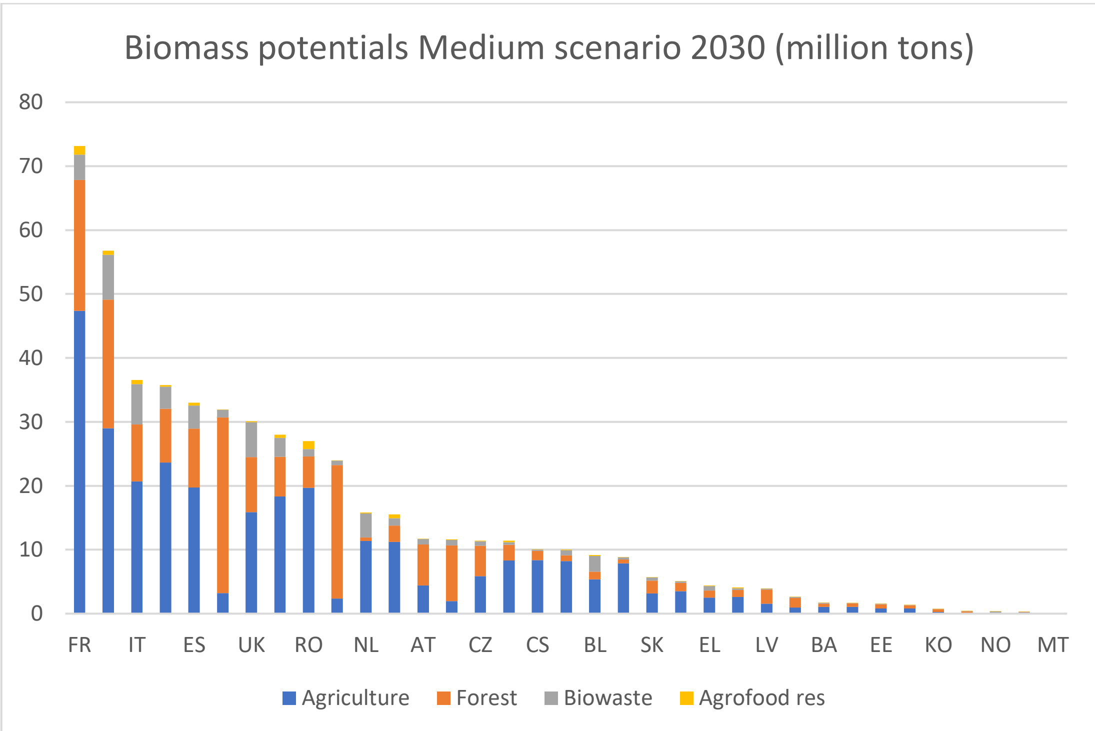


Figure A2 - 6 Biomass potentials in medium mobilization scenario in 2030 per country distribution over sectors delivering biomass.

When concentrating on the more detailed biomass types that make up the different sectoral contributions in Figure A2 - 7, it becomes clear that straw (made up of straw of cereals, stover, oil crops and sugar beet leaves) together with manure are the main contributors to the agricultural potential. They make up together between 30% and 50% of the total biomass potential in the different scenarios. Primary and secondary forestry biomass is the second most important group with a contribution per scenario ranging between 30% and 35% in all scenarios and in 2030 and 2050. It is a fairly constant biomass group.  Also, the contribution of biomass crops grown on abandoned, degraded and as inter or cover crops may become larger certainly towards 2050 and most strongly in the medium and high mobilization scenarios. In the low mobilization scenario, the biomass will rely relatively more strongly on residual biomass and waste.

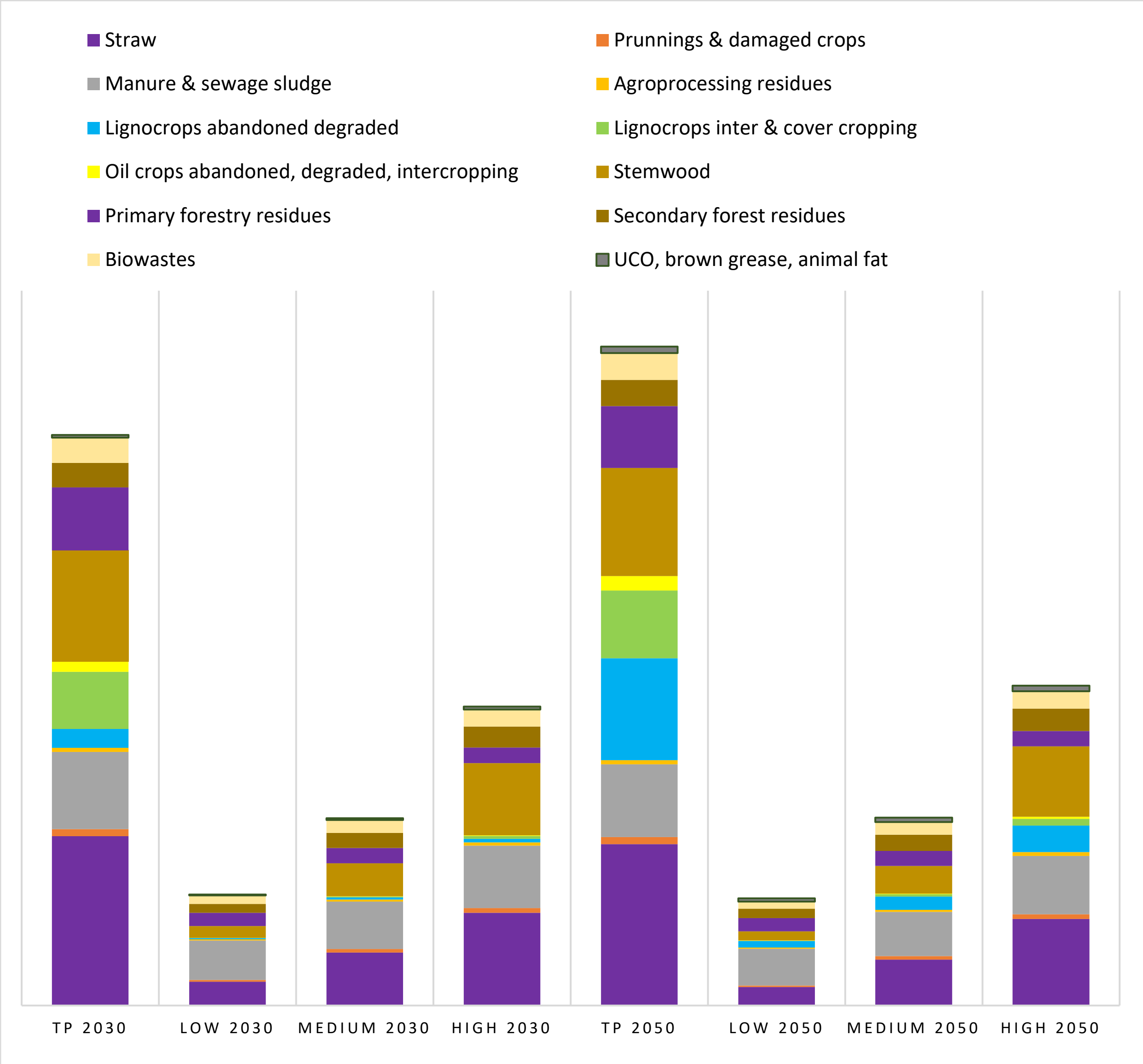


Figure A2 - 7 Biomass potentials in technical, low, medium and high potentials in 2030 and 2050 and distribution over biomass categories.

## 5. Cost-supply

For all biomass potentials the cost levels were also determined to construct cost-supply relations. In Figure A2 - 8 and Figure A2 - 9 an overview is given of the total cost-supply relation for the whole European region according to the medium mobilization scenario for 2030 and 2050. The cost level refers to the at-gate-cost, so the price of biomass per ton delivered to the plant gate assuming handling and transport of <=50 km.

The results show that in 2030 under the at gate cost level of 50€/tonnes (dm or oil[14]) 86% of the biomass potential can be delivered which equals to 424 million tonnes dm (or oil). The last 3% of the biomass can only be delivered above 150 €/tonnes dm (or oil in the case of oil crops and UCO). For the cost-supply relation in 2050 the relation and cost do not change much. Still 80% of the biomass can be delivered at gate for under 50 €/ton dm (or oil in the case of oil seeds or UCO). The last 5% has an at gate cost-price of >150 €/tonnes dm (or oil).

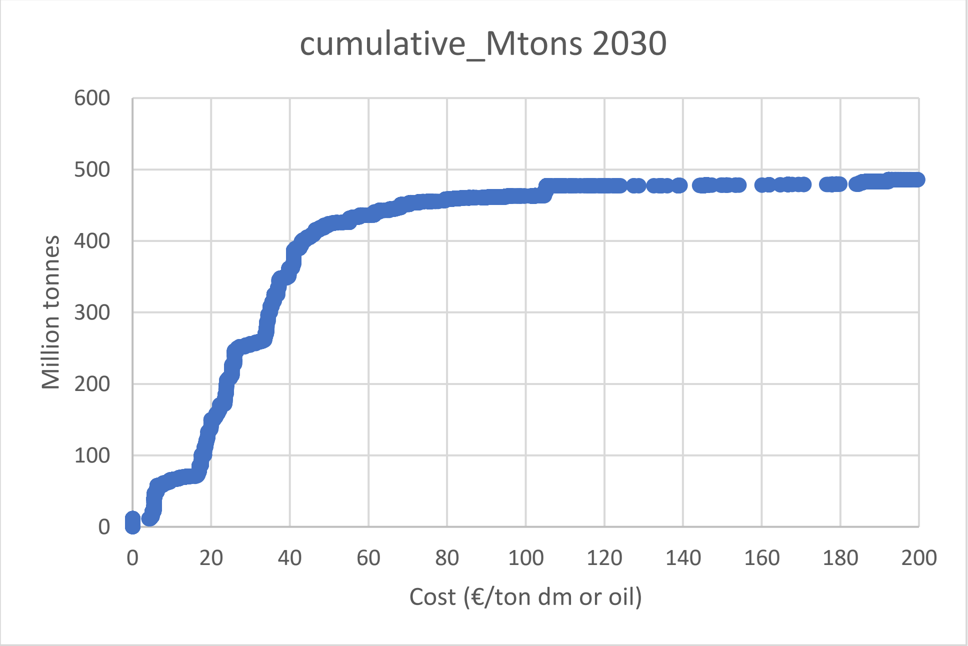


Figure A2 - 8 Cost supply of all biomass in Europe in medium mobilisation scenario for 2030, at gate cost level (biomass cost+ handling and transport 50km)

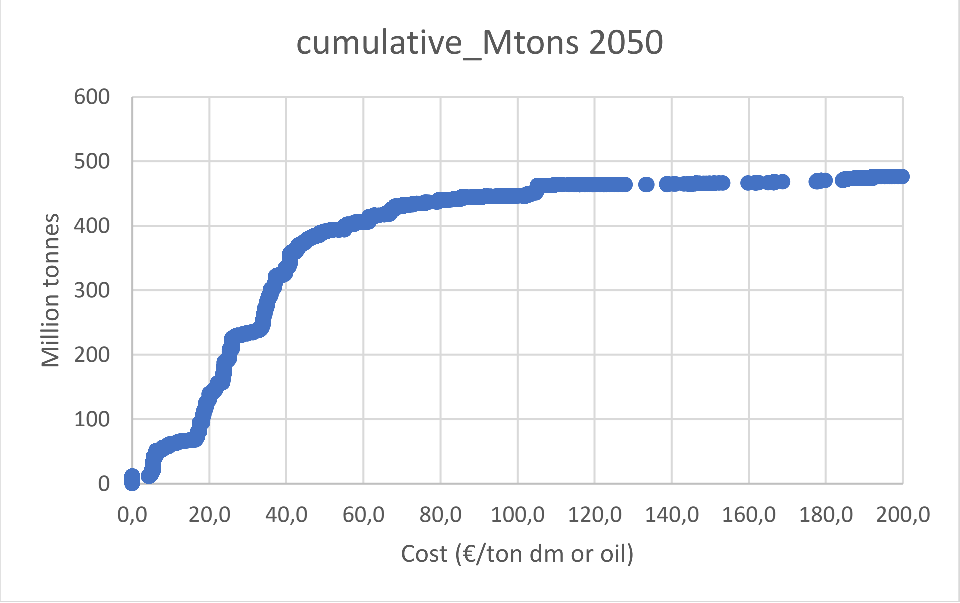


Figure A2 - 9 Cost supply of all biomass in Europe in medium mobilization scenario for 2050, at gate cost level (biomass cost+ handling and transport 50km)

[14] In the case of oil, the crushing of oil seeds is not included in the cost

## 6. Comparison of biomass potentials against PRIMES biomass demands

The question to be answered here is whether the biomass potentials assessed for 2030 and 2050 will be sufficient to satisfy all demands for biomass from the electricity, heat and biofuels sectors as assessed in Task 1 of this study by the PRIMES model in different scenarios. A distinction is made between the demand for biomass for electricity and heat (E&H) and for transport.

The biomass demands from the PRIMES runs with the biomass potentials in the low, medium, and high mobilization scenarios and the technical potential. This is done for biomass demands from PRIMES for the Scenarios Fit for 55 (FF55) and for the Repower EU. These 2 main PRIMES scenarios have also been further divided into 4 sub-scenarios (see Task 1 report).

In Table A2 - 9 an overview is presented of the biomass demands for transport fuels and for electricity and heat (E&H) in 2030 and 2050 in the 5 Fit for 55 scenarios and 4 Repower scenarios (See Task 1 report). In 2030 the largest biomass demand for the transport sector is in PRIMES-scenario FF55_IncrRoadAct with 83 MTOE and in the Repower_ESR_IncrRoadAct with 85 MTOE. In 2050 this demand is by far the highest in the Repower_ESR_IncrRoadAct reaching 99 MTOE. The lowest total biomass demand is in 2030 for FF55_LTD_HD and in 2050 for Repower ESR. The differences are however not very extreme between the sub-scenarios. The FF55_RED scenario is the most relevant in that it reflects the most recent policy ambitions of the REDII+ and shows biomass demands that are positioned somewhere average in comparison to the other scenarios. Biomass demand increases are 38% between 2030 and 2050 for biofuels and for other energy uses at a modest 18%.

In the FF55 scenarios the increase in biomass demands for other energy uses are relatively large (=>55% increase), while they remain smaller in the Repower scenarios (=<36%). Biomass for transport fuels demand increases between 2030 and 2050 are the largest (49% increase) in the FF55_LTD scenario. The smallest increase (10%) is for the FF55_ESR_IncrRoadAct.

| | PRIMES biomass use (2030) | | | PRIMES biomass use (2050) | | |
|---|---|---|---|---|---|---|
| MTOE | Transport | Other Energy | Total | Transport | Other Energy | Total |
| FF55_LTD | 57.5 | 135.2 | 192.7 | 85.7 | 209.0 | 294.8 |
| FF55_ESR | 78.1 | 133.5 | 211.6 | 88.7 | 210.3 | 299.0 |
| FF55_LTD_IncrRoadAct | 68.6 | 134.1 | 202.7 | 83.6 | 208.5 | 292.2 |
| FF55_ESR_IncrRoadAct | 83.0 | 133.0 | 216.0 | 91.6 | 210.2 | 301.8 |
| FF55_RED | 76.7 | 133.7 | 210.5 | 90.3 | 210.3 | 291.0 |
| Repower_LTD | 74.9 | 146.4 | 221.4 | 92.3 | 198.7 | 291.0 |
| Repower_ESR | 64.3 | 147.2 | 211.5 | 83.8 | 197.8 | 281.6 |
| Repower_LTD_IncrRoadAct | 79.0 | 146.4 | 225.4 | 90.0 | 198.0 | 288.0 |
| Repower_ESR_IncrRoadAct | 85.6 | 146.1 | 231.7 | 98.6 | 198.4 | 297.0 |

Table A2 - 9 PRIMES scenario biomass demands 2030 and 2050 (MTOE)

The biomass mixes used by the PRIMES scenarios are presented in Figure A2 - 10 and Figure A2 - 11 for 2030 and 2050 respectively. It becomes clear that the starch and sugar crops are practically phased out toward 2050. Both the transport and E&H demand is large for the solid primary and secondary biomass sources from forests and agriculture. The E&H sector clearly uses more gaseous biomass and most of the black liquor. The transport sector uses more the oil crops and non-agricultural oils and fats. Towards 2050 the lignocellulosic crops increase very strongly both for transport fuels and for E&H generation and this is also where the increase in biomass demands between 2030 and 2050 are expected to come from in the PRIMES scenarios.

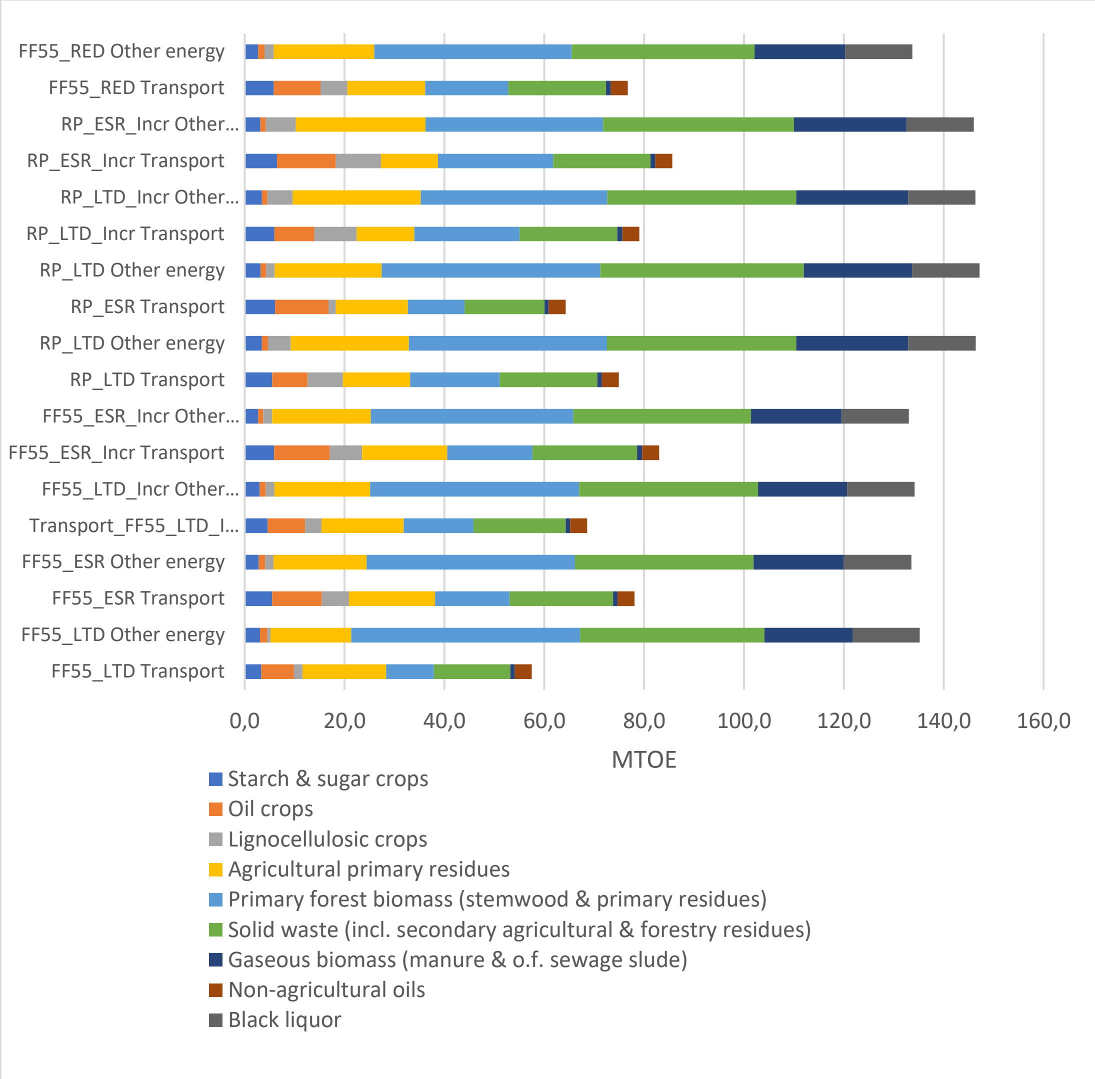


Figure A2 - 10 Biomass demands (KTOE) from PRIMES for transport (Trans) and for electricity and heat (E&H) classified according to type of biomass (2030)

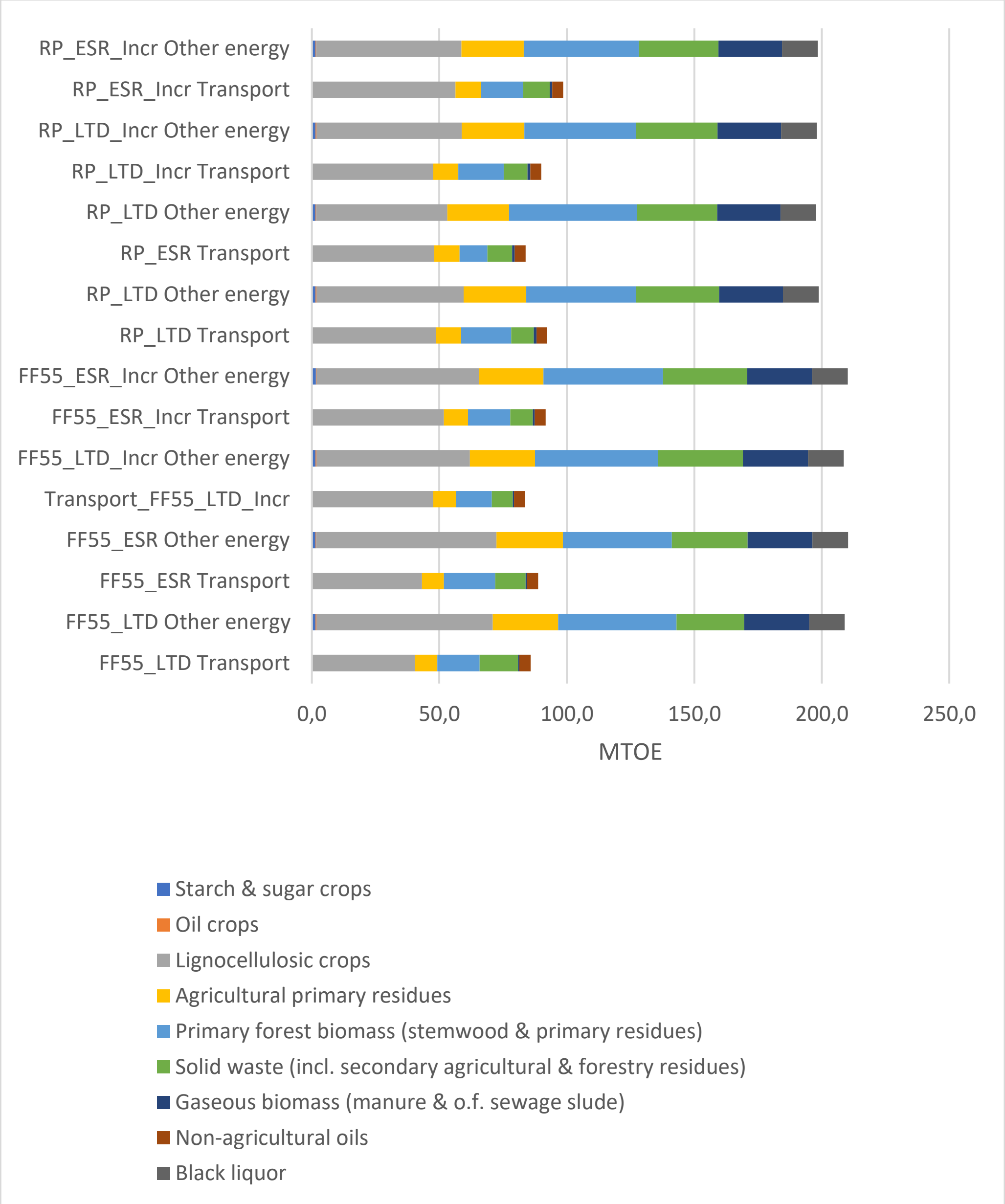


Figure A2 - 11 Biomass demands (KTOE) from PRIMES for transport (Trans) and for electricity and heat (E&H) classified according to type of biomass (2050)

In the Figure A2 - 12 for 203 and Figure A2 - 13 for 2050 a comparison is made of the total biomass demands in the PRIMES sub-scenarios and the biomass potentials for the Technical, low, medium, and high mobilization scenarios assessed in Task 2[15].

[15] It should be mentioned that comparison of the biomass quantities in PRIMES with the biomass potentials is influenced by differences in biomass conversion factors. PRIMES demands for biomass are traced back starting from the final biofuel technology uses. This is not the case for the biomass potentials. These were only converted from Tonnes dm or tonnes oil to MTOE using conversion factors obtained from PRIMES.

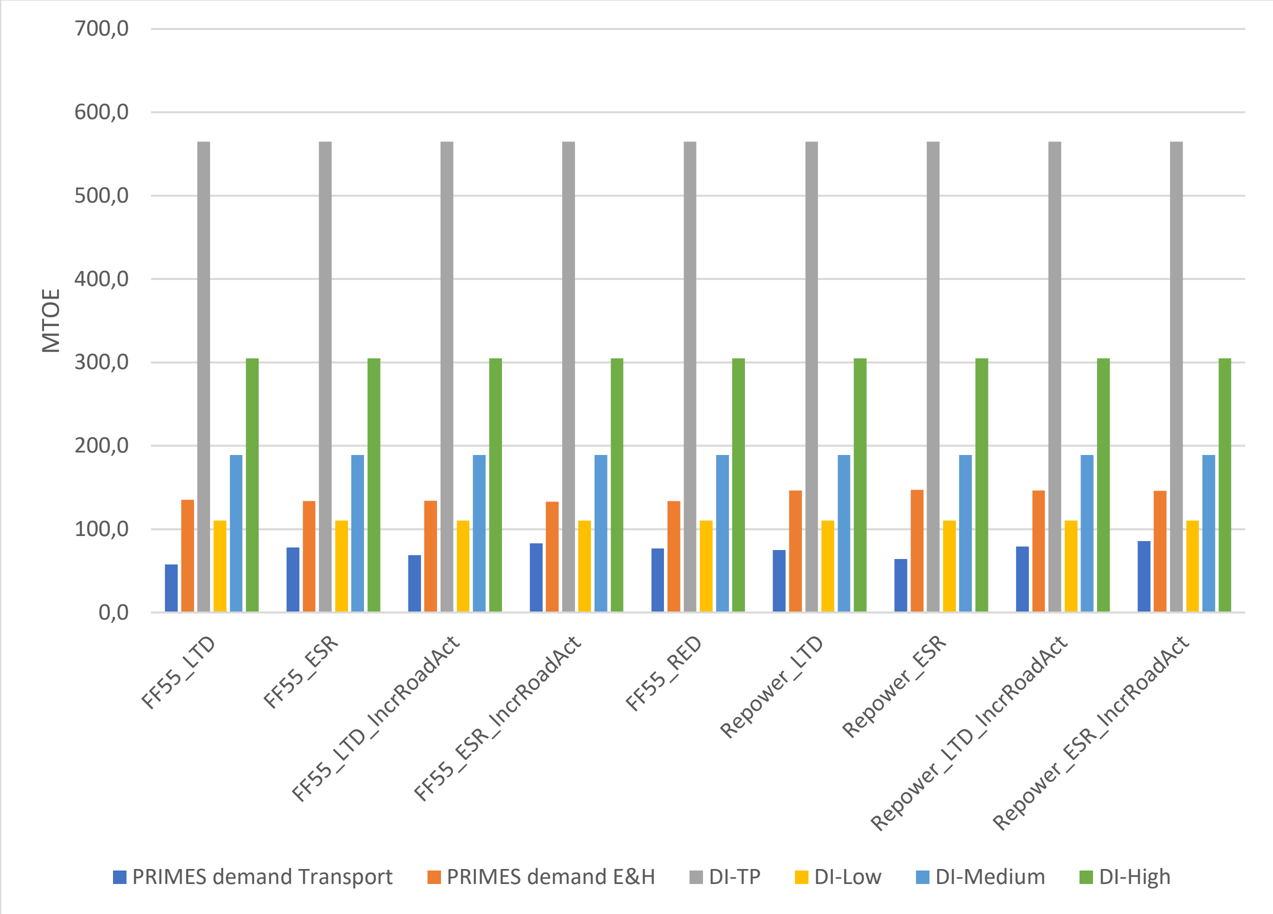


Figure A2 - 12 Comparison biomass demands for transport and E&H in PRIMES scenarios (2030) and biomass potentials in TP, Low, Medium, and High biomass mobilization scenarios

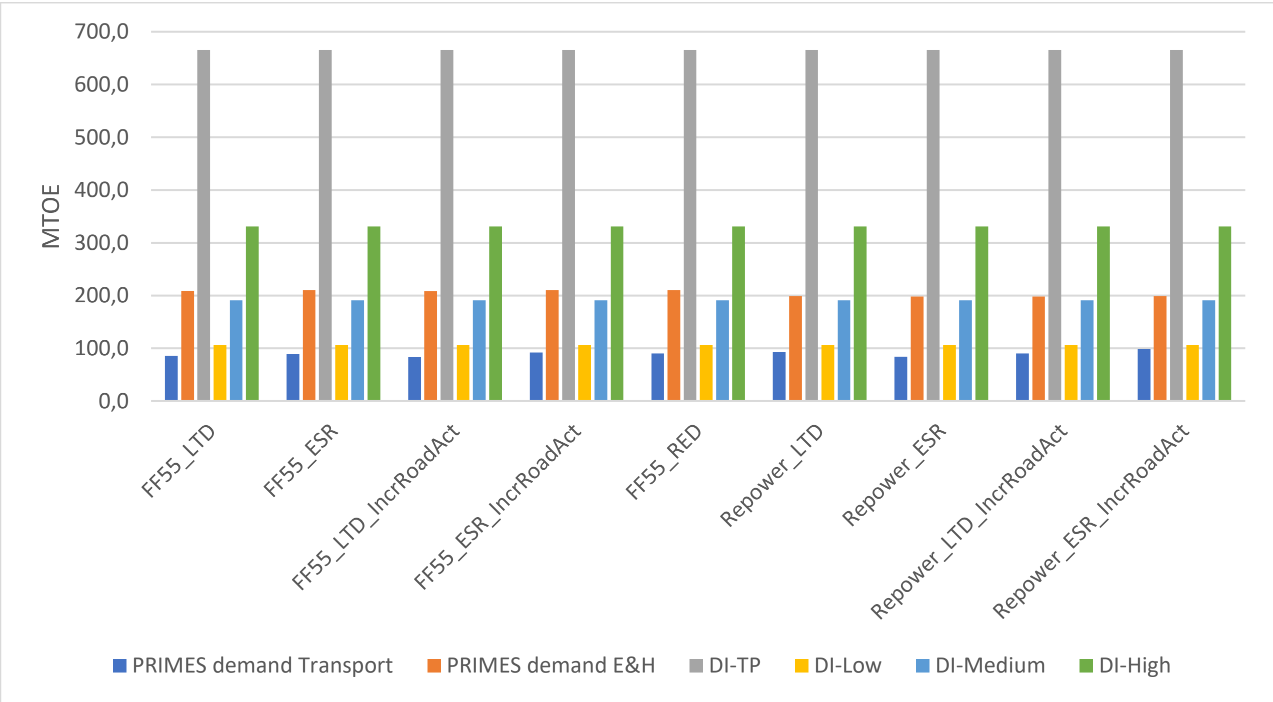


Figure A2 - 13 Comparison biomass demands for transport and E&H in PRIMES scenarios (2050) and biomass potentials in TP, Low, Medium, and High biomass mobilization scenarios

| 2030 | PRIMES biomass use (2030) | | | Total biomass potential (EU27) (2030) | | | | Difference (EU-27) (2030) | | | | Difference (EU + UK + Association countries) (2030) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MTOE | Transport | E&H | Total | TP | Low | Medium | High | TP | Low | Medium | High | TP | Low | Medium | High |
| FF55_LTD | 57 | 135 | 193 | 565 | 110 | 189 | 305 | 372 | -82 | -4 | 112 | 486 | -61 | 28 | 161 |
| FF55_ESR | 78 | 134 | 212 | 565 | 110 | 189 | 305 | 353 | -101 | -23 | 93 | 467 | -80 | 9 | 142 |
| FF55_LTD_IncrRoadAct | 69 | 134 | 203 | 565 | 110 | 189 | 305 | 362 | -92 | -14 | 102 | 476 | -71 | 18 | 151 |
| FF55_ESR_IncrRoadAct | 83 | 133 | 216 | 565 | 110 | 189 | 305 | 349 | -106 | -27 | 89 | 463 | -84 | 5 | 137 |
| FF55_RED | 77 | 134 | 210 | | | | | 354 | -100 | -22 | 94 | 468 | -79 | 10 | 143 |
| Repower_LTD | 75 | 146 | 221 | 565 | 110 | 189 | 305 | 343 | -111 | -32 | 83 | 457 | -90 | 0 | 132 |
| Repower_ESR | 64 | 147 | 211 | 565 | 110 | 189 | 305 | 353 | -101 | -22 | 93 | 467 | -80 | 10 | 142 |
| Repower_LTD_IncrRoadAct | 79 | 146 | 225 | 565 | 110 | 189 | 305 | 339 | -115 | -36 | 79 | 453 | -94 | -4 | 128 |
| Repower_ESR_IncrRoadAct | 86 | 146 | 232 | 565 | 110 | 189 | 305 | 333 | -121 | -43 | 73 | 447 | -100 | -11 | 122 |
| 2050 | PRIMES biomass use (2050) | | | Total biomass potential (EU27) (2050) | | | | Difference (EU-27) (2050) | | | | Difference (EU + UK + Association countries) (2050) | | | |
| MTOE | Transport | E&H | Total | TP | Low | Medium | High | TP | Low | Medium | High | TP | Low | Medium | High |
| FF55_LTD | 86 | 209 | 295 | 666 | 107 | 191 | 331 | 371 | -188 | -104 | 36 | 491 | -168 | -73 | 87 |
| FF55_ESR | 89 | 210 | 299 | 666 | 107 | 191 | 331 | 367 | -193 | -108 | 32 | 486 | -172 | -77 | 83 |
| FF55_LTD_IncrRoadAct | 84 | 209 | 292 | 666 | 107 | 191 | 331 | 373 | -186 | -101 | 39 | 493 | -166 | -70 | 90 |
| FF55_ESR_IncrRoadAct | 92 | 210 | 302 | 666 | 107 | 191 | 331 | 364 | -195 | -111 | 29 | 484 | -175 | -80 | 80 |
| FF55_RED | 90 | 210 | 301 | | | | | 365 | -194 | -110 | 30 | 485 | -174 | -79 | 81 |
| Repower_LTD | 92 | 199 | 291 | 666 | 107 | 191 | 331 | 375 | -184 | -100 | 40 | 494 | -164 | -69 | 91 |
| Repower_ESR | 84 | 198 | 282 | 666 | 107 | 191 | 331 | 384 | -175 | -91 | 49 | 504 | -155 | -60 | 100 |
| Repower_LTD_IncrRoadAct | 90 | 198 | 288 | 666 | 107 | 191 | 331 | 378 | -181 | -97 | 43 | 497 | -161 | -66 | 94 |
| Repower_ESR_IncrRoadAct | 99 | 198 | 297 | 666 | 107 | 191 | 331 | 369 | -190 | -106 | 34 | 488 | -170 | -75 | 85 |

Table A2 - 10 Comparison biomass demands for transport and E&H in PRIMES scenarios (2030 and 2050) and biomass potentials in TP, Low, Medium and High biomass mobilization scenarios

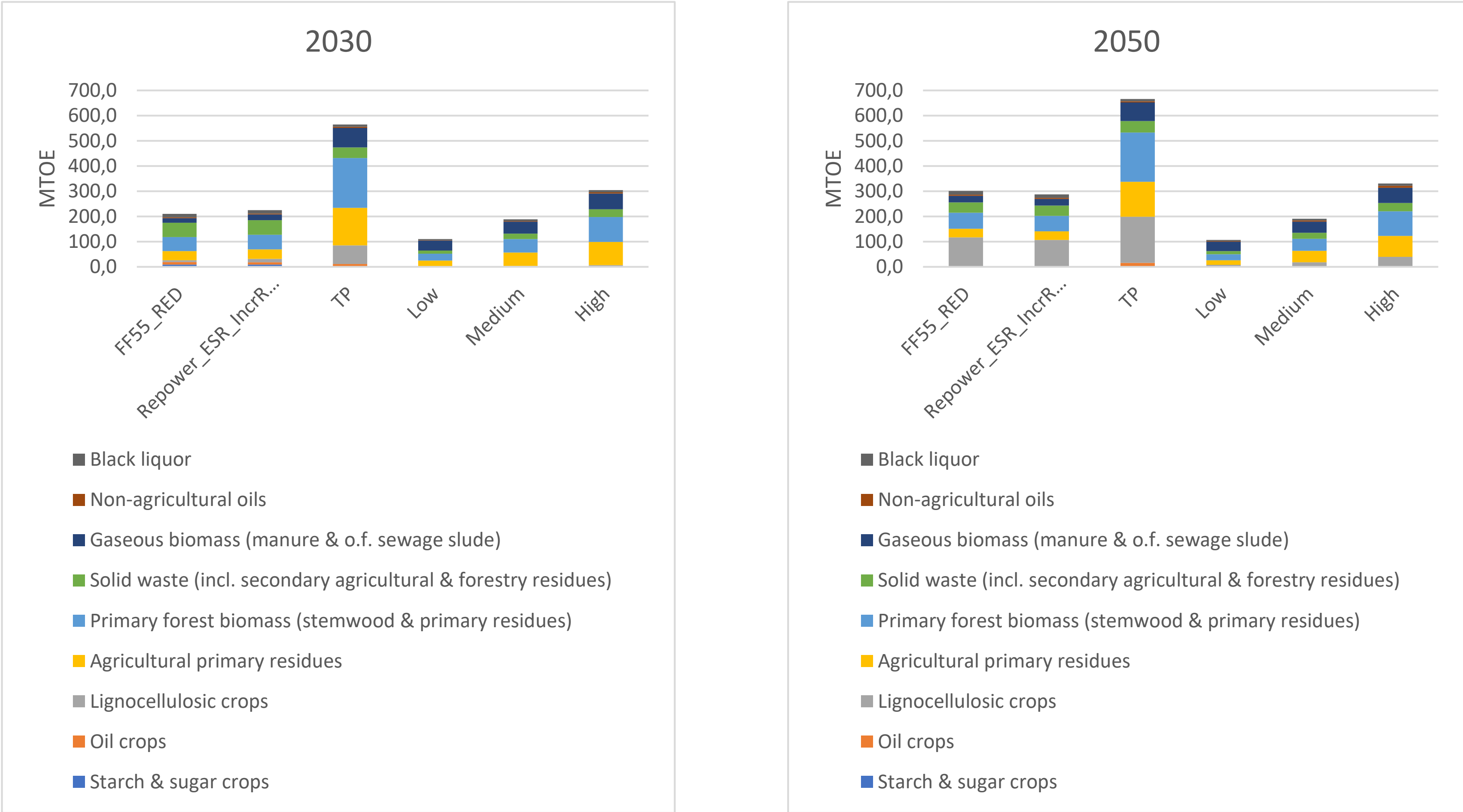


Figure A2 - 14 Comparison biomass demands for 2 PRIMES scenarios per biomass type compared to biomass potentials in TP and low, medium and high mobilisation scenarios

From the comparison it becomes clear that the total biomass demands from PRIMES for the combination of transport and E&H can certainly not be accommodated by the biomass potentials in the low and medium mobilisation scenarios in both 2030 and 2050.

In Table A2 - 11 an overview is given of the exact difference in biomass needs in the PRIMES scenarios and the supply in the biomass mobilization scenarios. Overall, one can see that in 2030 in most PRIMES scenarios the biomass demand can still be covered by the High mobilization scenario, certainly if additional biomass is also derived from the non-EU/Accession countries. In the 2050 situation even in the High mobilization scenario there is not enough biomass to fit the demands from PRIMES. For the Low mobilization scenario in 2050 almost 70% of the PRIMES demand cannot be satisfied, In the Medium scenario this would be around 30% and in the high mobilization scenario this would be possible.

Figure A2-15 provides a comparison at the level of biomass types for two main scenarios from the FF55_RED and RepowerEU scenarios. When comparing the demands at biomass group level there are several differences:

- The largest differences between PRIMES demands and the mobilisation scenarios occur especially for biomass from solid agricultural and forest residues and waste, particularly Primary and secondary forestry residues and stemwood. Even in the high mobilisation these very high PRIMES demands cannot be satisfied. This demand from PRIMES is both high for E&H and for Transport. So, this makes clear that between both sectors there will be much competition for the solid biomass.

- PRIMES only demands small amounts of biomass from the gaseous biomass (manure and organic fraction in sewage sludge) categories for transport, and most of the biomass is now going to the electricity and heat sector in PRIMES scenarios. Still the supply of the gaseous biomass in the mobilization scenarios, even the Low, is larger than what is in total demanded by PRIMES.

- This also applies to agricultural residues which in the medium and high mobilisation scenario are available at higher levels than what PRIMES is demanding.

- The high demand for lignocellulosic crops in PRIMES towards 2050 is not in line with the mobilization expectations in the three mobilisation scenarios, although in the TP it could be delivered. It seems however that PRIMES is more optimistic on the mobilization of this kind of biomass than what is expected in the 3 mobilisation scenarios.

- The demand for oil crops and non-agricultural oils in PRIMES can be satisfied in all mobilisation scenarios.

- PRIMES also demands large amounts of black liquor, while in the mobilization scenarios these are rather small. The reason is likely to be related to the fact that very high competing use levels have been assumed for the assessment of it in the mobilization scenarios. This is certainly not in line with the assessment in PRIMES that is likely using more recent data on black liquor availability and linking it more strongly to current practices in pulp and paper industry.

- Finally, PRIMES still demands crops for first generation biofuels, particularly in 2030. These are not part of the low, medium, and high potentials so this explains some mismatch for sugar and starch crops, but this is not a large amount.

It seems that more conversion technologies for biofuels need to be targeted towards biomass categories that are underutilized such as gaseous waste (manure and sewage sludge) and agricultural residues. If the dedicated cropping potential is indeed going to be mobilized on unused, degraded lands and as intercrops options to reach the high drop-in biofuel ambitions become more realistic.

# 7. Sensitivity analysis: comparing effect of scenario assumptions on final potentials

## 7.1. Comparison of effects of scenario assumptions on total potential

As described in the former chapter the sensitivity analysis in this study works through the range in scenario assumptions applied specifically per type of biomass. Here, an overview of the effect of these different scenario assumptions are provided, and worked out in terms of biomass potential quantities for the most influential assumptions and the larger biomass types.

The biomass categories having the largest contribution to the total biomass potential are presented in Figure A2 - 15. In the technical potential in 2030 by far the largest contribution comes from manure, primary residues from arable crops and stemwood.

In the low mobilization potential manure and primary residues are the largest categories, but a large amount of these residues is not available because of much stricter mobilization considerations such as competing uses, lower removal rates, lower yield increase expectations and adverse effects of climate change on yields. Overall, the low mobilization assumptions reduce the total biomass potential as compared to the technical potential by 1683 million tons (-81%) in 2030 and by 1734 million tons (-82%) in 2050. The stricter assumptions for the primary residues from arable crops take up 31% and 32% in 2030 and 2050 respectively of the difference between the technical and low mobilization scenarios. For stemwood these relative differences are 22% in both 2030 and 2050 respectively. For manure (solid and liquid) these shares are 8% in both 2030 and 2050.

The medium mobilization scenario assumptions lead to a reduction in biomass potential as compared to the technical potential of -1362 million tons (-66%) in 2030 and -1415 million tons (-68%) in 2050 respectively. For the high mobilization scenario this difference is -909 million tons (-45%) in 2030 and -940 million tons (-46%) in 2050.

In 2050 the contribution of crops from degraded and abandoned lands become more important. In the technical potential they may amount to 293 million tons in 2050, but in the low scenario due to assumptions on very limited stimulation (through market and policy) of taking up these crops, their potential will only amount 18 million tons in the low scenario. In the high scenario it can become 77 million tons. The latter is however still a fraction of what the technical potential is, namely 26% of total technical potential in 2050.

For the assessment of dedicated crops, as described in Appendix 2-4, several assessment steps were taken, and estimates had to be made of the amount of land available in abandonment and in degradation. This amount of land could then be combined with the crop mix suitable in every environmental zone and then multiplied with the average yield of the crop mix.

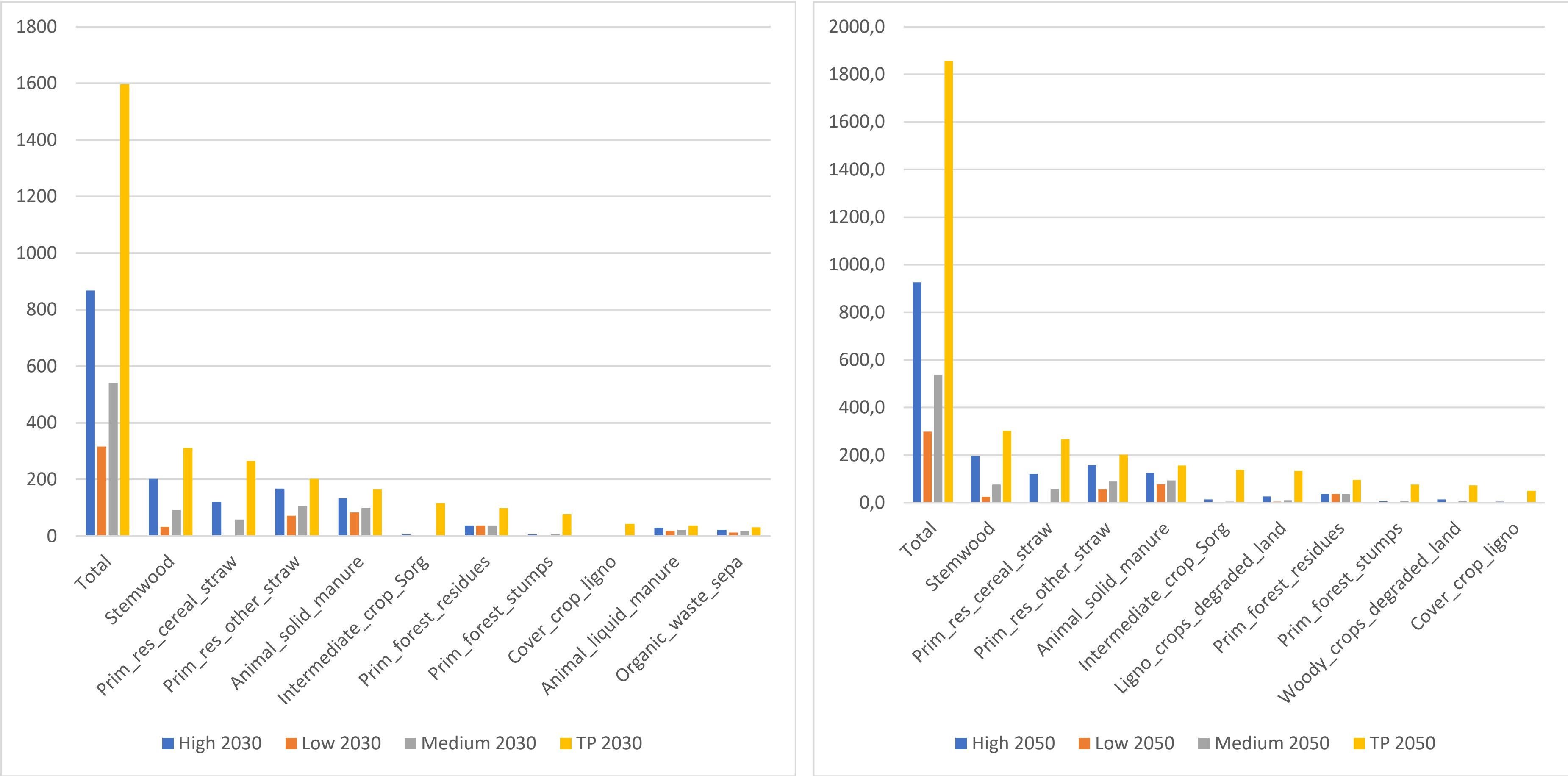


Figure A2 - 15 Top 10 biomass categories and total biomass (million ton) compared between technical, low, medium and high mobilization scenarios in 2030 (left) and 2050 (right)

## 7.2. Comparison to current biomass uses for energy and to potentials in other studies

To get a better understanding of the dimensions of biomass potentials per scenario a comparison is made with current uses of biomass in energy generation as reported by Eurostat. In 2021 Eurostat reported around 50 MTOE of domestic solid biomass from primary and secondary forestry and agricultural sector going to energy (see Table A2 - 11). This can be compared to the potential for 2030 in the different scenarios.

| MTOE | 2021 energy consumption | Low 2030 | Medium 2030 | High 2030 |
|---|---|---|---|---|
| **Primary biomass from forests** | 29.32 | 26.4 | 53.6 | 98.8 |
| **Secondary woody biomass (Chips, saw dust and other wood particles and wood pellets** | 11.0 | 12.8 | 22.0 | 30.8 |
| **Post consumer wood** | 1.9 | 3.8 | 6.7 | 9.1 |
| **Black liquor** | 2.8 | 4.5 | 6.8 | 9.0 |
| **Agricultural solid biomass** | 3.6 | 25.5 | 56.5 | 98.7 |
| **Renewable municipal waste** | 3.0 | 4.8 | 6.7 | 8.6 |

Table A2 - 11 Endogenous biomass for energy, 2021 (Eurostat)[16] compared to potentials 2030 in low, medium, and high mobilization scenario

From the comparison in Table A2 - 12 it becomes clear that the 2030 biomass potentials in the low mobilization scenario are not too far off although still above, the current solid biomass for energy consumption levels for most categories. For the medium and high mobilization scenarios one can see that current consumption levels are still very modest to what is estimated to be available by 2030 and is most pronounced for the agricultural solid biomass sources.

In Figure A2 - 16 the current potentials in the low, medium, and high mobilisation scenarios of this study are compared to the former scenario studies by JRC-Times, DG-RTD and Concawe (Imperial College (IC), Panoutsou, 2021). It is obvious that the potentials in this study, most clearly the low mobilisation, are providing more conservative results. This has several reasons, but one is that in time more insights are obtained about the many factors that influence on the competing uses and the mobilisation factors. Another factor is of course that all studies take different assumptions and data inputs ranging per mobilisation scenario and per biomass type.  The very low potential resulting from the low mobilisation scenario is because this scenario is a very conservative one where no priority is given any more to directing biomass towards bioenergy and biofuels.

[16] Statistics | Eurostat (europa.eu)

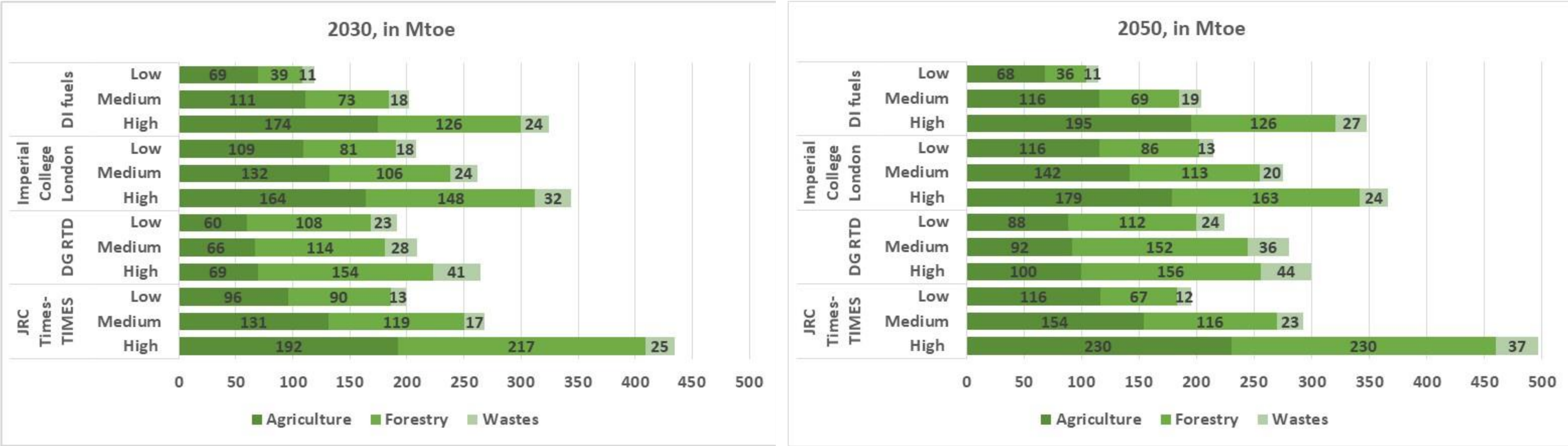


Figure A2 - 16 Comparison of biomass potentials in this study with those of former studies for EU-27 + UK

In fact, this is the only scenario where the competing use level is most in line with the competing use level of 9 EJ (≈ 209 MTOE), from the Materials Economic (2021) study (see next Section). Furthermore, in this low scenario the technological and innovation investments are not expected to be directed towards advanced biofuels which expresses itself in very limited yield increases in novel dedicated cropping options and mobilisation of other woody biomass supply and expectations of adverse effects of climate change on yields are also more pronounced. The medium mobilisation scenario in this study is still lagging behind the medium mobilisation scenario from Imperial College (IC) while the high mobilisation scenario is most in line in both studies. Differences between the current and IC assessment in medium mobilisation in agricultural biomass are mostly related to different input data used, more optimistic assumptions about yield increases and about mobilisation of dedicated cropping on degraded and unused lands. In the forest biomass competing use levels are expected to be lower in the Imperial College potentials, while the base data are similar as they are both building on the S2BIOM data.

Yield increase assumptions have large influent on agricultural potentials from both primary field residues (e.g., straw) and from dedicated crops on unused, degraded lands and in cover and intermediate cropping systems. In this study a yield increase is assumed for residues, as projected by CAPRI baseline 2021 plus an extra yield increase of 0%, 0.5% and 1% per year in the low, medium, and high mobilisation scenario respectively. In addition, the climate change expectation are expected to decline the yields in the Mediterranean zone (by 10% and 20% up to 2030 and 2050 in the low and by 5% and 10% in the Medium and no effect in High scenario) but will lead to extra increase in yields in the Boreal and Nemoral zone (5% and 10% in low, 5% and 15% in Medium and 15% and 25% in High mobilisation in 2030 and 2050 respectively). In the IC study the yield increase assumed on top of baseline yield developments from CAPRI (baseline 2015) were 0.9% per year for all scenarios and no climate change effects on yields were assumed. In addition, IC also assumed an extra yield increase in primary field residues because of management practice improvement of 1% per year, so in total the yield increase per year is at 1.9% per year.

For dedicated crops yield levels were higher in the IC study because part of the dedicated cropping can take place on abandoned lands with good quality lands, but in this study it was assumed that all dedicated crops would grow on low quality lands, so the yields were more modest, but yield increases were assumed to be larger then what was assumed in the IC study. Also, the land availability in IC, based on S2BIOM, is different from the land availability estimates in this study. In IC only the abandoned lands were considered which were estimated to be around 20 million hectares in 2030 and 2050. In this study the land availability for dedicated crops was assessed with new models and data and distinguishes between land abandoned and degraded land. This resulted in a total technical land availability of 8.3 million hectares in 2030 (3.3 abandoned and 5 million ha degraded) and almost 40 million in 2050 (7.6 million abandoned and 32 million degraded). Of this technical land available the assumption on the land share that would also be used for dedicated cropping were more modest in this study then the IC also because 2030 is close and see very little, large progress in dedicated cropping until now. On the other hand, the technical potential is very large so it is recommended that mobilisation of that land resource for a dedicated cropping, which may be combined with soil carbon sequestration if perennial crops are used, has a large potential. Finally, in this study an extra potential for cover and intermediate crops was added, which was not considered in the IC and also the other potential studies. Hence, although a modest mobilisation for it is assumed, it does explain part of the higher potentials for agriculture by 2050 in the high mobilisation scenario as compared to the IC study.

## 7.3. Review of competing uses assumptions and demand expectations for materials and chemicals

The competing uses have been addressed in this study using scenario assumptions. In the three mobilization scenarios the demands for biomass from competing uses outside the energy sectors were addressed in two ways.

Firstly, by already selecting low-ILUC risk biomass types, biomass that has no or low competition with food production. So, in principle the biomass potential estimates already exclude most of the biomass types and uses for food.

Secondly, by making assumptions about different levels of competing demands for biomass for both feed and biomaterials and biochemicals in the three mobilization scenarios. The low mobilization scenario has the highest competing use levels which implies that is leaves little biomass available for the energy demands from electricity, heat and transport fuels. In the high mobilization scenario these competing uses are assumed to be much lower and in the technical potential no competing uses are assumed.

The different competing use levels in the mobilisation scenarios were applied because there is currently limited information about how much biomass will be needed in the future for the material and chemical sectors, certainly at the level of biomass types. There is however one recent study that does give an indication about the rough amount of biomass expected to be additionally needed for biochemicals and biomaterials in the EU by 2050. This study was published by the Material Economics (2021) with the title '*EU Biomass Use in a Net-Zero Economy. A course correction for EU biomass*'. In this study A demand of between 9 to 17.5 EJ, (≈ 209 to 406 MTOE) was expected from Materials Economic (2021). After consultation with our advisors to the project of TNO, the lower end estimation of 9 EJ is to be seen as most realistic. According to the experts from TNO consulted about this demand, judge that this is a high-end estimation. There are several options to address these biochemical and biomaterial demands in biorefinery process with high efficiency and also one can expect that part of the demands for biochemicals and also textiles can be generated from biogenic $CO_2$. Therefore, it should be stressed out that the Material Economic review is the only available reference found and it has not been cross checked with other studies on the validity of the results. The demands in the Materials Economic report should therefore be seen as a strong over estimation and that a comparison with the lower potential of 9EJ was only made. Also, it is not clear in the Materials Economic report why these demands for biomass should all come from the EU and cannot (partly) be imported from outside the EU.

So, in the comparison with the competing use levels in the low medium and high scenarios, it turns out that this 9 EJ, (≈ 209 MTOE) is most in line with the competing use level of the low mobilization scenario which amounts to 193 MTOE. In medium and high mobilization scenarios these were 140 & 80 MTOE respectively.

## 7.4. Potentials for biomass types not assessed in this study

This study covered more potential biomass types than in other former studies, as discussed in Chapter 2 of this report. In spite of this, certain categories of biomass are still missing. These are tall oil pitch; crude glycerine; bagasse, nut shells; crude methanol, vinasse, DDGS; secondary residues of drinking products and algae.

This section elaborates a bit further on the question whether these missing biomass types are likely to substantially increase the total biomass potential towards 2030 and 2050.

As to 1G biofuel process residues, vinasse (thin stillage) and DDGS estimates were not made because they depend on the 1G biofuel production and this was assessed in Task 1 of this study independently of the total biomass potential assessment in Task 2 presented here.

However, in terms of potential size of these feedstocks, the following can be argued.

Vinasse is produced in the process of ethanol production from sugarbeet or sugarcane juice or from molasses. In addition, there is also thin stillage, which is vinasse coming from corn and wheat based ethanol. So, both are 1st generation ethanol coproducts. Flach et al. (2020) reports that about 6 million tonnes of sugar beets were used for ethanol production in the EU in 2020, producing about 600 million litres of ethanol. Assuming 10 litres vinasse per litre ethanol are produced, this leads to a current production of roughly 6 billion litres of sugarbeet vinasse per year in Europe. Vinasse contains about 7% solids per litre, which implies a total 420,000 tonnes dry mass of Vinasse produced. Since vinasse comes from 1G ethanol one cannot expect an increase of this amount to 2030 and it will be phased out by 2050. Furthermore, most of the Vinasse is going to animal feed, so this implies that competing use levels will be very high. With respect of thin stillage, Flach et al. (2020) reports current EU production for ethanol production of 6-7 million tonnes of corn and 2.5 to 3.5 million tonnes of wheat, for 2.5 to 3 billion litres of corn ethanol production and 1 to 1.4 billion litres of wheat ethanol production. This suggests a production of between 50 and 70 billion litres of thin stillage a year (assuming 15 litres per litre of ethanol) and this would lead at 7% solids per litre, to an amount of between 3500 and 4900 Kton thin stillage. This is significant, but most of it is already used for feed and it will be phased out towards 2050. The conclusion is that both for thin stillage and vinasse a very limited amount for biofuel production will be available in 2030 and no potential at all in 2050.

For DDGS (Distillers Grains and solubles), the story is rather similar as it is a 1G side product from biodiesel production and most of it is already going to feed production. Statista[17] tells us that the total amount of DDGS produced in EU is 3800 Kton in 2023 and is predicted to decline towards 3200 kton in 2030 (see Distiller's dry grains production volume EU-27 2018-2031 | Statista). It is also based on 1G biodiesel production. Thus, this will also be phased out towards 2050.

For the other non-assessed feedstock: Nut shells; crude methanol, secondary residues of drinking products are expected to be very small. Crude methanol is indirectly covered already in this study since it is a side product of paper mills. Often paper mills decide to make more black liquor or methanol. In this study the black liquor potential was assessed, but part of it is interchangeable with methanol. Also, residues from drinking products were indirectly included already because biowaste from fruit and vegetables was included as a potential in this study. The fruit part covers residues from juice industry.

Therefore, the overall conclusion is that the not-assessed biomass types will not be significant in size, certainly not by 2030 and also unlikely, or very limited, by 2050.

As to algae biomass for biofuels, information is still too limited to make meaningful estimates on their potential contribution to biofuel targets by 2050 (see also, Panoutsou, 2021).

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[17] Distiller's dry grains production volume EU-27 2018-2031 | Statista

## 8. Conclusions

The total biomass potentials available for the energy markets in the three mobilisation scenarios for 2030 range from 310, 524, 836 million dry tons (132, 221, 353 Mtoe). For 2050 this range is from 294, 520, 892 million tons (128, 222, 382 Mtoe).

By far the largest contribution of biomass comes from the agricultural sector with shares ranging around 55% in the low, medium, and high mobilization scenarios by 2030. Towards 2050 this agricultural biomass share increases further towards 57% in these three mobilization scenarios. The most important biomass types, with largest potential are primary residues from arable crops, manure and stemwood and primary forestry residues. Towards 2050 the dedicated lignocellulosic crops also become more important.

(At gate) cost levels were generated for the current situation and were kept constant towards 2030 and 2050. In the medium mobilization scenario, there is a total potential for Europe of 490 and 492 million tonnes dm (or oil in the case of oil crops and UCO) in 2030 and 2050 respectively. In 2030 more than 85% of potential biomass can be delivered at gate below a cost of 50 €/ton. In 2050 this percentage is 80%.

There are interesting differences between the amount and especially biomass groups quantified in the different scenario assumptions and the PRIMES demands. The most important is that by 2030 only in the medium and high mobilization scenario enough biomass is available to satisfy the biomass needs from PRIMES. Towards 2050 only in the high mobilization scenario the biomass demands for both the transport and electricity and heat sectors can be satisfied. Additional biomass from the Accession countries is certainly needed to cover the high demands for biomass predicted by the PRIMES model.

The competing use levels in the low mobilization scenario are most in line with the lower end 2050 demands from biochemicals and biomaterials (9 EJ ≈ 209 Mtoe).

More conversion technologies for drop-in fuels (then expected in the PRIMES model runs) need to be targeted towards biomass categories that are under-utilized such as gaseous biomass (manure and sewage sludge) and primary and secondary agricultural residues.

One of the few options to mobilize more biomass, which is certainly needed from the comparison with PRIMES, is through significantly increasing the biomass production on unused, degraded lands and from inter- and cover crops. The expectation of mobilizing this type of biomass were more modest in the low, medium, and high mobilization scenarios. However, the technical potential for these types of biomass groups confirm that faster mobilization may be possible.

There could also be additional biomass resources coming from algae by 2050, but this aspect still needs considerable research and expectations on the potential contribution of it are still very difficult to be made based on the current state of knowledge.

More R&I support in improving the conversion of biomass to biofuels, the resource efficiency and circularity is needed, to develop novel technologies and biomass resources, also agricultural protocols and practices for mobilization are necessary beyond 2030 and certainly in the path to 2050.

## 9. Literature


AIBI Bread Market Report 2013. (2015). In International Association of Plant Bakers, *AIBI.EU*. International Association of Plant Bakers. Retrieved May 11, 2023, from https://docplayer.net/19203294-Aibi-bread-market-report-2013-january-2015.html

Auvermann, B., Kalbasi, A., & Ahmed, A. (2004). Rendering. In *Carcass Disposal: A Comprehensive Review*. National Agricultural Biosecurity Center, Kansas State Univeristy. https://krex.k-state.edu/bitstream/handle/2097/662/Chapter4.pdf;sequence=15

Bylund, G., Malmgren, B., Holanowski, A., Hellman, M., Mattsson, G., Svensson, B., Pålsson, H., Lauritzen, K., Vilsgaard, T., Verweij, E., Bronsveld, E., Adamson, N., Pearse, J., Kouroutsidis, P., Mathisson, J., Franz, F., Svensson, C., Rehn, U. (2015). *Dairy Processing Handbook*. For: Tetra Pak. Available at: https://dairyprocessinghandbook.tetrapak.com/chapter/whey-processing

Dees, M., Hohl, M., Datta, P., Forsell, N., Leduc, S., Fitzgerald, J., Verkerk, H., Zudin, S., Lindner, M., Elbersen, B. S., Staritsky, I. G., Schrijver, R. A. M., Lesschen, J. P., van Diepen, C. A., Anttila, P., Prinz, R., Ramirez

Almeyda, J., Monti, A., Vis, M., Galindo, D. G., & (2017). Deliverable 1.6 A spatial data base on sustainable biomass cost-supply of lignocellulosic biomass in Europe - methods & data sources: Issue: 1.2. 20 Apr 2017, S2Biom. 177 p. https://www.s2biom.eu/images/Publications/D1.6_S2Biom_Spatial_data_methods_data_sources_Final_Final.pdf

EEA (2019). Climate changes adaptation in the agricultural sector in Europe. EEA report No. 04/2019. ISSN 1977-8449

EFPRA (2020). *Statistical overview of the Animal By-Products Industry in the EU in 2019.*

Elbersen, B.S.; Staritsky, I., Hengeveld G. &; Lesschen, J.P. (2016). Outlook of spatial biomass value chains in EU28. Deliverable 2.3 of the Biomass Policies project

Elbersen, B., Verzandvoort, S., Panoutsou, C. & Alexopoulou, E. (2022). BIKE Deliverable 2.2 Options to grow crops on unused, abandoned and/or severely degraded lands. https://www.bike-biofuels.eu/wp-content/uploads/2022/10/Deliverable-2.2-Final.pdf

European Commission (2019). *Refresh - Annexes to: D6.10 Valorisation spreadsheet tools - Learning tool for selected food side flows allowing users to indicate life cycle greenhouse gas emissions and costs.* Available at: https://eu-refresh.org/sites/default/files/D6.10%20REFRESH%20_FORKLIFT_Annexes%20.pdf

FEFAC (2020). *Direct inputs during the stakeholder consultation held in April-May 2020 and further personal communications.*

Flach, B., Lieberz, S., Bolla, S., & Riker, C. (2020). EU Biofuels Annual 2020. 21. https://gain.fas.usda.gov/.

Goryńska-Goldmann, E., Gazdecki, M., Rejman, K., Łaba, S., Kobus-Cisowska, J., & Szczepański, K. (2021). Magnitude, Causes and Scope for Reducing Food Losses in the Baking and Confectionery Industry—A Multi-Method Approach. *Agriculture*, *11*(10), 936. https://doi.org/10.3390/agriculture11100936

Greenea. (2016). *Analysis of the current development of household UCO collection systems in the EU*. European Waste-to-Advanced Biofuels Association. Retrieved May 1, 2023, from https://theicct.org/sites/default/files/publications/Greenea%20Report%20Household%20UCO%20Collection%20in%20the%20EU_ICCT_20160629.pdf

Gurría, P., González, H., Ronzon, T., Tamosiunas, S., López, R., García Condado, S., Ronchetti, G., Guillén, J., Banja, M., Fiore, G., M'Barek R., Biomass flows in the European Union: The EU Biomass Flows tool, version 2020, EUR 30454 EN, Publications Office of the European Union, Luxembourg, 2020, ISBN 978-92-76-25378-5, doi:10.2760/14342, JRC122379

Heuzé V., Thiollet H., Tran G., Boudon A., Bastianelli D., Lebas F. (2018). *Bakery waste*. Feedipedia, a programme by INRAE, CIRAD, AFZ and FAO. Available at https://www.feedipedia.org/node/70 Last updated on February 1, 2018, 15:46

Kumar H, Bhardwaj K, Sharma R, Nepovimova E, Kuča K, Dhanjal DS, Verma R, Bhardwaj P, Sharma S, Kumar D. Fruit and Vegetable Peels: Utilization of High Value Horticultural Waste in Novel Industrial Applications. Molecules. 2020 Jun 18;25(12):2812. doi: 10.3390/molecules25122812. PMID: 32570836; PMCID: PMC7356603.

Law Y, Jacobsen GE, Smith AM, Yuan Z, Lant P. Fossil organic carbon in wastewater and its fate in treatment plants. Water Res. 2013 Sep 15;47(14):5270-81. doi: 10.1016/j.watres.2013.06.002. Epub 2013 Jun 12. PMID: 23863394.

Material Economics (2021). EU Biomass Use in A Net-Zero Economy - A Course Correction for EU Biomass. https://materialeconomics.com/latest-updates/eu-biomass-use

Meijninger, W., Elbersen, B., van Eupen, M., Mantel, S., Ciria, P., Parenti, A., Sanz, M., Ortiz, P., Acciai, M., Monti, A. (2022). Identification of early abandonment in cropland through radar-based coherence data and application of a Random-Forest model. DOI - 10.1111/gcbb.12939, GCB Bioenergy.

Murawska, D. (2017). The Effect of Age on Growth Performance and Carcass Quality Parameters in Different Poultry Species. In *InTech eBooks*. https://doi.org/10.5772/64860

Mussatto S.I. (2014) *Brewer's spent grain: a valuable feedstock for industrial applications,* Journal of the Science of Food and Agriculture, 94(7), 1264-1275.

Panoutsou, P (2021). Sustainable biomass availability in the EU to 2050. Imperial College Consultants. London. Sustainable-Biomass-Availability-in-the-EU-Part-I-and-II-final-version.pdf (concawe.eu)

Panoutsou, C.; Giarola, S.; Ibrahim, D.; Verzandvoort, S.; Elbersen, B.; Sandford, C.; Malins, C.; Politi, M.; Vourliotakis, G.; Zita, V.E.; (2022). Opportunities for Low Indirect Land Use Biomass for Biofuels in Europe. Appl. Sci. 2022, 12, x. https://doi.org/10.3390/xxxxx

Sharma, P., Singh, S.P. Identification and profiling of microbial community from industrial sludge. Arch Microbiol 204, 234 (2022). https://doi.org/10.1007/s00203-022-02831-y

Spekreijse, J., Vikla, K., Vis, M., Boysen-Urban, K., Philippidis, G. and M'barek, R., Bio-based value chains for chemicals, plastics and pharmaceuticals, EUR 30653 EN, Publications Office of the European Union, Luxembourg, 2021, ISBN 978-92-76- 32459-1, doi:10.2760/712499, JRC124141

## Appendices belonging to Task 2 report

### Appendix 2-1: Overview of all biomass categories

The overview of biomass types assessed, and their unique DI-number is presented in the following Table A2 - 12.

| DI codes | Short name | Category | subcategory 1 | Additional category info | Link to RED |
|---|---|---|---|---|---|
| 1100 | Stemwood | Primary forestry production | Stemwood from final fellings & thinnings | Stemwood | |
| 1200 | Prim_forest_residues | Primary residues from forests | Logging residues from final fellings and thinings | Stem and crown biomass | REDII- Annex IX-A |
| 1220 | Prim_forest_stumps | Primary residues from forests | Logging residues from final fellings and thinings | Stumps from final fellings and thinnings | REDII- Annex IX-A |
| 5211 | Post_cons_wood_hazard | Post consumer wood | Hazardous post consumer wood | Post consumer wood | REDII- Annex IX-A |
| 5212 | Post_cons_wood_non_hazard | Post consumer wood | Non hazardous post consumer wood | Post consumer wood | REDII- Annex IX-A |
| 2101 | Ligno_crops_unused_land | Primary production of crops | Lignocellulosic crops from unused & abandoned lands | Biomass sorghum, miscanthus, switchgrass, giant reed, RCG, cardoon | REDII- Annex IX-A |
| 2102 | Oil_crops_unused_land | Primary production of crops | Oil crops from unused & abandoned lands | Cardoon, Camelina, Castor | REDII- Annex IX-A |
| 2103 | Woody_crops_unused_land | Primary production of crops | Woody crops from unused & abandoned lands | SRC Poplar, willow | REDII- Annex IX-A |
| 2104 | Ligno_crops_degraded_land | Primary production of crops | Lignocellulosic crops from severely degraded lands | Biomass sorghum, miscanthus, switchgrass, giant reed, RCG, cardoon | Annex IX-A Non food crops grown in severely degraded lands |
| 2105 | Oil_crops_degraded_land | Primary production of crops | Oil crops from severely degraded lands | Cardoon, Camelina, Castor | Annex IX-A Non food crops grown in severely degraded lands |
| 2106 | Woody_crops_degraded_land | Primary production of crops | Woody crops from severely degraded lands | SRC Poplar, willow | Annex IX-A Non food crops grown in severely degraded lands |
| 2107 | Intermediate_crop_Sorg | Primary production of intermediate, cover crops | Lignocellulosic crops from good & medium quality agricultural land | Biomass sorghum | Annex IX-B_new_Intermediate crops, such as catch crops and cover crops 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 content is maintained |
| 2108 | Intermediate_crop_oil | Primary production of | Oil crops from good & medium agricultural land | Camelina | Annex IX-B_new_Intermediate crops, such as catch |

| DI codes | Short name | Category | subcategory 1 | Additional category info | Link to RED |
|---|---|---|---|---|---|
| | | intermediate, cover crops | | | crops and cover crops 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 content is maintained |
| 2109 | Cover_crop_ligno | Primary production of intermediate, cover crops | Cover crop | Unknown crop but assumed 4 ton dm/ha/yr | Annex IX-B_new_Intermediate crops, such as catch crops and cover crops 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 content is maintained |
| 2201 | Prim_res_cereal_straw | Agricultural residues | Cereals straw | Straw/stubbles | REDII- Annex IX-A |
| 2202 | Prim_res_other_straw | Agricultural residues | Straw from oil seed rape, sunflower, grain maize (stover), rice | Straw/stubbles | REDII- Annex IX-A |
| 2203 | Prim_res_sugar_leaves | Agricultural residues | Sugarbeet leaves | Straw/stubbles | REDII- Annex IX-A |
| 2204 | Prim_res_perm_crops | Agricultural residues | Residues from vineyards, fruit trees, olive trees, citrus, nuts | Woody prunning & orchards residues | REDII- Annex IX-A |
| 2205 | Prim_res_damaged_crops | Agricultural residues | Damaged crops that are not fit for use in the food or feed chain | Residue at harvest of crop | REDII- Annex IX-B_new - 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 |
| 2301 | Animal_solid_manure | Agricultural residues | Animal solid manure | Solid manure from bovine, pig, sheep & goat, poultry | REDII- Annex IX-A |
| 2302 | Animal_liquid_manure | Agricultural residues | Animal liquid manure | Liquid | REDII- Annex IX-A |
| 4111 | Sec_res_sawdust | Secondary residues from wood industries | Sawdust | Saw mill residues | REDII- Annex IX-A |
| 4112 | Sec_res_other_sawmill | Secondary residues from wood industries | Other sawmill residues (excl sawdust) | Other residues (conifers & non-conifers) | REDII- Annex IX-A |

| DI codes | Short name | Category | subcategory 1 | Additional category info | Link to RED |
|---|---|---|---|---|---|
| 4121 | Sec_res_semi_wood bp | Secondary residues from wood industries | Residues from industries producing semi finished wood based panels | Residues from industries producing semi finished wood based panels | REDII- Annex IX-A |
| 4122 | Sec_res_other_wood | Secondary residues from wood industries | Residues from further woodprocessing | Residues from further woodprocessing | REDII- Annex IX-A |
| 4131 | Sec_res_bark | Secondary residues from wood industries | Bark | Secondary residues from pulp and paper industry | REDII- Annex IX-A |
| 4132 | Sec_res_black_liquor | Secondary residues from wood industries | Black liquor | Secondary residues from pulp and paper industry | REDII- Annex IX-A |
| 413201* | | Secondary residues from wood industries | Tall oil pitch obtained from Black liquor | Secondary residues from pulp and paper industry | REDII- Annex IX-A_new |
| 413202* | | Secondary residues from wood industries | Raw methanol from kraft pulping stemming from the production of wood pulp | Secondary residues from pulp and paper industry | REDII- Annex IX-A_new |
| 4201 | Sec_res_rice_husk | Secondary residues of industry utilising agricultural products | Rice husk | By-products and residues from food & feed processing industry | REDII- Annex IX-A |
| 4202 | Sec_res_grapes | Secondary residues of industry utilising agricultural products | Grape pomace: Pressed grape dregs, stalks and seeds | By-products and residues from food & feed processing industry | REDII- Annex IX-A |
| 4203 | Sec_res_cereal_bran | Secondary residues of industry utilising agricultural products | Cereal bran | By-products and residues from food & feed processing industry | REDII- Annex IX-A |
| 4204 | Sec_res_maize_cobs | Secondary residues of industry utilising agricultural products | Cobs cleaned from grain maize | By-products and residues from food & feed processing industry | REDII- Annex IX-A |
| 4205 | Sec_res_olive_stone s | Secondary residues of industry utilising agricultural products | olive stones | By-products and residues from food & feed processing industry | REDII- Annex IX-A |
| 4206 | Sec_res_sgb_bagas se | Secondary residues of industry utilising agricultural products | Bagasse from sugarbeet | By-products and residues from food & feed processing industry | REDII- Annex IX-A |
| 4207 | Sec_res_olive_pom mace | Secondary residues of industry utilising agricultural products | Deoiled olive pomace | By-products and residues from food & feed processing industry | REDII- Annex IX-B_new |

| DI codes | Short name | Category | subcategory 1 | Additional category info | Link to RED |
|---|---|---|---|---|---|
| 4208 | Sec_res_BSG | Secondary residues of industry utilising agricultural products | Brewers' Spent Grain not fit for use in the food and feed chain | By-products and residues from food & feed processing industry | REDII- Annex IX-B_new |
| 4209 | Sec_res_LWP | Secondary residues of industry utilising agricultural products | Liquid whey permeate | By-products and residues from food & feed processing industry | REDII- Annex IX-B_new |
| 4210 | Sec_res_ADRW | Secondary residues of industry utilising agricultural products | Alcoholic distillery residues and wastes (fusel oils) not fit for use in the food or feed chain | By-products from industry | REDII- Annex IX-A_new |
| 4211 | Sec_res_Bakery | Secondary residues of industry utilising agricultural products | Bakery and confectionary residues and waste not fit for use in the food and feed chain | By-products and residues from food & feed processing industry | REDII- Annex IX-B_new |
| 4212** | Sec_res_drink_prod | Secondary residues of industry utilising agricultural products | Drink production residues and waste not fit for use in the food and feed chain; | By-products and residues from food & feed processing industry | REDII- Annex IX-B_new |
| 4213* | Sec_res_vinasse | Secondary residues of industry utilising agricultural products | Vinasse excluding thin stillage and sugarbeet vinasse | By-products and residues from food & feed processing industry | REDII- Annex IX-B_new |
| 4214 | Sec_res_DUR | Secondary residues of industry utilising agricultural products | Dextrose ultrafiltration retentate | By-products and residues from food & feed processing industry | REDII- Annex IX-B_new |
| 4215* | Sec_res_DDGS | Secondary residues of industry utilising agricultural products | Technical corn oil: the Distillers' Dried Grains and Solubles (DDGS) | By-products and residues from industry | REDII- Annex IX-A |
| 4216 | Sec_res_ani_fats12 | Secondary residues of industry utilising agricultural products | Animal fats: Animal fats classified as categories 1 and 2 in accordance with Regulation (EC) No 1069/2009 | By-products and residues from food & feed processing industry | REDII- Annex IX-B |
| 4217* | Sec_res_Cglycerin | Secondary residues of industry utilising agricultural products | Crude glycerin from biodiesel production | By-products from industry | REDII- Annex IX-A |
| 5101 | Organic_waste_sepa | Biodegradable (industrial & municipal) waste | Organic waste separately collected | Separately collected biowaste: Biodegradable waste of separately collected municipal waste | REDII- Annex IX-A |

| DI codes | Short name | Category | subcategory 1 | Additional category info | Link to RED |
|---|---|---|---|---|---|
| | | | | (excluding textile and paper) | |
| 5102 | Organic_waste_mixed | Biodegradable (industrial & municipal) waste | Organic fraction of municipal waste in mixed waste | Biowaste as part of integrally collected municipal waste: Biodegradable waste of not separately collected municipal waste | REDII- Annex IX-A |
| 5104 | Waste_fruit_vegetable | Biodegradable (industrial & municipal) waste | Fruit and vegetable residues and waste not fit for use in the food and feed chain, excluding tails, leaves, stalks and husks | Food waste | REDII- Annex IX-B_new |
| 5106 | Waste_UCO | Biodegradable (industrial & municipal) waste | Used cooking oil | Food waste | REDII- Annex IX-B |
| 5107 | Waste_brown_grease | Biodegradable (industrial & municipal) waste | Brown grease | By-products from retail, service sectors | REDII- Annex IX-B_new |
| 5108 | Waste_sewagesludge_org | Biodegradable (industrial & municipal) waste | Sewage sludge: Organic fraction in waste waters | Waste water treatment residue | REDII- Annex IX-A |

*These categories are included in the draft Annex to the Commission Delegated Directive amending Annex IX. They are either residues or co-products generated in conversion processes of biomass to transport fuels. They are included for completeness but have not been assessed because they depend on the biomass to biofuel conversion technology mix modelled in Task 1 with the PRIMES model.
** These categories have so far not been assessed, either because they overlap too much with other categories, so as to avoid overlap between categories, or in the case of the algae categories, data is still too limited, and their estimate is challenging. Instead in Annex X a basic review is presented, and a first estimate is made of their potential in 2050. The inclusion of their potential is only addressed in the concluding chapter of this Task 2 report.

Table A2 - 12 The overview of biomass categories (see also excel with cost-supply results)

The biomass types are organised in the following categories:

Primary dedicated biomass: *This is Biomass that has been purposely grown as such or that constitutes the primary result of production.*

This category is then subdivided in the following categories:

- Primary forestry production
- Primary production of lignocellulosic crops
- Primary production of woody crops
- Primary production of oil crops
- Algae

Primary residues: This is biomass that is generated as an element of production and/or management but is not the main product. The primary residues are parts of biomass that can be left on the field or in the forest after harvesting of the main biomass product.

This category is subdivided in:

- Primary residues from forests
- Primary residues from agriculture
- Aquatic residues

Secondary biomass: The secondary residues are all forms of biomass that arise from processing of the biomass in industry. Such residues typically are available in larger quantities at processing facilities, such as the agrofood industry, saw- and paper mills, and the like.

This category is subdivided in:

- Secondary residues
- Secondary residues from wood industries
- Secondary residues from industry utilising agricultural products

Tertiary residues or waste: The tertiary residues or wastes are those sources that have already had a use (post-consumer) and that consist partly or fully of biological material such as organic fraction of municipal solid waste (MSW), waste and demolition wood, sludges, and so on.

This category is subdivided in:

- Biodegradable municipal waste
- Biodegradable industrial waste
- Biodegradable waste
- Sewage sludge
- Post consumer wood

In the following first a summary overview is given of all potential per scenario and year. This is followed by a more detailed explanation of the assessment of biomass potential and cost levels.

## Appendix 2-2 Total biomass potentials per country, per scenarios for 2030 and 2050

| | | 2030 | 2030 | 2030 | 2030 | | 2050 | 2050 | 2050 | 2050 |
|---|---|---|---|---|---|---|---|---|---|---|
| | Short name | High | Low | Medium | Technical | | High | Low | Medium | Technical |
| **1100** | **Stemwood** | 202.6 | 32.7 | 92.1 | 311.7 | | 196.9 | 25.4 | 77.0 | 302.8 |
| **1200** | **Prim_forest_residues** | 37.4 | 37.4 | 37.4 | 98.7 | | 36.8 | 36.8 | 36.8 | 95.8 |
| **1220** | **Prim_forest_stumps** | 5.5 | 0.0 | 5.5 | 77.5 | | 5.9 | 0.0 | 5.9 | 77.3 |
| **5211** | **Post_cons_wood_hazard** | 4.9 | 2.5 | 3.7 | 4.9 | | 5.6 | 2.8 | 4.2 | 5.6 |
| **5212** | **Post_cons_wood_non_hazard** | 15.2 | 6.1 | 11.4 | 27.2 | | 18.8 | 6.2 | 14.1 | 30.8 |
| **2101** | **Ligno_crops_unused_land** | 4.7 | 1.5 | 2.9 | 16.6 | | 21.1 | 6.4 | 12.3 | 49.5 |
| **2102*** | **Oil_crops_unused_land** | 0.2 | 0.1 | 0.1 | 0.7 | | 0.9 | 0.3 | 0.5 | 2.2 |
| **2103** | **Woody_crops_unused_land** | 1.7 | 0.3 | 0.8 | 17.2 | | 12.5 | 3.9 | 7.4 | 29.2 |
| **2104** | **Ligno_crops_degraded_land** | 2.8 | 0.9 | 1.7 | 10.1 | | 26.6 | 4.8 | 11.0 | 133.2 |
| **2105*** | **Oil_crops_degraded_land** | 0.1 | 0.0 | 0.0 | 0.8 | | 1.2 | 0.2 | 0.5 | 5.8 |
| **2106** | **Woody_crops_degraded_land** | 0.9 | 0.2 | 0.4 | 9.4 | | 14.6 | 2.7 | 6.1 | 72.9 |
| **2107** | **Intermediate_crop_Sorg** | 5.8 | 0.5 | 2.2 | 116.4 | | 13.9 | 1.0 | 4.6 | 138.6 |
| **2108*** | **Intermediate_crop_oil** | 1.3 | 0.1 | 0.5 | 26.9 | | 3.2 | 0.2 | 1.1 | 32.2 |
| **2109** | **Cover_crop_ligno** | 2.1 | 0.2 | 0.8 | 42.8 | | 5.1 | 0.4 | 1.8 | 50.9 |
| **2201** | **Prim_res_cereal_straw** | 121.1 | 0.0 | 58.5 | 265.8 | | 121.5 | 0.0 | 58.7 | 266.6 |
| **2202** | **Prim_res_other_straw** | 167.6 | 71.5 | 105.9 | 202.5 | | 157.1 | 57.2 | 89.6 | 201.8 |
| **2203** | **Prim_res_sugar_leaves** | 4.6 | 1.4 | 2.6 | 5.7 | | 4.2 | 0.9 | 2.0 | 6.0 |
| **2204** | **Prim_res_perm_crops** | 10.2 | 4.1 | 7.3 | 16.2 | | 10.3 | 4.1 | 7.3 | 16.3 |
| **2205** | **Prim_res_damaged_crops** | 3.3 | 0.9 | 2.1 | 3.7 | | 3.1 | 0.4 | 1.9 | 3.9 |
| **2301** | **Animal_solid_manure** | 132.9 | 83.1 | 99.7 | 166.2 | | 125.3 | 78.3 | 94.0 | 156.7 |
| **2302** | **Animal_liquid_manure** | 29.6 | 18.5 | 22.2 | 36.9 | | 27.1 | 16.9 | 20.3 | 33.9 |
| **4111** | **Sec_res_sawdust** | 9.2 | 3.1 | 6.1 | 12.2 | | 9.5 | 3.2 | 6.4 | 12.7 |
| **4112** | **Sec_res_other_sawmill** | 1.7 | 0.6 | 1.1 | 2.3 | | 2.0 | 0.7 | 1.4 | 2.7 |
| **4121** | **Sec_res_semi_woodbp** | 3.2 | 1.1 | 2.1 | 4.3 | | 3.8 | 1.3 | 2.5 | 5.1 |
| **4122** | **Sec_res_other_wood** | 13.9 | 4.6 | 9.2 | 18.5 | | 15.8 | 5.3 | 10.5 | 21.1 |
| **4131** | **Sec_res_bark** | 5.5 | 2.7 | 4.1 | 5.5 | | 6.3 | 3.1 | 4.7 | 6.3 |
| **4132** | **Sec_res_black_liquor** | 25.7 | 12.9 | 19.3 | 25.7 | | 25.7 | 12.9 | 19.3 | 25.7 |

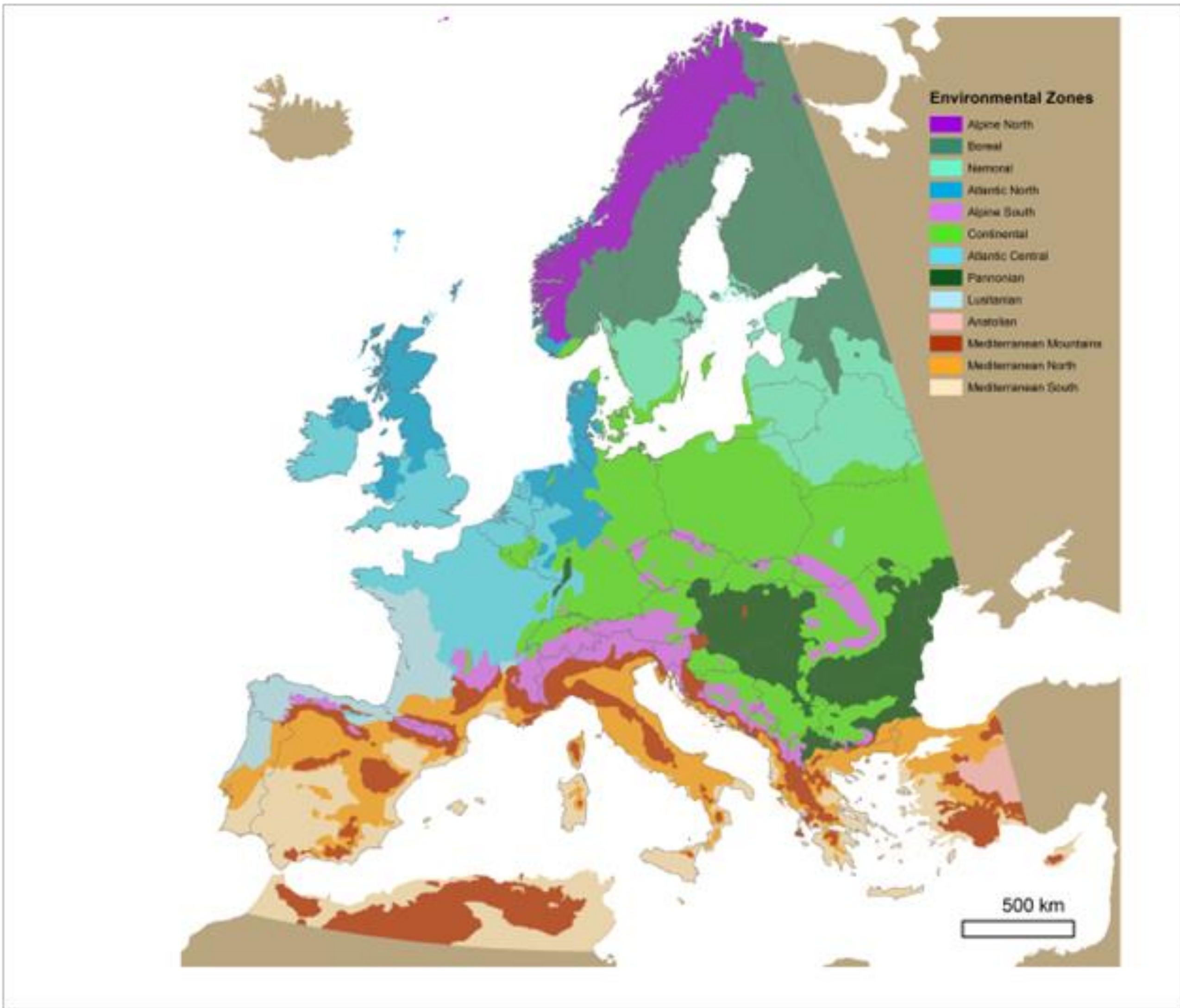
| | | 2030 | 2030 | 2030 | 2030 | | 2050 | 2050 | 2050 | 2050 |
|---|---|---|---|---|---|---|---|---|---|---|
| | Short name | High | Low | Medium | Technical | | High | Low | Medium | Technical |
| **4201** | **Sec_res_rice_husk** | 0.0 | 0.0 | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 |
| **4202** | **Sec_res_grapes** | 0.0 | 0.0 | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 |
| **4203** | **Sec_res_cereal_bran** | 0.0 | 0.0 | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 |
| **4204** | **Sec_res_maize_cobs** | 5.6 | 1.9 | 3.7 | 7.4 | | 0.0 | 0.0 | 0.0 | 0.0 |
| **4205** | **Sec_res_olive_stones** | 0.0 | 0.0 | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 |
| **4206** | **Sec_res_sgb_bagasse** | 0.0 | 0.0 | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 |
| **4207** | **Sec_res_olive_pommace** | 0.0 | 0.0 | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 |
| **4208** | **Sec_res_BSG** | 1.4 | 0.5 | 1.0 | 1.6 | | 1.4 | 0.4 | 0.9 | 1.6 |
| **4209** | **Sec_res_LWP** | 0.2 | 0.1 | 0.2 | 0.3 | | 0.2 | 0.1 | 0.2 | 0.3 |
| **4210** | **Sec_res_ADRW** | 0.0 | 0.0 | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 |
| **4211** | **Sec_res_Bakery** | 1.0 | 0.6 | 0.8 | 0.9 | | 1.0 | 0.5 | 0.8 | 0.9 |
| **4214** | **Sec_res_DUR** | 0.3 | 0.3 | 0.6 | 1.0 | | 2.8 | 0.4 | 1.2 | 2.8 |
| **5101** | **Organic_waste_sepa** | 21.6 | 12.1 | 16.8 | 30.9 | | 18.9 | 9.3 | 14.0 | 31.6 |
| **5102** | **Organic_waste_mixed** | 4.1 | 2.7 | 3.4 | 5.9 | | 3.1 | 1.8 | 2.5 | 5.2 |
| **5104** | **Waste_fruit_vegetable** | 2.0 | 0.6 | 1.3 | 2.1 | | 2.1 | 0.4 | 1.2 | 2.1 |
| **5106*** | **Waste_UCO** | 3.9 | 1.3 | 2.1 | 2.2 | | 8.9 | 2.4 | 4.3 | 2.2 |
| **5107** | **Waste_brown_grease** | 2.5 | 0.0 | 0.9 | 3.1 | | 2.3 | 0.0 | 0.9 | 3.1 |
| **5108** | **Waste_sewagesludge_org** | 12.0 | 8.9 | 10.8 | 12.7 | | 11.3 | 7.5 | 10.1 | 12.6 |
| | **Total** | **868.6** | **315.6** | **541.6** | **1594.5** | | **927.0** | **298.1** | **537.8** | **1847.9** |

*Million tonnes oil

Table A2 - 13 Overview of total biomass potentials (million tonnes dm) per scenario in 2030 and 2050

## Appendix 2-3 Environmental zones

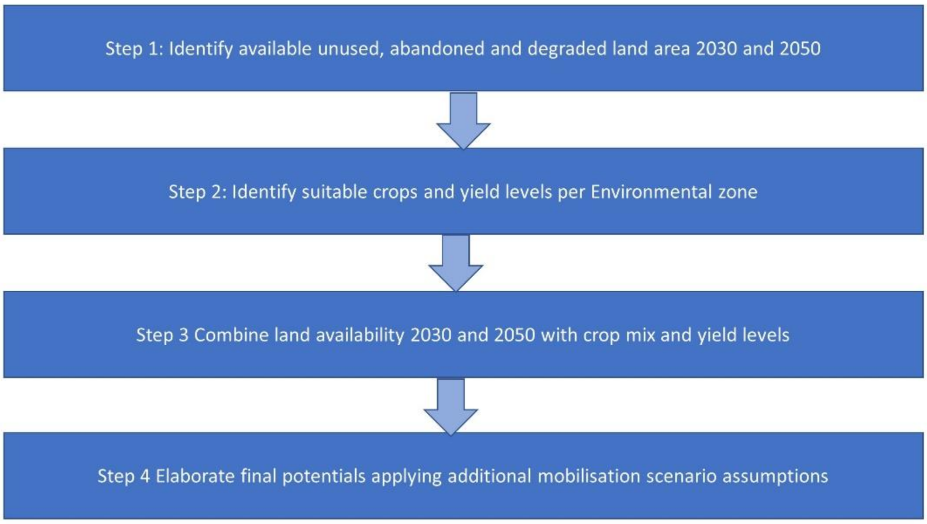
Specific crop mixes and climate change scenarios are assumed per environmental (Climate) zone in Europe. For this the Environmental zonation of Europe is used (se underneath map and sources of information).




Sources: Metzger, Marc J. (2018). The Environmental Stratification of Europe, [dataset]. University of Edinburgh. https://doi.org/10.7488/ds/2356 (map contents)
Metzger M.J., Bunce R.G.H, Jongman R.H.G, Mücher C.A., Watkins J.W. (2005). "A climatic stratification of the environment of Europe". Global Ecology and Biogeography 14: 549-563 - https://doi.org/10.1111/j.1466-822x.2005.00190.x (description of the classification procedure)
https://datashare.ed.ac.uk/handle/10283/3091 (image)

## Appendix 2-4 Detailed description of assessment of biomass potentials from agriculture

**Dedicated crops from unused, abandoned, and degraded lands (2101, 2102, 2103, 2104, 2105, 2106)**




**Step 1: Identify land availability from abandoned and degraded land**

*Abandonment 2030 and 2050:*

For the mapping and quantification of abandoned lands 2 main data inputs were used:

1. CAPRI land use changes between 2020, 2030 and 2050. The comparison in time results in an amount of land that is no longer used for agriculture in 2030 and 2050. This land is assumed to be abandoned. This comparison could be done at regional level

2. CAPRI land use 2030 and 2050 for New Energy Crops (NERC). This is land that in the CAPRI baseline was already allocated to dedicated lignocellulosic and woody crops to be demanded for advance biofuel production.

3. Likelihood map for abandonment based on LUCAS and Maxent and BBN (Bayesian Believe Network) modelling (MAGIC). This GIS assessment classified lands (in the agricultural Corine Land cover class) at km2 level in classes with high and low likelihood (risk) for abandonment. In this map the HNV farmland areas and Natura 2000 areas are excluded!

The information of CAPRI on NERC and abandoned lands is combined into a total area and this is compared with the area in every region scoring in the highest likelihood class for abandonment. The final maximum abandoned area per region is then selected as follows:

$\text{Land}_{\text{abandoned}} = \text{NERC}_{\text{Capri}} + ((\text{Abandoned}_{\text{Capri}} + \text{NERC}) \sim \text{Abanoned}_{\text{Likelihood}})$

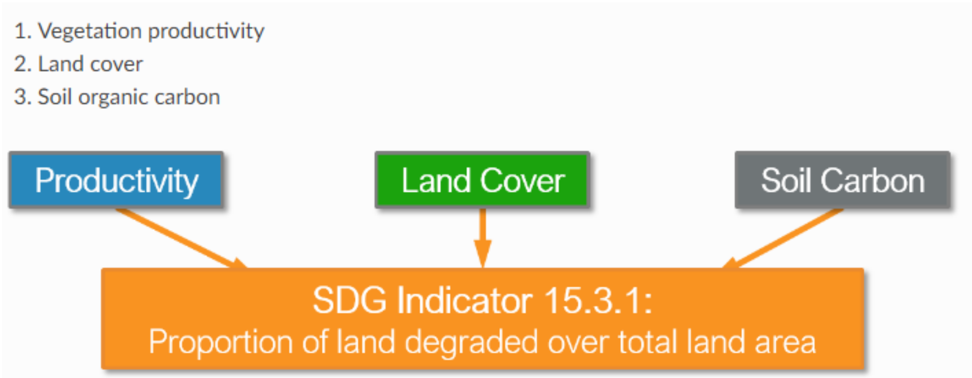
*Where*

$\text{Land}_{\text{abandoned}}$ = Total land abandoned per region in technical potential
$\text{NERC}_{\text{Capri}}$ = Land claimed already in CAPRI baseline for new energy crops (woody and lignocellulosic crops)
$\text{Abandoned}_{\text{Capri}}$ = Difference between agricultural land 2020 and 2030 and 2050
$\text{Abanoned}_{\text{Likelihood}}$ = Area of agricultural land (excluding Natura 2000 & HNV farmland) in the highest risk class for land abandonment

*Identify degraded lands:*

To identify lands that are degraded the approach for assessing the SDG indicator 'proportion of land that is degraded over total land area' (SDG15.3.1) was used. The assessment method was elaborated by JRC and is explained here: https://docs.trends.earth/en/latest/for_users/features/landdegradation.html.

This indicator is composed of 3 sub-indicators:

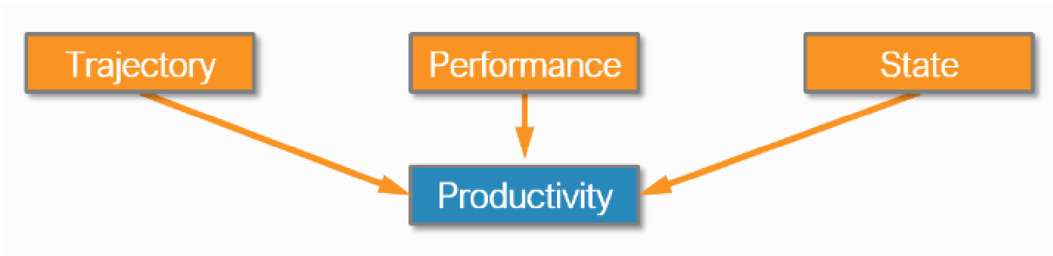



1. Productivity

The vegetation productivity is expressed in a Net Primary Productivity (NPP) and is the net amount of carbon assimilated after photosynthesis and autotrophic respiration over a given period of time (Clark et al. 2001) and is typically represented in units such as kg/ha/yr. In order to assess this JRC used the surrogates of NPP which is the Normalized Difference Vegetation Index (NDVI). From the bi-weekly products from MODIS and AVHRR annual integrals of NDVI are computed (computed as the mean annual NDVI for simplicity of interpretation of results). These annual integrals of NDVI were then used by JRC to compute each of the productivity indicators

For further details on the calculation of these 3 indicators, see https://docs.trends.earth/en/latest/for_users/features/landdegradation.html.

These three productivity indicators were then integrated into one final productivity indicator:




And classified as follows:

**Aggregating Land Productivity metrics**

| Trend | State | Performance | 5 Classes | 3 Classes |
|---|---|---|---|---|
| Improving | Improving | Stable | Improving | Improving |
| Improving | Improving | Degrading | Improving | Improving |
| Improving | Stable | Stable | Improving | Improving |
| Improving | Stable | Degrading | Improving | Improving |
| Improving | Degrading | Stable | Improving | Improving |
| Improving | Degrading | Degrading | Moderate decline | Degrading |
| Stable | Improving | Stable | Stable | Stable |
| Stable | Improving | Degrading | Stable | Stable |
| Stable | Stable | Stable | Stable | Stable |
| Stable | Stable | Degrading | Stressed | Stable |
| Stable | Degrading | Stable | Moderate decline | Degrading |
| Stable | Degrading | Degrading | Degrading | Degrading |
| Degrading | Improving | Stable | Degrading | Degrading |
| Degrading | Improving | Degrading | Degrading | Degrading |
| Degrading | Stable | Stable | Degrading | Degrading |
| Degrading | Stable | Degrading | Degrading | Degrading |
| Degrading | Degrading | Stable | Degrading | Degrading |
| Degrading | Degrading | Degrading | Degrading | Degrading |

2. Land cover flow index

The productivity index is then further combined with the land cover transitions derived between 2020 and 2030 and 2050. These transitions for future land cover changes were elaborated in the Koevoet project (REFERENCE) and covered expectation about future land use changes at km2 level based on future land use change scenarios. These future land use transitions were then combined as follows:

Land cover in target year

| Land cover in initial year | Tree-covered | Grassland | Cropland | Wetland | Artificial | Other land | Water body |
|---|---|---|---|---|---|---|---|
| Tree-covered | 0 | - | - | - | - | - | 0 |
| Grassland | + | 0 | + | - | - | - | 0 |
| Cropland | + | - | 0 | - | - | - | 0 |
| Wetland | - | - | - | 0 | - | - | 0 |
| Artificial | + | + | + | + | 0 | + | 0 |
| Other land | + | + | + | + | - | 0 | 0 |
| Water body | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Legend**

| Degradation | Stable | Improvement |
|---|---|---|
| - | 0 | + |

*The "Grassland" class consists of grassland, shrub, and sparsely vegetated areas (if the default aggregation is used).

After this classification of the land cover flows the table of degradation typologies by land cover transition was computed to provide the land cover sub-indicator of potential land degradation.

3. State of Carbon

Finally, this combined map is further combined with the Soil Organic Carbon map. For this Soilgrids is used. Per land cover class a C conversion factor is used as in the table underneath to calculate per land cover transition the changes in carbon stock. If the reduction of carbon stock is expected to be more than 10% then there is degradation.

| LU coefficients | Forest | Grasslands | Croplands | Wetlands | Artifical areas | Bare lands | Water bodies |
|---|---|---|---|---|---|---|---|
| Forest | 1 | 1 | f | 1 | 0.1 | 0.1 | 1 |
| Grasslands | 1 | 1 | f | 1 | 0.1 | 0.1 | 1 |
| Croplands | 1/f | 1/f | 1 | 1/0.71 | 0.1 | 0.1 | 1 |
| Wetlands | 1 | 1 | 0.71 | 1 | 0.1 | 0.1 | 1 |
| Artifical areas | 2 | 2 | 2 | 2 | 1 | 1 | 1 |
| Bare lands | 2 | 2 | 2 | 2 | 1 | 1 | 1 |
| Water bodies | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

Changes in SOC are better studied for land cover transitions involving agriculture, and for that reason there is a different set of coefficients for each of the main global climatic regions: Temperate Dry (f = 0.80), Temperate Moist (f = 0.69), Tropical Dry (f = 0.58), Tropical Moist (f = 0.48), and Tropical Montane (f = 0.64).

***Total abandoned and degraded land area 2030 and 2050***

Results in land availability show (see Table A2 - 14) a total of 3.3 million hectares in 2030 to 7.6 million hectares in 2050 in the technical scenario.

| In hectares | 2030-Abandoned | 2050-Abandoned | 2030-Degraded | 2050-Degraded |
|---|---|---|---|---|
| **Technical potential** | 3,350,798 | 7,633,725 | 4,996,751 | 31,958,700 |
| **Low scenario** | 816,717 | 3,586,324 | 100,024 | 1,599,210 |
| **Medium scenario** | 823,891 | 3,256,127 | 250,059 | 3,198,420 |
| **High scenario** | 1,159,915 | 4,405,475 | 500,118 | 6,396,840 |

Table A2 - 14 Abandoned and degraded land per scenario 2030 and 2050

**Step 2 Identify suitable crops and yield level per environmental zone**

The selection of crops (based on crop suitability) and crop yields was derived from MAGIC and BIKE project. In the following tables the crop mixes per environmental zones are presented which were combined with the land availability per scenario. The tables show the baseline yields possible in marginal circumstances per environmental zone and also the yield development expectations applying the yield increases and climate change effects on yields according to the scenario assumptions (see Section 3.4).

| | Yield oil (ton/ha/year) | | | Yield ton dm/ha/year | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Oil crop | | | Woody | | Lignocellulosic | | | | | |
| | Cardoon | Camelina | Castor | Willow | Poplar | Biomass sorghum | Miscanthus | Switchgrass | Giant reed | Reed Canary grass | Cardoon |
| **ALS** | | | | | | | | | | | |
| **ATC** | 0.28 | 0.4 | | 6 | 7 | | 8 | 10 | | 7 | 8 |
| **ATN** | | 0.4 | | 6 | | | 8 | 10 | | 7 | |
| **BOR** | | | | | | | | | | 7 | |
| **CON** | | 0.4 | | 6 | 7 | 9 | 9 | 12 | | 7 | |
| **LUS** | 0.28 | 0.4 | | 6 | 7 | 12 | 9 | 12 | 11 | 7 | 10 |
| **MDM** | 0.28 | 0.4 | 0.75 | | 7 | 12 | 9 | 12 | 11 | 7 | 10 |
| **MDN** | 0.28 | 0.4 | 0.75 | | 7 | 12 | 9 | 12 | 11 | 7 | 10 |
| **MDS** | 0.28 | 0.4 | 0.75 | | | 12 | 9 | 12 | 11 | 7 | 10 |
| **NEM** | | 0.4 | | 6 | | | | | | 7 | |
| **PAN** | 0.28 | 0.4 | | 6 | | 9 | 9 | 12 | | 7 | 10 |

Table A2 - 15 Crop mixes and yields used on abandoned and degraded lands per environmental zone (See Appendix 3 for abbreviations and locations of zones)

| | High 2020 yields | | | High 2050 yields | | |
|---|---|---|---|---|---|---|
| | Average yield (seeds/ha/year) | Average yield (ton dm/ha/year) | Average yield (seeds/ha/year) | Average yield (seeds/ha/year) | Average yield (ton dm/ha/year) | Average yield (seeds/ha/year) |
| | Oil crops | Woody crops | Lignocellulosic crops | Oil crops | Woody crops | Lignocellulosic crops |
| **ALS** | - | - | - | - | - | - |
| **ATC** | 0.38 | 7.18 | 9.11 | 0.46 | 8.76 | 11.12 |
| **ATN** | 0.44 | 6.63 | 9.21 | 0.54 | 8.09 | 11.23 |
| **BOR** | 0.00 | 0.00 | 8.89 | 0.00 | 0.00 | 11.79 |
| **CON** | 0.44 | 7.18 | 10.22 | 0.54 | 8.76 | 12.47 |
| **LUS** | 0.38 | 7.18 | 11.23 | 0.46 | 8.76 | 13.70 |
| **MDM** | 0.53 | 7.73 | 11.23 | 0.64 | 9.43 | 13.70 |
| **MDN** | 0.53 | 7.73 | 11.23 | 0.64 | 9.43 | 13.70 |
| **MDS** | 0.53 | 0.00 | 11.23 | 0.64 | 0.00 | 13.70 |
| **NEM** | 0.51 | 7.62 | 8.89 | 0.67 | 10.11 | 11.79 |
| **PAN** | 0.38 | 6.63 | 10.38 | 0.46 | 8.09 | 12.67 |

Table A2 - 16 Crop mixes and yields used on abandoned and degraded lands base line yields for technical scenario and high mobilisation scenario

| | Low 2030 | | | Low 2030 | | |
|---|---|---|---|---|---|---|
| | Average yield (seeds/ha/year) | Average yield (ton dm/ha/year) | Average yield (seeds/ha/year) | Average yield (seeds/ha/year) | Average yield (ton dm/ha/year) | Average yield (seeds/ha/year) |
| | Oil crops | Woody crops | Lignocellulosic crops | Oil crops | Woody crops | Lignocellulosic crops |
| **ALS** | | | | | | |
| **ATC** | 0.35 | 6.63 | 8.42 | 0.36 | 6.90 | 8.76 |
| **ATN** | 0.41 | 6.12 | 8.50 | 0.42 | 6.37 | 8.85 |
| **BOR** | 0.00 | 0.00 | 7.50 | 0.00 | 0.00 | 8.18 |
| **CON** | 0.41 | 6.63 | 9.44 | 0.42 | 6.90 | 9.82 |
| **LUS** | 0.35 | 6.63 | 10.37 | 0.36 | 6.90 | 10.79 |
| **MDM** | 0.44 | 6.43 | 9.33 | 0.40 | 5.95 | 8.64 |
| **MDN** | 0.44 | 6.43 | 9.33 | 0.40 | 5.95 | 8.64 |
| **MDS** | 0.44 | 0.00 | 9.33 | 0.40 | 0.00 | 8.64 |
| **NEM** | 0.41 | 6.43 | 7.50 | 0.47 | 7.01 | 8.18 |
| **PAN** | 0.36 | 6.12 | 9.59 | 0.36 | 6.69 | 9.98 |

Table A2 - 17 Crop mixes and yields used on abandoned and degraded lands yields for Low mobilisation scenario

| | Medium 2020 yields | | | Medium 2050 yields | | |
|---|---|---|---|---|---|---|
| | Average yield (seeds/ha/year) | Average yield (ton dm/ha/year) | Average yield (seeds/ha/year) | Average yield (seeds/ha/year) | Average yield (ton dm/ha/year) | Average yield (seeds/ha/year) |
| | Oil crops | Woody crops | Lignocellulosic crops | Oil crops | Woody crops | Lignocellulosic crops |
| **ALS** | | | | | | |
| **ATC** | 0.36 | 6.83 | 8.67 | 0.39 | 7.55 | 9.58 |
| **ATN** | 0.42 | 6.31 | 8.76 | 0.46 | 6.97 | 9.68 |
| **BOR** | 0.00 | 0.00 | 8.09 | 0.00 | 0.00 | 9.35 |
| **CON** | 0.42 | 6.83 | 9.72 | 0.46 | 7.55 | 10.74 |
| **LUS** | 0.36 | 6.83 | 10.69 | 0.39 | 7.55 | 11.81 |
| **MDM** | 0.48 | 6.62 | 10.15 | 0.50 | 7.32 | 10.63 |
| **MDN** | 0.48 | 6.62 | 10.15 | 0.50 | 7.32 | 10.63 |
| **MDS** | 0.48 | 0.00 | 10.15 | 0.50 | 0.00 | 10.63 |
| **NEM** | 0.46 | 6.94 | 8.09 | 0.53 | 8.01 | 9.35 |
| **PAN** | 0.36 | 6.31 | 9.88 | 0.39 | 6.97 | 10.92 |

Table A2 - 18 Crop mixes and yields used on abandoned and degraded lands yields for Medium mobilisation scenario

**Step 3 Combine land availability 2030 and 2050 with crop mix and yield levels**

In this step the land availability per scenario is multiplied by the crop yield. The crop mix assumed on the available abandoned and degraded land is assumed to be distributed evenly over oil crops, woody crops, and lignocellulosic crops. So, every crop group gets in third of the available land per scenario.

**Step 4 Elaborate final potentials applying additional mobilisation scenario assumptions**

The scenario assumptions for the allocation of crops to land and the development in the future are presented in the Table underneath.

| Issue | Technical potential | Low mobilisation | Medium mobilisation | High mobilisation |
|---|---|---|---|---|
| Land availability:<br>-Abandoned land<br>-Degraded land | 100% abandoned used<br>100% degraded used | Only NECR* from CAPRI baseline in 2030 & 2050 | NECR* from CAPRI baseline + 10 % of abandoned and 5% of degraded land in 2030. In 2050 this is 15% of abandoned and 10% of degraded land | NECR* from CAPRI baseline + 20 % of abandoned and 10% of degraded land in 2030. In 2050 this is 30% of abandoned and 20% of degraded land |
| Yield increases | 1% per year | 0.2% per year | 0.5% per year | 1% per year |
| Climate change effect on yields | No effect on yields | In Mediterranean zone: up to 2030 10% total yield decrease and up to 2050 20% yield **de**crease<br>In Boreal & Nemoral zone: 2030: 5%/2050: 10% yield **in**crease in all crops | In Mediterranean zone: up to 2030 5% total yield decrease and up to 2050 10% yield **de**crease<br>In Boreal & Nemoral zone: 2030: 5%/2050: 15% yield **in**crease in all crops | In Mediterranean zone: NO yield decrease expected<br>In Boreal & Nemoral zone:<br>2030: 15%/2050: 25% yield **in**crease in all crops |

Table A2 - 19 Crop mixes and yields used on abandoned and degraded lands yields for Medium mobilisation scenario

**Biomass from intermediate and cover crops on conventional lands**

In existing agricultural lands several practices already exist that are relatively common in cropping land which involve the use of cover, catch and or green manure crops, but mostly do not involve the harvesting of these crops. The definition by Eurostat of arable land covered with **cover crop or intermediate crop**[18] is *an area of arable land on which plants are sown specifically to reduce the loss of soil, nutrients, and plant protection products during the winter or other periods when the land would otherwise be bare and susceptible to losses. The economic interest of these crops is low, and the main goal is soil and nutrient protection. Normally they are ploughed in during spring before sowing another crop and are not harvested or used for grazing. Agricultural land with no plant cover or where there are just plant residues on the top is especially vulnerable to soil erosion and nutrient and pesticide loss. In efforts to reduce losses which are harmful both to the environment and to the economy one of the most efficient tools is keeping the land covered with plants at all times. These crops should not be mistaken for normal winter crops or grassland.*

An overview of the practices using cover, catch or green manure crops was made in a study by Smit (2019) for a couple of regions spread over the EU. In principle, as specified by Smit (2019) **cover crops** are crops grown for the protection of the surface which would otherwise be bare against erosion and nutrient losses. **Catch crops** are meant to 'catch' and immobilise available nitrogen remaining in the soil after the harvest of the main crop. Generally, they can be under sown just before harvest of the preceding main crop. Finally, there are **green manure crops** which is any crop ploughed under to maintain soil organic matter and fertility.

One of the strategies for obtaining additional biomass for e.g., drop-in fuels without causing additional land demand is also through the introduction of new crops to existing cropping systems. These crops adding additional biomass production (per hectare) to existing cropping systems can provide extra lignocellulosic material or oil, starch, or sugar to be harvested beside the conventional and main (food)crop. Any cellulosic material produced from cover and intermediate crops is already covered in Annex IX under the definition of "other cellulosic material". So, if the cover or intermediate crops refer to oil and starch crops the 'additionality' principle does not necessarily apply. In the draft Annex to the Commission Delegated Directive amending Annex IX it is proposed to add **intermediate crops** to Annex IXB (so a feedstock to be capped) and these are defined as:

"*Intermediate crops, such as catch crops and cover crops 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 content is maintained*".

In addition, in the REDII (2018) another definition is used for **cover crop**: " temporary, short-term sown pastures comprising grass-legume mixture with a low starch content to obtain fodder for livestock and improve soil fertility for obtaining higher yields of arable main crops."

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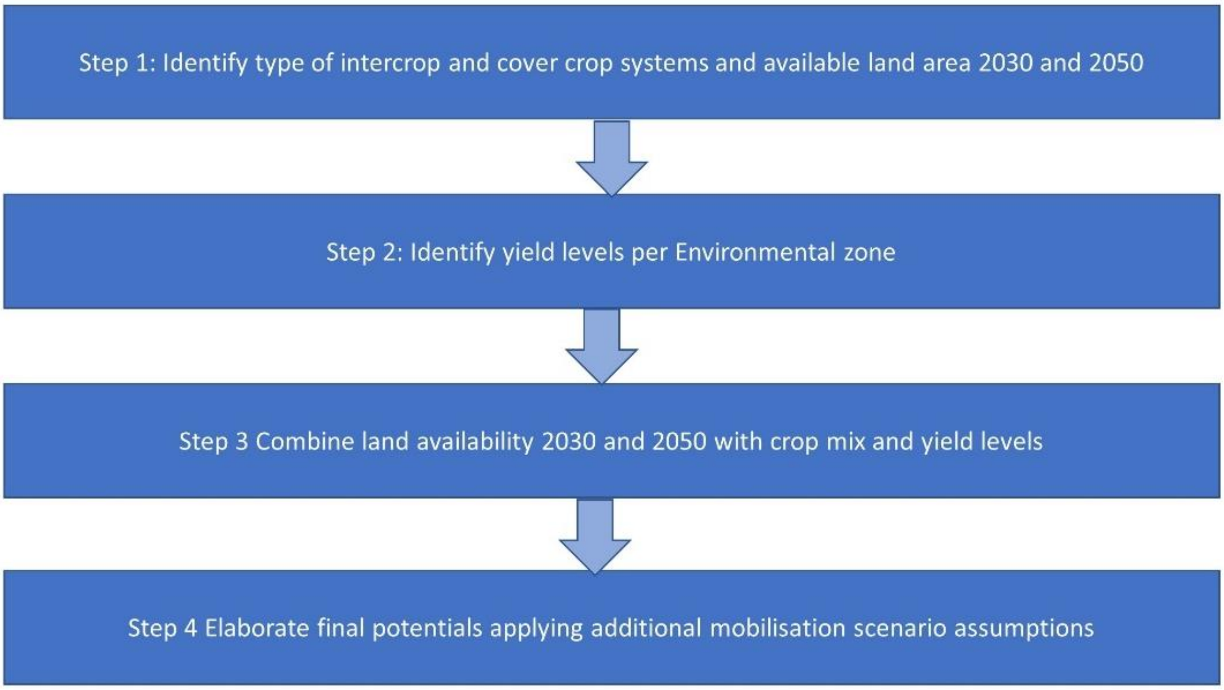
[18] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Soil_cover

For the assessment of biomass potentials for drop-in fuels the focus should be on cropping systems that both provide the advantages of cover or intermediate crops and provide additional biomass that can be harvested/ removed from the field.

For the full assessment the stepwise approach was followed:




**Step 1 Identify type of intercrop and cover crop systems and available land area 2030 and 2050**

Three cropping systems were selected based on the experiences with intercropping in MAGIC and BIKE.

1. Intercropping with biomass sorghum in Mediterranean, Lusitanian, Continental, and Pannonian climate zones where growing season is long enough to combine winter crops (wheat, barley, oil seed rape) for food with a short season biomass crop. Experience in trials was obtained with this in MAGIC (Mediterranean, different locations) and in Germany (Martin & Barthelmes, 2016).

2. Intercropping with Camelina oil crop in Mediterranean, Lusitanian, Continental, and Pannonian climate zones where growing season is long enough to combine winter crops (wheat, barley, oil seed rape) for food with a short season oil crop. Experience in trials was obtained with this in BIKE and MAGIC (Mediterranean, different locations) (Elbersen et al., 2022 and Alexopoulou, 2018).

3. For the Atlantic, Continental, Lusitanian, and Pannonian zone the growing season it too short for an intercrop. Instead, a novel cropping systems is expected to be developed in which a cover crop (after winter) is harvested delivering biomass, 4-ton dm per year, while also providing the function of soil coverage during winter to avoid erosion and leaching of remaining excess nitrogen to water.

The land availability for these 3 systems is assessed as follows:

1. For intercropping with biomass sorghum data were collected from Ballot et al. (2022) who estimated the different crop rotations practices in all EU regions based on LUCAS points on land management. From this per region an arable land area share could be derived of rotations only using winter crops and leaving lands fallow over spring and summer period.

2. For intercropping with the oil crop Camelina the same land as for biomass sorghum from (Ballot et al. (2022) was used allocating half of the land to sorghum and half to Camelina.

3. For the harvested cover crop the practice was in principle to be practices in all arable land where rotational cropping is practiced. For the technical potential this would cover all the arable land, but for the mobilisation scenarios only a share of this land would be covered by this practice. See Step 4.

In Table A2 - 20 an overview is given of the land availability per scenario.

| Hectares mln | 2030-Land intercropping | 2050-Land intercropping | Cover crop 2030 | Cover crop 2050 |
|---|---|---|---|---|
| **Technical potential** | 28.00 | 26.00 | 0.28 | 0.27 |
| **Low senario** | 0.08 | 0.16 | 0.001 | 0.003 |
| **Medium scenario** | 0.34 | 0.64 | 0.01 | 0.01 |
| **High scenario** | 0.84 | 1.59 | 0.01 | 0.00 |

Table A2 - 20 Land availability (EU-27) for intercrops and cover crops in the scenarios

### Step 2 Identify suitable crops and yield levels for intercrops and cover crops

| | High 2030 yields | | | High 2050 yields | | |
|---|---|---|---|---|---|---|
| | Average yield (seeds/ha/year) | Average yield (ton dm/ha/yr) | Average yield (ton dm/ha/yr) | Average yield (seeds/ha/yr) | Average yield (ton dm/ha/yr) | Average yield (ton dm/ha/yr) |
| | Oil crop Camelina (ton oil seeds) | Lignocellulose (biomass sorghum) (ton dm) | Any cover crop (ton dm) | Oil crop Camelina (ton oil seeds) | Lignocellulose (biomass sorghum) (ton dm) | Any cover crop (ton dm) |
| **ALS** | 0 | 0 | 0 | 0 | 0 | 0 |
| **ATC** | 0.00 | 0.00 | 4.42 | 0.00 | 0.00 | 5.39 |
| **ATN** | 0.00 | 0.00 | 4.42 | 0.00 | 0.00 | 5.39 |
| **BOR** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **CON** | 2.21 | 9.94 | 4.42 | 2.70 | 12.13 | 5.39 |
| **LUS** | 2.76 | 9.94 | 4.42 | 3.37 | 12.13 | 5.39 |
| **MDM** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **MDN** | 3.31 | 13.26 | 0.00 | 4.04 | 16.17 | 0.00 |
| **MDS** | 3.31 | 13.26 | 0.00 | 4.04 | 16.17 | 0.00 |
| **NEM** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **PAN** | 2.21 | 9.94 | 4.42 | 2.70 | 12.13 | 5.39 |

Table A2 - 21 Crop mixes and yields used on arable land for technical scenario and high mobilisation scenario

| | Low 2030 | | | Low 2030 | | |
|---|---|---|---|---|---|---|
| | Average yield (seeds/ha/year) | Average yield (ton dm/ha/yr) | Average yield (ton dm/ha/yr) | Average yield (seeds/ha/yr) | Average yield (ton dm/ha/yr) | Average yield (ton dm/ha/yr) |
| | Oil crop Camelina (ton oil seeds) | Lignocellulose (biomass sorghum) (ton dm) | Any cover crop (ton dm) | Oil crop Camelina (ton oil seeds) | Lignocellulose (biomass sorghum) (ton dm) | Any cover crop (ton dm) |
| **ALS** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **ATC** | 0.00 | 0.00 | 4.08 | 0.00 | 0.00 | 4.25 |
| **ATN** | 0.00 | 0.00 | 4.08 | 0.00 | 0.00 | 4.25 |
| **BOR** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **CON** | 2.04 | 9.18 | 4.08 | 2.12 | 9.56 | 4.25 |
| **LUS** | 2.55 | 9.18 | 4.08 | 2.65 | 9.56 | 4.25 |
| **MDM** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **MDN** | 2.75 | 11.02 | 0.00 | 2.55 | 10.19 | 0.00 |
| **MDS** | 2.75 | 11.02 | 0.00 | 2.55 | 10.19 | 0.00 |
| **NEM** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **PAN** | 2.04 | 9.18 | 4.08 | 2.12 | 9.56 | 4.25 |

Table A2 - 22 Crop mixes and yields used on arable lands yields for Low mobilisation scenario

| | Medium 2020 yields | | | Medium 2050 yields | | |
|---|---|---|---|---|---|---|
| | Oil crop Camelina (ton oil seeds) | Lignocellulose (biomass sorghum) (ton dm) | Harvested (ton dm) | Oil crop Camelina (ton oil seeds) | Lignocellulose (biomass sorghum) (ton dm) | Harvested (ton dm) |
| | Oil crops | Woody crops | Lignocellulo sic crops | Oil crops | Woody crops | Lignocellulosic crops |
| **ALS** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **ATC** | 0.00 | 0.00 | 4.20 | 0.00 | 0.00 | 4.65 |
| **ATN** | 0.00 | 0.00 | 4.20 | 0.00 | 0.00 | 4.65 |
| **BOR** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **CON** | 2.10 | 9.46 | 4.20 | 2.32 | 10.45 | 4.65 |
| **LUS** | 2.63 | 9.46 | 4.20 | 2.90 | 10.45 | 4.65 |
| **MDM** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **MDN** | 3.00 | 11.98 | 0.00 | 3.14 | 12.54 | 0.00 |
| **MDS** | 3.00 | 11.98 | 0.00 | 3.14 | 12.54 | 0.00 |
| **NEM** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **PAN** | 2.10 | 9.46 | 4.20 | 2.32 | 10.45 | 4.65 |

Table A2 - 23 Crop mixes and yields used on arable lands yields for Medium mobilisation scenario

**Step 3 Combine land availability 2030 and 2050 with crop mix and yield levels**

In this step the land availability per scenario is multiplied by the crop yield. The crop mix assumed on the available arable land

**Step 4 Elaborate final potentials applying additional mobilisation scenario assumptions**

The scenario assumptions for the allocation of crops to land and the development in the future are presented in the Table underneath.

| Description of biomass category | Issue | Technical potential | Low mobilisation | Medium mobilisation | High mobilisation |
|---|---|---|---|---|---|
| Intermediate crops LUCAS (Ballot et al., 2022) | How much | (50% Oil crop (camelina) and 50% biomass sorghum) | 50% Oil crop (camelina) and 50% biomass sorghum | 50% Oil crop (camelina) and 50% biomass sorghum | 50% Oil crop (camelina) and 50% biomass sorghum |
| | ENZ | Intercrops in MDN, MDS, CON, PAN, LUS** | Where: in MDN, MDS, CON, PAN, LUS** | Where: in MDN, MDS, CON, PAN, LUS** | Where: in MDN, MDS, CON, PAN, LUS** |
| | Available land? | 100% of available arable land with only wintercrops | In 2030 0.5% and 1% in 2050 of available arable land with only wintercrops | In 2030 2% and 4% in 2050 of available arable land with only wintercrops | In 2030 5% and 10% in 2050 of available arable land with only wintercrops |
| | Yield increase assumed | 1% per year | 0.2% per year | 0.5% per year | 1% per year |
| | Climate change effect on yields (based on EEA, 2019) | No effect on yields | In Mediterranean zone: up to 2030 10% total yield decrease and up to 2050 20% yield **de**crease<br>In Boreal & Nemoral zone:<br>2030: 5%/2050: 10% yield **in**crease in all crops | In Mediterranean zone: up to 2030 5% total yield decrease and up to 2050 10% yield **de**crease<br>In Boreal & Nemoral zone:<br>2030: 5%/2050: 15% yield **in**crease in all crops | In Mediterranean zone: NO yield decrease expected<br>In Boreal & Nemoral zone:<br>2030: 15%/2050: 25% yield **in**crease in all crops |
| Cover crops | ENZ | ATN, ATC, CON, LUS, PAN | ATN, ATC, CON, LUS, PAN | ATN, ATC, CON, LUS, PAN | ATN, ATC, CON, LUS, PAN |
| | Available land? | All arable land with rotational crops | 0.5% in 2030 and 1% in 2050 of available arable land | 2% in 2030 and 4% in 2050 of available arable land | 5% in 2030 and 10% in 2050 of available arable land |

| Description of biomass category | Issue | Technical potential | Low mobilisation | Medium mobilisation | High mobilisation |
|---|---|---|---|---|---|
| | Yield increase assumed | 1% per year | 0.2% per year | 0.5% per year | 1% per year |
| | Climate change effect on yields (based on EEA, 2019) | See above | See above | See above | See above |

Table A2 - 24 Scenario assumptions for intermediate and cover crops

**Biomass from crop residues from arable and permanent crops (2201, 2202, 2203, 2204, 2205)**

The overall calculation of the technical potential of pruning residues follows the same formula as for residues from rotational arable crops:

RESIDUE_YIELDi = AREAi * RES_YIELDi * DM_CONTENTi.

| | Predicted | Transformation | Transformation parameters | | | | Linear regression parameters | | |
|---|---|---|---|---|---|---|---|---|---|
| Crop | variable | of | γ | δ | xi | λ | a | b | CI |
| Wheat | HI | LT (Equation 6) | -0.2551 | 1.0835 | 0.2034 | 0.4006 | 0.3093 | -1.2958 | 1.5067 |
| Barley | HI | LT (Equation 6) | -0.0705 | 0.5421 | 0.2817 | 0.3063 | 0.3319 | -0.8631 | 1.1952 |
| Rice | HI | LT (Equation 6) | -1.6054 | 2.3282 | 0.0687 | 0.5663 | 0.2823 | -1.431 | 1.4469 |
| Sunflower | HI | HS (Equation 7) | -0.3057 | 3.8491 | 0.3111 | 0.1717 | 0.1715 | -0.4522 | 1.9114 |
| Rapeseed | HI | HS (Equation 7) | 0 | 3.2858 | 0.2637 | 0.1575 | 0.188 | -0.7453 | 1.8212 |
| Maize | HI | LT (Equation 6) | -1.6992 | 1.2752 | -0.2218 | 0.8428 | 0.2509 | -1.9424 | 1.105 |
| Sorghum | HI | LT (Equation 6) | -0.553 | 1.3866 | -0.1036 | 0.7427 | 0.3446 | -1.0251 | 1.2173 |
| Soybean | HI | LT (Equation 6) | -0.0819 | 1.0113 | 0.191 | 0.2299 | 0.7659 | -2.2731 | 1.3811 |
| Sugar beet | R | HS (Equation 7) | 0.5345 | 2.8868 | 6.0578 | 2.8308 | -0.1067 | 1.8538 | 1.7528 |
| Potato | R | LT (Equation 6) | 2.6877 | 1.2031 | 0.6951 | 16.7831 | 0.0617 | -0.5178 | 1.7609 |

*Source : Garcia Condado et al. (2019)*

Table A2 - 25 Parameter values of empirical regression model equations for estimation of harvest index of crops with relatively stable HI which is weakly correlated with the economic yield (Y)

The approach to predict crop residue potentials by Garcia Condado et al. (2019) is scientifically robust and covers the 10 main crops grown in the EU. It can only be used to assess the residual aboveground biomass for a selection of arable crops grown in the EU.

**Liquid and solid manure (2301, 2302)**

For the calculation of the manure potential, the Miterra model was used, which uses the CAPRI livestock and land use patterns (for current and future situation) and the GAINS/RAINS nitrogen excretion factors as input. The model calculates exactly per region and farm size group how much solid and wet manure is produced in stables, as only that part of the manure can be collected. The manure availability is calculated for both liquid and solid manure.

**Food processing residues (4201, 4202, 4203, 4204, 4205, 4207, 4208, 4209, 4210, 4211, 4214, 4216)**

See calculation factors used in table underneath.

| Additional category info | Area/production source | Residue factor | Factor |
|---|---|---|---|
| Rice husk | Production of rice (area*yield) | Rice husk is approximately 20% of the processed rice, with average moisture content of 10% ((Nikolaou, 2002)). It is assumed that all rice produced in the S2BIOM countrie is locally processed (S2BIOM) | 0.2*0.9 |
| Grape pomace: Pressed grape dregs, stalks and seeds | Production of grapes (area*yield) | Grape pomace represents approximately 20% of the weight of grapes processed (Arvanitoyannis & Varzakas, 2008). The moisture content of grape pomace is between 50%-72% (Cvejic Hohervorst et al (2017). | 0.2*0.39 |
| Cereal bran | The basis is: total amount of cereals processed in every country. So net domestic cereal production and imports = Domestic productionc ereals – export cereals + import cereals<br>The data on total domestic production, exports and imports levels were available from CAPRI for 2030 and 2050 for all EU and several European non-EU countries. | In wheat processing 20% to 25% wheat offals (Kent et al., 1994). Wheat bran represents roughly 50% of wheat offals and about 10 to 19% of the kernel, depending on the variety and milling process (WMC, 2008; Prikhodko et al., 2009; Hassan et al., 2008). . So the residue to yield factor used is 10% of cereals processed domestically. | *0.1*0.9 |
| Cobs cleaned from grain maize | Either the grain maize production level, or total hectares with MAIZ. | The relative potential yield of maize cobs was established as 18.7%<br>of the grain mass, while the wet cob yield recorded in the field after<br>mechanical harvesting was 1.6 t ha–1. The total solid content was 60%. (Bandini et al, 2016*) | Ha grain maize*1.6*0.6 |
| olive stones | Production of olives (for oil and 30% of table olives) 2030 & 2050 | Olive pitts make up between 10%-12.5% of the weight of olive according to Garcia et al. 2012 and Pattarra et al., 2010) (S2BIOM). 15% moisture in olive stone was assumed | *0.1125*0.85 |
| Bagasse from sugarbeet (not sugar cane, as this practically does not grow in Europe) also called sugarbeet pulp | Production of sugarbeet (area*yield) | Approximately 10 dry tons of a fibrous residue (called bagasse) are produced for every ton of cane sugar while about 0.5 dry tons of residue are produced for every ton of beet sugar (Dale, B (2003)**.<br>Generally, standard sugar beets contain 16-20% sugar by weight. So 1 ton sugarbeet delivers 0.18 ton of sugar (Duraisam et al, 2017). | *0.18*0.5 (dry ton bagasse) |
| Deoiled olive pomace | Production of olives (area*yield) | 7.38 kg of olives for 1 liter olive oil. This leads to 2.56 kg deoiled olive pommace. 50% moisture content (Tawara, 2019) | *(2.56/7.38)*0.5 |
| Animal fats | CAPRI data on pigs, cattle, sheep and poultry meat production (in thousand tonnes slaughtered) | Animal fats category 1 and 2 residue availability = (slaughtered meat )/(animal heads )×fatty tissue x animal fat | |

Table A2 - 26 Scenario assumptions for agrofood residues

Animal fats in categories 1 and 2 are animal fats that present risks for human and animal health and therefore have little application possibilities. However, they could be used for biofuels.

It is quantified by taking input data as follows:

- CAPRI data on pigs, cattle, sheep, and poultry meat production (in thousand tonnes slaughtered) from 2015 on country level.

- Fatty tissues percentage per animal obtained for cattle, sheep, and pigs from Auvermann et al. (2004) and poultry from Murawska (2017).

For pigs, cattle, sheep, and poultry the animal fat cat. 1 and 2 is calculated separately and thereafter summed up to obtain the total animal fats cat. 1 and 2 per country. The distribution towards NUTS-2 regions is based on population size from CAPRI 2030 and 2050.

**Animal fats category 1 and 2 residue availability =** $\frac{\textit{slaughtered meat}}{\textit{animal heads}} \times \textit{fatty tissue x animal fat}$

*Where:*

- Animal fats category 1 and 2 residue availability = total animal fat category 1 and 2 residues available on country level produced as by-product from animal slaughtering for use in biofuels and competing uses.

- **Slaughtered meat** = meat production from pigs, cattle, sheep and poultry on country level in tonnes.

- **Animal heads** = number of animals slaughtered (thousand heads) on country level.

- **Fatty tissue** = percentage of fatty tissue in pigs (30%), cattle (11%), sheep (22%) and poultry (13%).

- **Animal fat** = of the animal fat produced in one animal 17% is category 1 and 2 animal fat (EFPRA, 2020).

**II. Detailed description of assessment of secondary biomass potentials from industrial processing**

- See SWOT factsheets in Appendix 2-7.

## Appendix 2-5 Cost assessments

| DI codes | Short name | Assessment of base line 2020 roadside cost | Sources used |
|---|---|---|---|
| 1100 | Stemwood | Based on S2BIOM cost calculations for 2015 (See Appendix 2, cost calculations). Here these S2BIOM cost levels were projected to 2020 by correcting for known, national specific inflation development (Based on Eurostat). | S2BIOM: Dees et al., 2017 |
| 1200 | Prim_forest_residues | | |
| 1220 | Prim_forest_stumps | | |
| 5211 | Post_cons_wood_hazard | Amounts to 20% of the average (national) stemwood road side cost level | S2BIOM: Dees et al., 2017 |
| 5212 | Post_cons_wood_non_hazard | Amounts to 40% of the average (national) stemwood road side cost level | S2BIOM: Dees et al., 2017 |
| 2101; 2104 | Ligno_crops_unused_land; Ligno_crops_degraded_land | Based on S2BIOM cost calculations for 2015 (See Appendix 2, cost calculations) taking the average road side cost of a mix of crops suitable per region (Biomass sorghum, miscanthus, switchgrass, giant reed, RCG, cardoon) . The S2BIOM cost levels were projected to 2020 levels by correcting for known, national specific inflation development (Based on Eurostat). | S2BIOM: Dees et al., 2017 |
| 2102; 2105 | Oil_crops_unused_land; Oil_crops_degraded_land | Data derived from BIKE project cost calculations. Deliverable 2.2 Figure 4.5). This EU average cost level was further translated to national cost levels expressing the avarage labour and diesel price costs levels in every country to an index (EU average=100) | Panoutsou et al., (2022) and Elbersen et al., (2022) |
| 2103; 2106 | Woody_crops_unused_land; Woody_crops_degraded_land | Based on S2BIOM cost calculations for 2015 (See Appendix 2, cost calculations) taking the average road side cost of a mix of woody crops suitable per region (SRC willow and poplar). The S2BIOM cost levels were projected to 2020 levels by correcting for known, national specific inflation development (based on Eurostat). | S2BIOM: Dees et al., 2017 |
| 2107 | Intermediate_crop_sorgh | Based on S2BIOM cost calculations for 2015 (See Appendix 2, cost calculations) taking the average road side cost of biomass sorghum on good agricultural land. The S2BIOM cost levels were projected to 2020 levels by correcting for known, national specific inflation development (based on Eurostat). | S2BIOM: Dees et al., 2017 |
| 2108 | Intermediate_crop_oil | Data derived from BIKE project cost calculations (Elbersen et al., (2022). Deliverable 2.2 Figure 4.5). This EU average cost level was further translated to national cost levels expressing the avarage labour and diesel price costs levels in every country to an index (EU average=100) | Panoutsou et al., (2022) and Elbersen et al., (2022) |
| 2109 | Cover_crop_ligno | Crop type unknown. Assumed that handling was similar to straw harvesting & forwarding. Costs were assumed to be the same as for cereal straw. | S2BIOM: Dees et al., 2018 |
| 2201 | Prim_res_cereal_straw | Based on S2BIOM cost calculations for 2015 (See Appendix 2, cost calculations) taking the national average road side cost. The S2BIOM cost levels were projected to 2020 levels by correcting for known, national specific inflation development (based on Eurostat). | S2BIOM: Dees et al., 2017 |
| 2202 | Prim_res_other_straw | | |
| 2203 | Prim_res_sugar_leaves | | |
| 2204 | Prim_res_perm_crops | | |
| 2205 | Prim_res_damaged_crops | Used S2BIOM road side cost level for straw. After all, the crops still need to be handled /harvested/removed from field | |
| 2301 | Animal_solid_manure | Based on Biomass Policies cost calculations for 2015 (See Appendix 2, cost calculations). Liquid manure at 0 €/ton dm and solid manure at 28 or 12 €/ton dm in 2020 (corrected for known, national specific inflation development (based on Eurostat)). | Elbersen et al., 2016 |
| 2302 | Animal_liquid_manure | | |

| DI codes | Short name | Assessment of base line 2020 roadside cost | Sources used |
|---|---|---|---|
| 4111 | Sec_res_sawdust | Based on price of sawdust 2022 in Austria (13-15 €/M3 or 67€/ton dm). This Austrian cost level was further translated to national cost levels expressing the average labour and diesel price costs levels in every country to an index (Austria=100) | https://www.timber-online.net/wood_products/2022/04/wood-chips-sawdust-04-2022.html#:~:text=According%20to%20the%20Timber%20Online,cubic%20meter%2C%20loaded%20ex%20sawmill. |
| 4112 | Sec_res_other_sawmill | Same as saw dust price level | See 4111 |
| 4121 | Sec_res_semi_woodbp | Same as saw dust price level | See 4111 |
| 4122 | Sec_res_other_wood | Same as saw dust price level | See 4111 |
| 4131 | Sec_res_bark | Based on price of bark 2022 in Ireland (70 €/ton dm). This Irish price level was further translated to national cost levels expressing the average labour and diesel price costs levels in every country to an index (Ireland=100) | |
| 4132 | Sec_res_black_liquor | Same as saw dust price level | See 4111 |
| 4201 | Sec_res_rice_husk | Around 50 €/ton dm | https://pellets-wood.com/buy-b532_0.html |
| 4202 | Sec_res_grapes | Same as for rice husk | See 4201 |
| 4203 | Sec_res_cereal_bran | Price level found in Italy 2023, but converted to 2020 price level according to inflation correction. | https://www.clal.it/en/index.php?section=conf_cereali#crusca |
| 4204 | Sec_res_maize_cobs | Same as for cereal bran | See 4203 |
| 4205 | Sec_res_olive_stones | Around 230 €/ton dm | https://pellets-wood.com/olive-pits-300-ton-per-month-in-big-bag-and-15kg-o23352.html |
| 4206 | Sec_res_sgb_bagasse | Same as for cereal bran | See 4203 |
| 4207 | Sec_res_olive_pommace | Around 180 €/ton dm | https://link.springer.com/article/10.1007/s11367-022-02031-2/tables/1 |
| 4208 | Sec_res_BSG | Around 85 €/ton dm | https://edepot.wur.nl/529917 |
| 4209 | Sec_res_LWP | Around 75 €/ton dm | https://www.clal.it/en/index.php?section=siero_milano |
| 4210 | Sec_res_ADRW | Around 85 €/ton dm (same as BSG) | https://edepot.wur.nl/529917 |
| 4211 | Sec_res_Bakery | Around 140 €/ton dm | https://ec.europa.eu/eurostat/databrowser/view/PRC_FSC_IDX__custom_5989766/default/table?lang=en |
| 4216 | Sec_res_ani_fats12 | Around 699 €/ton oil | Several websites |
| 5101 | Organic_waste_sepa | Assumed 0 € road side cost | S2BIOM: Dees et al., 2017 |
| 5102 | Organic_waste_mixed | Assumed 0 € road side cost | S2BIOM: Dees et al., 2017 |
| 5103 | Waste_retail_wholesale | Assumed 0 € road side cost | S2BIOM: Dees et al., 2017 |
| 5104 | Waste_fruit_vegetable | Assumed 0 € road side cost | S2BIOM: Dees et al., 2017 |
| 5106 | Waste_UCO | 1400 €/ton oil | Several websites |
| 5107 | Waste_brown_grease | 440 €/ton oil | Several websites |
| 5108 | Waste_sewagesludge_org | Assumed 0 € road side cost | |

Table A2 - 27 Cost level assessment per biomass type

*Cost calculations*

1. For biomass overlapping with S2BIOM categories S2BIOM cost calculations were used but corrected for inflation until 2020

2. For biomass categories overlapping with Biomass Policies categories (e.g., manure) BP cost levels were used, but corrected for inflation until 2020

3. For future cost these were assumed to remain stable between 2020 and 2030 and 2050.

4. Transport cost:

   – Use transport cost calculation model (link)

   – Calculate 2020 per biomass type transport in wet and dry over different distance classes: 20 km, 50 km, 100 km, 200 km

   – For every biomass type a transport type is selected per distance class (there are 3 transport options in the transport model)

## Appendix 2-7 SWOT Factsheets with summary results and evaluation for every biomass potential

The different biomass types assessed in this study are presented in the Table underneath together with a numbering in the factsheets (in last column) they are described in.

| Biomass DI codes | Short name | Category | subcategory 1 | Additional category info | SWOT - Factsheet no. |
|---|---|---|---|---|---|
| **1100** | **Stemwood** | Primary forestry production | Stemwood from final fellings & thinnings | Stemwood | 1 |
| **1200** | **Prim_forest_residues** | Primary residues from forests | Logging residues from final fellings and thinings | Stem and crown biomass | 1 |
| **1220** | **Prim_forest_stumps** | Primary residues from forests | Logging residues from final fellings and thinings | Stumps from final fellings and thinnings | 1 |
| **5211** | **Post_cons_wood_hazard** | Post consumer wood | Hazardous post consumer wood | Post consumer wood | 2 |
| **5212** | **Post_cons_wood_non_hazard** | Post consumer wood | Non hazardous post consumer wood | Post consumer wood | 2 |
| **2101** | **Ligno_crops_unused_land** | Primary production of crops | Lignocellulosic crops from unused & abandoned lands | Biomass sorghum, miscanthus, switchgrass, giant reed, RCG, cardoon | 3 |
| **2102** | **Oil_crops_unused_land** | Primary production of crops | Oil crops from unused & abandoned lands | Cardoon, Camelina, Castor | 3 |
| **2103** | **Woody_crops_unused_land** | Primary production of crops | Woody crops from unused & abandoned lands | SRC Poplar, willow | 3 |
| **2104** | **Ligno_crops_degraded_land** | Primary production of crops | Lignocellulosic crops from severely degraded lands | Biomass sorghum, miscanthus, switchgrass, giant reed, RCG, cardoon | 3 |

| Biomass DI codes | Short name | Category | subcategory 1 | Additional category info | SWOT - Factsheet no. |
|---|---|---|---|---|---|
| **2105** | **Oil_crops_degraded_land** | Primary production of crops | Oil crops from severely degraded lands | Cardoon, Camelina, Castor | 3 |
| **2106** | **Woody_crops_degraded_land** | Primary production of crops | Woody crops from severely degraded lands | SRC Poplar, willow | 3 |
| **2107** | **Intermediate_crop_Sorg** | Primary production of intermediate, cover crops | Lignocellulosic crops from good & medium quality agricultural land | Biomass sorghum | 4 |
| **2108** | **Intermediate_crop_oil** | Primary production of intermediate, cover crops | Oil crops from good & medium agricultural land | Camelina | 4 |
| **2109** | **Cover_crop_ligno** | Primary production of intermediate, cover crops | Cover crop | Onknown crop but assume 4 ton dm/ha/yr | 4 |
| **2201** | **Prim_res_cereal_straw** | Agricultural residues | Cereals straw | Straw/stubbles | 5 |
| **2202** | **Prim_res_other_straw** | Agricultural residues | Straw from oil seed rape, sunflower, grain maize (stover), rice | Straw/stubbles | 5 |
| **2203** | **Prim_res_sugar_leaves** | Agricultural residues | Sugarbeet leaves | Straw/stubbles | 5 |
| **2204** | **Prim_res_perm_crops** | Agricultural residues | Residues from vineyards, fruit trees, olive trees, citrus, nuts | Woody prunning & orchards residues | 6 |
| **2205** | **Prim_res_damaged_crops** | Agricultural residues | 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 | Residue at harvest of crop | 6 |
| **2301** | **Animal_solid_manure** | Agricultural residues | Animal solid manure | Solid manure from bovine, pig, sheep & goat, poultry | 7 |
| **2302** | **Animal_liquid_manure** | Agricultural residues | Animal liquid manure | Liquid | 7 |
| **4111** | **Sec_res_sawdust** | Secondary residues from wood industries | Sawdust | Saw mill residues | 8 |
| **4112** | **Sec_res_other_sawmill** | Secondary residues from wood industries | Other sawmill residues (excl sawdust) | Other residues (conifers & non-conifers) | 8 |
| **4121** | **Sec_res_semi_woodbp** | Secondary residues from wood industries | Residues from industries producing semi finished wood based panels | Residues from industries producing semi finished wood based panels | 8 |
| **4122** | **Sec_res_other_wood** | Secondary residues from wood industries | Residues from further woodprocessing | Residues from further woodprocessing | 8 |

| Biomass DI codes | Short name | Category | subcategory 1 | Additional category info | SWOT - Factsheet no. |
|---|---|---|---|---|---|
| **4131** | **Sec_res_bark** | Secondary residues from wood industries | Bark | Secondary residues from pulp and paper industry | 8 |
| **4132** | **Sec_res_black_liquor** | Secondary residues from wood industries | Black liquor | Secondary residues from pulp and paper industry | 8 |
| **4201** | **Sec_res_rice_husk** | Secondary residues of industry utilising agricultural products | Rice husk | By-products and residues from food & feed processing industry | 9 |
| **4202** | **Sec_res_grapes** | Secondary residues of industry utilising agricultural products | Grape pomace: Pressed grape dregs, stalks and seeds | By-products and residues from food & feed processing industry | 9 |
| **4203** | **Sec_res_cereal_bran** | Secondary residues of industry utilising agricultural products | Cereal bran | By-products and residues from food & feed processing industry | 9 |
| **4204** | **Sec_res_maize_cobs** | Secondary residues of industry utilising agricultural products | Cobs cleaned from grain maize | By-products and residues from food & feed processing industry | 9 |
| **4205** | **Sec_res_olive_stones** | Secondary residues of industry utilising agricultural products | olive stones | By-products and residues from food & feed processing industry | 9 |
| **4206** | **Sec_res_sgb_bagasse** | Secondary residues of industry utilising agricultural products | Bagasse from sugarbeet | By-products and residues from food & feed processing industry | 9 |
| **4207** | **Sec_res_olive_pommace** | Secondary residues of industry utilising agricultural products | Deoiled olive pomace | By-products and residues from food & feed processing industry | 9 |
| **4208** | **Sec_res_BSG** | Secondary residues of industry utilising agricultural products | Brewers' Spent Grain not fit for use in the food and feed chain | By-products and residues from food & feed processing industry | 10 |

| Biomass DI codes | Short name | Category | subcategory 1 | Additional category info | SWOT - Factsheet no. |
|---|---|---|---|---|---|
| **4209** | **Sec_res_LWP** | Secondary residues of industry utilising agricultural products | Liquid whey permeate | By-products and residues from food & feed processing industry | 11 |
| **4210** | **Sec_res_ADRW** | Secondary residues of industry utilising agricultural products | Alcoholic distillery residues and wastes (fusel oils) not fit for use in the food or feed chain | By-products from industry | 12 |
| **4211** | **Sec_res_Bakery** | Secondary residues of industry utilising agricultural products | Bakery and confectionary residues and waste not fit for use in the food and feed chain | By-products and residues from food & feed processing industry | 13 |
| **4214** | **Sec_res_DUR** | Secondary residues of industry utilising agricultural products | Dextrose ultrafiltration retentate | By-products and residues from food & feed processing industry | 14 |
| **4216** | **Sec_res_ani_fats12** | Secondary residues of industry utilising agricultural products | Animal fats: Animal fats classified as categories 1 and 2 in accordance with Regulation (EC) No 1069/2009 | By-products and residues from food & feed processing industry | 15 |
| **5101** | **Organic_waste_sepa** | Biodegradable (industrial & municipal) waste | Organic waste separately collected | Separately collected biowaste: Biodegradable waste of separately collected municipal waste (excluding textile and paper) | 16 |
| **5102** | **Organic_waste_mixed** | Biodegradable (industrial & municipal) waste | Organic fraction of municipal waste in mixed waste | Biowaste as part of integrally collected municipal waste: Biodegradable waste of not separately collected municipal waste | 16 |
| **5104** | **Waste_fruit_vegetable** | Biodegradable (industrial & municipal) waste | Fruit and vegetable residues and waste not fit for use in the food and feed chain, excluding tails, leaves, stalks and husks | Food waste | 17 |
| **5106** | **Waste_UCO** | Biodegradable (industrial & municipal) waste | Used cooking oil | Food waste | 18 |
| **5107** | **Waste_brown_grease** | Biodegradable (industrial & municipal) waste | Brown grease | By-products from retail, service sectors | 19 |
| **5108** | **Waste_sewagesludge_org** | Biodegradable (industrial & municipal) waste | Sewage sludge: Organic fraction in waste waters | Waste water treatment residue | 20 |

Table A2 - 28 Overview of biomass types and related fact sheet number

## SWOT 1 – Stemwood (1100), Primary forestry residues (1200) and Forest stumps (1220)

**Description of approach**

The potential for stemwood is based on the S2BIOM assessment and refers to stemwood from final fellings and thinning. In S2BIOM the central model to assess biomass potentials from forests was the European Forest Information Scenario model (EFISCEN). For further details on the assessment see main report Section 3.2.

| DI codes | Description of biomass category | Issue | Technical potential | Low mobilisation | Medium mobilisation | High mobilisation |
|---|---|---|---|---|---|---|
| 1100, 1200, 1220 | Stemwood, primary harvesting residues and stumps | Area | Forest area available for wood supply. Excluding protected and protective areas. | Forest area available for wood supply minus 5%. Excluding protected and protective areas. | Forest area available for wood supply. Excluding protected and protective areas. | Forest area available for wood supply. Excluding protected and protective areas. |
| | | Growth | Growth based on regional/ national conditions (incl. climate change effect). | Growth based on regional/ national conditions (incl. climate change effect). | Growth based on regional/ national conditions (incl. climate change effect). | Growth based on regional/ national conditions (incl. climate change effect). |
| | | **Yield** | Yield according to regional management guidelines for age limits for thinnings and final fellings. | Yield according to regional management guidelines for age limits for thinnings and final fellings. | Yield according to regional management guidelines for age limits for thinnings and final fellings. | Yield according to regional management guidelines for age limits for thinnings and final fellings. |
| | | Technical & environmental constraints | Max volume of stemwood that could be harvested annually during 50-year periods. Technical constraints on residue and stump extraction (recovery rate) | Max volume of stemwood that could be harvested annually during 50-year periods. Local extraction constraints according to site productivity, slope, soil and water protection, biodiversity, soil bearing capacity. Increase in protected forest by 5% plus increase in retained trees by 5% plus no stump extraction. | Max volume of stemwood that could be harvested annually during 50-year periods. Local extraction constraints according to site productivity, slope, soil and water protection, biodiversity, soil bearing capacity. Increase in protected forest by 5% plus increase in retained trees by 5% plus no stump extraction. | Max volume of stemwood that could be harvested annually during 50-year periods. Local extraction constraints according to site productivity, slope, soil and water protection, biodiversity, soil bearing capacity. Increase in protected forest by 5% plus increase in retained trees by 5% plus no stump extraction. |
| | | Competing use | No competing use | Roundwood production for material use subtracted from BP. | Roundwood production for material use excluding production of pulp and paper and board industry subtracted. | No competing use |

Table A2 - 29 Scenario assumptions

## Results

| | | 2030 | 2030 | 2050 | 2050 |
|---|---|---|---|---|---|
| | **Technical** | **TP mln ton** | **%/total** | **TP mln ton** | **%/total** |
| **1100** | Stemwood | 202.6 | 19.5% | 302.8 | 16.4% |
| **1200** | Prim_forest_residues | 98.7 | 6.2% | 95.8 | 5.2% |
| **1220** | Prim_forest_stumps | 77.5 | 4.9% | 77.3 | 4.2% |
| | | | | | |
| | | 2030 | 2030 | 2050 | 2050 |
| | **Low scenario** | **Low mln ton** | **%/total** | **Low mln ton** | **%/total** |
| **1100** | Stemwood | 32.7 | 10.4% | 25.4 | 8.5% |
| **1200** | Prim_forest_residues | 37.4 | 11.9% | 36.8 | 12.3% |
| **1220** | Prim_forest_stumps | 0.0 | 0.0% | 0.0 | 0.0% |
| | | | | | |
| | | 2030 | 2030 | 2050 | 2050 |
| | **Medium scenario** | **Medium mln ton** | **%/total** | **Medium mln ton** | **%/total** |
| **1100** | Stemwood | 92.1 | 17.0% | 77.0 | 14.3% |
| **1200** | Prim_forest_residues | 37.4 | 6.9% | 36.8 | 6.8% |
| **1220** | Prim_forest_stumps | 5.5 | 1.0% | 5.9 | 1.1% |
| | | | | | |
| | | 2030 | 2030 | 2050 | 2050 |
| | **High scenario** | **High mln ton** | **%/total** | **High mln ton** | **%/total** |
| **1100** | Stemwood | 202.6 | 23.3% | 196.9 | 21.2% |
| **1200** | Prim_forest_residues | 37.4 | 4.3% | 36.8 | 4.0% |
| **1220** | Prim_forest_stumps | 5.5 | 0.6% | 5.9 | 0.6% |

Table A2 - 30 Total Europe in 2030 and 2050 for technical, low, medium, and high mobilisation scenario

| | 1100: Stemwood | | | | 1200: primary residues | | | | 1220: Stumps | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | high | low | medium | tp | high | low | medium | tp | high | low | medium | tp |
| **AL** | 537 | 326 | 409 | 827 | 122 | 122 | 122 | 180 | - | - | - | 226 |
| **AT** | 8,152 | 604 | 3,192 | 12,542 | 1,461 | 1,461 | 1,461 | 4,381 | - | - | - | 3,564 |
| **BA** | 1,611 | - | 92 | 2,479 | 207 | 207 | 207 | 496 | - | - | - | 82 |
| **BG** | 2,106 | 582 | 1,395 | 3,240 | 776 | 776 | 776 | 1,832 | - | - | - | 747 |
| **BL*** | 1,600 | 240 | 589 | 2,461 | 253 | 253 | 253 | 806 | - | - | - | 496 |
| **CS** | 1,882 | 779 | 1,063 | 2,896 | 315 | 315 | 315 | 583 | - | - | - | 55 |
| **CY** | 10 | 5 | 7 | 15 | 3 | 3 | 3 | 6 | - | - | - | 2 |
| **CZ** | 6,088 | 293 | 1,682 | 9,366 | 1,998 | 1,998 | 1,998 | 3,626 | - | - | - | 1,792 |
| **DE** | 27,404 | 5,692 | 13,456 | 42,161 | 2,667 | 2,667 | 2,667 | 14,282 | - | - | - | 8,645 |
| **DK** | 1,051 | 171 | 543 | 1,616 | 234 | 234 | 234 | 537 | - | - | - | 282 |
| **EE** | 3,496 | - | - | 5,378 | 313 | 313 | 313 | 916 | - | - | - | 739 |
| **EL** | 1,246 | 589 | 785 | 1,917 | 207 | 207 | 207 | 640 | - | - | - | 119 |
| **ES** | 6,455 | 2,070 | 4,880 | 9,931 | 2,061 | 2,061 | 2,061 | 4,241 | - | - | - | 3,994 |
| **FI** | 19,432 | - | 9,055 | 29,896 | 2,510 | 2,510 | 2,510 | 10,592 | 1,916 | - | 1,916 | 8,709 |
| **FR** | 24,429 | 7,327 | 13,622 | 37,584 | 4,568 | 4,568 | 4,568 | 10,914 | - | - | - | 7,645 |
| **HR** | 1,999 | 290 | 789 | 3,076 | 188 | 188 | 188 | 528 | - | - | - | 452 |
| **HU** | 3,113 | 662 | 1,502 | 4,790 | 765 | 765 | 765 | 1,718 | - | - | - | 1,105 |
| **IR** | 1,262 | - | 302 | 1,941 | 159 | 159 | 159 | 377 | - | - | - | 458 |
| **IT** | 7,676 | 4,893 | 6,284 | 11,809 | 1,680 | 1,680 | 1,680 | 3,341 | - | - | - | 3,651 |
| **KO** | 520 | 270 | 350 | 800 | 85 | 85 | 85 | 196 | - | - | - | 11 |
| **LT** | 2,629 | - | 514 | 4,045 | 424 | 424 | 424 | 1,434 | - | - | - | 1,115 |
| **LV** | 5,019 | - | 636 | 7,721 | 1,027 | 1,027 | 1,027 | 2,512 | - | - | - | 2,091 |
| **MK** | 503 | 333 | 410 | 774 | 76 | 76 | 76 | 191 | - | - | - | 10 |
| **MO** | 513 | 175 | 266 | 789 | 39 | 39 | 39 | 183 | - | - | - | 29 |
| **MT** | - | - | - | - | - | - | - | - | - | - | - | - |
| **NL** | 477 | 77 | 305 | 734 | 25 | 25 | 25 | 139 | - | - | - | 102 |
| **NO** | - | - | - | - | - | - | - | - | - | - | - | - |
| **PL** | 12,193 | - | 3,720 | 18,759 | 1,733 | 1,733 | 1,733 | 5,489 | - | - | - | 5,105 |
| **PT** | 4,737 | 399 | 4,109 | 7,288 | 2,255 | 2,255 | 2,255 | 2,610 | - | - | - | 3,966 |
| **RO** | 8,733 | 522 | 1,673 | 13,435 | 1,805 | 1,805 | 1,805 | 3,826 | - | - | - | 2,202 |

| | 1100: Stemwood | | | | 1200: primary residues | | | | 1220: Stumps | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | high | low | medium | tp | high | low | medium | tp | high | low | medium | tp |
| **SE** | 27,414 | 1,884 | 11,149 | 42,175 | 4,330 | 4,330 | 4,330 | 13,048 | 3,099 | - | 3,099 | 10,950 |
| **SI** | 2,749 | - | 955 | 4,230 | 350 | 350 | 350 | 1,048 | - | - | - | 1,042 |
| **SK** | 2,765 | 63 | 585 | 4,254 | 606 | 606 | 606 | 2,026 | - | - | - | 938 |
| **TR** | 6,791 | 125 | 2,026 | 10,448 | 2,871 | 2,871 | 2,871 | 3,420 | - | - | - | 5,277 |
| **UK** | 7,991 | 4,323 | 5,767 | 12,294 | 1,305 | 1,305 | 1,305 | 2,604 | 512 | - | 512 | 1,920 |
| **Totalal** | 202,585 | 32,693 | 92,110 | 311,669 | 37,421 | 37,421 | 37,421 | 98,724 | 5,527 | - | 5,527 | 77,521 |

*Belgium & Luxembourg*

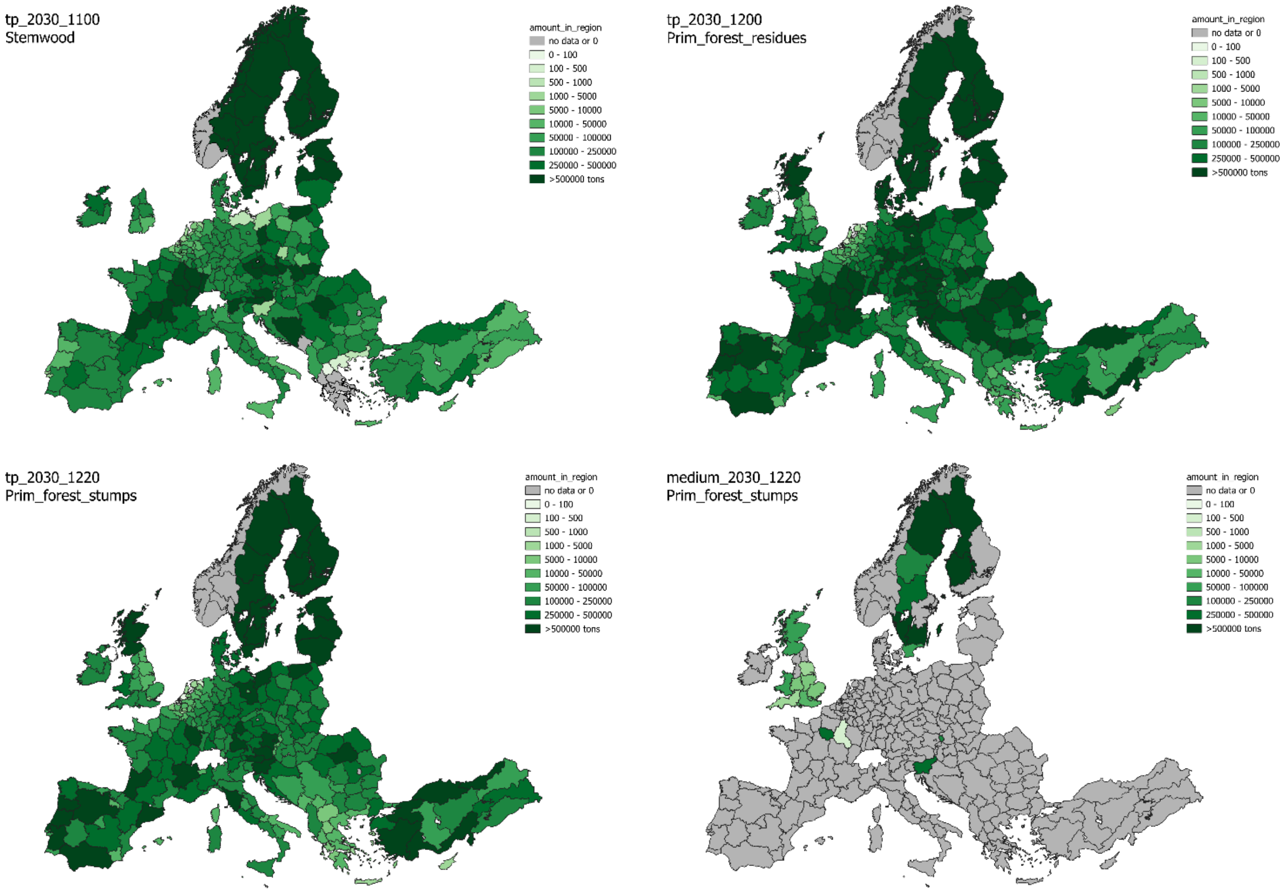
Table A2 - 31 Supply per country and scenario for 2030 (Kton dm)

| | 1100: Stemwood | | | | 1200: primary residues | | | | 1220: Stumps | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | high | low | medium | tp | high | low | medium | tp | high | low | medium | tp |
| **AL** | 455 | 235 | 305 | 699 | 101 | 101 | 101 | 148 | - | - | - | 178 |
| **AT** | 7,993 | 187 | 2,280 | 12,297 | 1,462 | 1,462 | 1,462 | 4,237 | - | - | - | 3,370 |
| **BA** | 1,325 | - | - | 2,038 | 170 | 170 | 170 | 407 | - | - | - | 67 |
| **BG** | 2,121 | 559 | 1,359 | 3,263 | 770 | 770 | 770 | 1,745 | - | - | - | 791 |
| **BL*** | 1,659 | 247 | 661 | 2,552 | 260 | 260 | 260 | 849 | - | - | - | 512 |
| **CS** | 1,500 | 430 | 637 | 2,308 | 251 | 251 | 251 | 465 | - | - | - | 44 |
| **CY** | 11 | 5 | 7 | 16 | 3 | 3 | 3 | 7 | - | - | - | 2 |
| **CZ** | 6,091 | 202 | 1,436 | 9,371 | 2,124 | 2,124 | 2,124 | 3,901 | - | - | - | 1,819 |
| **DE** | 28,512 | 4,515 | 12,637 | 43,864 | 2,755 | 2,755 | 2,755 | 14,185 | - | - | - | 9,075 |
| **DK** | 968 | 1 | 403 | 1,489 | 221 | 221 | 221 | 449 | - | - | - | 269 |
| **EE** | 3,132 | - | - | 4,818 | 284 | 284 | 284 | 846 | - | - | - | 687 |
| **EL** | 1,148 | 381 | 555 | 1,766 | 191 | 191 | 191 | 589 | - | - | - | 109 |
| **ES** | 6,495 | 2,269 | 4,952 | 9,992 | 2,133 | 2,133 | 2,133 | 4,294 | - | - | - | 4,078 |
| **FI** | 19,196 | - | 8,191 | 29,532 | 2,761 | 2,761 | 2,761 | 10,883 | 2,088 | - | 2,088 | 9,371 |
| **FR** | 22,640 | 5,495 | 10,625 | 34,831 | 4,462 | 4,462 | 4,462 | 9,642 | - | - | - | 7,715 |
| **HR** | 1,889 | 243 | 702 | 2,906 | 178 | 178 | 178 | 507 | - | - | - | 404 |
| **HU** | 2,964 | 299 | 945 | 4,559 | 728 | 728 | 728 | 1,615 | - | - | - | 1,073 |
| **IR** | 1,500 | - | 269 | 2,308 | 193 | 193 | 193 | 440 | - | - | - | 637 |

| | 1100: Stemwood | | | | 1200: primary residues | | | | 1220: Stumps | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | high | low | medium | tp | high | low | medium | tp | high | low | medium | tp |
| **IT** | 6,706 | 3,490 | 4,783 | 10,317 | 1,527 | 1,527 | 1,527 | 2,932 | - | - | - | 3,239 |
| **KO** | 527 | 248 | 329 | 811 | 87 | 87 | 87 | 199 | - | - | - | 11 |
| **LT** | 2,435 | - | - | 3,746 | 403 | 403 | 403 | 1,369 | - | - | - | 1,003 |
| **LV** | 5,046 | - | 286 | 7,762 | 1,062 | 1,062 | 1,062 | 2,588 | - | - | - | 2,132 |
| **MK** | 303 | 149 | 194 | 466 | 46 | 46 | 46 | 115 | - | - | - | 6 |
| **MO** | 375 | 15 | 88 | 577 | 28 | 28 | 28 | 134 | - | - | - | 21 |
| **MT** | - | - | - | - | - | - | - | - | - | - | - | - |
| **NL** | 440 | 44 | 262 | 677 | 24 | 24 | 24 | 123 | - | - | - | 99 |
| **NO** | - | - | - | - | - | - | - | - | - | - | - | - |
| **PL** | 11,124 | - | 2,091 | 17,114 | 1,587 | 1,587 | 1,587 | 4,843 | - | - | - | 4,715 |
| **PT** | 4,341 | 324 | 3,689 | 6,678 | 2,047 | 2,047 | 2,047 | 2,379 | - | - | - | 3,620 |
| **RO** | 8,000 | - | 191 | 12,307 | 1,649 | 1,649 | 1,649 | 3,560 | - | - | - | 1,880 |
| **SE** | 28,780 | 1,465 | 11,522 | 44,278 | 4,830 | 4,830 | 4,830 | 13,915 | 3,432 | - | 3,432 | 12,164 |
| **SI** | 2,553 | - | - | 3,928 | 330 | 330 | 330 | 1,011 | - | - | - | 957 |
| **SK** | 2,632 | 73 | 567 | 4,050 | 626 | 626 | 626 | 2,181 | - | - | - | 866 |
| **TR** | 6,024 | 102 | 1,250 | 9,268 | 2,528 | 2,528 | 2,528 | 2,984 | - | - | - | 4,797 |
| **UK** | 7,967 | 4,413 | 5,796 | 12,257 | 961 | 961 | 961 | 2,260 | 416 | - | 416 | 1,542 |
| **Total** | 196,851 | 25,392 | 77,011 | 302,847 | 36,782 | 36,782 | 36,782 | 95,803 | 5,937 | - | 5,937 | 77,254 |

*Belgium & Luxembourg

Table A2 - 32 Supply per country and scenario for 2050 (Kton dm)




Map 1 Distribution over Europe

## Evaluation

### General observations

Describe general observations on e.g., approach of assessment, scenario approach, results in numbers (amounts and price levels), spatial distribution, comparison with PRIMES

The assessment is based on the FP7 project S2Biom that was finalised in 2016. This study included a robust assessment framework, which was implemented across Europe. The assessment framework was reviewed by a number of sector experts. As such, the assessment approach is very credible.

Main report indicates that also cost calculations are based on S2Biom with inflation correction to 2020. Ideally, the calculations could have been corrected using the differentiated inflation increases in fuel prices; labour costs and machinery.

Differentiating cost data for the different scenarios by applying different inflation rates increases the uncertainty. The scenario framework set for low versus high potential relates to technical & environmental constraints and possible competition for the feedstocks. There is no link to inflation.

The comparison with the PRIMES results is surprising/alarming as even the minimum deployment in PRIMES is larger than the technical potential analysed in this study both for 2030 and 2050. When PRIMES low demand data is compared, they appear more than 3.5 times and 2.5 times of the high potential figures in this study for 2030 and 2050, respectively.

It would have been interesting to clarify what assumptions had the major impact on the results. Even the high mobilisation scenario comprises 50% of the technical potential, where no competition is taken into account. Was this due to local extraction constraints or mainly due to the assumption of additional 5% increase in protected forests, or 5% increase in retained trees??

### Strength

*Please indicate what you regard as a strength in the assessment of results*

The results are based on a harmonised methodology across the EU. It fallows a robust methodology, reviewed by the sector experts.

EFICEN uses the national forest inventory data, thus, it describes the current status of forests very well.

### Weaknesses

*Please indicate what you regard as a weakness in the assessment*

*A comparison of the current utilisation rates and the future potential projections and some clarifications regarding what the reasons for deviations may be (especially if the potential assessment figures are lower than the current utilisation, could be used as some sort of a sanity check.*

*At the gate cost estimates can be confusing, especially when they are differentiated for 2030 and 2050, using different inflation corrections. There is, however, no correct way of calculating future production costs. Some suggestions are as follows:*

- Option 1. Keep it constant for all scenarios and all years
- Option 2. Keep it same for all scenarios, but increase up to 2050, using the GDP growth projections

### Options for improvement?

Please indicate what <u>can</u> or <u>really needs</u> to be improved.

Would be good to include the REDIII approach to wood and how the methodology and the data introduced in this fact sheet relate to REDIII conditions, such as cascading use, no financial support to use of saw logs, veneer logs, industrial grade roundwood, stumps and roots to produce energy.

## SWOT 2 – Post consumer wood hazardous (5211) and post-consumer wood non-hazardous (5212)

### Description of approach

The potential for post-consumer wood is based on the S2BIOM assessment. It comprises packaging materials, demolition wood, and timber from building sites and fractions of used wood from residential (municipal waste), industrial and commercial activities. For further details on the assessment see main report Section 3.3.

| DI codes | Description of biomass category | Issue | Technical potential | Low mobilisation | Medium mobilisation | High mobilisation |
|---|---|---|---|---|---|---|
| 5211, 5212 | Post-consumer wood waste hazardous and non hazardous | Baseline situation in 2020 and future cascading and competing use | All collectable post-consumer wood can be collected used for energy generation. About 5% of available post-consumer wood cannot be recovered for technical reasons. | Assumes increased cascading use in 2020, 2030 and 2050. This assumes (following Circular Economy Package) a 75% of material recycling of packaging wood in 2030. (also 75% in 2050). Other types of waste wood (e.g. particle board, MDF, OSB, plywood) are not expected to exceed 50% recycling. For non-hazardous waste wood a material application of 49.2% in 2020 and 61.5% in 2030. In 2050 80.25% will go to material uses. 50% of all hazardous waste wood is assumed to be available for energy generation by 2030 and 2050. | The base potential: 2030: for non-hazardous woodwaste: current material use in 2020 + 25% extra material use in 2030 and 2050. For hazardous wood waste 25% to material use in 2030 and 2050. | Only substraction of 2020 material uses for non-hazardous waste. In 2030 and 2050 no additional material uses. For hazardous waste wood all available for energy. |

Table A2 - 33 Scenario assumptions (see also Main report section 3.4.3 and Table A2-7)

### Results

| | | 2030 | 2030 | 2050 | 2050 |
|---|---|---|---|---|---|
| | Technical | TP mln ton | %/total | TP mln ton | %/total |
| 5211 | Post_cons_wood_hazard | 4.9 | 0.3% | 5.6 | 0.3% |
| 5212 | Post_cons_wood_non_hazard | 27.2 | 1.7% | 30.8 | 1.7% |
| | | | | | |
| | | 2030 | 2030 | 2050 | 2050 |
| | Low scenario | Low mln ton | %/total | Low mln ton | %/total |
| **5211** | Post_cons_wood_hazard | 2.5 | 0.8% | 2.8 | 0.9% |
| **5212** | Post_cons_wood_non_hazard | 6.1 | 1.9% | 6.2 | 2.1% |
| | | | | | |
| | | 2030 | 2030 | 2050 | 2050 |
| | Medium scenario | Medium mln ton | %/total | Medium mln ton | %/total |
| **5211** | Post_cons_wood_hazard | 3.7 | 0.7% | 4.2 | 0.8% |
| **5212** | Post_cons_wood_non_hazard | 11.4 | 2.1% | 14.1 | 2.6% |
| | | | | | |
| | | 2030 | 2030 | 2050 | 2050 |
| | High scenario | High mln ton | %/total | High mln ton | %/total |
| **5211** | Post_cons_wood_hazard | 4.9 | 0.6% | 0.6% | 0% |
| **5212** | Post_cons_wood_non_hazard | 15.2 | 1.7% | 2.0% | 1% |

Table A2 - 34 Total Europe in 2030 and 2050 for technical, low, medium and high mobilisation scenario

| | Post consumer wood hazardous (5211) 2030 | | | | Post consumer wood hazardous (5211) 2050 | | | |
|---|---|---|---|---|---|---|---|---|
| | high | low | medium | tp | high | low | medium | tp |
| | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons |
| **AL** | 16,282 | 8,141 | 12,211 | 16,282 | 46,072 | 22,730 | 34,554 | 89,444 |
| **AT** | 88,194 | 44,097 | 66,146 | 88,194 | 221,872 | 110,936 | 166,404 | 484,494 |
| **BA** | 31,389 | 15,695 | 23,542 | 31,389 | 106,974 | 43,821 | 80,231 | 172,438 |
| **BG** | 7,472 | 3,736 | 5,604 | 7,472 | 28,733 | 10,431 | 21,550 | 41,046 |
| **BL** | 153,430 | 76,715 | 115,072 | 153,430 | 211,174 | 105,587 | 158,381 | 842,867 |
| **CS** | 35,354 | 17,677 | 26,516 | 35,354 | 96,475 | 48,238 | 72,357 | 194,218 |
| **CY** | 8,601 | 4,300 | 6,451 | 8,601 | 27,341 | 12,007 | 20,506 | 47,250 |
| **CZ** | 74,645 | 37,323 | 55,984 | 74,645 | 317,949 | 104,207 | 238,462 | 410,064 |
| **DE** | 752,442 | 376,221 | 564,332 | 752,442 | 2,937,746 | 933,573 | 2,203,310 | 3,673,689 |
| **DK** | 93,514 | 46,757 | 70,136 | 93,514 | 461,768 | 130,549 | 346,326 | 513,721 |
| **EE** | 16,860 | 8,430 | 12,645 | 16,860 | 67,002 | 23,537 | 50,251 | 92,618 |
| **EL** | 73,983 | 36,991 | 55,487 | 73,983 | 315,788 | 103,282 | 236,841 | 406,424 |
| **ES** | 324,883 | 162,442 | 243,662 | 324,883 | 775,345 | 387,672 | 581,509 | 1,784,747 |
| **FI** | 98,407 | 49,204 | 73,805 | 98,407 | 279,769 | 137,380 | 209,827 | 540,601 |
| **FR** | 479,583 | 239,792 | 359,687 | 479,583 | 371,079 | 185,540 | 278,309 | 2,634,593 |
| **HR** | 28,090 | 14,045 | 21,067 | 28,090 | 70,410 | 35,205 | 52,808 | 154,310 |
| **HU** | 51,798 | 25,899 | 38,849 | 51,798 | 228,452 | 72,312 | 171,339 | 284,554 |
| **IR** | 46,197 | 23,099 | 34,648 | 46,197 | 94,060 | 47,030 | 70,545 | 253,784 |
| **IT** | 527,806 | 263,903 | 395,854 | 527,806 | 1,454,547 | 727,274 | 1,090,910 | 2,899,504 |
| **KO** | - | - | - | - | - | - | - | - |
| **LT** | 28,716 | 14,358 | 21,537 | 28,716 | 116,593 | 40,089 | 87,445 | 157,754 |
| **LV** | 24,616 | 12,308 | 18,462 | 24,616 | 102,609 | 34,364 | 76,956 | 135,227 |
| **MK** | 10,983 | 5,492 | 8,238 | 10,983 | 36,941 | 15,333 | 27,706 | 60,338 |
| **MO** | 1,034 | 517 | 776 | 1,034 | 5,011 | 1,444 | 3,758 | 5,682 |
| **MT** | 2,148 | 1,074 | 1,611 | 2,148 | 7,912 | 2,999 | 5,934 | 11,802 |
| **NL** | 90,889 | 45,444 | 68,166 | 90,889 | 564,698 | 280,811 | 423,524 | 1,105,014 |
| **NO** | - | - | - | - | - | - | - | - |
| **PL** | 361,750 | 180,875 | 271,313 | 361,750 | 1,766,204 | 505,015 | 1,324,653 | 1,987,277 |
| **PT** | 59,690 | 29,845 | 44,767 | 59,690 | 261,047 | 83,329 | 195,785 | 327,907 |
| **RO** | 171,621 | 85,810 | 128,716 | 171,621 | 761,549 | 239,588 | 571,162 | 942,800 |

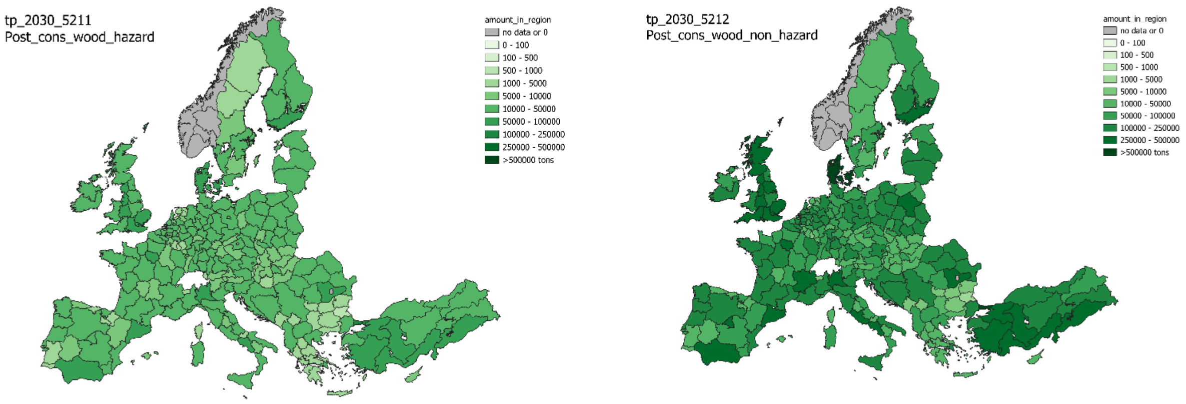
| | Post consumer wood hazardous (5211) 2030 | | | | Post consumer wood hazardous (5211) 2050 | | | |
|---|---|---|---|---|---|---|---|---|
| | high | low | medium | tp | high | low | medium | tp |
| | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons |
| **SE** | 80,958 | 40,479 | 60,719 | 80,958 | 428,910 | 113,020 | 321,683 | 444,743 |
| **SI** | 13,134 | 6,567 | 9,851 | 13,134 | 63,818 | 18,336 | 47,863 | 72,152 |
| **SK** | 22,572 | 11,286 | 16,929 | 22,572 | 70,740 | 31,511 | 53,055 | 123,999 |
| **TR** | 571,369 | 285,684 | 428,527 | 571,369 | 1,387,506 | 693,753 | 1,040,629 | 3,138,818 |
| **UK** | 570,001 | 285,000 | 427,501 | 570,001 | 1,502,191 | 751,095 | 1,126,643 | 3,131,304 |

Table A2 - 35 Cost supply per country per year and scenario for Post consumer wood hazardous (5211) 2030 and 2050

| | Post consumer wood non-hazardous (5211) 2030 | | | | Post consumer wood non-hazardous (5211) 2050 | | | |
|---|---|---|---|---|---|---|---|---|
| | high | low | medium | tp | high | low | medium | tp |
| | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons |
| **AL** | 21,145 | 10,572 | 15,858 | 21,145 | 72,786 | 35,747 | 54,589 | 116,158 |
| **AT** | 93,582 | 46,791 | 70,186 | 93,582 | 251,471 | 125,735 | 188,603 | 514,093 |
| **BA** | 40,374 | 20,187 | 30,280 | 40,374 | 156,330 | 57,758 | 117,248 | 221,794 |
| **BG** | 9,615 | 4,808 | 7,211 | 9,615 | 40,508 | 11,945 | 30,381 | 52,821 |
| **BL** | 170,190 | 85,095 | 127,642 | 170,190 | 303,246 | 151,623 | 227,435 | 934,939 |
| **CS** | 44,827 | 22,414 | 33,620 | 44,827 | 148,515 | 74,258 | 111,386 | 246,258 |
| **CY** | 8,601 | 4,300 | 6,451 | 8,601 | 27,341 | 10,159 | 20,506 | 47,250 |
| **CZ** | 97,690 | 48,845 | 73,267 | 97,690 | 444,545 | 106,652 | 333,409 | 536,660 |
| **DE** | 807,067 | 403,533 | 605,300 | 807,067 | 3,204,443 | 472,143 | 2,403,332 | 3,940,386 |
| **DK** | 93,152 | 46,576 | 69,864 | 93,152 | 459,776 | 18,070 | 344,832 | 511,730 |
| **EE** | 21,282 | 10,641 | 15,961 | 21,282 | 91,296 | 24,612 | 68,472 | 116,912 |
| **EL** | 85,690 | 42,845 | 64,268 | 85,690 | 380,105 | 74,761 | 285,079 | 470,741 |
| **ES** | 363,499 | 181,749 | 272,624 | 363,499 | 987,480 | 493,740 | 740,610 | 1,996,883 |
| **FI** | 112,683 | 56,341 | 84,512 | 112,683 | 358,192 | 173,808 | 268,644 | 619,024 |
| **FR** | 500,706 | 250,353 | 375,529 | 500,706 | 487,116 | 243,558 | 365,337 | 2,750,629 |
| **HR** | 35,567 | 17,784 | 26,675 | 35,567 | 111,488 | 55,744 | 83,616 | 195,388 |
| **HU** | 65,718 | 32,859 | 49,288 | 65,718 | 304,919 | 63,975 | 228,689 | 361,022 |
| **IR** | 49,799 | 24,899 | 37,349 | 49,799 | 113,845 | 56,922 | 85,384 | 273,569 |
| **IT** | 610,209 | 305,105 | 457,657 | 610,209 | 1,907,231 | 953,616 | 1,430,423 | 3,352,188 |

| | Post consumer wood non-hazardous (5211) 2030 | | | | Post consumer wood non-hazardous (5211) 2050 | | | |
|---|---|---|---|---|---|---|---|---|
| | high | low | medium | tp | high | low | medium | tp |
| | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons |
| **KO** | - | - | - | - | - | - | - | - |
| **LT** | 37,633 | 18,816 | 28,225 | 37,633 | 165,574 | 44,349 | 124,180 | 206,735 |
| **LV** | 31,495 | 15,748 | 23,621 | 31,495 | 140,400 | 34,438 | 105,300 | 173,018 |
| **MK** | 13,934 | 6,967 | 10,450 | 13,934 | 53,149 | 19,951 | 39,862 | 76,546 |
| **MO** | 1,325 | 663 | 994 | 1,325 | 6,610 | 1,064 | 4,957 | 7,281 |
| **MT** | 2,626 | 1,313 | 1,970 | 2,626 | 10,537 | 3,249 | 7,903 | 14,428 |
| **NL** | 93,341 | 46,671 | 70,006 | 93,341 | 594,514 | 294,009 | 445,886 | 1,134,830 |
| **NO** | - | - | - | - | - | - | - | - |
| **PL** | 482,942 | 241,471 | 362,206 | 482,942 | 2,431,971 | 417,802 | 1,823,978 | 2,653,044 |
| **PT** | 69,700 | 34,850 | 52,275 | 69,700 | 316,038 | 58,386 | 237,028 | 382,898 |
| **RO** | 221,337 | 110,668 | 166,003 | 221,337 | 1,034,664 | 219,272 | 775,998 | 1,215,915 |
| **SE** | 87,889 | 43,945 | 65,917 | 87,889 | 466,988 | 19,353 | 350,241 | 482,821 |
| **SI** | 17,061 | 8,530 | 12,795 | 17,061 | 85,388 | 14,039 | 64,041 | 93,723 |
| **SK** | 30,126 | 15,063 | 22,594 | 30,126 | 112,238 | 47,972 | 84,179 | 165,497 |
| **TR** | 672,104 | 336,052 | 504,078 | 672,104 | 1,940,893 | 970,447 | 1,455,670 | 3,692,206 |
| **UK** | 593,149 | 296,574 | 444,862 | 593,149 | 1,629,354 | 814,677 | 1,222,015 | 3,258,467 |

Table A2 - 36 Cost supply per country per year and scenario for Post consumer wood non-hazardous (5212) 2030 and 2050




Map 1 Distribution over Europe

# Evaluation

### General observations

*Describe general observations on e.g. approach of assessment, scenario approach, results in numbers (amounts and price levels), spatial distribution, comparison with PRIMES*

It is indicated that the assessment is based on S2Biom. It is not clear whether the figures are based on the copy-paste of S2Biom base assessments or whether any updates were included. My understanding is that base data from S2Biom is used as technical potential. This potential is considered as high mobilisation. For low mobilisation this technical potential is reduced by 50% for competing uses for materials production.

COMMENT authors: Indeed the evaluator is right. The S2BIOM Technical potential is used as baseline and these have been further elaborated for the low, medium and high mobilisation scenarios.

### Strength

*Please indicate what you regard as a strength in the assessment of results*

It uses the S2Biom methodology/data(?), where information from different member states were applied. Thus, if follows a harmonised approach.

### Weaknesses

*Please indicate what you regard as a weakness in the assessment*

S2Biom assessments were based on the historic relationship between the solid wood consumption per capita and share of post-consumer wood in the total national solid wood consumption in 2007. This appears to be quite outdated and may not be anymore representative.

COMMENT authors: Since the S2BIOM data were only provided until 2030 for 2050 the historic trend of this resource between 2012 to 2030 was further continued towards 2050 In the scenarios assumptions (see next) stricter competing use levels were applied then in S2BIOM because new additional bioeconomy uses can be expected particularly towards 2050.

### Options for improvement?

*Please indicate what <u>can</u> or <u>really needs</u> to be improved.*

The ratios implemented in the calculation of post-consumer wood can be cross-checked for a (limited) number of countries, or countries where such data is available. Having said that, I am not sure whether such information is available.

## SWOT 3– Ligno crops (2101 & 2104), oil crops (2102 & 2105), woody crops (2103 & 2106) from unused or degraded lands

### Description of approach

For the assessment of dedicated crops on future abandoned and degraded lands new estimates were made of:

- The amount of abandoned lands by 2030 and 2050 (based on CAPRI baseline run 2008-2050, see also Section 3.1 and Annex 4 of main report)

*For Identification and quantification of abandoned lands:*

Two main data inputs were used:

- CAPRI land use changes between 2020, 2030 and 2050. The comparison in time results in an amount of land that is no longer used for agriculture in 2030 and 2050. This land is assumed to be abandoned. This comparison could be done at regional level

- CAPRI land use 2030 and 2050 for New Energy Crops (NERC). This is land that in the CAPRI baseline was already allocated to dedicated lignocellulosic and woody crops to be demanded for advance biofuel production.

- Likelihood map for abandonment based on LUCAS and Maxent and BBN (Bayesian Believe Network) modelling (MAGIC). This GIS assessment classified lands (in the agricultural Corine Land cover class) at km2 level in classes with high and low likelihood (risk) for abandonment. In this map the HNV farmland areas and Natura 2000 areas are excluded!

The information of CAPRI on NERC and abandoned lands is combined into a total area and this is compared with the area in every region scoring in the highest likelihood class for abandonment. The final maximum abandoned area per region is then selected as follows:

$Land_{abandoned} = NERC_{Capri} + ((Abandoned_{Capri} + NERC) \sim Abanoned_{Likelihood})$

*Where*

$Land_{abandoned}$ = Total land abandoned per region in technical potential

$NERC_{Capri}$ = Land claimed already in CAPRI baseline for new energy crops (woody and lignocellulosic crops)

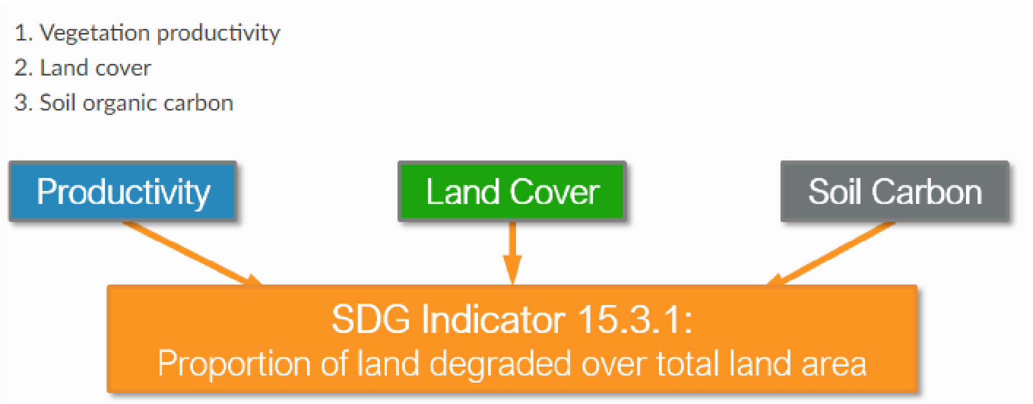
$Abandoned_{Capri}$ = Difference between agricultural land 2020 and 2030 and 2050

$Abanoned_{Likelihood}$ = Area of agricultural land (excluding Natura 2000 & HNV farmland) in the highest risk class for land abandonment

*For identification and quantification of degraded lands:*

The approach for assessing the SDG indicator 'proportion of land that is degraded over total land area' (SDG15.3.1) was used, but taking the expected land use flows for 2020-2050 as assessed in future modelling by CAPRI and allocated to land cover classes. The assessment method of the SDG indicator was originally elaborated by JRC and is explained here: https://docs.trends.earth/en/latest/for_users/features/landdegradation.html.

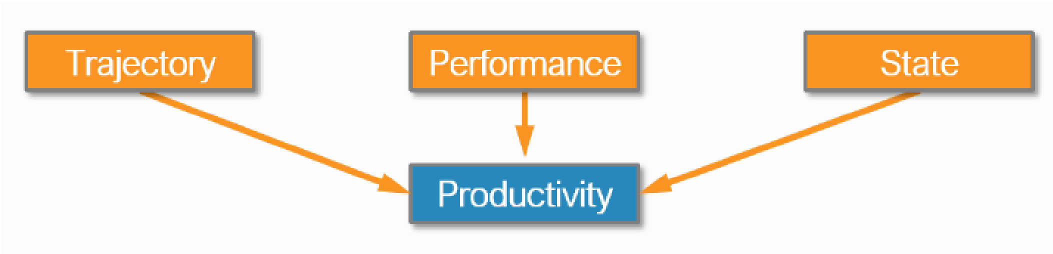
This indicator is composed of 3 sub-indicators:




*1. Productivity.*

The vegetation productivity is expressed in a Net Primary Productivity (NPP) and is the net amount of carbon assimilated after photosynthesis and autotrophic respiration over a given period of time (Clark et al. 2001) and is typically represented in units such as kg/ha/yr. In order to assess this JRC used the surrogates of NPP which is the Normalized Difference Vegetation Index (NDVI). From the bi-weekly products from MODIS and AVHRR annual integrals of NDVI are computed (computed as the mean annual NDVI for simplicity of interpretation of results). These annual integrals of NDVI were then used by JRC to compute each of the productivity indicators.

These three productivity indicators were then integrated into one final productivity indicator:




And classified as follows:

**Aggregating Land Productivity metrics**

| Trend | State | Performance | 5 Classes | 3 Classes |
|---|---|---|---|---|
| Improving | Improving | Stable | Improving | Improving |
| Improving | Improving | Degrading | Improving | Improving |
| Improving | Stable | Stable | Improving | Improving |
| Improving | Stable | Degrading | Improving | Improving |
| Improving | Degrading | Stable | Improving | Improving |
| Improving | Degrading | Degrading | Moderate decline | Degrading |
| Stable | Improving | Stable | Stable | Stable |
| Stable | Improving | Degrading | Stable | Stable |
| Stable | Stable | Stable | Stable | Stable |
| Stable | Stable | Degrading | Stressed | Stable |
| Stable | Degrading | Stable | Moderate decline | Degrading |
| Stable | Degrading | Degrading | Degrading | Degrading |
| Degrading | Improving | Stable | Degrading | Degrading |
| Degrading | Improving | Degrading | Degrading | Degrading |
| Degrading | Stable | Stable | Degrading | Degrading |
| Degrading | Stable | Degrading | Degrading | Degrading |
| Degrading | Degrading | Stable | Degrading | Degrading |
| Degrading | Degrading | Degrading | Degrading | Degrading |

*2. Land cover flow index*

The productivity index is then further combined with the land cover transitions derived between 2020 and 2030 and 2050. These transitions for future land cover changes were elaborated for 2020-2050 and covered expectation about future land use changes at km2 level based on future land use change scenarios (from Capri and Koevoet projects). These future land use transitions were then combined as follows:

Land cover in target year

| Land cover in initial year | Tree-covered | Grassland | Cropland | Wetland | Artificial | Other land | Water body |
|---|---|---|---|---|---|---|---|
| Tree-covered | 0 | - | - | - | - | - | 0 |
| Grassland | + | 0 | + | - | - | - | 0 |
| Cropland | + | - | 0 | - | - | - | 0 |
| Wetland | - | - | - | 0 | - | - | 0 |
| Artificial | + | + | + | + | 0 | + | 0 |
| Other land | + | + | + | + | - | 0 | 0 |
| Water body | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Legend**

| Degradation | Stable | Improvement |
|---|---|---|
| - | 0 | + |

*The "Grassland" class consists of grassland, shrub, and sparsely vegetated areas (if the default aggregation is used).

After this classification of the land cover flows the table of degradation typologies by land cover transition was computed to provide the land cover sub-indicator of potential land degradation.

3. State of Carbon

Finally this combined map is further combined with the Soil Organic Carbon map. For this Soilgrids is used. Per land cover class a C conversion factor is used as in the table underneath to calculate per land cover transition the changes in carbon stock. If the reduction of carbon stock is expected to be more then 10% then there is degradation.

| LU coefficients | Forest | Grasslands | Croplands | Wetlands | Artifical areas | Bare lands | Water bodies |
|---|---|---|---|---|---|---|---|
| Forest | 1 | 1 | f | 1 | 0.1 | 0.1 | 1 |
| Grasslands | 1 | 1 | f | 1 | 0.1 | 0.1 | 1 |
| Croplands | 1/f | 1/f | 1 | 1/0.71 | 0.1 | 0.1 | 1 |
| Wetlands | 1 | 1 | 0.71 | 1 | 0.1 | 0.1 | 1 |
| Artifical areas | 2 | 2 | 2 | 2 | 1 | 1 | 1 |
| Bare lands | 2 | 2 | 2 | 2 | 1 | 1 | 1 |
| Water bodies | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

Changes in SOC are better studied for land cover transitions involving agriculture, and for that reason there is a different set of coefficients for each of the main global climatic regions: Temperate Dry (f = 0.80), Temperate Moist (f = 0.69), Tropical Dry (f = 0.58), Tropical Moist (f = 0.48), and Tropical Montane (f = 0.64).

*Total abandoned and degraded land area 2030 and 2050*

Results in land availability show (see Table AA2- 3) a total of 3.3 million hectares in 2030 to 7.6 million hectares in 2050 in the technical scenario.

| In hectares | 2030-Abandoned | 2050-Abandoned | 2030-Degraded | 2050-Degraded |
|---|---|---|---|---|
| **Technical potential** | 3,350,798 | 7,633,725 | 4,996,751 | 31,958,700 |
| **Low scenario** | 816,717 | 3,586,324 | 100,024 | 1,599,210 |
| **Medium scenario** | 823,891 | 3,256,127 | 250,059 | 3,198,420 |
| **High scenario** | 1,159,915 | 4,405,475 | 500,118 | 6,396,840 |

Table A2 - 37 Abandoned and degraded land per scenario 2030 and 2050

- **The yield levels for the suitable intermediate crops in every environmental zone (see also Annex 3 & 4 of main report)**

The selection of crops (based on crop suitability) and crop yields was derived from MAGIC and BIKE project. In the following tables the crop mixes per environmental zones are presented which were combined with the land availability per scenario.

| | Yield oil (ton/ha/year) | | | Yield ton dm/ha/year | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Oil crop | | | Woody | | Lignocellulosic | | | | | |
| | Cardoon | Camelina | Castor | Willow | Poplar | Biomass sorghum | Miscanthus | Switchgrass | Giant reed | Reed Canary grass | Cardoon |
| **ALS** | | | | | | | | | | | |
| **ATC** | 0.28 | 0.4 | | 6 | 7 | | 8 | 10 | | 7 | 8 |
| **ATN** | | 0.4 | | 6 | | | 8 | 10 | | 7 | |
| **BOR** | | | | | | | | | | 7 | |
| **CON** | | 0.4 | | 6 | 7 | 9 | 9 | 12 | | 7 | |
| **LUS** | 0.28 | 0.4 | | 6 | 7 | 12 | 9 | 12 | 11 | 7 | 10 |
| **MDM** | 0.28 | 0.4 | 0.75 | | 7 | 12 | 9 | 12 | 11 | 7 | 10 |
| **MDN** | 0.28 | 0.4 | 0.75 | | 7 | 12 | 9 | 12 | 11 | 7 | 10 |
| **MDS** | 0.28 | 0.4 | 0.75 | | | 12 | 9 | 12 | 11 | 7 | 10 |
| **NEM** | | 0.4 | | 6 | | | | | | 7 | |
| **PAN** | 0.28 | 0.4 | | 6 | | 9 | 9 | 12 | | 7 | 10 |

Table A2 - 38 Crop mixes and yields (ton dry mass or ton oil/ha/yr) used on abandoned and degraded lands per environmental zone (See Annex 3 for abbreviations and locations of zones)

| | High 2020 yields | | | High 2050 yields | | |
|---|---|---|---|---|---|---|
| | Average yield (seeds/ha/year) | Average yield (ton dm/ha/year) | Average yield (seeds/ha/year) | Average yield (seeds/ha/year) | Average yield (ton dm/ha/year) | Average yield (seeds/ha/year) |
| | Oil crops | Woody crops | Lignocellulosic crops | Oil crops | Woody crops | Lignocellulosic crops |
| **ALS** | - | - | - | - | - | - |
| **ATC** | 0.38 | 7.18 | 9.11 | 0.46 | 8.76 | 11.12 |
| **ATN** | 0.44 | 6.63 | 9.21 | 0.54 | 8.09 | 11.23 |
| **BOR** | 0.00 | 0.00 | 8.89 | 0.00 | 0.00 | 11.79 |
| **CON** | 0.44 | 7.18 | 10.22 | 0.54 | 8.76 | 12.47 |
| **LUS** | 0.38 | 7.18 | 11.23 | 0.46 | 8.76 | 13.70 |
| **MDM** | 0.53 | 7.73 | 11.23 | 0.64 | 9.43 | 13.70 |
| **MDN** | 0.53 | 7.73 | 11.23 | 0.64 | 9.43 | 13.70 |
| **MDS** | 0.53 | 0.00 | 11.23 | 0.64 | 0.00 | 13.70 |
| **NEM** | 0.51 | 7.62 | 8.89 | 0.67 | 10.11 | 11.79 |
| **PAN** | 0.38 | 6.63 | 10.38 | 0.46 | 8.09 | 12.67 |

Table A2 - 39 Crop mixes and yields used on abandoned and degraded lands base line yields for technical scenario and high mobilisation scenario

| | Low 2030 | | | Low 2030 | | |
|---|---|---|---|---|---|---|
| | Average yield (seeds/ha/year) | Average yield (ton dm/ha/year) | Average yield (seeds/ha/year) | Average yield (seeds/ha/year) | Average yield (ton dm/ha/year) | Average yield (seeds/ha/year) |
| | Oil crops | Woody crops | Lignocellulosic crops | Oil crops | Woody crops | Lignocellulosic crops |
| **ALS** | | | | | | |
| **ATC** | 0.35 | 6.63 | 8.42 | 0.36 | 6.90 | 8.76 |
| **ATN** | 0.41 | 6.12 | 8.50 | 0.42 | 6.37 | 8.85 |
| **BOR** | 0.00 | 0.00 | 7.50 | 0.00 | 0.00 | 8.18 |
| **CON** | 0.41 | 6.63 | 9.44 | 0.42 | 6.90 | 9.82 |
| **LUS** | 0.35 | 6.63 | 10.37 | 0.36 | 6.90 | 10.79 |
| **MDM** | 0.44 | 6.43 | 9.33 | 0.40 | 5.95 | 8.64 |
| **MDN** | 0.44 | 6.43 | 9.33 | 0.40 | 5.95 | 8.64 |
| **MDS** | 0.44 | 0.00 | 9.33 | 0.40 | 0.00 | 8.64 |
| **NEM** | 0.41 | 6.43 | 7.50 | 0.47 | 7.01 | 8.18 |
| **PAN** | 0.36 | 6.12 | 9.59 | 0.36 | 6.69 | 9.98 |

Table A2 - 40 Crop mixes and yields used on abandoned and degraded lands yields for Low mobilisation scenario

| | Medium 2020 yields | | | Medium 2050 yields | | |
|---|---|---|---|---|---|---|
| | Average yield (seeds/ha/year) | Average yield (ton dm/ha/year) | Average yield (seeds/ha/year) | Average yield (seeds/ha/year) | Average yield (ton dm/ha/year) | Average yield (seeds/ha/year) |
| | Oil crops | Woody crops | Lignocellulosic crops | Oil crops | Woody crops | Lignocellulosic crops |
| **ALS** | | | | | | |
| **ATC** | 0.36 | 6.83 | 8.67 | 0.39 | 7.55 | 9.58 |
| **ATN** | 0.42 | 6.31 | 8.76 | 0.46 | 6.97 | 9.68 |
| **BOR** | 0.00 | 0.00 | 8.09 | 0.00 | 0.00 | 9.35 |
| **CON** | 0.42 | 6.83 | 9.72 | 0.46 | 7.55 | 10.74 |
| **LUS** | 0.36 | 6.83 | 10.69 | 0.39 | 7.55 | 11.81 |
| **MDM** | 0.48 | 6.62 | 10.15 | 0.50 | 7.32 | 10.63 |
| **MDN** | 0.48 | 6.62 | 10.15 | 0.50 | 7.32 | 10.63 |
| **MDS** | 0.48 | 0.00 | 10.15 | 0.50 | 0.00 | 10.63 |
| **NEM** | 0.46 | 6.94 | 8.09 | 0.53 | 8.01 | 9.35 |
| **PAN** | 0.36 | 6.31 | 9.88 | 0.39 | 6.97 | 10.92 |

Table A2 - 41 Crop mixes and yields used on abandoned and degraded lands yields for Medium mobilisation scenario

## Results

| | | 2030 | 2030 | 2050 | 2050 |
|---|---|---|---|---|---|
| | Technical | TP mln ton | %/total | TP mln ton | %/total |
| 2101 | Ligno_crops_unused_land | 16.6 | 1.0% | 49.5 | 2.7% |
| 2102 | Oil_crops_unused_land | 0.7 | 0.0% | 2.2 | 0.1% |
| 2103 | Woody_crops_unused_land | 17.2 | 1.1% | 29.2 | 1.6% |
| 2104 | Ligno_crops_degraded_land | 10.1 | 0.6% | 133.2 | 7.2% |
| 2105 | Oil_crops_degraded_land | 0.8 | 0.0% | 5.8 | 0.3% |
| 2106 | Woody_crops_degraded_land | 9.4 | 0.6% | 72.9 | 3.9% |
| | | 2030 | 2030 | 2050 | 2050 |
| | Low scenario | Low mln ton | %/total | Low mln ton | %/total |
| 2101 | Ligno_crops_unused_land | 1.5 | 0.5% | 6.4 | 2.1% |
| 2102 | Oil_crops_unused_land | 0.1 | 0.0% | 0.3 | 0.1% |

| | | 2030 | 2030 | 2050 | 2050 |
|---|---|---|---|---|---|
| | Technical | TP mln ton | %/total | TP mln ton | %/total |
| 2103 | Woody_crops_unused_land | 0.3 | 0.1% | 3.9 | 1.3% |
| 2104 | Ligno_crops_degraded_land | 0.9 | 0.3% | 4.8 | 1.6% |
| 2105 | Oil_crops_degraded_land | 0.0 | 0.0% | 0.2 | 0.1% |
| 2106 | Woody_crops_degraded_land | 0.2 | 0.1% | 2.7 | 0.9% |
| | | 2030 | 2030 | 2050 | 2050 |
| | Medium scenario | Medium mln ton | %/total | Medium mln ton | %/total |
| **2101** | Ligno_crops_unused_land | 2.9 | 2.1% | 12.3 | 2.6% |
| **2102** | Oil_crops_unused_land | 0.1 | 0.5% | 0.5 | 2.3% |
| **2103** | Woody_crops_unused_land | 0.8 | 0.0% | 7.4 | 0.1% |
| **2104** | Ligno_crops_degraded_land | 1.7 | 0.1% | 11.0 | 1.4% |
| **2105** | Oil_crops_degraded_land | 0.0 | 0.3% | 0.5 | 2.0% |
| **2106** | Woody_crops_degraded_land | 0.4 | 0.0% | 6.1 | 0.1% |
| | | 2030 | 2030 | 2050 | 2050 |
| | High scenario | High mln ton | %/total | High mln ton | %/total |
| **2101** | Ligno_crops_unused_land | 4.7 | 0.5% | 21.1 | 2.3% |
| **2102** | Oil_crops_unused_land | 0.2 | 0.0% | 0.9 | 0.1% |
| **2103** | Woody_crops_unused_land | 1.7 | 0.2% | 12.5 | 1.3% |
| **2104** | Ligno_crops_degraded_land | 2.8 | 0.3% | 26.6 | 2.9% |
| **2105** | Oil_crops_degraded_land | 0.1 | 0.0% | 1.2 | 0.1% |
| **2106** | Woody_crops_degraded_land | 0.9 | 0.1% | 14.6 | 1.6% |

Table A2 - 42 Total Europe in 2030 and 2050 for technical, low, medium and high mobilisation scenario

| | 2101: Ligno_crops_unused_land | | | | 2102: Oil_crops_unused_land | | | | 2103: Woody_crops_unused_land | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | High | Low | Medium | tp | High | Low | Medium | tp | High | Low | Medium | tp |
| AL | | | | | | | | | | | | |
| AT | 19714 | 2842 | 10844 | 86262 | 839 | 121 | 461 | 3671 | 13727 | 1975 | 7549 | 60081 |
| BA | | | | | | | | | | | | |
| BG | 124351 | 2122 | 60258 | 612564 | 5377 | 92 | 2606 | 26489 | 87381 | 1491 | 42343 | 430450 |
| BL | 17581 | | 8365 | 87905 | 742 | | 353 | 3710 | 13120 | | 6242 | 65598 |
| CS | 24592 | 0 | 11701 | 122960 | 1063 | 0 | 506 | 5317 | 17281 | 0 | 8222 | 86405 |
| CY | 4399 | 1749 | 2939 | 13582 | 206 | 82 | 138 | 637 | 0 | 0 | 0 | 0 |
| CZ | 81957 | 6190 | 42184 | 382975 | 3544 | 268 | 1824 | 16561 | 57592 | 4350 | 29643 | 269118 |
| DE | 252801 | 29791 | 135628 | 1134981 | 11097 | 1316 | 5958 | 49782 | 182855 | 21358 | 98004 | 821771 |
| DK | 10285 | 952 | 5384 | 47305 | 494 | 46 | 258 | 2271 | 7405 | 685 | 3876 | 34060 |
| EE | 6429 | 0 | 3059 | 32145 | 278 | 0 | 132 | 1390 | 4518 | 0 | 2149 | 22588 |
| EL | 110707 | 1122 | 50650 | 548134 | 5191 | 53 | 2375 | 25699 | | | | |
| ES | 932162 | 401558 | 641168 | 2743076 | 42384 | 18417 | 29222 | 123784 | 355905 | 160867 | 238266 | 1014775 |
| FI | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| FR | 672084 | 301892 | 473876 | 2037688 | 28284 | 12608 | 19886 | 86101 | 497126 | 224123 | 348785 | 1504459 |
| HR | 54856 | 50663 | 52200 | 54856 | 2372 | 2191 | 2257 | 2372 | 38548 | 35601 | 36681 | 38548 |
| HU | 114410 | 7804 | 58456 | 538254 | 4138 | 296 | 2114 | 19469 | 73028 | 4981 | 37312 | 343566 |
| IR | 14054 | | 6687 | 70271 | 579 | | 276 | 2896 | 11073 | | 5268 | 55365 |
| IT | 823357 | 415284 | 597988 | 2118307 | 38603 | 19471 | 28037 | 99317 | 501720 | 250033 | 343653 | 1305362 |
| KO | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| LT | 24007 | 13556 | 18406 | 61322 | 1038 | 586 | 796 | 2652 | 16870 | 9526 | 12934 | 43091 |
| LV | 3372 | 3114 | 3209 | 3372 | 146 | 135 | 139 | 146 | 2370 | 2189 | 2255 | 2370 |
| MK | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| MO | 308 | 0 | 147 | 1541 | 13 | 0 | 6 | 67 | 217 | 0 | 103 | 1083 |
| MT | 374 | 311 | 338 | 374 | 18 | 15 | 16 | 18 | 0 | 0 | 0 | 0 |
| NL | 32712 | 1931 | 16559 | 155193 | 1403 | 86 | 712 | 6644 | 25224 | 1462 | 12755 | 119792 |
| NO | 6487 | 0 | 2952 | 32434 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| PL | 203362 | 39652 | 117186 | 845074 | 8794 | 1715 | 5067 | 36544 | 142903 | 27864 | 82347 | 593836 |
| PT | 76611 | 4903 | 38409 | 360629 | 2923 | 197 | 1466 | 13703 | 35268 | 1646 | 17465 | 169169 |
| RO | 218571 | 7944 | 108087 | 1058452 | 9452 | 344 | 4674 | 45771 | 153591 | 5582 | 75953 | 743777 |

| | 2101: Ligno_crops_unused_land | | | | 2102: Oil_crops_unused_land | | | | 2103: Woody_crops_unused_land | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | High | Low | Medium | tp | High | Low | Medium | tp | High | Low | Medium | tp |
| SE | 15995 | | 7279 | 79976 | 355 | | 162 | 1775 | 5325 | | 2424 | 26626 |
| SI | 12933 | 1005 | 6671 | 60309 | 559 | 43 | 288 | 2608 | 9088 | 706 | 4688 | 42379 |
| SK | 43683 | 6632 | 22499 | 204003 | 1757 | 279 | 905 | 8210 | 29498 | 4563 | 15190 | 137782 |
| TR | 553746 | 0 | 250294 | 2768729 | 25963 | 0 | 11753 | 129813 | 381268 | 0 | 163264 | 1906338 |
| UK | 198416 | 162423 | 178080 | 288614 | 8940 | 7368 | 8049 | 12787 | 148700 | 121224 | 133202 | 218468 |

Table A2 - 43 Supply on unused lands per country and scenario for 2030

| | 2104: Ligno_crops_degraded_land | | | | 2105: Oil_crops_degraded_land | | | | 2106: Woody_crops_degraded_land | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | High | Low | Medium | tp | High | Low | Medium | tp | High | Low | Medium | tp |
| AL | | | | | | | | | | | | |
| AT | 30879 | 5704 | 14692 | 308792 | 1258 | 236 | 599 | 12585 | 20999 | 3879 | 9991 | 209993 |
| BA | | | | | | | | | | | | |
| BG | 79108 | 14612 | 37639 | 791081 | 3421 | 632 | 1628 | 34209 | 55589 | 10268 | 26449 | 555895 |
| BL | 23579 | 4355 | 11219 | 235788 | 1019 | 188 | 485 | 10188 | 16602 | 3067 | 7899 | 166023 |
| CS | 119 | 22 | 57 | 1195 | 5 | 1 | 2 | 52 | 84 | 16 | 40 | 840 |
| CY | 18190 | 3024 | 8222 | 181904 | 853 | 142 | 385 | 8529 | 0 | 0 | 0 | 0 |
| CZ | 55604 | 10271 | 26456 | 556044 | 2405 | 444 | 1144 | 24045 | 39073 | 7217 | 18591 | 390734 |
| DE | 212227 | 39201 | 100976 | 2122267 | 9268 | 1712 | 4410 | 92683 | 153482 | 28350 | 73025 | 1534820 |
| DK | 2066 | 382 | 983 | 20656 | 99 | 18 | 47 | 992 | 1487 | 275 | 708 | 14873 |
| EE | 1509 | 279 | 718 | 15086 | 65 | 12 | 31 | 652 | 1060 | 196 | 504 | 10601 |
| EL | 177339 | 29481 | 80158 | 1773392 | 8315 | 1382 | 3758 | 83146 | | | | |
| ES | 254280 | 43339 | 116310 | 2542798 | 11145 | 1888 | 5084 | 111453 | 90231 | 15682 | 40396 | 902310 |
| FI | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| FR | 161955 | 29407 | 76402 | 1619552 | 6870 | 1245 | 3238 | 68703 | 118457 | 21530 | 55460 | 1184573 |
| HR | 12164 | 2247 | 5787 | 121635 | 526 | 97 | 250 | 5260 | 8547 | 1579 | 4067 | 85473 |
| HU | 74892 | 13833 | 35633 | 748920 | 2709 | 525 | 1289 | 27089 | 47803 | 8830 | 22744 | 478034 |
| IR | 5191 | 959 | 2470 | 51907 | 214 | 40 | 102 | 2139 | 4090 | 755 | 1946 | 40896 |
| IT | 278403 | 46282 | 125839 | 2784029 | 13053 | 2170 | 5900 | 130530 | 179119 | 29777 | 76701 | 1791192 |
| KO | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| LT | 2349 | 434 | 1118 | 23494 | 102 | 19 | 48 | 1016 | 1651 | 305 | 785 | 16509 |

| | 2104: Ligno_crops_degraded_land | | | | 2105: Oil_crops_degraded_land | | | | 2106: Woody_crops_degraded_land | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | High | Low | Medium | tp | High | Low | Medium | tp | High | Low | Medium | tp |
| LV | 2055 | 380 | 978 | 20546 | 89 | 16 | 42 | 888 | 1444 | 267 | 687 | 14438 |
| MK | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| MO | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| MT | 182 | 30 | 82 | 1822 | 9 | 1 | 4 | 85 | 0 | 0 | 0 | 0 |
| NL | 18821 | 3476 | 8955 | 188212 | 803 | 148 | 382 | 8028 | 14558 | 2689 | 6926 | 145578 |
| NO | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| PL | 75138 | 13879 | 35750 | 751377 | 3249 | 600 | 1546 | 32492 | 52799 | 9753 | 25122 | 527995 |
| PT | 66057 | 11556 | 30598 | 660570 | 2679 | 465 | 1236 | 26786 | 20019 | 3696 | 9519 | 200187 |
| RO | 75538 | 13953 | 35940 | 755377 | 3266 | 603 | 1554 | 32665 | 53081 | 9805 | 25255 | 530806 |
| SE | 9936 | 1714 | 4572 | 99357 | 343 | 58 | 158 | 3428 | 5273 | 916 | 2435 | 52725 |
| SI | 11971 | 2211 | 5696 | 119708 | 518 | 96 | 246 | 5177 | 8412 | 1554 | 4002 | 84119 |
| SK | 35995 | 6649 | 17126 | 359948 | 1421 | 269 | 676 | 14208 | 24058 | 4444 | 11447 | 240581 |
| TR | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| UK | 33932 | 6268 | 16144 | 339317 | 1494 | 276 | 711 | 14944 | 25774 | 4761 | 12263 | 257737 |

Table A2 - 44 Supply on degraded lands per country and scenario for 2030

| | 2101: Ligno_crops_unused_land | | | | 2102: Oil_crops_unused_land | | | | 2103: Woody_crops_unused_land | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | High | Low | Medium | tp | High | Low | Medium | tp | High | Low | Medium | tp |
| AL | | | | | | | | | | | | |
| AT | 142675 | 40339 | 83531 | 356099 | 6063 | 1713 | 3549 | 15137 | 99284 | 28200 | 58119 | 247843 |
| BA | | | | | | | | | | | | |
| BG | 835681 | 34867 | 379110 | 2682327 | 36138 | 1508 | 16394 | 115993 | 587235 | 24501 | 266401 | 1884878 |
| BL | 75539 | 13821 | 40104 | 210860 | 3182 | 580 | 1688 | 8890 | 56613 | 10458 | 30110 | 157735 |
| CS | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| CY | 26125 | 10397 | 16527 | 48590 | 1225 | 487 | 775 | 2278 | 0 | 0 | 0 | 0 |
| CZ | 587286 | 207606 | 366566 | 1342691 | 25396 | 8978 | 15852 | 58062 | 412688 | 145885 | 257587 | 943512 |
| DE | 1471466 | 338817 | 819263 | 3901307 | 64388 | 14968 | 35927 | 170289 | 1065051 | 242711 | 591604 | 2831257 |
| DK | 51331 | 0 | 22115 | 171102 | 2464 | 0 | 1062 | 8213 | 36958 | 0 | 15923 | 123193 |
| EE | 39392 | 2942 | 18580 | 122592 | 1703 | 127 | 803 | 5301 | 27681 | 2067 | 13056 | 86146 |
| EL | 968927 | 158453 | 473196 | 2643082 | 45428 | 7429 | 22186 | 123922 | | | | |

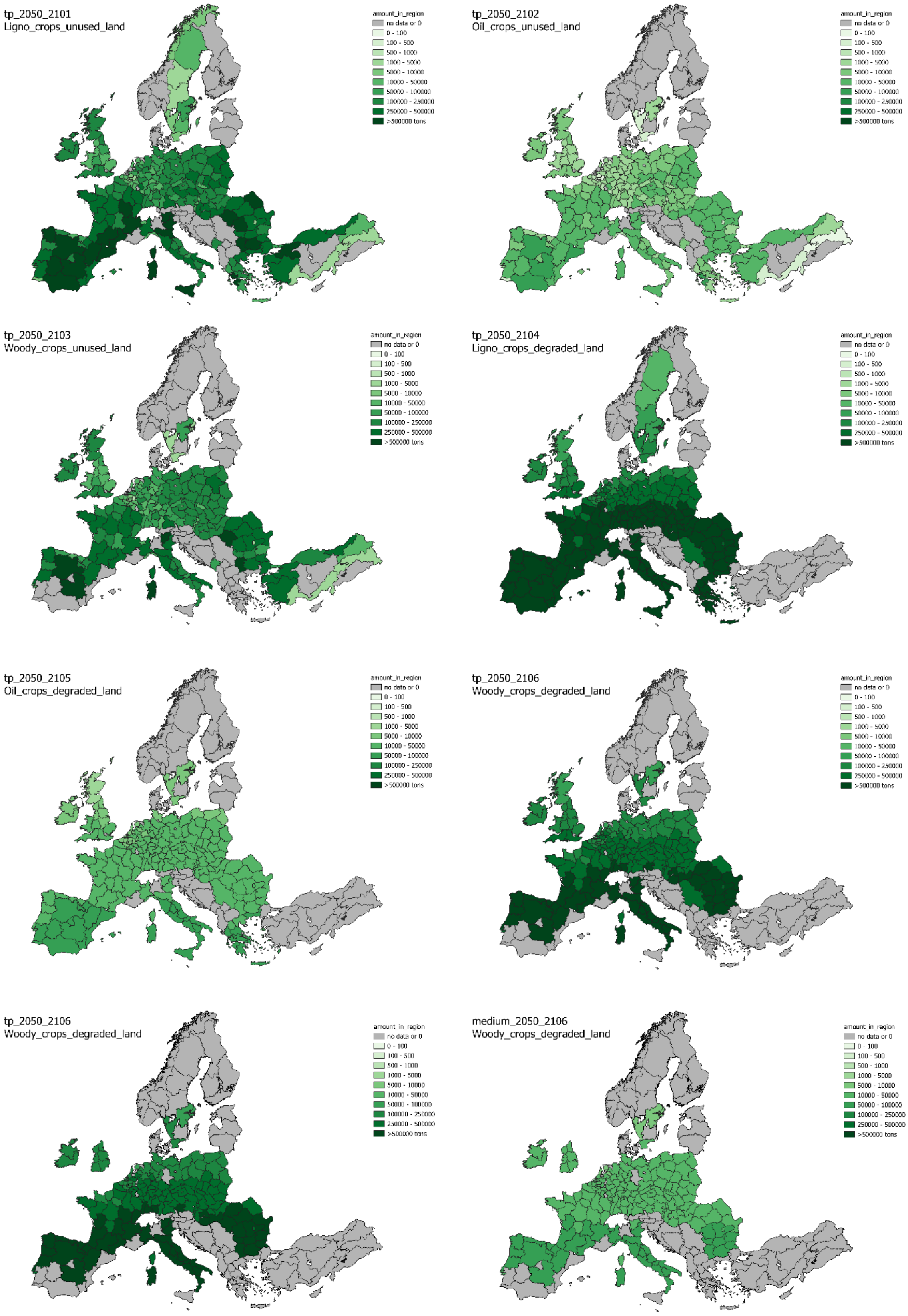
| | 2101: Ligno_crops_unused_land | | | | 2102: Oil_crops_unused_land | | | | 2103: Woody_crops_unused_land | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **High** | **Low** | **Medium** | **tp** | **High** | **Low** | **Medium** | **tp** | **High** | **Low** | **Medium** | **tp** |
| ES | 4246130 | 1547257 | 2604726 | 8522935 | 194299 | 70766 | 119091 | 388924 | 1570711 | 629586 | 1000436 | 2967249 |
| FI | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| FR | 3320020 | 1222259 | 2079173 | 7360121 | 140512 | 51004 | 87509 | 313253 | 2446304 | 907999 | 1537002 | 5405448 |
| HR | 217723 | 171512 | 187605 | 217723 | 9415 | 7417 | 8113 | 9415 | 152994 | 120522 | 131831 | 152994 |
| HU | 614666 | 106014 | 322800 | 1734873 | 22233 | 3835 | 11676 | 62751 | 392340 | 71052 | 206043 | 1107366 |
| IR | 130831 | 41658 | 79150 | 312713 | 5392 | 1717 | 3262 | 12888 | 103079 | 32821 | 62361 | 246380 |
| IT | 2949266 | 877490 | 1683483 | 6581973 | 138277 | 41141 | 78931 | 308597 | 1829368 | 533218 | 1037418 | 4123649 |
| KO | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| LT | 85044 | 66994 | 73280 | 85044 | 3678 | 2897 | 3169 | 3678 | 59761 | 47077 | 51494 | 59761 |
| LV | 20359 | 16038 | 17543 | 20359 | 880 | 694 | 759 | 880 | 14307 | 11270 | 12328 | 14307 |
| MK | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| MO | 42120 | 0 | 18147 | 140401 | 1821 | 0 | 785 | 6071 | 29598 | 0 | 12752 | 98660 |
| MT | 1335 | 842 | 1036 | 1335 | 63 | 39 | 49 | 63 | 0 | 0 | 0 | 0 |
| NL | 124487 | | 53633 | 414958 | 5341 | | 2301 | 17804 | 95973 | | 41348 | 319910 |
| NO | 46844 | 0 | 18567 | 156147 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| PL | 1740692 | 687979 | 1126217 | 3764508 | 75273 | 29750 | 48701 | 162790 | 1223189 | 483444 | 791395 | 2645330 |
| PT | 308794 | 13091 | 135332 | 986107 | 11973 | 518 | 5214 | 38167 | 134258 | 4775 | 59819 | 433212 |
| RO | 1414188 | 305209 | 776205 | 3809928 | 61154 | 13198 | 33566 | 164754 | 993754 | 214471 | 545441 | 2677247 |
| SE | 71277 | 19976 | 39754 | 172071 | 2320 | 688 | 1316 | 5492 | 35092 | 10550 | 19998 | 82673 |
| SI | 59147 | 11526 | 31786 | 163016 | 2558 | 498 | 1375 | 7049 | 41563 | 8099 | 22336 | 114552 |
| SK | 204670 | 81595 | 110573 | 560951 | 8238 | 3397 | 4446 | 22603 | 138243 | 56735 | 74643 | 379121 |
| TR | 624211 | 0 | 242039 | 2080703 | 29266 | 0 | 11348 | 97554 | 429785 | 0 | 166649 | 1432615 |
| UK | 652813 | 421683 | 511879 | 927014 | 29366 | 19128 | 23113 | 41230 | 489715 | 314742 | 383123 | 700114 |

Table A2 - 45 Supply on unused lands per country and scenario for 2050

| | 2104: Ligno_crops_degraded_land | | | | 2105: Oil_crops_degraded_land | | | | 2106: Woody_crops_degraded_land | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | High | Low | Medium | tp | High | Low | Medium | tp | High | Low | Medium | tp |
| AL | | | | | | | | | | | | |
| AT | 443095 | 87262 | 190900 | 2215473 | 18057 | 3556 | 7780 | 90287 | 301316 | 60321 | 129817 | 1506581 |
| BA | | | | | | | | | | | | |
| BG | 1155913 | 227644 | 498007 | 5779565 | 49985 | 9844 | 21535 | 249927 | 812263 | 159966 | 349951 | 4061316 |
| BL | 617414 | 121592 | 266003 | 3087068 | 26109 | 5142 | 11249 | 130544 | 458610 | 90318 | 197585 | 2293050 |
| CS | 88354 | 17400 | 38066 | 441769 | 3821 | 752 | 1646 | 19104 | 62086 | 12227 | 26749 | 310432 |
| CY | 265749 | 41869 | 103045 | 1328747 | 12460 | 1963 | 4831 | 62299 | 0 | 0 | 0 | 0 |
| CZ | 840898 | 165605 | 362288 | 4204491 | 36363 | 7161 | 15667 | 181816 | 590901 | 116371 | 254581 | 2954507 |
| DE | 3089345 | 608411 | 1330997 | 15446723 | 134836 | 26554 | 58092 | 674180 | 2235327 | 440222 | 963056 | 11176633 |
| DK | 30102 | 5928 | 12969 | 150510 | 1445 | 285 | 623 | 7224 | 21673 | 4268 | 9338 | 108367 |
| EE | 21195 | 4174 | 9132 | 105975 | 917 | 181 | 395 | 4583 | 14894 | 2933 | 6417 | 74469 |
| EL | 2935302 | 462459 | 1138167 | 14676510 | 137622 | 21683 | 53363 | 688112 | | | | |
| ES | 3706057 | 617150 | 1473407 | 18530287 | 162409 | 26700 | 64191 | 812043 | 1316287 | 228646 | 533651 | 6581434 |
| FI | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| FR | 2679109 | 507394 | 1132130 | 13395544 | 114055 | 21514 | 48102 | 570275 | 1960797 | 372230 | 829547 | 9803983 |
| HR | 173965 | 34260 | 74950 | 869823 | 7523 | 1482 | 3241 | 37614 | 122245 | 24075 | 52668 | 611227 |
| HU | 1080141 | 212721 | 465362 | 5400705 | 39069 | 7694 | 16832 | 195345 | 689452 | 142568 | 297040 | 3447258 |
| IR | 73613 | 14497 | 31715 | 368064 | 3034 | 597 | 1307 | 15169 | 57998 | 11422 | 24988 | 289990 |
| IT | 4054117 | 638729 | 1571989 | 20270584 | 190078 | 29947 | 73703 | 950391 | 2607378 | 410794 | 1011014 | 13036889 |
| KO | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| LT | 34078 | 6711 | 14682 | 170391 | 1474 | 290 | 635 | 7368 | 23947 | 4716 | 10317 | 119734 |
| LV | 30005 | 5909 | 12927 | 150027 | 1298 | 256 | 559 | 6488 | 21085 | 4152 | 9084 | 105424 |
| MK | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| MO | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| MT | 134747 | 21230 | 52248 | 673737 | 6318 | 995 | 2450 | 31588 | 0 | 0 | 0 | 0 |
| NL | 489000 | 96303 | 210678 | 2444998 | 20926 | 4121 | 9016 | 104629 | 377541 | 74352 | 162658 | 1887707 |
| NO | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| PL | 1083352 | 213354 | 466745 | 5416758 | 46848 | 9226 | 20184 | 234238 | 761274 | 149924 | 327983 | 3806370 |
| PT | 1088029 | 189353 | 441501 | 5440143 | 44892 | 7673 | 18063 | 224460 | 377209 | 70895 | 158805 | 1886045 |

| | 2104: Ligno_crops_degraded_land | | | | 2105: Oil_crops_degraded_land | | | | 2106: Woody_crops_degraded_land | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **High** | **Low** | **Medium** | **tp** | **High** | **Low** | **Medium** | **tp** | **High** | **Low** | **Medium** | **tp** |
| RO | 1189908 | 234339 | 512654 | 5949540 | 51455 | 10134 | 22169 | 257277 | 836152 | 164670 | 360243 | 4180758 |
| SE | 154825 | 27663 | 62580 | 774126 | 5321 | 958 | 2162 | 26607 | 81720 | 14746 | 33243 | 408600 |
| SI | 171305 | 33737 | 73804 | 856524 | 7408 | 1459 | 3192 | 37039 | 120376 | 23707 | 51862 | 601882 |
| SK | 525784 | 103547 | 226526 | 2628921 | 20754 | 4087 | 8942 | 103772 | 351420 | 70970 | 151404 | 1757101 |
| TR | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| UK | 485145 | 95544 | 209017 | 2425727 | 21371 | 4209 | 9208 | 106857 | 368461 | 72564 | 158746 | 1842307 |

Table A2 - 46 Supply on degraded lands per country and scenario for 2050




Map 1 Distribution over Europe

## Evaluation

### General observations

*Describe general observations on e.g. approach of assessment, scenario approach, results in numbers (amounts and price levels), spatial distribution, comparison with PRIMES*

An elaborate model is used to calculate the abandoned and degraded land on a regional level and results of previous projects are used to estimated expected yields of different crop types.

### Strength

*Please indicate what you regard as a strength in the assessment of results*

The methodology for evaluating abandoned and degraded land is very detailed and builds upon results of previous projects.

### Weaknesses

*Please indicate what you regard as a weakness in the assessment*

The percentages used in various mobilization scenarios are ad hoc parameters.

The methodology for estimating the land that is abandoned or degraded is not benchmarked for current data (or at least details are not shown in this factsheet).

### Options for improvement?

*Please indicate what can or really needs to be improved.*

It should be clarified whether the average crop yield in the different mobilization scenarios is based on a simple arithmetic average of the crops suitable for each climate zone or whether another methodology is employed.

The way abandoned/degraded land is “divided” between oil, woody and lignocellulosic crops should be elaborated.

COMMENT authors: Crops yields are based on work in both MAGIC and BIKE projects and were based on real experiments in the different climate zones.

## SWOT 4 – Intermediate crops sorghum and oil crops (2107 & 2008) and cover crops (2109)

### Description of approach

For the assessment of the potential from intermediate and cover crops three steps were followed:

- **Identify type of intercrop and cover crop systems and available land area 2030 and 2050**

Three cropping systems were selected based on the experiences with intecropping in MAGIC and BIKE.

1) Intercropping with biomass sorghum in Mediterranean, Lusitanian, Continental and Pannonian climate zones where growing season is long enough to combine wintercrops (wheat, barley, oil seed rape) for food with a short season biomass crop. Experience in trials was obtained with this in MAGIC (Mediterranean, different locations) and in Germany (Martin & Barthelmes, 2016).

2) Intercropping with Camelina oil crop in Mediterranean, Lusitanian, Continental and Pannonian climate zones where growing season is long enough to combine wintercrops (wheat, barley, oil seed rape) for food with a short season oil crop. Experience in trials was obtained with this in BIKE and MAGIC (Mediterranean, different locations) (Elbersen et al., 2022 and Alexopoulou, 2018).

3) For the Atlantic, Continental, Lusitanian and Pannonian zone the growing season it too short for and intercrop. Instead a novel cropping systems is expected to be developed in which a cover crop (after winter) is harvested delivering biomass, 4 ton dm per year, while also providing the function of soil coverage during winter to avoid erosion and leaching of remaining excess nitrogen to water.

- **The amount of lands by 2030 and 2050 (see also Annex 4 of main report)**

For intercropping with biomass sorghum data were collected from Ballot et al. (2022) who estimated the different crop rotations practices in all EU regions based on LUCAS points on land management. From this per region an arable land area share could be derived of rotations only using winter crops and leaving lands fallow over spring and summer period.

For intercropping with the oil crop Camelina the same land as for biomass sorghum from (Ballot et al. (2022) was used allocating half of the land to sorghum and half to Camelina.

For the harvested cover crop the practice was in principle to be practices in all arable land where rotational cropping is practiced. For the technical potential this would cover all the arable land, but for the mobilisation scenarios only a share of this land would be covered by this practice. See scenario assumptions.

This then resulted in land availability as in Table 1.

| Hectares | 2030-Land intercropping | 2050-Land intercropping | Cover crop 2030 | Cover crop 2050 |
|---|---|---|---|---|
| **Technical potential** | 28,364,851 | 26,358,309 | 279,966 | 273,288 |
| **Low senario** | 84,487 | 158,784 | 1,400 | 2,733 |
| **Medium scenario** | 337,949 | 635,138 | 5,599 | 10,932 |
| **High scenario** | 844,873 | 1,587,845 | 13,998 | 273 |

Table A2 - 47 Land availability for intercrops and cover crops in the scenarios

- **The suitable lignocellulosic , oil and woody crop mix per environmental zone (see also Annex 3 & 4 of main report)**

| | High 2030 yields | | | High 2050 yields | | |
|---|---|---|---|---|---|---|
| | **Oil crop Camelina (ton oil seeds)** | **Lignocellulose (biomass sorghum) (ton dm)** | **Harvested (ton dm)** | **Oil crop Camelina (ton oil seeds)** | **Lignocellulose (biomass sorghum) (ton dm)** | **Harvested (ton dm)** |
| **ALS** | 0 | 0 | 0 | 0 | 0 | 0 |
| **ATC** | 0.00 | 0.00 | 4.42 | 0.00 | 0.00 | 5.39 |

| | High 2030 yields | | | High 2050 yields | | |
|---|---|---|---|---|---|---|
| | Oil crop Camelina (ton oil seeds) | Lignocellulose (biomass sorghum) (ton dm) | Harvested (ton dm) | Oil crop Camelina (ton oil seeds) | Lignocellulose (biomass sorghum) (ton dm) | Harvested (ton dm) |
| **ATN** | 0.00 | 0.00 | 4.42 | 0.00 | 0.00 | 5.39 |
| **BOR** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **CON** | 2.21 | 9.94 | 4.42 | 2.70 | 12.13 | 5.39 |
| **LUS** | 2.76 | 9.94 | 4.42 | 3.37 | 12.13 | 5.39 |
| **MDM** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **MDN** | 3.31 | 13.26 | 0.00 | 4.04 | 16.17 | 0.00 |
| **MDS** | 3.31 | 13.26 | 0.00 | 4.04 | 16.17 | 0.00 |
| **NEM** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **PAN** | 2.21 | 9.94 | 4.42 | 2.70 | 12.13 | 5.39 |

Table A2 - 48 Crop mixes and yields used on arable land for technical scenario and high mobilisation scenario (Tonnes/ha/yr)

| | Low 2030 | | | Low 2030 | | |
|---|---|---|---|---|---|---|
| | Oil crop Camelina (ton oil seeds) | Lignocellulose (biomass sorghum) (ton dm) | Harvested (ton dm) | Oil crop Camelina (ton oil seeds) | Lignocellulose (biomass sorghum) (ton dm) | Harvested (ton dm) |
| **ALS** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **ATC** | 0.00 | 0.00 | 4.08 | 0.00 | 0.00 | 4.25 |
| **ATN** | 0.00 | 0.00 | 4.08 | 0.00 | 0.00 | 4.25 |
| **BOR** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **CON** | 2.04 | 9.18 | 4.08 | 2.12 | 9.56 | 4.25 |
| **LUS** | 2.55 | 9.18 | 4.08 | 2.65 | 9.56 | 4.25 |
| **MDM** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **MDN** | 2.75 | 11.02 | 0.00 | 2.55 | 10.19 | 0.00 |
| **MDS** | 2.75 | 11.02 | 0.00 | 2.55 | 10.19 | 0.00 |
| **NEM** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **PAN** | 2.04 | 9.18 | 4.08 | 2.12 | 9.56 | 4.25 |

Table A2 - 49 Crop mixes and yields used on arable lands yields for Low mobilisation scenario (Tonnes/ha/yr)

| | Medium 2020 yields | | | Medium 2050 yields | | |
|---|---|---|---|---|---|---|
| | Oil crop Camelina (ton oil seeds) | Lignocellulose (biomass sorghum) (ton dm) | Harvested (ton dm) | Oil crop Camelina (ton oil seeds) | Lignocellulose (biomass sorghum) (ton dm) | Harvested (ton dm) |
| **ALS** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **ATC** | 0.00 | 0.00 | 4.20 | 0.00 | 0.00 | 4.65 |
| **ATN** | 0.00 | 0.00 | 4.20 | 0.00 | 0.00 | 4.65 |
| **BOR** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **CON** | 2.10 | 9.46 | 4.20 | 2.32 | 10.45 | 4.65 |
| **LUS** | 2.63 | 9.46 | 4.20 | 2.90 | 10.45 | 4.65 |
| **MDM** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **MDN** | 3.00 | 11.98 | 0.00 | 3.14 | 12.54 | 0.00 |
| **MDS** | 3.00 | 11.98 | 0.00 | 3.14 | 12.54 | 0.00 |
| **NEM** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **PAN** | 2.10 | 9.46 | 4.20 | 2.32 | 10.45 | 4.65 |

Table A2 - 50 Crop mixes and yields used on arable lands yields for Medium mobilisation scenario (Tonnes/ha/yr)

- **Combine land availability 2030 and 2050 with crop mix and yield levels**

In this step the land availability per scenario is multiplied by the crop yield. The crop mix assumed on the available arable land. Results in land availability show (see Table 2) the land availability for intermediate crops and for cover crops in the different scenarios. Cover crop are is much smaller then the land available for intermediate crops. Differences between what is technically possible and what is taken up in the scenarios is very different because of relatively low mobilisation rates assumed.

| Hectares | 2030-Land intercropping | 2050-Land intercropping | Cover crop 2030 | Cover crop 2050 |
|---|---|---|---|---|
| **Technical potential** | 28,364,851 | 26,358,309 | 279,966 | 273,288 |
| **Low senario** | 84,487 | 158,784 | 1,400 | 2,733 |
| **Medium scenario** | 337,949 | 635,138 | 5,599 | 10,932 |
| **High scenario** | 844,873 | 1,587,845 | 13,998 | 27,300 |

Table A2 - 51 Land availability (Hectares) for intercrops and cover crops in the scenarios

- **Apply the scenario assumptions**

The scenario assumptions for the allocation of crops to land and the development in the future are presented in the Table 7.

| Description of biomass category | Issue | Technical potential | Low mobilisation | Medium mobilisation | High mobilisation |
|---|---|---|---|---|---|
| Intermediate crops LUCAS (Ballot et al., 2022) | How much | (50% Oil crop (camelina) and 50% biomass sorghum) | 50% Oil crop (camelina) and 50% biomass sorghum | 50% Oil crop (camelina) and 50% biomass sorghum | 50% Oil crop (camelina) and 50% biomass sorghum |
| | ENZ | Intercrops in MDN, MDS, CON, PAN, LUS** | Where: in MDN, MDS, CON, PAN, LUS** | Where: in MDN, MDS, CON, PAN, LUS** | Where: in MDN, MDS, CON, PAN, LUS** |
| | Available land? | 100% of available arable land with only wintercrops | In 2030 0.5% and 1% in 2050 of available arable land with only wintercrops | In 2030 2% and 4% in 2050 of available arable land with only wintercrops | In 2030 5% and 10% in 2050 of available arable land with only wintercrops |
| | Yield increase assumed | 1% per year | 0.2% per year | 0.5% per year | 1% per year |
| | Climate change effect on yields (based on EEA, 2019) | No effect on yields | In Mediterranean zone: up to 2030 10% total yield decrease and up to 2050 20% yield **de**crease<br>In Boreal & Nemoral zone: 2030: 5%/2050: 10% yield **in**crease in all crops | In Mediterranean zone: up to 2030 5% total yield decrease and up to 2050 10% yield **de**crease<br>In Boreal & Nemoral zone: 2030: 5%/2050: 15% yield **in**crease in all crops | In Mediterranean zone: NO yield decrease expected<br>In Boreal & Nemoral zone: 2030: 15%/2050: 25% yield **in**crease in all crops |
| Cover crops | ENZ | ATN, ATC, CON, LUS, PAN | ATN, ATC, CON, LUS, PAN | ATN, ATC, CON, LUS, PAN | ATN, ATC, CON, LUS, PAN |
| | Available land? | All arable land with rotational crops | 0.5% in 2030 and 1% in 2050 of available arable land | 2% in 2030 and 4% in 2050 of available arable land | 5% in 2030 and 10% in 2050 of available arable land |

| Description of biomass category | Issue | Technical potential | Low mobilisation | Medium mobilisation | High mobilisation |
|---|---|---|---|---|---|
| | Yield increase assumed | 1% per year | 0.2% per year | 0.5% per year | 1% per year |
| | Climate change effect on yields (based on EEA, 2019) | See above | See above | See above | See above |

Table A2 - 52 Scenario assumptions for intermediate and cover crops

## Results

| | | 2030 | 2030 | 2050 | 2050 |
|---|---|---|---|---|---|
| | Technical | TP mln ton | %/total | TP mln ton | %/total |
| **2107** | Intermediate_crop_Sorg | 116.4 | 7.3% | 138.6 | 7.5% |
| **2108** | Intermediate_crop_oil | 26.9 | 1.7% | 32.2 | 1.7% |
| **2109** | Cover_crop_ligno | 42.8 | 2.7% | 50.9 | 2.8% |
| | Low scenario | Low mln ton | %/total | Low mln ton | %/total |
| **2107** | Intermediate_crop_Sorg | 0.5 | 0.2% | 1.0 | 0.3% |
| **2108** | Intermediate_crop_oil | 0.1 | 0.0% | 0.2 | 0.1% |
| **2109** | Cover_crop_ligno | 0.2 | 0.1% | 0.4 | 0.1% |
| | Medium scenario | Medium mln ton | %/total | Medium mln ton | %/total |
| **2107** | Intermediate_crop_Sorg | 2.2 | 0.4% | 4.6 | 0.4% |
| **2108** | Intermediate_crop_oil | 0.5 | 0.1% | 1.1 | 0.1% |
| **2109** | Cover_crop_ligno | 0.8 | 0.2% | 1.8 | 0.2% |
| | High scenario | High mln ton | %/total | High mln ton | %/total |
| **2107** | Intermediate_crop_Sorg | 5.8 | 0.7% | 13.9 | 1.5% |
| **2108** | Intermediate_crop_oil | 1.3 | 0.2% | 3.2 | 0.3% |
| **2109** | Cover_crop_ligno | 2.1 | 0.2% | 5.1 | 0.5% |

Table A2 - 53 Total Europe in 2030 and 2050 for technical, low, medium and high mobilisation scenario

Table A2 - 54 Biomass supply per country per year and scenario for oil, ligno and cover crops in 2030

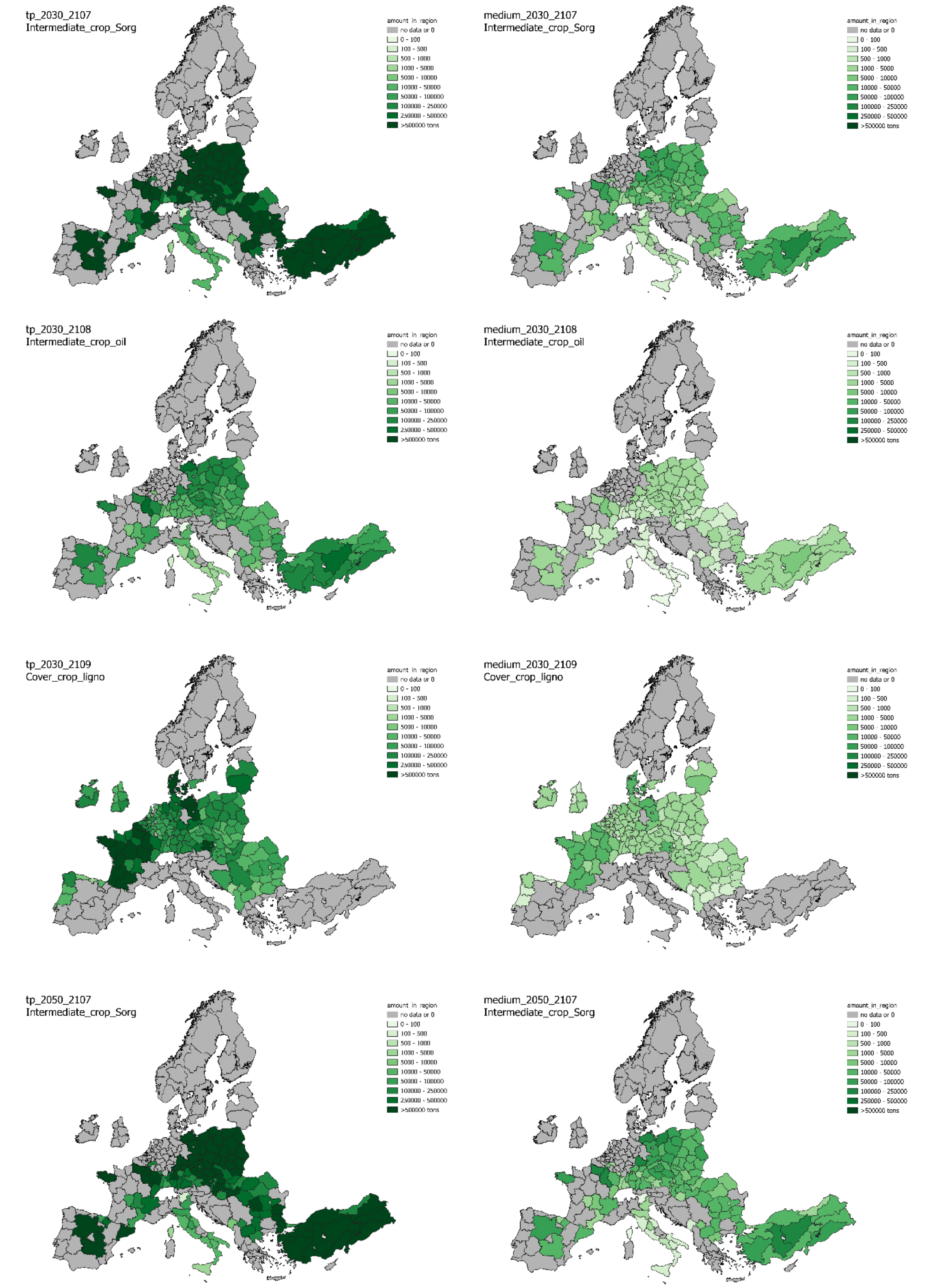
| | Intermediate crop sorghum (2107) | | | | Intermediate oil crop (2108) | | | | Cover crop (2109) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | High | Low | Medium | TP | High | Low | Medium | TP | High | Low | Medium | TP |
| AL | 8,567 | 791 | 3,261 | 171,348 | 1,904 | 176 | 725 | 38,077 | 2,733 | 252 | 1,040 | 54,662 |
| AT | 60,657 | 5,602 | 23,088 | 1,213,131 | 13,479 | 1,245 | 5,131 | 269,585 | 74,417 | 6,873 | 28,326 | 1,488,347 |
| BA | 10,009 | 924 | 3,810 | 200,177 | 2,224 | 205 | 847 | 44,484 | 4,858 | 449 | 1,849 | 97,155 |
| BG | 134,808 | 12,450 | 51,312 | 2,696,162 | 29,957 | 2,767 | 11,403 | 599,147 | 11,050 | 1,021 | 4,206 | 220,994 |
| BL | 14,631 | 1,351 | 5,569 | 292,620 | 3,251 | 300 | 1,238 | 65,027 | 96,372 | 8,900 | 36,682 | 1,927,436 |
| CS | 67,381 | 6,223 | 25,648 | 1,347,629 | 14,974 | 1,383 | 5,699 | 299,473 | 9,642 | 891 | 3,670 | 192,843 |
| CY | - | - | - | - | - | - | - | - | - | - | - | - |
| CZ | 404,420 | 37,350 | 153,936 | 8,088,394 | 89,871 | 8,300 | 34,208 | 1,797,421 | 32,905 | 3,039 | 12,525 | 658,104 |
| DE | 859,735 | 79,401 | 327,244 | 17,194,704 | 191,052 | 17,645 | 72,721 | 3,821,045 | 435,648 | 40,235 | 165,822 | 8,712,956 |
| DK | - | - | - | - | - | - | - | - | 91,903 | 8,488 | 34,981 | 1,838,063 |
| EE | - | - | - | - | - | - | - | - | - | - | - | - |
| EL | 4,871 | 405 | 1,761 | 97,422 | 1,218 | 101 | 440 | 24,356 | - | - | - | - |
| ES | 191,429 | 15,954 | 69,308 | 3,828,579 | 47,984 | 4,000 | 17,375 | 959,678 | 28,608 | 2,642 | 10,889 | 572,164 |
| FI | - | - | - | - | - | - | - | - | - | - | - | - |
| FR | 589,223 | 54,247 | 223,926 | 11,784,458 | 133,681 | 12,304 | 50,796 | 2,673,629 | 874,187 | 80,736 | 332,745 | 17,483,735 |
| HR | 37,643 | 3,477 | 14,328 | 752,862 | 8,365 | 773 | 3,184 | 167,303 | 38,432 | 3,549 | 14,628 | 768,633 |
| HU | 154,916 | 14,307 | 58,966 | 3,098,310 | 34,426 | 3,179 | 13,104 | 688,513 | 36,029 | 3,328 | 13,714 | 720,585 |
| IR | - | - | - | - | - | - | - | - | 37,411 | 3,455 | 14,240 | 748,213 |
| IT | 25,236 | 2,098 | 9,125 | 504,717 | 6,309 | 524 | 2,281 | 126,179 | - | - | - | - |
| KO | 14,095 | 1,302 | 5,365 | 281,906 | 3,132 | 289 | 1,192 | 62,646 | 1,622 | 150 | 617 | 32,441 |
| LT | 195,133 | 18,022 | 74,274 | 3,902,658 | 43,363 | 4,005 | 16,505 | 867,257 | 19,084 | 1,763 | 7,264 | 381,688 |
| LV | 175,711 | 16,228 | 66,881 | 3,514,213 | 39,047 | 3,606 | 14,863 | 780,936 | 12,879 | 1,189 | 4,902 | 257,577 |
| MK | 16,239 | 1,500 | 6,181 | 324,783 | 3,609 | 333 | 1,374 | 72,174 | 2,688 | 248 | 1,023 | 53,751 |
| MO | 155 | 14 | 59 | 3,109 | 35 | 3 | 13 | 691 | 1,094 | 101 | 416 | 21,874 |
| MT | - | - | - | - | - | - | - | - | - | - | - | - |
| NL | - | - | - | - | - | - | - | - | 75,037 | 6,930 | 28,562 | 1,500,741 |
| NO | - | - | - | - | - | - | - | - | - | - | - | - |
| PL | 977,297 | 90,259 | 371,992 | 19,545,935 | 217,177 | 20,058 | 82,665 | 4,343,541 | 103,288 | 9,539 | 39,315 | 2,065,754 |
| PT | - | - | - | - | - | - | - | - | 3,150 | 291 | 1,199 | 62,996 |
| RO | 119,158 | 11,005 | 45,356 | 2,383,164 | 26,480 | 2,446 | 10,079 | 529,592 | 29,820 | 2,754 | 11,350 | 596,399 |

| | Intermediate crop sorghum (2107) | | | | Intermediate oil crop (2108) | | | | Cover crop (2109) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | High | Low | Medium | TP | High | Low | Medium | TP | High | Low | Medium | TP |
| SE | 77,643 | 7,171 | 29,554 | 1,552,864 | 17,254 | 1,594 | 6,567 | 345,081 | 4,099 | 379 | 1,560 | 81,980 |
| SI | | | | | | | | | | | | |
| SK | 104,098 | 9,614 | 39,623 | 2,081,956 | 23,133 | 2,136 | 8,805 | 462,657 | 8,472 | 782 | 3,225 | 169,448 |
| TR | 1,579,346 | 131,275 | 571,094 | 31,586,920 | 394,837 | 32,819 | 142,774 | 7,896,730 | - | - | - | - |
| UK | - | - | - | - | - | - | - | - | 105,396 | 9,734 | 40,117 | 2,107,920 |

Table A2 - 55 Biomass supply per country per year and scenario for oil, ligno and cover crops in 2050

| | Intermediate crop sorghum (2107) | | | | Intermediate oil crop (2108) | | | | Cover crop (2109) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | High | Low | Medium | TP | High | Low | Medium | TP | High | Low | Medium | TP |
| AL | 29,726 | 2,342 | 10,246 | 297,261 | 6,606 | 520 | 2,277 | 66,058 | 6,670 | 525 | 2,299 | 66,698 |
| AT | 141,533 | 11,149 | 48,782 | 1,415,329 | 31,452 | 2,478 | 10,840 | 314,518 | 176,075 | 13,870 | 60,687 | 1,760,750 |
| BA | 30,137 | 2,374 | 10,387 | 301,367 | 6,697 | 528 | 2,308 | 66,970 | 11,854 | 934 | 4,086 | 118,544 |
| BG | 318,064 | 25,056 | 109,626 | 3,180,637 | 70,681 | 5,568 | 24,361 | 706,808 | 27,868 | 2,195 | 9,605 | 278,684 |
| BL | 34,650 | 2,730 | 11,943 | 346,504 | 7,700 | 607 | 2,654 | 77,001 | 232,123 | 18,286 | 80,005 | 2,321,229 |
| CS | 218,862 | 17,241 | 75,435 | 2,188,622 | 48,636 | 3,831 | 16,763 | 486,360 | 23,894 | 1,882 | 8,235 | 238,940 |
| CY | - | - | - | - | - | - | - | - | - | - | - | - |
| CZ | 859,165 | 67,681 | 296,127 | 8,591,652 | 190,926 | 15,040 | 65,806 | 1,909,256 | 77,150 | 6,077 | 26,591 | 771,496 |
| DE | 1,957,093 | 154,171 | 674,547 | 19,570,932 | 434,910 | 34,260 | 149,899 | 4,349,096 | 1,040,560 | 81,970 | 358,647 | 10,405,597 |
| DK | - | - | - | - | - | - | - | - | 215,188 | 16,951 | 74,168 | 2,151,876 |
| EE | - | - | - | - | - | - | - | - | - | - | - | - |
| EL | 19,914 | 1,255 | 6,177 | 199,136 | 4,978 | 314 | 1,544 | 49,784 | - | - | - | - |
| ES | 442,167 | 27,979 | 137,410 | 4,421,667 | 110,742 | 7,011 | 34,422 | 1,107,423 | 66,215 | 5,216 | 22,822 | 662,148 |
| FI | - | - | - | - | - | - | - | - | - | - | - | - |
| FR | 1,317,209 | 103,332 | 453,056 | 13,172,095 | 298,447 | 23,402 | 102,629 | 2,984,471 | 2,071,194 | 163,159 | 713,874 | 20,711,938 |
| HR | 118,417 | 9,328 | 40,814 | 1,184,168 | 26,315 | 2,073 | 9,070 | 263,148 | 93,788 | 7,388 | 32,326 | 937,882 |
| HU | 338,606 | 26,674 | 116,706 | 3,386,058 | 75,246 | 5,928 | 25,935 | 752,457 | 84,477 | 6,655 | 29,116 | 844,766 |
| IR | - | - | - | - | - | - | - | - | 88,982 | 7,010 | 30,669 | 889,816 |
| IT | 15,345 | 967 | 4,760 | 153,451 | 3,836 | 242 | 1,190 | 38,363 | - | - | - | - |
| KO | 39,506 | 3,112 | 13,617 | 395,064 | 8,779 | 692 | 3,026 | 87,792 | 3,958 | 312 | 1,364 | 39,583 |
| LT | 467,230 | 36,806 | 161,039 | 4,672,298 | 103,829 | 8,179 | 35,786 | 1,038,289 | 47,581 | 3,748 | 16,400 | 475,807 |

| | Intermediate crop sorghum (2107) | | | | Intermediate oil crop (2108) | | | | Cover crop (2109) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **High** | **Low** | **Medium** | **TP** | **High** | **Low** | **Medium** | **TP** | **High** | **Low** | **Medium** | **TP** |
| LV | 410,329 | 32,324 | 141,427 | 4,103,293 | 91,184 | 7,183 | 31,428 | 911,843 | 32,303 | 2,545 | 11,134 | 323,031 |
| MK | 47,301 | 3,726 | 16,303 | 473,012 | 10,511 | 828 | 3,623 | 105,114 | 6,559 | 517 | 2,261 | 65,587 |
| MO | 515 | 41 | 177 | 5,148 | 114 | 9 | 39 | 1,144 | 2,489 | 196 | 858 | 24,894 |
| MT | - | - | - | - | - | - | - | - | - | - | - | - |
| NL | - | - | - | - | - | - | - | - | 175,945 | 13,860 | 60,643 | 1,759,449 |
| NO | - | - | - | - | - | - | - | - | - | - | - | - |
| PL | 2,202,620 | 173,512 | 759,172 | 22,026,198 | 489,471 | 38,558 | 168,705 | 4,894,711 | 242,170 | 19,077 | 83,468 | 2,421,700 |
| PT | - | - | - | - | - | - | - | - | 7,329 | 577 | 2,526 | 73,287 |
| RO | 231,372 | 18,226 | 79,746 | 2,313,717 | 51,416 | 4,050 | 17,721 | 514,159 | 69,916 | 5,508 | 24,098 | 699,158 |
| SE | 204,280 | 16,092 | 70,409 | 2,042,798 | 45,396 | 3,576 | 15,646 | 453,955 | 10,076 | 794 | 3,473 | 100,756 |
| SI | | | | | | | | | | | | |
| SK | 242,488 | 19,102 | 83,578 | 2,424,876 | 53,886 | 4,245 | 18,573 | 538,861 | 19,994 | 1,575 | 6,891 | 199,942 |
| TR | 4,178,092 | 263,305 | 1,296,048 | 41,780,915 | 1,044,523 | 65,826 | 324,012 | 10,445,229 | - | - | - | - |
| UK | - | - | - | - | - | - | - | - | 256,930 | 20,240 | 88,556 | 2,569,301 |




*Map 1 Distribution over Europe**

## Evaluation

### General observations

*Describe general observations on e.g. approach of assessment, scenario approach, results in numbers (amounts and price levels), spatial distribution, comparison with PRIMES*

The overall approach of the assessment builds upon work done in previous EU projects (MAGIC, BIKE) as well as on modelling results. Overall, this is considered as a very appropriate methodology considering the biomass type evaluated.

### Strength

*Please indicate what you regard as a strength in the assessment of results*

The fact that the model builds upon results of previous EU projects and robust models is a strength.

### Weaknesses

*Please indicate what you regard as a weakness in the assessment*

The assumptions of land that would be available for the various mobilization scenarios are ad hoc are significantly lower than the technical potential. This suggests that the technical potential is a very theoretical concept for such cropping systems.

The third type of cropping system considered is not based on results of previous projects and no other reference is provided. Therefore, it is not clear whether its assumptions for biomass productivity are totally valid.

### Options for improvement?

*Please indicate what can or really needs to be improved.*

Units in Tables 2, 3 and 4 are confusing – the legend says they are yields, but the info does not mention t/ha.

COMMENT authors: Unit added

## SWOT 5 – Primary residues of arable crops (2201, 2202, 2203)

### Description of approach

For the assessment of primary residues:

- The amount of production per crop by 2030 and 2050 is derived from CAPRI baseline (see Section 3.1 and Annex 4 of main report)
- The residue amount is calculated taking the Garcia Condado main product residue relationships (See also Annex 4).

The overall calculation of the technical potential follows this formula:

RESIDUE_YIELDi = AREAi * RES_YIELDi * DM_CONTENTi.

| | Predicted | Transformation | Transformation parameters | | | | Linear regression parameters | | |
|---|---|---|---|---|---|---|---|---|---|
| Crop | variable | of | γ | δ | xi | λ | a | b | CI |
| Wheat | HI | LT (Equation 6) | -0.2551 | 1.0835 | 0.2034 | 0.4006 | 0.3093 | -1.2958 | 1.5067 |
| Barley | HI | LT (Equation 6) | -0.0705 | 0.5421 | 0.2817 | 0.3063 | 0.3319 | -0.8631 | 1.1952 |
| Rice | HI | LT (Equation 6) | -1.6054 | 2.3282 | 0.0687 | 0.5663 | 0.2823 | -1.431 | 1.4469 |
| Sunflower | HI | HS (Equation 7) | -0.3057 | 3.8491 | 0.3111 | 0.1717 | 0.1715 | -0.4522 | 1.9114 |
| Rapeseed | HI | HS (Equation 7) | 0 | 3.2858 | 0.2637 | 0.1575 | 0.188 | -0.7453 | 1.8212 |
| Maize | HI | LT (Equation 6) | -1.6992 | 1.2752 | -0.2218 | 0.8428 | 0.2509 | -1.9424 | 1.105 |
| Sorghum | HI | LT (Equation 6) | -0.553 | 1.3866 | -0.1036 | 0.7427 | 0.3446 | -1.0251 | 1.2173 |
| Soybean | HI | LT (Equation 6) | -0.0819 | 1.0113 | 0.191 | 0.2299 | 0.7659 | -2.2731 | 1.3811 |
| Sugar beet | R | HS (Equation 7) | 0.5345 | 2.8868 | 6.0578 | 2.8308 | -0.1067 | 1.8538 | 1.7528 |
| Potato | R | LT (Equation 6) | 2.6877 | 1.2031 | 0.6951 | 16.7831 | 0.0617 | -0.5178 | 1.7609 |

Source: Garcia Condado et al. (2019)

Table A2 - 56 Parameter values of empirical regression model equations for estimation of harvest index of crops with relatively stable HI which is weakly correlated with the economic yield (Y).

The approach to predict crop residue potentials by Garcia Condado et al. (2019) is scientifically robust and covers the 10 main crops grown in the EU. It can only be used to assess the residual aboveground biomass for a selection of arable crops grown in the EU.

- Application of the scenario assumptions (see Table 2)

| DI codes | Description of biomass category | Issue | Technical potential | Low mobilisation | Medium mobilisation | High mobilisation |
|---|---|---|---|---|---|---|
| 2201, 2202, 2203, | Primary residues from arable land | *Area change 2030 & 2050* | According to CAPRI 2.7 BAU: crop area, yield & production levels 2030 & 2050 | According to CAPRI 2.7 BAU: crop area, yield & production levels 2030 & 2050 | According to CAPRI 2.7 BAU: crop area, yield & production levels 2030 & 2050 | According to CAPRI 2.7 BAU: crop area, yield & production levels 2030 & 2050 |
| | | *Yield change* | As in CAPRI BAU | As in CAPRI BAU | As in CAPRI BAU + 0.5% yield increase per year | As in CAPRI BAU + 1% yield increase per year |
| | | *Removal rate in field* | 100% for all crops | Cereals: 35%<br>Oil crops: 40%<br>Rice: 30% | Cereals: 40%<br>Oil crops: 50%<br>Rice: 40% | Cereals: 45%<br>Oil crops: 60%<br>Rice: 50% |

| DI codes | Description of biomass category | Issue | Technical potential | Low mobilisation | Medium mobilisation | High mobilisation |
|---|---|---|---|---|---|---|
| | | | | Stover: 50%<br>Sugarbeet leaves: 50% | Stover: 60%<br>Sugarbeet leaves: 60% | Stover: 70%<br>Sugarbeet leaves: 70% |
| | | *Competing use* | 0% competing use | For animals (bedding, feed) and other biobased uses (building, biochemicals, paper) 2030 (2050) Cereals: 100% (100%) Oil crops: 10% (20%) Rice: 10% (20%) Stover: 30% (50%)<br>Sugarbeet leaves: 50% (70%) | For animals (bedding, feed) and other biobased uses (building, biochemicals, paper) 2030 (2050)<br>Cereals: 50% (50%)<br>Oil crops: 5% (10%)<br>Rice: 5% (10%)<br>Stover: 20% (40%)<br>Sugarbeet leaves: 30% (50%) | For animals (bedding, feed) and other biobased uses (building, biochemicals, paper) 2030 (2050)<br>Cereals: 25% (25%)<br>Oil crops: 0% (0%)<br>Rice: 0% (0%)<br>Stover: 10% (20%)<br>Sugarbeet leaves: 15% (25%) |
| | | *Climate change* | No effect on residue yields | In Mediterranean zone: up to 2030 10% total yield decrease and up to 2050 20% yield **de**crease<br>In Boreal & Nemoral zone:<br>2030: 5%/2050: 10% yield **in**crease in all crops | In Mediterranean zone: up to 2030 5% total yield decrease and up to 2050 10% yield **de**crease<br>In Boreal & Nemoral zone:<br>2030: 5%/2050: 15% yield **in**crease in all crops | In Mediterranean zone: NO yield decrease expected<br>In Boreal & Nemoral zone:<br>2030: 15%/2050: 25% yield **in**crease in all crops |

Table A2 - 57 *Scenario assumptions*

## Results

Results of total potentials are presented in Table 3

| | | 2030 | 2030 | 2050 | 2050 |
|---|---|---|---|---|---|
| | Technical | TP mln ton | %/total | TP mln ton | %/total |
| | | | | | |
| **2201** | Prim_res_cereal_straw | 265.8 | 16.7% | 266.6 | 14.4% |
| **2202** | Prim_res_other_straw | 202.5 | 12.7% | 201.8 | 10.9% |
| **2203** | Prim_res_sugar_leaves | 5.7 | 0.4% | 6.0 | 0.3% |
| | | 2030 | 2030 | 2050 | 2050 |
| | Low scenario | Low mln ton | %/total | Low mln ton | %/total |
| **2201** | Prim_res_cereal_straw | 0.0 | 0.0% | 0.0% | 0% |
| **2202** | Prim_res_other_straw | 71.5 | 22.6% | 19.2% | 18% |
| **2203** | Prim_res_sugar_leaves | 1.4 | 0.4% | 0.3% | 0% |
| | | 2030 | 2030 | 2050 | 2050 |
| | Medium scenario | Medium mln ton | %/total | Medium mln ton | %/total |
| **2201** | Prim_res_cereal_straw | 58.5 | 10.8% | 58.7 | 10.9% |
| **2202** | Prim_res_other_straw | 105.9 | 19.6% | 89.6 | 16.7% |
| **2203** | Prim_res_sugar_leaves | 2.6 | 0.5% | 2.0 | 0.4% |
| | | 2030 | 2030 | 2050 | 2050 |
| | High scenario | High mln ton | %/total | High mln ton | %/total |
| **2201** | Prim_res_cereal_straw | 121.1 | 13.9% | 121.5 | 13.1% |
| **2202** | Prim_res_other_straw | 167.6 | 19.3% | 157.1 | 17.0% |
| **2203** | Prim_res_sugar_leaves | 4.6 | 0.5% | 4.2 | 0.5% |

Table A2 - 58 Total Europe in 2030 and 2050 for technical, low, medium and high mobilisation scenario

| | Prim_res_cereal_straw (2201) | | | | Prim_res_other_straw (2202) | | | | Prim_res_sugar_leaves | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | high | low | medium | tp | high | low | medium | tp | high | low | medium | tp |
| AL | 200,752 | | 96,934 | 440,608 | 438,722 | 180,597 | 272,402 | 515,934 | | | | |
| AT | 1,335,943 | | 645,064 | 2,932,110 | 2,149,451 | 902,866 | 1,347,897 | 2,559,990 | 127,315 | 39,625 | 73,227 | 158,499 |
| BA | 197,462 | | 95,345 | 433,387 | 1,351,994 | 556,469 | 839,401 | 1,589,812 | | | | |
| BG | 3,719,839 | | 1,796,136 | 8,164,256 | 8,990,716 | 3,882,552 | 5,716,329 | 10,908,401 | | | | |
| BL | 911,660 | | 440,198 | 2,000,901 | 1,221,965 | 506,651 | 761,398 | 1,443,519 | 128,675 | 40,048 | 74,009 | 160,193 |
| CS | 1,458,471 | | 704,227 | 3,201,033 | 9,930,982 | 4,116,022 | 6,186,773 | 11,728,779 | 133,883 | 41,669 | 77,005 | 166,676 |
| CY | 17,373 | | 8,389 | 38,130 | | | | | | | | |
| CZ | 3,450,977 | | 1,666,316 | 7,574,162 | 4,210,125 | 1,844,384 | 2,696,063 | 5,149,860 | 125,312 | 39,001 | 72,075 | 156,006 |
| DE | 15,416,581 | | 7,443,946 | 33,836,118 | 17,976,479 | 7,855,350 | 11,497,089 | 21,953,547 | 832,077 | 258,972 | 478,580 | 1,035,888 |
| DK | 3,479,608 | | 1,680,140 | 7,637,000 | 1,341,230 | 593,388 | 863,177 | 1,650,992 | 106,416 | 33,121 | 61,207 | 132,482 |
| EE | 640,593 | | 309,312 | 1,405,965 | 264,270 | 117,453 | 170,471 | 326,259 | | | | |
| EL | 498,631 | | 240,766 | 1,094,390 | 907,631 | 375,125 | 565,174 | 1,094,380 | 1,325 | 412 | 762 | 1,650 |
| ES | 7,609,404 | | 3,674,225 | 16,701,024 | 3,868,309 | 1,639,102 | 2,438,462 | 4,736,103 | 94,586 | 29,439 | 54,402 | 117,754 |
| FI | 2,294,147 | | 1,107,736 | 5,035,165 | 97,906 | 43,514 | 63,156 | 120,872 | 4,183 | 1,302 | 2,406 | 5,208 |
| FR | 19,434,022 | | 9,383,780 | 42,653,546 | 31,975,379 | 13,720,220 | 20,264,666 | 38,612,550 | 920,722 | 286,561 | 529,566 | 1,146,246 |
| HR | 712,091 | | 343,835 | 1,562,888 | 2,419,126 | 1,011,446 | 1,513,548 | 2,872,788 | 53,018 | 16,501 | 30,494 | 66,004 |
| HU | 3,466,328 | | 1,673,728 | 7,607,852 | 13,046,668 | 5,480,041 | 8,181,334 | 15,539,279 | 56,483 | 17,580 | 32,487 | 70,319 |
| IR | 707,336 | | 341,540 | 1,552,453 | 83,001 | 36,889 | 53,541 | 102,470 | | | | |
| IT | 1,751,101 | | 845,525 | 3,843,294 | 8,045,403 | 3,308,221 | 5,000,224 | 9,807,462 | 76,016 | 23,659 | 43,722 | 94,636 |
| KO | 273,497 | | 132,059 | 600,268 | 184,952 | 76,129 | 114,833 | 217,494 | | | | |
| LT | 2,122,718 | | 1,024,961 | 4,658,915 | 1,913,555 | 843,598 | 1,229,300 | 2,350,144 | 32,169 | 10,012 | 18,503 | 40,049 |
| LV | 1,535,631 | | 741,484 | 3,370,383 | 763,626 | 339,389 | 492,586 | 942,748 | | | | |
| MK | 252,847 | | 122,088 | 554,945 | 272,150 | 112,294 | 169,347 | 328,699 | | | | |
| MO | 2,647 | | 1,278 | 5,809 | 21,122 | 8,692 | 13,113 | 24,835 | | | | |
| MT | 686 | | 331 | 1,506 | | | | | | | | |
| NL | 664,008 | | 320,618 | 1,457,356 | 185,434 | 77,875 | 116,272 | 220,823 | 166,301 | 51,759 | 95,650 | 207,035 |
| NO | | | | | | | | | | | | |
| PL | 11,886,344 | | 5,739,360 | 26,087,999 | 12,962,993 | 5,626,170 | 8,262,371 | 15,762,337 | 585,136 | 182,115 | 336,549 | 728,460 |
| PT | 99,560 | | 48,073 | 218,513 | 458,126 | 187,609 | 284,319 | 564,626 | 813 | 253 | 468 | 1,012 |
| RO | 6,130,118 | | 2,959,947 | 13,454,305 | 20,832,552 | 8,716,269 | 13,038,764 | 24,759,445 | 84,991 | 26,452 | 48,883 | 105,808 |

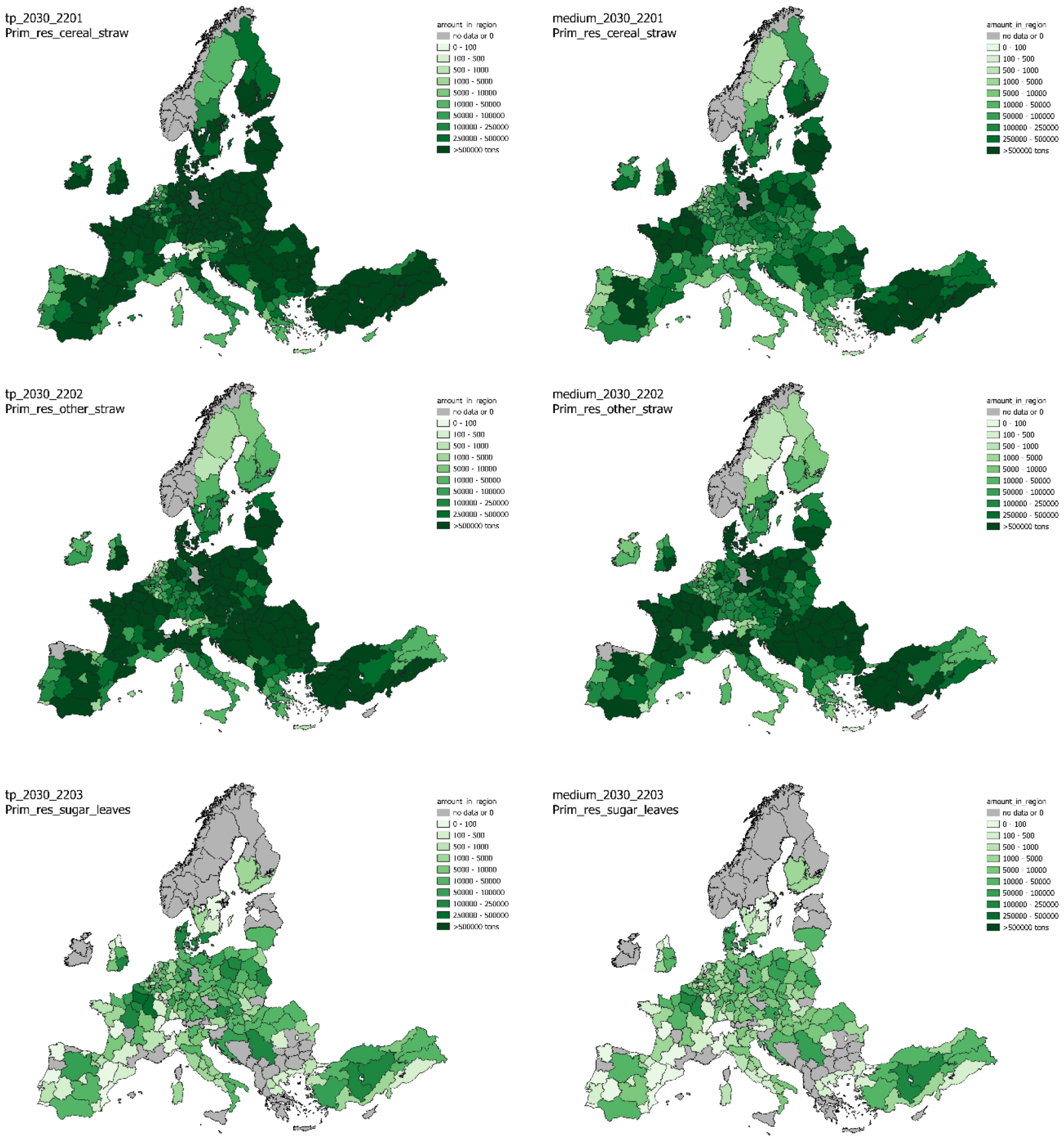
| | Prim_res_cereal_straw (2201) | | | | Prim_res_other_straw (2202) | | | | Prim_res_sugar_leaves | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | high | low | medium | tp | high | low | medium | tp | high | low | medium | tp |
| SE | 2,251,848 | | 1,087,312 | 4,942,327 | 773,990 | 343,417 | 498,845 | 954,511 | 84,145 | 26,189 | 48,397 | 104,756 |
| SI | 150,944 | | 72,884 | 331,290 | 231,918 | 97,368 | 145,398 | 276,128 | | | | |
| SK | 1,224,399 | | 591,205 | 2,687,295 | 3,098,629 | 1,309,562 | 1,949,008 | 3,704,743 | 50,297 | 15,654 | 28,929 | 62,617 |
| TR | 18,242,673 | | 8,808,533 | 40,038,788 | 11,477,058 | 4,831,257 | 7,213,364 | 14,091,536 | 613,355 | 190,898 | 352,780 | 763,592 |
| UK | 8,956,324 | | 4,324,590 | 19,657,226 | 6,132,307 | 2,716,288 | 3,948,953 | 7,554,353 | 276,149 | 85,947 | 158,831 | 343,790 |

Table A2 - 59 Biomass supply per country per year and scenario in 2030

| | Prim_res_cereal_straw (2201) | | | | Prim_res_other_straw (2202) | | | | Prim_res_sugar_leaves | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | high | low | medium | tp | high | low | medium | tp | high | low | medium | tp |
| AL | 280,330 | | 135,358 | 615,264 | 532,023 | 176,090 | 278,891 | 703,520 | | | | |
| AT | 1,249,242 | | 603,201 | 2,741,821 | 1,027,173 | 375,500 | 586,630 | 1,309,616 | 138,149 | 29,238 | 64,323 | 194,919 |
| BA | 267,077 | | 128,959 | 586,176 | 1,913,421 | 632,819 | 1,002,368 | 2,530,879 | | | | |
| BG | 3,614,827 | | 1,745,431 | 7,933,776 | 11,809,620 | 4,410,689 | 6,871,808 | 14,931,666 | | | | |
| BL | 972,387 | | 469,520 | 2,134,184 | 1,222,681 | 406,391 | 643,253 | 1,614,475 | 127,604 | 27,006 | 59,414 | 180,042 |
| CS | 2,011,306 | | 971,165 | 4,414,388 | 12,505,917 | 4,188,189 | 6,622,100 | 16,470,117 | 104,727 | 22,164 | 48,762 | 147,763 |
| CY | 23,035 | | 11,123 | 50,557 | | | | | | | | |
| CZ | 3,120,537 | | 1,506,761 | 6,848,916 | 3,864,139 | 1,513,860 | 2,344,176 | 4,787,958 | 141,510 | 29,949 | 65,888 | 199,662 |
| DE | 15,585,295 | | 7,525,410 | 34,206,409 | 15,802,695 | 6,100,966 | 9,464,527 | 19,704,122 | 700,043 | 148,157 | 325,946 | 987,716 |
| DK | 2,946,549 | | 1,422,751 | 6,467,048 | 617,463 | 239,287 | 371,034 | 768,668 | 194,571 | 41,179 | 90,594 | 274,527 |
| EE | 521,135 | | 251,632 | 1,143,781 | 131,094 | 51,790 | 80,113 | 161,844 | | | | |
| EL | 579,921 | | 280,017 | 1,272,803 | 352,682 | 117,931 | 187,029 | 468,188 | 3,712 | 786 | 1,728 | 5,238 |
| ES | 7,493,647 | | 3,618,331 | 16,446,961 | 2,007,242 | 767,503 | 1,194,080 | 2,526,142 | 84,889 | 17,966 | 39,525 | 119,773 |
| FI | 2,407,565 | | 1,162,501 | 5,284,094 | 17,981 | 7,103 | 10,988 | 22,198 | 2,420 | 512 | 1,127 | 3,414 |
| FR | 18,810,502 | | 9,082,711 | 41,285,051 | 29,675,444 | 10,833,956 | 16,928,688 | 37,856,679 | 826,656 | 174,954 | 384,898 | 1,166,357 |
| HR | 1,015,281 | | 490,232 | 2,228,326 | 1,630,929 | 553,719 | 873,812 | 2,137,600 | 45,326 | 9,593 | 21,104 | 63,953 |
| HU | 3,037,686 | | 1,466,756 | 6,667,074 | 11,173,974 | 3,856,355 | 6,071,754 | 14,559,674 | 35,087 | 7,426 | 16,337 | 49,505 |
| IR | 673,796 | | 325,345 | 1,478,840 | 15,061 | 5,950 | 9,204 | 18,594 | | | | |
| IT | 912,090 | | 440,405 | 2,001,843 | 2,830,125 | 983,196 | 1,575,688 | 3,871,222 | 372 | 79 | 173 | 525 |
| KO | 315,534 | | 152,357 | 692,530 | 239,640 | 79,293 | 125,590 | 316,919 | | | | |
| LT | 1,867,708 | | 901,829 | 4,099,223 | 3,037,739 | 1,197,945 | 1,853,481 | 3,753,240 | 59,572 | 12,608 | 27,737 | 84,052 |

| | Prim_res_cereal_straw (2201) | | | | Prim_res_other_straw (2202) | | | | Prim_res_sugar_leaves | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | high | low | medium | tp | high | low | medium | tp | high | low | medium | tp |
| LV | 1,738,440 | | 839,411 | 3,815,507 | 288,069 | 113,805 | 176,042 | 355,641 | | | | |
| MK | 327,064 | | 157,924 | 717,835 | 393,991 | 131,868 | 209,330 | 524,348 | | | | |
| MO | 4,208 | | 2,032 | 9,236 | 34,928 | 11,550 | 18,296 | 46,201 | | | | |
| MT | 664 | | 321 | 1,457 | | | | | | | | |
| NL | 591,123 | | 285,425 | 1,297,388 | 94,436 | 35,671 | 55,491 | 118,830 | 138,382 | 29,287 | 64,432 | 195,248 |
| NO | | | | | | | | | | | | |
| PL | 10,737,441 | | 5,184,608 | 23,566,400 | 12,999,745 | 5,052,418 | 7,831,342 | 16,163,155 | 574,042 | 121,490 | 267,279 | 809,935 |
| PT | 194,812 | | 94,065 | 427,570 | 93,824 | 31,739 | 50,669 | 126,819 | 3 | 1 | 1 | 4 |
| RO | 5,412,939 | | 2,613,655 | 11,880,251 | 19,653,012 | 6,857,176 | 10,780,525 | 25,507,801 | 89,966 | 19,040 | 41,889 | 126,937 |
| SE | 2,663,199 | | 1,285,934 | 5,845,155 | 85,083 | 32,803 | 50,896 | 106,151 | 87,422 | 18,502 | 40,705 | 123,347 |
| SI | 206,043 | | 99,488 | 452,220 | 33,540 | 11,769 | 18,488 | 43,436 | | | | |
| SK | 1,189,650 | | 574,427 | 2,611,030 | 2,749,156 | 986,429 | 1,544,888 | 3,530,537 | 37,177 | 7,868 | 17,310 | 52,455 |
| TR | 21,433,098 | | 10,349,040 | 47,041,092 | 14,810,565 | 5,270,652 | 8,389,455 | 19,911,763 | 499,788 | 105,775 | 232,705 | 705,168 |
| UK | 9,287,928 | | 4,484,706 | 20,385,027 | 5,501,273 | 2,158,132 | 3,341,261 | 6,812,531 | 357,939 | 75,754 | 166,660 | 505,029 |

Table A2 - 60 Biomass supply per country and scenario in 2050




Map 1 Distribution over Europe

# Evaluation

## General observations

*Describe general observations on e.g. approach of assessment, scenario approach, results in numbers (amounts and price levels), spatial distribution, comparison with PRIMES*

The overall approach follows a very well established methodology for evaluating the biomass potential of agricultural residues. Results appear in line with previous publications for primary residues from arable crops. The spatial distribution is in line with the areas of cultivation of arable crops.

Results of PRIMES appear to be somewhere between the low and medium mobilization potential scenarios of this model. The reasons for this are not fully clear, since there are no details provided on the PRIMES model.

### Strength

*Please indicate what you regard as a strength in the assessment of results*

Methodology is clear and well established.

Input data on future production of arable crops are based on a well established model.

Wide coverage of crop types, covering almost all the major ones.

### Weaknesses

*Please indicate what you regard as a weakness in the assessment*

Percentage factors considered for the removal rates in the field and competing uses are ad hoc parameters.

Removal rates for stover are higher than cereal straw; it is unclear whether this is something that can be expected.

Mobilization scenarios do not take into account the difficulties that the structure of the agricultural sector may impose, e.g. small size of holdings, spatial distribution, etc. Modelling this would be very difficult, so to some extent, these parameters could be assumed to influence the mobilizaton in a blanket way, I.e. further reducing the percentages considered in this study.

### Options for improvement?

Please indicate what can or really needs to be improved.

Cotton is not considered in this evaluation. At the moment, this is a crops that is only relevant for Greece and some smaller areas of Spain and Bulgaria. However, the potential in Greece alone is significant for the country and perhaps it should be considered for in a follow-up study.

## SWOT 6 – Primary residues of permanent crops (2204) and damaged crops (2205)

### Description of approach

For the assessment of primary residues:

- The amount of production per crop by 2030 and 2050 is derived from CAPRI baseline (see Section 3.1 and Annex 4 of main report)
- The residue amount for permanent crops is calculated taking the S2BIOM residue levels per crop and adapting to CAPRI 2020, 2030 and 2050 production levels
- For damaged crops a fixed share of damaged crops was assumed. See scenario assumptions in Table 1.

| DI codes | Description of biomass category | Issue | Technical potential | Low mobilisation | Medium mobilisation | High mobilisation |
|---|---|---|---|---|---|---|
| 2204 | Primary residues from permanent crops | *Area change 2030 & 2050* | According to CAPRI 2.7 BAU: crop area, yield & production levels 2030 & 2050 | According to CAPRI 2.7 BAU: crop area, yield & production levels 2030 & 2050 | According to CAPRI 2.7 BAU: crop area, yield & production levels 2030 & 2050 | According to CAPRI 2.7 BAU: crop area, yield & production levels 2030 & 2050 |
| | | *Yield change* | As in CAPRI BAU | As in CAPRI BAU | As in CAPRI BAU | As in CAPRI BAU |
| | | *Removal rate in field* | 100% for all crops | Apple& pear: 50%<br>Soft fruit: 50%<br>Vineyards: 50%<br>Olives: 50%<br>Citrus: 50% | Apple& pear: 60%<br>Soft fruit: 60%<br>Vineyards: 60%<br>Olives: 60%<br>Citrus: 60% | Apple& pear: 70%<br>Soft fruit: 70%<br>Vineyards: 70%<br>Olives: 70%<br>Citrus: 70% |
| | | *Competing use* | 0% competing use | For other biobased uses (building, biochemicals, paper) 2030 & 2050)<br>Apple& pear: 50%<br>Soft fruit: 50%<br>Vineyards: 50%<br>Olives: 50%<br>Citrus: 50% | For other biobased uses (building, biochemicals, paper) 2030 (2050)<br>Apple& pear: 25% Soft fruit: 25%<br>Vineyards: 25% Olives: 25% Citrus: 25% | For other biobased uses (building, biochemicals, paper) 2030 (2050) Apple& pear: 10% Soft fruit: 10%<br>Vineyards: 10%<br>Olives: 10%<br>Citrus: 10% |
| 2205 | Damaged crops | *Damaged crops level* | 1% of total production in 2030 & 2050 | 0.5% (2030) and 0.45% (2050) of total production | 0.8% (2030) and 0.8% (2050) of total production | 1% of total production in 2030 & 2050 |
| | | *Yield increase crops* | As in CAPRI + 0.5% a year | As in Capri | As in Capri + 0.2% a year | As in CAPRI + 0.5% a year |
| | | *Competing use* | 0% | 50% (2030) & 75% (2050) | 30% (2030) & 40% (2050) | 10% (2030) & 20% (2050) |

Table A2 - 61 Scenario assumptions for residues from permanent crops

## Results

Results of total potentials are presented in Table 2

| | | 2030 | 2030 | 2050 | 2050 |
|---|---|---|---|---|---|
| | Technical | TP mln ton | %/total | TP mln ton | %/total |
| **2204** | Prim_res_perm_crops | 16.2 | 0.8% | 16.3 | 0.8% |
| **2205** | Prim_res_damaged_crops | 3.7 | 0.2% | 3.9 | 0.2% |
| | | | | | |
| | | 2030 | 2030 | 2050 | 2050 |
| | Low scenario | Low mln ton | %/total | Low mln ton | %/total |
| **2204** | Prim_res_perm_crops | 4.1 | 1.0% | 4.1 | 1.1% |
| **2205** | Prim_res_damaged_crops | 0.9 | 0.2% | 0.4 | 0.1% |
| | | | | | |
| | | 2030 | 2030 | 2050 | 2050 |
| | Medium scenario | Medium mln ton | %/total | Medium mln ton | %/total |
| **2204** | Prim_res_perm_crops | 7.3 | 1.0% | 7.3 | 1.1% |
| **2205** | Prim_res_damaged_crops | 2.1 | 0.3% | 1.9 | 0.3% |
| | | | | | |
| | | 2030 | 2030 | 2050 | 2050 |
| | High scenario | High mln ton | %/total | High mln ton | %/total |
| **2204** | Prim_res_perm_crops | 10.2 | 0.9% | 10.3 | 0.9% |
| **2205** | Prim_res_damaged_crops | 3.3 | 0.3% | 3.1 | 0.3% |
| | | | | | |

Table A2 - 62 Total Europe in 2030 and 2050 for technical, low, medium and high mobilisation scenario

| | Primary residues permanent crops (2204) | | | | Damaged crops (2205) | | | |
|---|---|---|---|---|---|---|---|---|
| | Sum of high | Sum of low | Sum of medium | Sum of tp | Sum of high | Sum of low | Sum of medium | Sum of tp |
| AL | 80,896 | 32,101 | 57,783 | 128,406 | 7,263 | 2,018 | 4,519 | 8,070 |
| AT | 30,902 | 12,263 | 22,073 | 49,050 | 49,313 | 13,698 | 30,684 | 54,793 |
| BA | 115,751 | 45,933 | 82,679 | 183,732 | 11,792 | 3,276 | 7,337 | 13,102 |
| BG | 116,045 | 46,049 | 82,889 | 184,198 | 106,958 | 29,711 | 66,552 | 118,842 |
| BL | 13,439 | 5,333 | 9,599 | 21,331 | 39,080 | 10,856 | 24,316 | 43,422 |
| CS | 238,533 | 94,656 | 170,381 | 378,624 | 85,796 | 23,832 | 53,384 | 95,329 |
| CY | 34,798 | 13,809 | 24,856 | 55,235 | 554 | 154 | 345 | 615 |
| CZ | 6,692 | 2,656 | 4,780 | 10,622 | 81,980 | 22,772 | 51,010 | 91,089 |
| DE | 125,210 | 49,687 | 89,436 | 198,746 | 461,000 | 128,056 | 286,845 | 512,223 |
| DK | 4,571 | 1,814 | 3,265 | 7,256 | 80,428 | 22,341 | 50,044 | 89,364 |
| EE | 3,959 | 1,571 | 2,828 | 6,284 | 11,442 | 3,178 | 7,120 | 12,714 |
| EL | 936,665 | 371,692 | 669,046 | 1,486,770 | 29,665 | 8,240 | 18,458 | 32,961 |
| ES | 4,006,767 | 1,589,987 | 2,861,976 | 6,359,947 | 183,918 | 51,088 | 114,438 | 204,353 |
| FI | 5,595 | 2,220 | 3,996 | 8,880 | 40,499 | 11,250 | 25,199 | 44,999 |
| FR | 549,793 | 218,172 | 392,709 | 872,687 | 667,053 | 185,293 | 415,055 | 741,170 |
| HR | 59,626 | 23,661 | 42,590 | 94,645 | 31,170 | 8,658 | 19,394 | 34,633 |
| HU | 107,688 | 42,733 | 76,920 | 170,934 | 147,918 | 41,088 | 92,038 | 164,353 |
| IR | 879 | 349 | 628 | 1,395 | 18,311 | 5,086 | 11,393 | 20,345 |
| IT | 1,961,381 | 778,326 | 1,400,987 | 3,113,303 | 161,074 | 44,743 | 100,224 | 178,971 |
| KO | 1,448 | 574 | 1,034 | 2,298 | 7,828 | 2,174 | 4,871 | 8,697 |
| LT | 7,071 | 2,806 | 5,051 | 11,224 | 49,269 | 13,686 | 30,656 | 54,743 |
| LV | 3,634 | 1,442 | 2,596 | 5,768 | 26,568 | 7,380 | 16,531 | 29,520 |
| MK | 26,321 | 10,445 | 18,801 | 41,780 | 5,656 | 1,571 | 3,519 | 6,284 |
| MO | 14,401 | 5,715 | 10,287 | 22,859 | 363 | 101 | 226 | 404 |
| MT | 621 | 246 | 443 | 985 | 51 | 14 | 32 | 57 |
| NL | 9,321 | 3,699 | 6,658 | 14,795 | 24,772 | 6,881 | 15,414 | 27,525 |
| NO | | | | | | | | |
| PL | 429,759 | 170,539 | 306,971 | 682,157 | 314,620 | 87,394 | 195,764 | 349,578 |
| PT | 799,964 | 317,446 | 571,403 | 1,269,784 | 9,307 | 2,585 | 5,791 | 10,341 |
| RO | 186,040 | 73,825 | 132,885 | 295,301 | 188,433 | 52,343 | 117,247 | 209,370 |

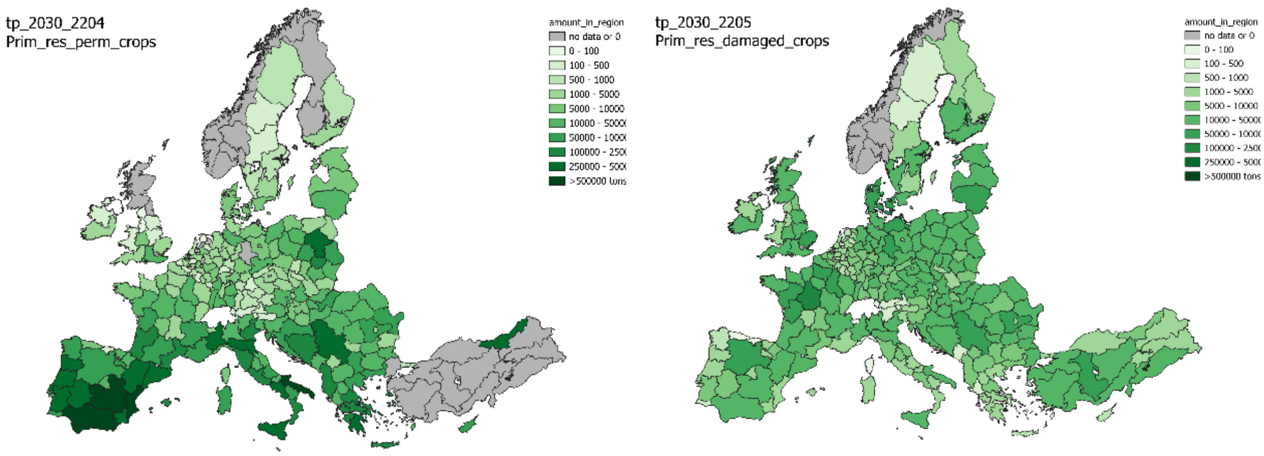
| | Primary residues permanent crops (2204) | | | | Damaged crops (2205) | | | |
|---|---|---|---|---|---|---|---|---|
| | Sum of high | Sum of low | Sum of medium | Sum of tp | Sum of high | Sum of low | Sum of medium | Sum of tp |
| SE | 6,415 | 2,546 | 4,582 | 10,182 | 49,764 | 13,823 | 30,964 | 55,293 |
| SI | 16,951 | 6,727 | 12,108 | 26,906 | 4,736 | 1,315 | 2,947 | 5,262 |
| SK | 14,173 | 5,624 | 10,123 | 22,496 | 40,867 | 11,352 | 25,428 | 45,408 |
| TR | 302,971 | 120,226 | 216,408 | 480,906 | 186,139 | 51,705 | 115,820 | 206,821 |
| UK | 14,819 | 5,881 | 10,585 | 23,523 | 216,145 | 60,040 | 134,490 | 240,161 |

Table A2 - 63 Biomass supply per country and scenario in 2030

| | Primary residues permanent crops (2204) | | | | Damaged crops (2205) | | | |
|---|---|---|---|---|---|---|---|---|
| | Sum of high | Sum of low | Sum of medium | Sum of tp | Sum of high | Sum of low | Sum of medium | Sum of tp |
| AL | 90,529 | 35,924 | 64,664 | 143,697 | 8,903 | 1,252 | 5,342 | 11,128 |
| AT | 29,436 | 11,681 | 21,026 | 46,725 | 35,258 | 4,958 | 21,155 | 44,072 |
| BA | 117,815 | 46,752 | 84,153 | 187,007 | 19,477 | 2,739 | 11,686 | 24,346 |
| BG | 97,878 | 38,840 | 69,913 | 155,362 | 116,787 | 16,423 | 70,072 | 145,984 |
| BL | 15,124 | 6,002 | 10,803 | 24,007 | 39,923 | 5,614 | 23,954 | 49,904 |
| CS | 242,617 | 96,277 | 173,298 | 385,107 | 139,854 | 19,667 | 83,912 | 174,817 |
| CY | 37,823 | 15,009 | 27,016 | 60,036 | 488 | 69 | 293 | 611 |
| CZ | 2,781 | 1,103 | 1,986 | 4,414 | 67,860 | 9,543 | 40,716 | 84,824 |
| DE | 123,388 | 48,963 | 88,134 | 195,853 | 413,303 | 58,121 | 247,982 | 516,628 |
| DK | 4,159 | 1,650 | 2,971 | 6,601 | 62,927 | 8,849 | 37,756 | 78,659 |
| EE | 7,513 | 2,981 | 5,366 | 11,925 | 8,397 | 1,181 | 5,038 | 10,496 |
| EL | 1,118,978 | 444,039 | 799,270 | 1,776,155 | 24,767 | 3,483 | 14,860 | 30,958 |
| ES | 3,965,846 | 1,573,748 | 2,832,747 | 6,294,994 | 147,658 | 20,764 | 88,595 | 184,573 |
| FI | 5,470 | 2,171 | 3,907 | 8,683 | 40,193 | 5,652 | 24,116 | 50,241 |
| FR | 429,911 | 170,600 | 307,079 | 682,398 | 629,991 | 88,593 | 377,995 | 787,489 |
| HR | 58,544 | 23,232 | 41,817 | 92,927 | 29,393 | 4,133 | 17,636 | 36,741 |
| HU | 89,962 | 35,699 | 64,259 | 142,797 | 125,823 | 17,694 | 75,494 | 157,279 |
| IR | 801 | 318 | 572 | 1,272 | 15,611 | 2,195 | 9,366 | 19,513 |
| IT | 1,905,077 | 755,983 | 1,360,769 | 3,023,932 | 95,818 | 13,474 | 57,491 | 119,772 |
| KO | 1,059 | 420 | 756 | 1,680 | 11,983 | 1,685 | 7,190 | 14,979 |

| | Primary residues permanent crops (2204) | | | | Damaged crops (2205) | | | |
|---|---|---|---|---|---|---|---|---|
| | Sum of high | Sum of low | Sum of medium | Sum of tp | Sum of high | Sum of low | Sum of medium | Sum of tp |
| LT | 6,316 | 2,506 | 4,511 | 10,025 | 44,570 | 6,268 | 26,742 | 55,712 |
| LV | 4,378 | 1,737 | 3,127 | 6,948 | 25,150 | 3,537 | 15,090 | 31,438 |
| MK | 30,263 | 12,009 | 21,616 | 48,036 | 6,836 | 961 | 4,102 | 8,546 |
| MO | 13,778 | 5,467 | 9,841 | 21,870 | 497 | 70 | 298 | 621 |
| MT | 335 | 133 | 240 | 532 | 45 | 6 | 27 | 56 |
| NL | 11,143 | 4,422 | 7,960 | 17,688 | 20,485 | 2,881 | 12,291 | 25,607 |
| NO | | | | | | | | |
| PL | 549,348 | 217,995 | 392,391 | 871,981 | 267,691 | 37,644 | 160,614 | 334,613 |
| PT | 799,582 | 317,294 | 571,130 | 1,269,177 | 6,443 | 906 | 3,866 | 8,054 |
| RO | 154,652 | 61,370 | 110,466 | 245,480 | 170,585 | 23,988 | 102,351 | 213,231 |
| SE | 6,882 | 2,731 | 4,916 | 10,924 | 52,626 | 7,401 | 31,576 | 65,783 |
| SI | 17,855 | 7,085 | 12,754 | 28,342 | 3,794 | 534 | 2,277 | 4,743 |
| SK | 12,466 | 4,947 | 8,905 | 19,788 | 36,274 | 5,101 | 21,765 | 45,343 |
| TR | 290,252 | 115,179 | 207,323 | 460,717 | 232,357 | 32,675 | 139,414 | 290,447 |
| UK | 12,263 | 4,866 | 8,760 | 19,466 | 207,341 | 29,157 | 124,405 | 259,176 |

Table A2 - 64 Biomass supply per country and scenario in 2050




Map 1 Distribution over Europe

## Evaluation

### General observations

Describe general observations on e.g. approach of assessment, scenario approach, results in numbers (amounts and price levels), spatial distribution, comparison with PRIMES

For permanent crops, the approach is an improvement over the S2Biom one, since it avoids the Residue-to-Surface Ratio (RSR) which does not consider crop density levels and may also yield peculiar results, especially on the regional level) over the Residue-to-Product Ratio (RPR) ratio. Although RPR ratios for permanent crops are not as well established as for herbaceous crops, the approach is probably more robust.

The third alternative for estimating the biomass potential from permanent crops, i.e. Residue-to-Tree ratio, would be difficult to be employed in this study, since the CAPRI model does not provide the number of trees as an output.

A comparison with other results of other studies / literature is not available – the paper of Garcia & Dyjakon (https://www.mdpi.com/1996-1073/12/8/1513) may be relevant to compare, even if it uses the RSR for its calculations.

A comparison with PRIMES is not possible, since that model considers totally different biomass categories.

For the technical potential, it may be useful to include values also for a baseline, historical year (e.g. 2019) to see the future evolution.

For damaged crops, the approach is quite simple, and assumes a specific percentage of total crop production that is affected by various damages.

### Strength

Please indicate what you regard as a strength in the assessment of results

The methodology is easy to apply and follows a well-established logic.

The results are in line with the expectations – countries with higher shares of permanent crops in their agricultural sector also exhibit higher shares of biomass potential from these residues.

**Weaknesses**

Please indicate what you regard as a weakness in the assessment

Biomass from plantation removals of permanent crops (i.e. for trees that are at the end of their productive life or when the farmers wish to change the variety or crop for economic reasons) is not considered in this report. Admittedly, this is a difficult category to handle, and we are not aware of any studies that have attempted to do so. Perhaps a simplified approach, like that for damaged crops could be employed, e.g. assuming that 1 % of the total cultivated area is uprooted every year. An estimate for the biomass productivity of such uprootings would also have to be made.

The assumption that climate change does not have an impact on the residue yield can be contested. First, the study does not use a "true" residue yield – the residue yield is affected by the production level of the crops (olives, fruits, grapes, etc.) and this is turn is affected by climate change – as can be be already seen in olive oil production in the Mediterranean. Second, climate change will like prompt farmers to change crops, thus affecting residue levels (producing more quantities of plantation removals in the short term and changing.

The "Removal rate in field" and "Competing use" percentages are ad hoc parameters, the levels of which are chosen arbitrarily. It would be good to clarify the current state of affairs, which is practically very low levels of removals and practically zero competing uses (beyond a few small-scale, local energy generation applications).

The "damaged crops level" percentage is an ad hoc parameter, the choice of which is not clearly explained.

**Options for improvement?**

Please indicate what can or really needs to be improved.

The residue factors and moisture levels for permanent crop residues should be referenced in the report.

Nut trees are not included in the permanent crop types; if CAPRI does not provide data for them, then it should be clearly stated.

It would be good to indicate clearly that the "damaged crops" is something relevant for all crop types, not just for permanent crops.

It is not fully clear whether the "removal rate in field" parameter considers technical limitations (can residues be removed in a mechanized way?) or sustainability considerations (should part of the residues be left on the field as soil cover and aiming to improve soil organic carbon?) or both. Perhaps this could be explained.

## SWOT 7 –Solid and liquid manure (2301 & 2302)

### Description of approach

For the assessment of manure we build on the Biomass Policies assessment of manure potential but updated the amounts to 2030 and 2050 animal number levels from CAPRI BAU scenario.

For the conversion to dry mass we assumed:

- For solid manure: 40% dm
- For liquid: 8% dm

| DI codes | Description of biomass category | Issue | Technical potential | Low mobilisation | Medium mobilisation | High mobilisation |
|---|---|---|---|---|---|---|
| l, 2302 | Liquid and solid manure from stables | Amount of animals | According to CAPRI 2.7 BAU: type of animals and heads in 2030 & 2050 | According to CAPRI 2.7 BAU: type of animals and heads in 2030 & 2050 | According to CAPRI 2.7 BAU: type of animals and heads in 2030 & 2050 | According to CAPRI 2.7 BAU: type of animals and heads in 2030 & 2050 |
| | | Manure produced in stables (based on Biomass Policies application of Miterra-Europe model, Elbersen et al., 2016) | For cattle, pig, sheep & goat, poultry: 100% of **solid and liquid manure** available. Rest directly to other on-farm uses | For cattle, pig, sheep & goat, poultry: 50% of **solid and liquid manure** available. Rest directly to other on-farm uses | For cattle, pig, sheep & goat, poultry: 60% of **solid and liquid manure** available. Rest directly to other on-farm uses | For cattle, pig, sheep & goat, poultry: 80% of **solid and liquid manure** available. Rest directly to other on-farm uses |

Table A2 - 65 *Scenario assumptions*

### Results

Results of total potentials are presented in Table 2

| | | 2030 | 2030 | 2050 | 2050 |
|---|---|---|---|---|---|
| | Technical | TP mln ton | %/total | TP mln ton | %/total |
| **2301** | Animal_solid_manure | 166.2 | 8.0% | 156.7 | 7.4% |
| **2302** | Animal_liquid_manure | 36.9 | 1.8% | 33.9 | 1.6% |
| | | | | | |
| | | | | | |
| | Low scenario | Low mln ton | %/total | Low mln ton | %/total |
| **2301** | Animal_solid_manure | 83.1 | 21.3% | 78.3 | 20.7% |
| **2302** | Animal_liquid_manure | 18.5 | 4.7% | 16.9 | 4.5% |
| | | | | | |
| | | | | | |
| | Medium scenario | Medium mln ton | %/total | Medium mln ton | %/total |
| **2301** | Animal_solid_manure | 99.7 | 14.0% | 94.0 | 13.5% |
| **2302** | Animal_liquid_manure | 22.2 | 3.1% | 20.3 | 2.9% |
| | | | | | |
| | | | | | |
| | High scenario | High mln ton | %/total | High mln ton | %/total |
| **2301** | Animal_solid_manure | 132.9 | 11.4% | 125.3 | 10.7% |
| **2302** | Animal_liquid_manure | 29.6 | 2.5% | 27.1 | 2.3% |
| | | | | | |

Table A2 - 66 Total Europe in 2030 and 2050 for technical, low, medium and high mobilisation scenario

| | Animal solid manure (2301) | | | | Animal liquid manure (2302) | | | |
|---|---|---|---|---|---|---|---|---|
| | Sum of high | Sum of low | Sum of medium | Sum of tp | Sum of high | Sum of low | Sum of medium | Sum of tp |
| AL | 680,621 | 425,388 | 510,465 | 850,776 | 122,563 | 76,602 | 91,922 | 153,203 |
| AT | 2,464,287 | 1,540,180 | 1,848,216 | 3,080,359 | 431,780 | 269,862 | 323,835 | 539,725 |
| BA | | | | | | | | |
| BG | 305,430 | 190,894 | 229,073 | 381,788 | 175,547 | 109,717 | 131,660 | 219,434 |
| BL | 4,741,640 | 2,963,525 | 3,556,230 | 5,927,051 | 498,223 | 311,389 | 373,667 | 622,778 |
| CS | 990,416 | 619,010 | 742,812 | 1,238,020 | 424,544 | 265,340 | 318,408 | 530,680 |
| CY | 198,717 | 124,198 | 149,038 | 248,396 | 29,246 | 18,279 | 21,934 | 36,557 |
| CZ | 989,507 | 618,442 | 742,130 | 1,236,884 | 323,901 | 202,438 | 242,926 | 404,876 |
| DE | 4,826,324 | 3,016,453 | 3,619,743 | 6,032,905 | 8,920,993 | 5,575,620 | 6,690,744 | 11,151,241 |
| DK | 6,974,132 | 4,358,832 | 5,230,599 | 8,717,665 | 290,762 | 181,727 | 218,072 | 363,453 |
| EE | 330,367 | 206,480 | 247,775 | 412,959 | 73,602 | 46,001 | 55,202 | 92,003 |
| EL | 850,822 | 531,764 | 638,116 | 1,063,527 | 284,295 | 177,684 | 213,221 | 355,369 |
| ES | 11,237,517 | 7,023,448 | 8,428,138 | 14,046,896 | 1,166,685 | 729,178 | 875,013 | 1,458,356 |
| FI | 1,351,995 | 844,997 | 1,013,997 | 1,689,994 | 169,529 | 105,956 | 127,147 | 211,911 |
| FR | 15,186,249 | 9,491,405 | 11,389,686 | 18,982,811 | 4,013,123 | 2,508,202 | 3,009,842 | 5,016,404 |
| HR | 411,879 | 257,425 | 308,909 | 514,849 | 270,392 | 168,995 | 202,794 | 337,990 |
| HU | 660,536 | 412,835 | 495,402 | 825,670 | 425,399 | 265,875 | 319,050 | 531,749 |
| IR | 9,476,932 | 5,923,082 | 7,107,699 | 11,846,164 | 417,092 | 260,683 | 312,819 | 521,365 |
| IT | 14,310,470 | 8,944,044 | 10,732,853 | 17,888,088 | 1,711,187 | 1,069,492 | 1,283,390 | 2,138,984 |
| KO | | | | | | | | |
| LT | 1,242,102 | 776,313 | 931,576 | 1,552,627 | 142,166 | 88,854 | 106,625 | 177,708 |
| LV | 117,348 | 73,343 | 88,011 | 146,685 | 128,567 | 80,354 | 96,425 | 160,708 |
| MK | 554,133 | 346,333 | 415,600 | 692,667 | 75,898 | 47,436 | 56,923 | 94,872 |
| MO | | | | | | | | |
| MT | | | | | | | | |
| NL | 14,199,629 | 8,874,768 | 10,649,722 | 17,749,536 | 227,481 | 142,175 | 170,610 | 284,351 |
| NO | | | | | | | | |
| PL | 8,169,646 | 5,106,029 | 6,127,235 | 10,212,058 | 2,309,830 | 1,443,644 | 1,732,372 | 2,887,287 |
| PT | 970,332 | 606,458 | 727,749 | 1,212,915 | 290,592 | 181,620 | 217,944 | 363,240 |
| RO | 3,300,713 | 2,062,946 | 2,475,535 | 4,125,892 | 625,133 | 390,708 | 468,850 | 781,416 |

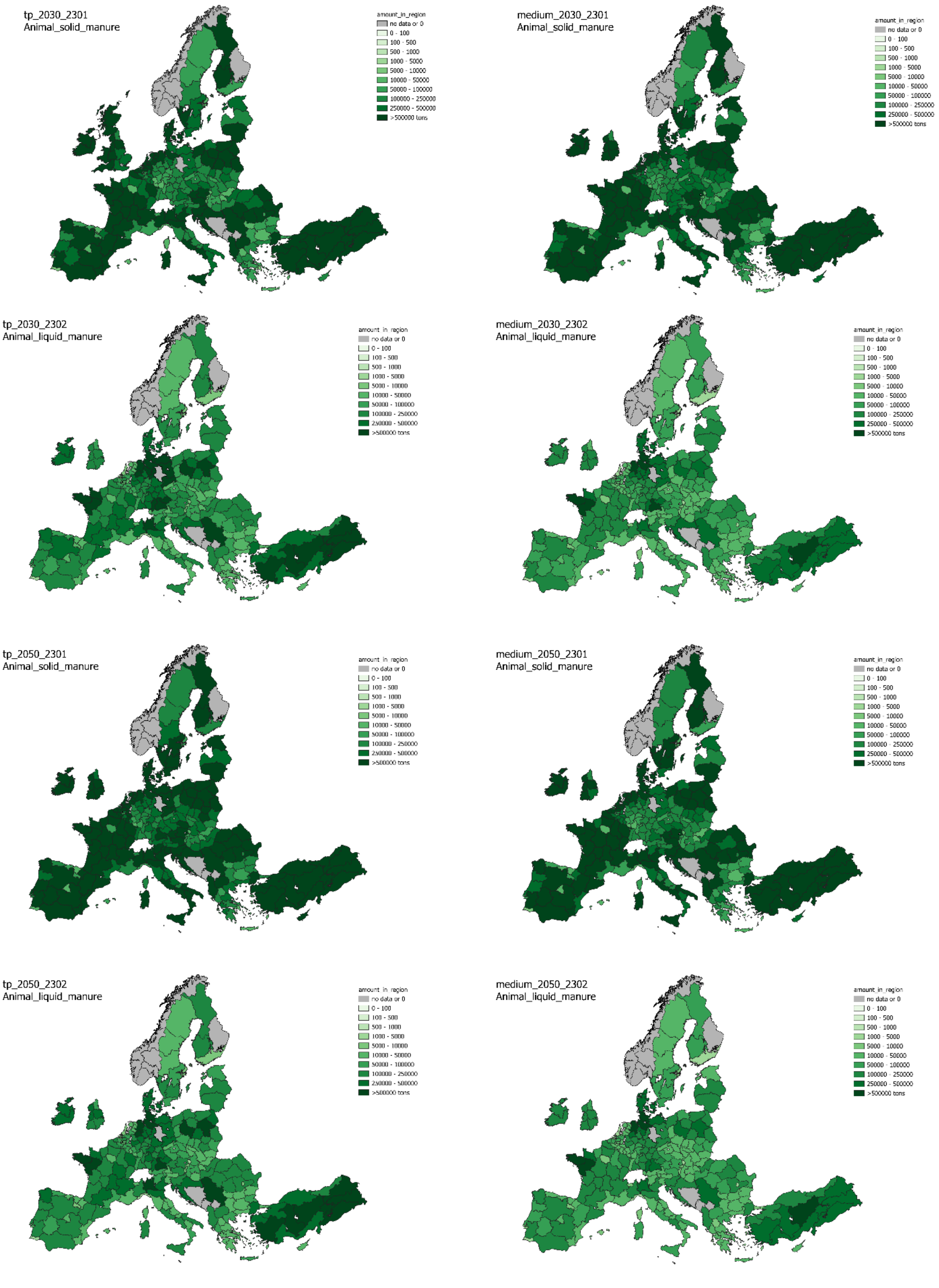
| | Animal solid manure (2301) | | | | Animal liquid manure (2302) | | | |
|---|---|---|---|---|---|---|---|---|
| | Sum of high | Sum of low | Sum of medium | Sum of tp | Sum of high | Sum of low | Sum of medium | Sum of tp |
| SE | 1,587,893 | 992,433 | 1,190,920 | 1,984,866 | 340,461 | 212,788 | 255,346 | 425,576 |
| SI | 789,746 | 493,591 | 592,310 | 987,183 | 122,582 | 76,614 | 91,936 | 153,227 |
| SK | 451,133 | 281,958 | 338,350 | 563,917 | 88,575 | 55,359 | 66,431 | 110,719 |
| TR | 18,549,006 | 11,593,129 | 13,911,755 | 23,186,258 | 3,462,917 | 2,164,323 | 2,597,188 | 4,328,646 |
| UK | 7,018,627 | 4,386,642 | 5,263,970 | 8,773,283 | 1,988,038 | 1,242,524 | 1,491,029 | 2,485,048 |

Table A2 - 67 Biomass supply per country and scenario for 2030

| | Animal solid manure (2301) | | | | Animal liquid manure (2302) | | | |
|---|---|---|---|---|---|---|---|---|
| | Sum of high | Sum of low | Sum of medium | Sum of tp | Sum of high | Sum of low | Sum of medium | Sum of tp |
| AL | 650,370 | 406,481 | 487,778 | 812,963 | 128,088 | 80,055 | 96,066 | 160,109 |
| AT | 2,193,952 | 1,371,220 | 1,645,464 | 2,742,441 | 368,623 | 230,389 | 276,467 | 460,779 |
| BA | | | | | | | | |
| BG | 283,081 | 176,926 | 212,311 | 353,852 | 141,634 | 88,521 | 106,225 | 177,042 |
| BL | 4,324,032 | 2,702,520 | 3,243,024 | 5,405,040 | 482,578 | 301,611 | 361,933 | 603,222 |
| CS | 809,994 | 506,246 | 607,495 | 1,012,492 | 396,072 | 247,545 | 297,054 | 495,090 |
| CY | 218,209 | 136,380 | 163,657 | 272,761 | 25,667 | 16,042 | 19,250 | 32,083 |
| CZ | 820,900 | 513,063 | 615,675 | 1,026,125 | 248,665 | 155,415 | 186,498 | 310,831 |
| DE | 4,251,570 | 2,657,232 | 3,188,678 | 5,314,463 | 7,152,436 | 4,470,273 | 5,364,327 | 8,940,545 |
| DK | 7,261,655 | 4,538,535 | 5,446,241 | 9,077,069 | 289,123 | 180,702 | 216,842 | 361,403 |
| EE | 247,617 | 154,761 | 185,713 | 309,522 | 48,772 | 30,483 | 36,579 | 60,965 |
| EL | 806,838 | 504,274 | 605,128 | 1,008,547 | 286,315 | 178,947 | 214,736 | 357,894 |
| ES | 12,538,979 | 7,836,862 | 9,404,234 | 15,673,724 | 1,079,882 | 674,926 | 809,911 | 1,349,852 |
| FI | 1,314,011 | 821,257 | 985,508 | 1,642,514 | 166,073 | 103,796 | 124,555 | 207,591 |
| FR | 15,052,201 | 9,407,625 | 11,289,151 | 18,815,251 | 3,858,389 | 2,411,493 | 2,893,792 | 4,822,986 |
| HR | 406,285 | 253,928 | 304,714 | 507,856 | 264,789 | 165,493 | 198,592 | 330,986 |
| HU | 585,214 | 365,759 | 438,910 | 731,517 | 382,448 | 239,030 | 286,836 | 478,060 |
| IR | 9,543,025 | 5,964,391 | 7,157,269 | 11,928,782 | 424,239 | 265,150 | 318,180 | 530,299 |
| IT | 13,842,146 | 8,651,341 | 10,381,610 | 17,302,683 | 1,622,870 | 1,014,294 | 1,217,153 | 2,028,588 |
| KO | | | | | | | | |
| LT | 918,052 | 573,783 | 688,539 | 1,147,565 | 119,753 | 74,846 | 89,815 | 149,692 |

| | Animal solid manure (2301) | | | | Animal liquid manure (2302) | | | |
|---|---|---|---|---|---|---|---|---|
| | **Sum of high** | **Sum of low** | **Sum of medium** | **Sum of tp** | **Sum of high** | **Sum of low** | **Sum of medium** | **Sum of tp** |
| LV | 97,480 | 60,925 | 73,110 | 121,850 | 109,845 | 68,653 | 82,384 | 137,307 |
| MK | 517,053 | 323,158 | 387,790 | 646,316 | 70,673 | 44,170 | 53,005 | 88,341 |
| MO | | | | | | | | |
| MT | | | | | | | | |
| NL | 13,414,970 | 8,384,356 | 10,061,228 | 16,768,713 | 238,290 | 148,931 | 178,717 | 297,862 |
| NO | | | | | | | | |
| PL | 7,031,346 | 4,394,591 | 5,273,510 | 8,789,183 | 2,106,561 | 1,316,601 | 1,579,921 | 2,633,202 |
| PT | 1,026,371 | 641,482 | 769,778 | 1,282,964 | 287,433 | 179,646 | 215,575 | 359,292 |
| RO | 3,069,049 | 1,918,156 | 2,301,787 | 3,836,311 | 701,563 | 438,477 | 526,172 | 876,954 |
| SE | 1,673,104 | 1,045,690 | 1,254,828 | 2,091,380 | 351,382 | 219,614 | 263,537 | 439,228 |
| SI | 673,667 | 421,042 | 505,250 | 842,083 | 106,967 | 66,855 | 80,225 | 133,709 |
| SK | 408,099 | 255,062 | 306,074 | 510,123 | 78,038 | 48,774 | 58,529 | 97,548 |
| TR | 14,567,236 | 9,104,523 | 10,925,427 | 18,209,045 | 3,584,698 | 2,240,436 | 2,688,524 | 4,480,873 |
| UK | 6,780,797 | 4,237,998 | 5,085,598 | 8,475,996 | 1,959,213 | 1,224,508 | 1,469,410 | 2,449,016 |

Table A2 - 68 Biomass supply per country and scenario in 2050




Map 1 Distribution over Europe

## Evaluation

### General observations

Describe general observations on e.g. approach of assessment, scenario approach, results in numbers (amounts and price levels), spatial distribution, comparison with PRIMES

The overall methodology builds upon work done in previous EU projects and is considered appropriate for this type of assessment.

The results of the PRIMES model are lower than the low mobilization scenario of this work. Without knowing the details of the assumptions of the PRIMES model, a further comparison is not possible.

### Strength

Please indicate what you regard as a strength in the assessment of results

Expanding on previous work of EU projects and the fact that future number of animals is based on the well-established CAPRI model is a strength.

### Weaknesses

Please indicate what you regard as a weakness in the assessment

The percentages used in the various mobilization scenarios are ad hoc parameters.

Due to the high moisture content of manure, mobilization is not only affected by competing uses, but also by the size of the farms (smaller farms might have to go for on-farm applications if they cannot meet economies of scale for anaerobic digestion). This parameters can be considered to be incorporated in the percentage of the various mobilization scenarios, but it is not evaluated independently in this approach.

### Options for improvement?

Please indicate what can or really needs to be improved.

No specific point for improvement.

## SWOT 8 –Secondary forestry residues (4111, 4112, 4121, 4122, 4131, 4132)

### Description of approach

For the assessment of the secondary forestry residues we build on the S2BIOM assessment. They cover 6 types of biomass: sawdust, other sawmill residues, residue from industries producing semi-finished wood based panels; residues from further wood processing, bark and black liquor. In section 3.2 of the main report it is explained how these were assessed. In this study the S2BIOM potentials, that only run until 2030, were further projected to 2050 extending the past trend 2010 to 2030 towards 2050.

| DI codes | Description of biomass category | Issue | Technical potential | Low mobilisation | Medium mobilisation | High mobilisation |
|---|---|---|---|---|---|---|
| 4111; 4112; 4121 | Sawdust, other sawmill residues and residue from industries producing semi-finished wood based panels | Competing use | All collectable residue can be collected used for energy generation. No competing use | 75% to competing use (material) | 50% to competing use (material) | 25% to competing use (material) |
| 4122; 4131; 4132 | residues from further wood processing, bark, black liquor | Competing use | All collectable residue can be collected used for energy generation. No competing use | 75% to competing use (material) | 50% to competing use (material) | 25% to competing use (material) |

Table A2 - 69 *Scenario assumptions*

### Results

Results of total potentials are presented in Table 2.

| | | 2030 | 2030 | 2050 | 2050 |
|---|---|---|---|---|---|
| | Technical | TP mln ton | %/total | TP mln ton | %/total |
| **4111** | Sec_res_sawdust | 12.2 | 0.8% | 12.7 | 0.6% |
| **4112** | Sec_res_other_sawmill | 2.3 | 0.1% | 2.7 | 0.1% |
| **4121** | Sec_res_semi_woodbp | 4.3 | 0.3% | 5.0 | 0.2% |
| **4122** | Sec_res_other_wood | 18.5 | 1.2% | 21.1 | 1.0% |
| **4131** | Sec_res_bark | 5.5 | 0.3% | 6.3 | 0.3% |
| **4132** | Sec_res_black_liquor | 25.7 | 1.6% | 25.7 | 1.2% |
| | | 2030 | 2030 | 2050 | 2050 |
| | Low scenario | Low mln ton | %/total | Low mln ton | %/total |
| **4111** | Sec_res_sawdust | 3.1 | 0.8% | 3.2 | 0.8% |
| **4112** | Sec_res_other_sawmill | 0.6 | 0.1% | 0.7 | 0.2% |
| **4121** | Sec_res_semi_woodbp | 1.1 | 0.3% | 1.3 | 0.3% |
| **4122** | Sec_res_other_wood | 4.6 | 1.2% | 5.3 | 1.4% |
| **4131** | Sec_res_bark | 2.7 | 0.7% | 3.1 | 0.8% |
| **4132** | Sec_res_black_liquor | 12.9 | 3.3% | 12.9 | 3.4% |
| | | 2030 | 2030 | 2050 | 2050 |
| | Medium scenario | Medium mln ton | %/total | Medium mln ton | %/total |
| **4111** | Sec_res_sawdust | 6.1 | 0.9% | 6.4 | 0.9% |
| **4112** | Sec_res_other_sawmill | 1.1 | 0.2% | 1.4 | 0.2% |
| **4121** | Sec_res_semi_woodbp | 2.1 | 0.3% | 2.5 | 0.4% |
| **4122** | Sec_res_other_wood | 9.2 | 1.3% | 10.5 | 1.5% |
| **4131** | Sec_res_bark | 4.1 | 0.6% | 4.7 | 0.7% |
| **4132** | Sec_res_black_liquor | 19.2 | 2.7% | 19.3 | 2.8% |
| | | 2030 | 2030 | 2050 | 2050 |

| | | 2030 | 2030 | 2050 | 2050 |
|---|---|---|---|---|---|
| | High scenario | High mln ton | %/total | High mln ton | %/total |
| **4111** | Sec_res_sawdust | 9.1 | 0.8% | 9.5 | 0.8% |
| **4112** | Sec_res_other_sawmill | 1.7 | 0.1% | 2.0 | 0.2% |
| **4121** | Sec_res_semi_woodbp | 3.2 | 0.3% | 3.8 | 0.3% |
| **4122** | Sec_res_other_wood | 13.9 | 1.2% | 15.8 | 1.3% |
| **4131** | Sec_res_bark | 5.4 | 0.3% | 6.3 | 0.5% |
| **4132** | Sec_res_black_liquor | 25.7 | 2.2% | 25.7 | 2.2% |

Table A2 - 70 Total Europe in 2030 and 2050 for technical, low, medium and high mobilisation scenario

| | Sawdust (4111) | | | | Other sawmill residues (4112) | | | | Residues semi-finished wood ind (4121) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | high | low | medium | tp | high | low | medium | tp | high | low | medium | tp |
| AL | 1,617 | 539 | 1,078 | 2,156 | 8,069 | 2,690 | 5,380 | 10,759 | 332 | 111 | 221 | 443 |
| AT | 495,286 | 165,095 | 330,191 | 660,382 | 9,429 | 3,143 | 6,286 | 12,572 | 123,105 | 41,035 | 82,070 | 164,140 |
| BA | 103,696 | 34,565 | 69,131 | 138,261 | 62,894 | 20,965 | 41,929 | 83,859 | 9,007 | 3,002 | 6,004 | 12,009 |
| BG | 61,408 | 20,469 | 40,939 | 81,877 | 15,492 | 5,164 | 10,328 | 20,656 | 22,586 | 7,529 | 15,057 | 30,115 |
| BL | 71,406 | 23,802 | 47,604 | 95,208 | 17,853 | 5,951 | 11,902 | 23,803 | 45,470 | 15,157 | 30,313 | 60,627 |
| CS | 14,855 | 4,952 | 9,903 | 19,806 | 61,010 | 20,337 | 40,673 | 81,347 | 15,573 | 5,191 | 10,382 | 20,764 |
| CY | 485 | 162 | 323 | 646 | 66 | 22 | 44 | 88 | 102 | 34 | 68 | 136 |
| CZ | 335,778 | 111,926 | 223,852 | 447,704 | 23,424 | 7,808 | 15,616 | 31,232 | 75,009 | 25,003 | 50,006 | 100,012 |
| DE | 1,515,861 | 505,287 | 1,010,574 | 2,021,148 | 75,396 | 25,132 | 50,264 | 100,528 | 413,542 | 137,847 | 275,695 | 551,390 |
| DK | 28,722 | 9,574 | 19,148 | 38,297 | 12,699 | 4,233 | 8,466 | 16,932 | 10,583 | 3,528 | 7,055 | 14,110 |
| EE | 146,662 | 48,887 | 97,774 | 195,549 | 15,199 | 5,066 | 10,133 | 20,266 | 39,302 | 13,101 | 26,201 | 52,403 |
| EL | 13,371 | 4,457 | 8,914 | 17,827 | 16,944 | 5,648 | 11,296 | 22,592 | 9,831 | 3,277 | 6,554 | 13,108 |
| ES | 108,633 | 36,211 | 72,422 | 144,844 | 47,649 | 15,883 | 31,766 | 63,532 | 178,880 | 59,627 | 119,254 | 238,507 |
| FI | 981,968 | 327,323 | 654,646 | 1,309,291 | 5,064 | 1,688 | 3,376 | 6,752 | 313,523 | 104,508 | 209,016 | 418,031 |
| FR | 522,698 | 174,233 | 348,465 | 696,931 | 227,627 | 75,876 | 151,751 | 303,503 | 161,661 | 53,887 | 107,774 | 215,549 |
| HR | 13,855 | 4,618 | 9,237 | 18,473 | 107,147 | 35,716 | 71,431 | 142,863 | 12,079 | 4,026 | 8,052 | 16,105 |
| HU | 8,687 | 2,896 | 5,791 | 11,582 | 33,348 | 11,116 | 22,232 | 44,464 | 59,570 | 19,857 | 39,713 | 79,426 |
| IR | 117,536 | 39,179 | 78,357 | 156,714 | 118 | 39 | 79 | 157 | 21,961 | 7,320 | 14,641 | 29,281 |
| IT | 46,586 | 15,529 | 31,057 | 62,114 | 32,051 | 10,684 | 21,368 | 42,735 | 167,504 | 55,835 | 111,670 | 223,339 |
| KO | 1,838 | 613 | 1,225 | 2,451 | 1,665 | 555 | 1,110 | 2,219 | 256 | 85 | 171 | 342 |
| LT | 102,736 | 34,245 | 68,491 | 136,982 | 82,531 | 27,510 | 55,021 | 110,041 | 50,523 | 16,841 | 33,682 | 67,364 |
| LV | 366,717 | 122,239 | 244,478 | 488,956 | 118,683 | 39,561 | 79,122 | 158,244 | 142,248 | 47,416 | 94,832 | 189,663 |
| MK | 3,285 | 1,095 | 2,190 | 4,380 | 6,185 | 2,062 | 4,123 | 8,247 | 288 | 96 | 192 | 384 |
| MO | 16,030 | 5,343 | 10,687 | 21,374 | 7,899 | 2,633 | 5,266 | 10,533 | 961 | 320 | 641 | 1,282 |
| MT | - | - | - | - | - | - | - | - | - | - | - | - |
| NL | 13,085 | 4,362 | 8,723 | 17,446 | 6,538 | 2,179 | 4,359 | 8,718 | 564 | 188 | 376 | 752 |
| NO | - | - | - | - | - | - | - | - | - | - | - | - |
| PL | 606,264 | 202,088 | 404,176 | 808,352 | 97,209 | 32,403 | 64,806 | 129,612 | 362,364 | 120,788 | 241,576 | 483,152 |
| PT | 55,122 | 18,374 | 36,748 | 73,496 | 10,211 | 3,404 | 6,807 | 13,615 | 47,656 | 15,885 | 31,771 | 63,542 |
| RO | 445,553 | 148,518 | 297,035 | 594,070 | 266,547 | 88,849 | 177,698 | 355,395 | 404,512 | 134,837 | 269,674 | 539,349 |

| | Sawdust (4111) | | | | Other sawmill residues (4112) | | | | Residues semi-finished wood ind (4121) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | high | low | medium | tp | high | low | medium | tp | high | low | medium | tp |
| SE | 1,978,565 | 659,522 | 1,319,044 | 2,638,087 | 13,425 | 4,475 | 8,950 | 17,900 | 52,961 | 17,654 | 35,307 | 70,614 |
| SI | 95,230 | 31,743 | 63,486 | 126,973 | 16,417 | 5,472 | 10,944 | 21,889 | 60,321 | 20,107 | 40,214 | 80,429 |
| SK | 103,786 | 34,595 | 69,190 | 138,381 | 38,607 | 12,869 | 25,738 | 51,477 | 19,338 | 6,446 | 12,892 | 25,784 |
| TR | 425,704 | 141,901 | 283,803 | 567,605 | 264,392 | 88,131 | 176,261 | 352,522 | 331,286 | 110,429 | 220,857 | 441,715 |
| UK | 365,334 | 121,778 | 243,556 | 487,112 | 9,891 | 3,297 | 6,594 | 13,187 | 47,876 | 15,959 | 31,917 | 63,834 |

Table A2 - 71 Biomass supply sawdust, other saw mill residues and wood industries producing semi-finished wood products per country scenario in 2030

| | Residues other wood processing industries (4122) | | | | Bark (4131) | | | | Black liquor (4132)* | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | high | low | medium | tp | high | low | medium | tp | high | low | medium | tp |
| AL | 19,947 | 6,649 | 13,298 | 26,597 | - | - | - | - | - | - | - | - |
| AT | 349,663 | 116,554 | 233,109 | 466,217 | 191,092 | 95,546 | 143,319 | 191,092 | 1,273,789 | 636,894 | 955,342 | 1,273,789 |
| BA | 63,424 | 21,141 | 42,283 | 84,566 | 10,862 | 5,431 | 8,147 | 10,862 | 75,432 | 37,716 | 56,574 | 75,432 |
| BG | 109,941 | 36,647 | 73,294 | 146,587 | 19,205 | 9,603 | 14,404 | 19,205 | 129,753 | 64,876 | 97,315 | 129,753 |
| BL | 104,206 | 34,735 | 69,470 | 138,941 | 49,985 | 24,992 | 37,488 | 49,985 | 233,617 | 116,809 | 175,213 | 233,617 |
| CS | 62,425 | 20,808 | 41,617 | 83,233 | - | - | - | - | - | - | - | - |
| CY | 37,730 | 12,577 | 25,154 | 50,307 | - | - | - | - | - | - | - | - |
| CZ | 396,994 | 132,331 | 264,663 | 529,326 | 86,824 | 43,412 | 65,118 | 86,824 | 601,163 | 300,581 | 450,872 | 601,163 |
| DE | 1,815,878 | 605,293 | 1,210,585 | 2,421,170 | 348,189 | 174,094 | 261,142 | 348,189 | 1,590,860 | 795,430 | 1,193,145 | 1,590,860 |
| DK | 125,695 | 41,898 | 83,797 | 167,594 | 427 | 213 | 320 | 427 | - | - | - | - |
| EE | 162,246 | 54,082 | 108,164 | 216,327 | 26,062 | 13,031 | 19,546 | 26,062 | 72,429 | 36,214 | 54,322 | 72,429 |
| EL | 135,580 | 45,193 | 90,387 | 180,774 | - | - | - | - | - | - | - | - |
| ES | 687,782 | 229,261 | 458,521 | 917,042 | 274,287 | 137,143 | 205,715 | 274,287 | 1,854,370 | 927,185 | 1,390,777 | 1,854,370 |
| FI | 172,963 | 57,654 | 115,309 | 230,618 | 1,696,361 | 848,181 | 1,272,271 | 1,696,361 | 6,821,355 | 3,410,678 | 5,116,016 | 6,821,355 |
| FR | 898,973 | 299,658 | 599,315 | 1,198,630 | 214,981 | 107,490 | 161,235 | 214,981 | 1,238,344 | 619,172 | 928,758 | 1,238,344 |
| HR | 69,116 | 23,039 | 46,077 | 92,155 | - | - | - | - | - | - | - | - |
| HU | 370,224 | 123,408 | 246,816 | 493,633 | - | - | - | - | - | - | - | - |
| IR | 36,575 | 12,192 | 24,383 | 48,766 | 16 | 8 | 12 | 16 | - | - | - | - |
| IT | 1,118,675 | 372,892 | 745,783 | 1,491,566 | 33,510 | 16,755 | 25,133 | 33,510 | 24,999 | 12,499 | 18,749 | 24,999 |
| KO | 7,904 | 2,635 | 5,269 | 10,538 | - | - | - | - | - | - | - | - |
| LT | 328,774 | 109,591 | 219,182 | 438,365 | - | - | - | - | - | - | - | - |

| | Residues other wood processing industries (4122) | | | | Bark (4131) | | | | Black liquor (4132)* | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **high** | **low** | **medium** | **tp** | **high** | **low** | **medium** | **tp** | **high** | **low** | **medium** | **tp** |
| LV | 205,303 | 68,434 | 136,869 | 273,737 | - | - | - | - | - | - | - | - |
| MK | 14,167 | 4,722 | 9,445 | 18,890 | - | - | - | - | - | - | - | - |
| MO | 9,386 | 3,129 | 6,257 | 12,515 | - | - | - | - | - | - | - | - |
| MT | 6,717 | 2,239 | 4,478 | 8,956 | - | - | - | - | - | - | - | - |
| NL | 261,080 | 87,027 | 174,053 | 348,106 | 4,055 | 2,028 | 3,042 | 4,055 | - | - | - | - |
| NO | - | - | - | - | - | - | - | - | - | - | - | - |
| PL | 2,202,585 | 734,195 | 1,468,390 | 2,936,780 | 143,683 | 71,842 | 107,762 | 143,683 | 882,499 | 441,249 | 661,874 | 882,499 |
| PT | 285,925 | 95,308 | 190,616 | 381,233 | 346,149 | 173,074 | 259,611 | 346,149 | 2,403,810 | 1,201,905 | 1,802,857 | 2,403,810 |
| RO | 1,023,884 | 341,295 | 682,589 | 1,365,179 | - | - | - | - | - | - | - | - |
| SE | 403,218 | 134,406 | 268,812 | 537,624 | 1,901,605 | 950,803 | 1,426,204 | 1,901,605 | 7,833,756 | 3,916,878 | 5,875,317 | 7,833,756 |
| SI | 161,503 | 53,834 | 107,668 | 215,337 | 4,970 | 2,485 | 3,728 | 4,970 | 2,228 | 1,114 | 1,671 | 2,228 |
| SK | 161,659 | 53,886 | 107,773 | 215,546 | 99,617 | 49,809 | 74,713 | 99,617 | 679,548 | 339,774 | 509,661 | 679,548 |
| TR | 938,362 | 312,787 | 625,575 | 1,251,150 | 5,822 | 2,911 | 4,366 | 5,822 | - | - | - | - |
| UK | 1,109,147 | 369,716 | 739,431 | 1,478,862 | 18,547 | 9,274 | 13,910 | 18,547 | - | - | - | - |

**Black liquor is low because internal use in paper and pulp industry for own electricity and heat already subtracted. In PRIMES this is not the case, hence the higher levels of demands in PRIMES*

Table A2 - 72 Biomass other woodprocessing industries, bark and black liquor per country scenario in 2030

| | Sawdust (4111) | | | | Other sawmill residues (4112) | | | | Residues semi-finished wood ind (4121) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **high** | **low** | **medium** | **tp** | **high** | **low** | **medium** | **tp** | **high** | **low** | **medium** | **tp** |
| AL | 1,997 | 666 | 1,331 | 2,662 | 9,963 | 3,321 | 6,642 | 13,284 | 375 | 125 | 250 | 500 |
| AT | 349,588 | 116,529 | 233,059 | 466,117 | 6,655 | 2,218 | 4,437 | 8,874 | 134,805 | 44,935 | 89,870 | 179,740 |
| BA | 106,464 | 35,488 | 70,976 | 141,952 | 64,573 | 21,524 | 43,049 | 86,097 | 10,182 | 3,394 | 6,788 | 13,576 |
| BG | 67,566 | 22,522 | 45,044 | 90,089 | 17,045 | 5,682 | 11,364 | 22,727 | 23,949 | 7,983 | 15,966 | 31,931 |
| BL | 50,684 | 16,895 | 33,789 | 67,578 | 12,672 | 4,224 | 8,448 | 16,896 | 39,702 | 13,234 | 26,468 | 52,936 |
| CS | 18,340 | 6,113 | 12,227 | 24,454 | 75,327 | 25,109 | 50,218 | 100,435 | 17,606 | 5,869 | 11,737 | 23,474 |
| CY | 738 | 246 | 492 | 984 | 101 | 34 | 67 | 135 | 64 | 21 | 43 | 85 |
| CZ | 364,802 | 121,601 | 243,201 | 486,403 | 25,449 | 8,483 | 16,966 | 33,932 | 87,271 | 29,090 | 58,180 | 116,361 |
| DE | 1,391,311 | 463,770 | 927,541 | 1,855,082 | 69,201 | 23,067 | 46,134 | 92,268 | 455,099 | 151,700 | 303,399 | 606,798 |
| DK | 35,835 | 11,945 | 23,890 | 47,780 | 15,844 | 5,281 | 10,562 | 21,125 | - | - | - | - |
| EE | 148,414 | 49,471 | 98,942 | 197,885 | 15,381 | 5,127 | 10,254 | 20,508 | 47,022 | 15,674 | 31,348 | 62,696 |

| | Sawdust (4111) | | | | Other sawmill residues (4112) | | | | Residues semi-finished wood ind (4121) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **high** | **low** | **medium** | **tp** | **high** | **low** | **medium** | **tp** | **high** | **low** | **medium** | **tp** |
| EL | 20,356 | 6,785 | 13,570 | 27,141 | 25,795 | 8,598 | 17,197 | 34,394 | 6,168 | 2,056 | 4,112 | 8,224 |
| ES | 92,735 | 30,912 | 61,823 | 123,646 | 40,676 | 13,559 | 27,117 | 54,234 | 199,490 | 66,497 | 132,993 | 265,987 |
| FI | 825,520 | 275,173 | 550,347 | 1,100,694 | 4,257 | 1,419 | 2,838 | 5,676 | 311,067 | 103,689 | 207,378 | 414,756 |
| FR | 604,212 | 201,404 | 402,808 | 805,616 | 263,125 | 87,708 | 175,417 | 350,833 | 177,184 | 59,061 | 118,123 | 236,246 |
| HR | 15,799 | 5,266 | 10,533 | 21,066 | 122,182 | 40,727 | 81,455 | 162,910 | 18,078 | 6,026 | 12,052 | 24,104 |
| HU | 12,048 | 4,016 | 8,032 | 16,064 | 46,252 | 15,417 | 30,834 | 61,669 | 91,128 | 30,376 | 60,752 | 121,505 |
| IR | 154,509 | 51,503 | 103,006 | 206,012 | 155 | 52 | 103 | 207 | 22,395 | 7,465 | 14,930 | 29,860 |
| IT | 22,105 | 7,368 | 14,736 | 29,473 | 15,208 | 5,069 | 10,139 | 20,277 | 135,912 | 45,304 | 90,608 | 181,215 |
| KO | 2,269 | 756 | 1,513 | 3,026 | 2,055 | 685 | 1,370 | 2,740 | 290 | 97 | 193 | 386 |
| LT | 120,404 | 40,135 | 80,270 | 160,539 | 96,724 | 32,241 | 64,483 | 128,966 | 67,237 | 22,412 | 44,825 | 89,649 |
| LV | 474,219 | 158,073 | 316,146 | 632,292 | 153,474 | 51,158 | 102,316 | 204,632 | 217,879 | 72,626 | 145,253 | 290,505 |
| MK | 4,056 | 1,352 | 2,704 | 5,408 | 7,636 | 2,545 | 5,091 | 10,182 | 326 | 109 | 217 | 435 |
| MO | 19,792 | 6,597 | 13,195 | 26,389 | 9,753 | 3,251 | 6,502 | 13,004 | 1,087 | 362 | 724 | 1,449 |
| MT | - | - | - | - | - | - | - | - | - | - | - | - |
| NL | 14,281 | 4,760 | 9,521 | 19,042 | 7,136 | 2,379 | 4,758 | 9,515 | 564 | 188 | 376 | 752 |
| NO | - | - | - | - | - | - | - | - | - | - | - | - |
| PL | 907,713 | 302,571 | 605,142 | 1,210,284 | 145,544 | 48,515 | 97,029 | 194,059 | 428,733 | 142,911 | 285,822 | 571,644 |
| PT | 42,932 | 14,311 | 28,621 | 57,242 | 7,953 | 2,651 | 5,302 | 10,604 | 42,492 | 14,164 | 28,328 | 56,656 |
| RO | 626,779 | 208,926 | 417,852 | 835,705 | 374,963 | 124,988 | 249,975 | 499,950 | 618,467 | 206,156 | 412,312 | 824,623 |
| SE | 1,942,650 | 647,550 | 1,295,100 | 2,590,200 | 13,182 | 4,394 | 8,788 | 17,575 | 80,479 | 26,826 | 53,653 | 107,306 |
| SI | 143,777 | 47,926 | 95,851 | 191,703 | 24,786 | 8,262 | 16,524 | 33,048 | 87,845 | 29,282 | 58,563 | 117,126 |
| SK | 102,983 | 34,328 | 68,656 | 137,311 | 38,309 | 12,770 | 25,539 | 51,079 | 25,437 | 8,479 | 16,958 | 33,916 |
| TR | 494,584 | 164,861 | 329,723 | 659,446 | 307,171 | 102,390 | 204,781 | 409,562 | 391,314 | 130,438 | 260,876 | 521,752 |
| UK | 357,659 | 119,220 | 238,439 | 476,879 | 9,683 | 3,228 | 6,455 | 12,910 | 53,313 | 17,771 | 35,542 | 71,084 |

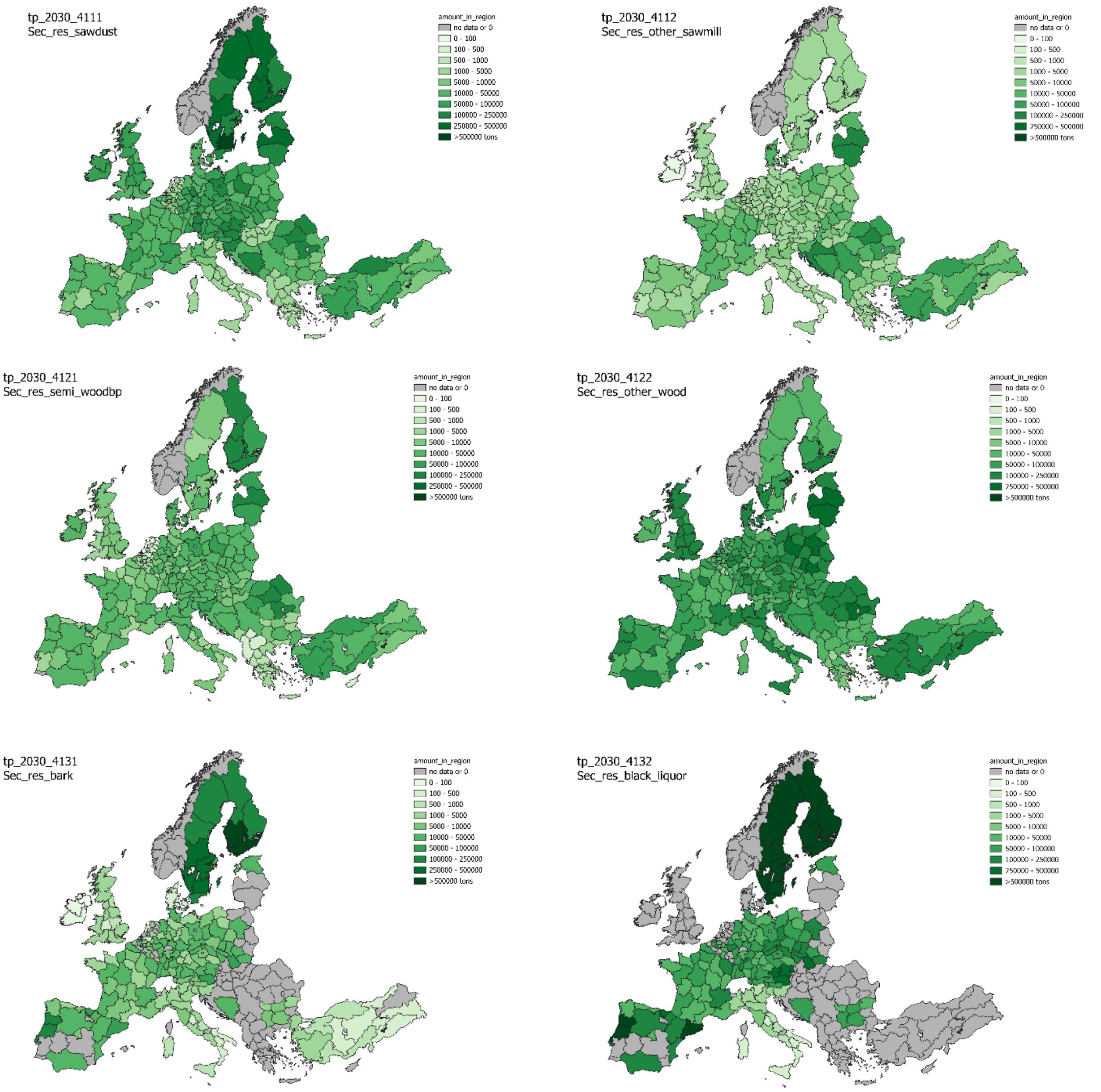
Table A2 - 73 Biomass supply sawdust, other saw mill residues and wood industries producing semi-finished wood products per country scenario in 2050

| | Residues other wood processing industries (4122) | | | | Bark (4131) | | | | Black liquor (4132)* | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | high | low | medium | tp | high | low | medium | tp | high | low | medium | tp |
| AL | 23,648 | 7,883 | 15,765 | 31,531 | - | - | - | - | - | - | - | - |
| AT | 325,786 | 108,595 | 217,191 | 434,382 | 156,298 | 78,149 | 117,223 | 156,298 | 1,273,789 | 636,894 | 955,342 | 1,273,789 |
| BA | 68,576 | 22,859 | 45,717 | 91,435 | 10,359 | 5,180 | 7,769 | 10,359 | 75,432 | 37,716 | 56,574 | 75,432 |
| BG | 118,812 | 39,604 | 79,208 | 158,416 | 18,316 | 9,158 | 13,737 | 18,316 | 129,753 | 64,876 | 97,315 | 129,753 |
| BL | 83,003 | 27,668 | 55,335 | 110,671 | 47,671 | 23,835 | 35,753 | 47,671 | 233,617 | 116,809 | 175,213 | 233,617 |
| CS | 74,006 | 24,669 | 49,337 | 98,675 | - | - | - | - | - | - | - | - |
| CY | 47,849 | 15,950 | 31,899 | 63,798 | - | - | - | - | - | - | - | - |
| CZ | 447,198 | 149,066 | 298,132 | 596,265 | 82,804 | 41,402 | 62,103 | 82,804 | 601,163 | 300,581 | 450,872 | 601,163 |
| DE | 1,846,260 | 615,420 | 1,230,840 | 2,461,680 | 368,705 | 184,352 | 276,529 | 368,705 | 1,590,860 | 795,430 | 1,193,145 | 1,590,860 |
| DK | 99,803 | 33,268 | 66,535 | 133,070 | 407 | 203 | 305 | 407 | - | - | - | - |
| EE | 180,519 | 60,173 | 120,346 | 240,692 | 24,855 | 12,428 | 18,641 | 24,855 | 72,429 | 36,214 | 54,322 | 72,429 |
| EL | 171,939 | 57,313 | 114,626 | 229,252 | - | - | - | - | - | - | - | - |
| ES | 687,516 | 229,172 | 458,344 | 916,687 | 261,588 | 130,794 | 196,191 | 261,588 | 1,854,370 | 927,185 | 1,390,777 | 1,854,370 |
| FI | 159,338 | 53,113 | 106,225 | 212,451 | 2,110,509 | 1,055,255 | 1,582,882 | 2,110,509 | 6,821,355 | 3,410,678 | 5,116,016 | 6,821,355 |
| FR | 1,013,049 | 337,683 | 675,366 | 1,350,732 | 205,028 | 102,514 | 153,771 | 205,028 | 1,238,344 | 619,172 | 928,758 | 1,238,344 |
| HR | 93,899 | 31,300 | 62,600 | 125,199 | - | - | - | - | - | - | - | - |
| HU | 542,814 | 180,938 | 361,876 | 723,753 | - | - | - | - | - | - | - | - |
| IR | 43,531 | 14,510 | 29,020 | 58,041 | 15 | 8 | 12 | 15 | - | - | - | - |
| IT | 740,862 | 246,954 | 493,908 | 987,817 | 31,959 | 15,979 | 23,969 | 31,959 | 24,999 | 12,499 | 18,749 | 24,999 |
| KO | 9,370 | 3,123 | 6,247 | 12,493 | - | - | - | - | - | - | - | - |
| LT | 413,838 | 137,946 | 275,892 | 551,784 | - | - | - | - | - | - | - | - |
| LV | 294,153 | 98,051 | 196,102 | 392,204 | - | - | - | - | - | - | - | - |
| MK | 16,796 | 5,599 | 11,197 | 22,394 | - | - | - | - | - | - | - | - |
| MO | 11,127 | 3,709 | 7,418 | 14,836 | - | - | - | - | - | - | - | - |
| MT | 6,717 | 2,239 | 4,478 | 8,956 | - | - | - | - | - | - | - | - |
| NL | 273,532 | 91,177 | 182,355 | 364,710 | 3,868 | 1,934 | 2,901 | 3,868 | - | - | - | - |
| NO | - | - | - | - | - | - | - | - | - | - | - | - |
| PL | 3,022,336 | 1,007,445 | 2,014,891 | 4,029,781 | 137,031 | 68,516 | 102,773 | 137,031 | 882,499 | 441,249 | 661,874 | 882,499 |
| PT | 239,530 | 79,843 | 159,686 | 319,373 | 330,123 | 165,062 | 247,592 | 330,123 | 2,403,810 | 1,201,905 | 1,802,857 | 2,403,810 |
| RO | 1,508,832 | 502,944 | 1,005,888 | 2,011,775 | - | - | - | - | - | - | - | - |

| | Residues other wood processing industries (4122) | | | | Bark (4131) | | | | Black liquor (4132)* | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **high** | **low** | **medium** | **tp** | **high** | **low** | **medium** | **tp** | **high** | **low** | **medium** | **tp** |
| SE | 538,196 | 179,399 | 358,798 | 717,595 | 2,365,862 | 1,182,931 | 1,774,396 | 2,365,862 | 7,833,756 | 3,916,878 | 5,875,317 | 7,833,756 |
| SI | 239,698 | 79,899 | 159,799 | 319,598 | 4,740 | 2,370 | 3,555 | 4,740 | 2,228 | 1,114 | 1,671 | 2,228 |
| SK | 190,934 | 63,645 | 127,289 | 254,579 | 95,006 | 47,503 | 71,254 | 95,006 | 679,548 | 339,774 | 509,661 | 679,548 |
| TR | 1,099,386 | 366,462 | 732,924 | 1,465,848 | 5,552 | 2,776 | 4,164 | 5,552 | - | - | - | - |
| UK | 1,165,199 | 388,400 | 776,800 | 1,553,599 | 17,689 | 8,844 | 13,266 | 17,689 | - | - | - | - |

**Black liquor is low because internal use in paper and pulp industry for own electricity and heat already subtracted. In PRIMES this is not the case, hence the higher levels of demands in PRIMES*

Table A2 - 74 Biomass other woodprocessing industries, bark and black liquor per country scenario in 2050




Map 1 Distribution over Europe

## Evaluation

### General observations

*Describe general observations on e.g. approach of assessment, scenario approach, results in numbers (amounts and price levels), spatial distribution, comparison with PRIMES*

The difference between PRIMES demand is very high. This requires a good explanation

### Strength

*Please indicate what you regard as a strength in the assessment of results*

### Weaknesses

*Please indicate what you regard as a weakness in the assessment*

### Options for improvement?

*Please indicate what <u>can</u> or <u>really needs</u> to be improved.*

## SWOT 9 –Secondary agricultural residues (4201, 4202, 4203, 4204, 4205, 4206, 4207)

### Description of approach

For the assessment of the secondary agricultural residues we partly build on S2BIOM factors, but most of the residues were newly assessed and many new ones were added. They cover 7 types of biomass as presented in the table underneath. The basic input data is either production level or crop area 2030 and 2050 derived from the CAPRI BAU scenario. For the scenario specific biomass potentials see Table 2 for rules applied.

| DI number | Additional category info | Area/production source | Residue factor | Factor |
|---|---|---|---|---|
| 4201 | Rice husk | Production of rice (area*yield) | Rice husk is approximately 20% of the processed rice, with average moisture content of 10% ((Nikolaou, 2002)). It is assumed that all rice produced in the S2BIOM countrie is locally processed (S2BIOM) | 0.2*0.9 |
| 4202 | Grape pomace: Pressed grape dregs, stalks and seeds | Production of grapes (area*yield) | Grape pomace represents approximately 20% of the weight of grapes processed (Arvanitoyannis & Varzakas, 2008). The moisture content of grape pomace is between 50%-72% (Cvejic Hohervorst et al (2017). | 0.2*0.39 |
| 4203 | Cereal bran | The basis is: total amount of cereals processed in every country. So net domestic cereal production and imports = Domestic productioncereals – exportcereals + importcereals The data on total domestic production, exports and imports levels were available from CAPRI for 2030 and 2050 for all EU and several European non-EU countries. | In wheat processing 20% to 25% wheat offals (Kent et al., 1994). Wheat bran represents roughly 50% of wheat offals and about 10 to 19% of the kernel, depending on the variety and milling process ( WMC, 2008; Prikhodko et al., 2009; Hassan et al., 2008). . So the residue to yield factor used is 10% of cereals processed domestically. | *0.1*0.9 |
| 4204 | Cobs cleaned from grain maize | Either the grain maize production level, or total hectares with MAIZ. | The relative potential yield of maize cobs was established as 18.7% of the grain mass, while the wet cob yield recorded in the field after mechanical harvesting was 1.6 t ha–1. The total solid content was 60%. (Bandini et al, 2016*) | Ha grain maize*1.6*0.6 |
| 4205 | olive stones | Production of olives (for oil and 30% of table olives) 2030 & 2050 | Olive pitts make up between 10%-12.5% of the weight of olive according to Garcia et al. 2012 and Pattarra et al., 2010) (S2BIOM). We assume 15% moisture in olive stone | *0.1125*0.85 |
| 4206 | Bagasse from sugarbeet (not sugar cane, as this practically does not grow in Europe) also called sugarbeet pulp | Production of sugarbeet (area*yield) | Approximately 10 dry tons of a fibrous residue (called bagasse) are produced for every ton of cane sugar while about 0.5 dry tons of residue are produced for every ton of beet sugar (Dale, B (2003)**. Generally, standard sugar beets contain 16-20% sugar by weight. So 1 ton sugarbeet delivers 0.18 ton of sugar (Duraisam et al, 2017). | *0.18*0.5 (dry ton bagasse) |
| 4207 | Deoiled olive pomace | Production of olives (area*yield) | 7.38 kg of olives for 1 liter olive oil. This leads to 2.56 kg deoiled olive pommace. 50% moisture content (Tawara, 2019) | *(2.56/7.38)*0.5 |

Table A2 - 75 Factors used for calculation

| DI codes | Description of biomass category | Issue | Technical potential | Low mobilisation | Medium mobilisation | High mobilisation |
|---|---|---|---|---|---|---|
| 4201, 4202, 4203, 4204, 4205, 4206, 4207, | Food processing residues | Amount of processed agricultural products | According to CAPRI 2.7 BAU 2030, 2050: or other published sources (see Annex 2) | According to CAPRI 2.7 BAU 2030, 2050: or other published sources (see Annex 2) | According to CAPRI 2.7 BAU 2030, 2050: or other published sources (see Annex 2) | According to CAPRI 2.7 BAU 2030, 2050: or other published sources (see Annex 2) |
| | | Competing uses | 0% competing use | 75% to competing uses | 50% to competing uses | 25% to competing uses |

Table A2 - 76 *Scenario assumptions*

## Results

Results of total potentials are presented in Table 3

| | | 2030 | 2030 | 2050 | 2050 |
|---|---|---|---|---|---|
| | Technical | TP mln ton | %/total | TP mln ton | %/total |
| **4201** | Sec_res_rice_husk | 0.0 | 0.0% | 0.0 | 0.0% |
| **4202** | Sec_res_grapes | 0.0 | 0.0% | 0.0 | 0.0% |
| **4203** | Sec_res_cereal_bran | 0.0 | 0.0% | 0.0 | 0.0% |
| **4204** | Sec_res_maize_cobs | 7.4 | 0.5% | 6.5 | 0.3% |
| **4205** | Sec_res_olive_stones | 0.0 | 0.0% | 0.0 | 0.0% |
| **4206** | Sec_res_sgb_bagasse | 0.0 | 0.0% | 0.0 | 0.0% |
| **4207** | Sec_res_olive_pommace | 0.0 | 0.0% | 0.0 | 0.0% |
| | | | | | |
| | Low scenario | Low mln ton | %/total | Low mln ton | %/total |
| **4201** | Sec_res_rice_husk | 0.0 | 0.0% | 0.0 | 0.0% |
| **4202** | Sec_res_grapes | 0.0 | 0.0% | 0.0 | 0.0% |
| **4203** | Sec_res_cereal_bran | 0.0 | 0.0% | 0.0 | 0.0% |
| **4204** | Sec_res_maize_cobs | 1.9 | 0.6% | 1.6 | 0.5% |
| **4205** | Sec_res_olive_stones | 0.0 | 0.0% | 0.0 | 0.0% |
| **4206** | Sec_res_sgb_bagasse | 0.0 | 0.0% | 0.0 | 0.0% |
| **4207** | Sec_res_olive_pommace | 0.0 | 0.0% | 0.0 | 0.0% |
| | | | | | |
| | Medium scenario | Medium mln ton | %/total | Medium mln ton | %/total |
| **4201** | Sec_res_rice_husk | 0.0 | 0.0% | 0.0 | 0.0% |
| **4202** | Sec_res_grapes | 0.0 | 0.0% | 0.0 | 0.0% |
| **4203** | Sec_res_cereal_bran | 0.0 | 0.0% | 0.0 | 0.0% |
| **4204** | Sec_res_maize_cobs | 3.7 | 0.7% | 3.2 | 0.6% |
| **4205** | Sec_res_olive_stones | 0.0 | 0.0% | 0.0 | 0.0% |
| **4206** | Sec_res_sgb_bagasse | 0.0 | 0.0% | 0.0 | 0.0% |
| **4207** | Sec_res_olive_pommace | 0.0 | 0.0% | 0.0 | 0.0% |
| | | | | | |
| | High scenario | High mln ton | %/total | High mln ton | %/total |
| **4201** | Sec_res_rice_husk | 0.0 | 0.0% | 0.0 | 0.0% |
| **4202** | Sec_res_grapes | 0.0 | 0.0% | 0.0 | 0.0% |
| **4203** | Sec_res_cereal_bran | 0.0 | 0.0% | 0.0 | 0.0% |
| **4204** | Sec_res_maize_cobs | 5.6 | 0.6% | 4.8 | 0.5% |
| **4205** | Sec_res_olive_stones | 0.0 | 0.0% | 0.0 | 0.0% |
| **4206** | Sec_res_sgb_bagasse | 0.0 | 0.0% | 0.0 | 0.0% |
| **4207** | Sec_res_olive_pommace | 0.0 | 0.0% | 0.0 | 0.0% |

Table A2 - 77  Total Europe in 2030 and 2050 for technical, low, medium and high mobilisation scenario

| | Rice husk (4201) | | | | Grape dregs (4202) | | | | Cereal bran (4203) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | high | low | medium | tp | high | low | medium | tp | high | low | medium | tp |
| AL | | | | | 0 | 0 | 0 | 0 | 51 | 17 | 34 | 67 |
| AT | | | | | | | | | 253 | 84 | 169 | 337 |
| BA | | | | | | | | | 63 | 21 | 42 | 84 |
| BG | 7 | 2 | 5 | 9 | | | | | 201 | 67 | 134 | 268 |
| BL | | | | | | | | | 454 | 151 | 303 | 605 |
| CS | | | | | | | | | 149 | 50 | 100 | 199 |
| CY | | | | | 0 | 0 | 0 | 0 | 37 | 12 | 25 | 49 |
| CZ | | | | | | | | | 299 | 100 | 199 | 398 |
| DE | | | | | | | | | 2,537 | 846 | 1,691 | 3,383 |
| DK | | | | | | | | | 567 | 189 | 378 | 756 |
| EE | | | | | | | | | 63 | 21 | 42 | 84 |
| EL | 16 | 5 | 11 | 22 | 5 | 2 | 3 | 7 | 230 | 77 | 153 | 307 |
| ES | 66 | 22 | 44 | 89 | 34 | 11 | 23 | 46 | 1,688 | 563 | 1,126 | 2,251 |
| FI | | | | | | | | | 225 | 75 | 150 | 301 |
| FR | 8 | 3 | 5 | 10 | 0 | 0 | 0 | 0 | 2,293 | 764 | 1,529 | 3,058 |
| HR | | | | | 0 | 0 | 0 | 0 | 71 | 24 | 47 | 94 |
| HU | 1 | 0 | 0 | 1 | | | | | 326 | 109 | 217 | 435 |
| IR | | | | | | | | | 228 | 76 | 152 | 304 |
| IT | 211 | 70 | 141 | 282 | 5 | 2 | 3 | 6 | 1,042 | 347 | 695 | 1,389 |
| KO | | | | | | | | | 43 | 14 | 28 | 57 |
| LT | | | | | | | | | 145 | 48 | 96 | 193 |
| LV | | | | | | | | | 112 | 37 | 75 | 149 |
| MK | 5 | 2 | 3 | 6 | 0 | 0 | 0 | 0 | 45 | 15 | 30 | 60 |
| MO | | | | | | | | | 14 | 5 | 9 | 19 |
| MT | | | | | | | | | 7 | 2 | 4 | 9 |
| NL | | | | | | | | | 723 | 241 | 482 | 964 |
| NO | | | | | | | | | | | | |
| PL | | | | | | | | | 1,665 | 555 | 1,110 | 2,220 |
| PT | 15 | 5 | 10 | 21 | 1 | 0 | 1 | 1 | 170 | 57 | 113 | 226 |
| RO | 5 | 2 | 4 | 7 | | | | | 473 | 158 | 316 | 631 |
| SE | | | | | | | | | 273 | 91 | 182 | 364 |
| SI | | | | | | | | | 43 | 14 | 29 | 57 |
| SK | | | | | | | | | 115 | 38 | 77 | 153 |
| TR | 88 | 29 | 58 | 117 | 15 | 5 | 10 | 20 | | | | |
| UK | | | | | | | | | 1,592 | 531 | 1,061 | 2,122 |

Table A2 - 78 Biomass supply per country per year and scenario in 2030 for rice husk, grape dregs and cereal bran

| | Maize cobs (4204) | | | | Olive stones (4205) | | | | Sugarbeet bagasse (4206) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | high | low | medium | tp | high | low | medium | tp | high | low | medium | tp |
| AL | 39,827 | 13,276 | 26,551 | 53,102 | 4 | 1 | 2 | 5 | | | | |
| AT | | | | | | | | | 276 | 92 | 184 | 368 |
| BA | | | | | 0 | 0 | 0 | 0 | | | | |
| BG | 308,163 | 102,721 | 205,442 | 410,883 | | | | | | | | |
| BL | | | | | | | | | 324 | 108 | 216 | 433 |
| CS | | | | | | | | | 196 | 65 | 131 | 262 |
| CY | | | | | 1 | 0 | 1 | 1 | | | | |
| CZ | | | | | | | | | 221 | 74 | 147 | 295 |
| DE | | | | | | | | | 1,889 | 630 | 1,259 | 2,518 |
| DK | | | | | | | | | 229 | 76 | 153 | 306 |
| EE | | | | | | | | | | | | |
| EL | 63,793 | 21,264 | 42,529 | 85,057 | 127 | 42 | 85 | 170 | 3 | 1 | 2 | 4 |
| ES | 167,388 | 55,796 | 111,592 | 223,185 | 634 | 211 | 423 | 845 | 238 | 79 | 159 | 318 |
| FI | | | | | | | | | 7 | 2 | 5 | 10 |
| FR | 1,277,761 | 425,920 | 851,841 | 1,703,682 | 2 | 1 | 2 | 3 | 2,321 | 774 | 1,547 | 3,095 |
| HR | 172,489 | 57,496 | 114,993 | 229,986 | 4 | 1 | 2 | 5 | 81 | 27 | 54 | 109 |
| HU | 872,101 | 290,700 | 581,400 | 1,162,801 | | | | | 86 | 29 | 58 | 115 |
| IR | | | | | | | | | | | | |
| IT | 582,138 | 194,046 | 388,092 | 776,184 | 207 | 69 | 138 | 276 | 135 | 45 | 90 | 180 |
| KO | | | | | | | | | | | | |
| LT | | | | | | | | | 51 | 17 | 34 | 68 |
| LV | | | | | | | | | | | | |
| MK | 22,942 | 7,647 | 15,294 | 30,589 | 1 | 0 | 0 | 1 | | | | |
| MO | | | | | 0 | 0 | 0 | 0 | | | | |
| MT | | | | | | | | | | | | |
| NL | | | | | | | | | 419 | 140 | 279 | 559 |
| NO | | | | | | | | | | | | |
| PL | | | | | | | | | 1,041 | 347 | 694 | 1,389 |
| PT | 29,805 | 9,935 | 19,870 | 39,740 | 46 | 15 | 31 | 61 | 1 | 0 | 1 | 1 |
| RO | 1,691,657 | 563,886 | 1,127,771 | 2,255,542 | | | | | 95 | 32 | 63 | 126 |
| SE | | | | | | | | | 162 | 54 | 108 | 216 |
| SI | 15,014 | 5,005 | 10,009 | 20,019 | 0 | 0 | 0 | 0 | | | | |
| SK | | | | | | | | | 99 | 33 | 66 | 133 |
| TR | 323,374 | 107,791 | 215,582 | 431,165 | 123 | 41 | 82 | 164 | 781 | 260 | 521 | 1,042 |
| UK | | | | | | | | | 619 | 206 | 413 | 826 |

Table A2 - 79  Biomass supply per country per year and scenario in 2030 for maize cobs, olive stones and sugarbeet bagasse

| | Olive pommace (4207) | | | |
|---|---|---|---|---|
| | high | low | medium | tp |
| AL | 6 | 2 | 4 | 8 |
| AT | | | | |
| BA | 0 | 0 | 0 | 0 |
| BG | | | | |
| BL | | | | |
| CS | | | | |
| CY | 2 | 1 | 1 | 2 |
| CZ | | | | |
| DE | | | | |
| DK | | | | |
| EE | | | | |
| EL | 219 | 73 | 146 | 293 |
| ES | 1,073 | 358 | 716 | 1,431 |
| FI | | | | |
| FR | 4 | 1 | 2 | 5 |
| HR | 6 | 2 | 4 | 9 |
| HU | | | | |
| IR | | | | |
| IT | 365 | 122 | 244 | 487 |
| KO | | | | |
| LT | | | | |
| LV | | | | |
| MK | 1 | 0 | 1 | 2 |
| MO | 0 | 0 | 0 | 1 |
| MT | | | | |
| NL | | | | |
| NO | | | | |
| PL | | | | |
| PT | 81 | 27 | 54 | 109 |
| RO | | | | |
| SE | | | | |
| SI | 0 | 0 | 0 | 1 |
| SK | | | | |
| TR | 189 | 63 | 126 | 252 |
| UK | | | | |

Table A2 - 80 Biomass supply per country and scenario for olive pomace in 2030

| | Rice husk (4201) | | | | Grape dregs (4202) | | | | Cereal bran (4203) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | high | low | medium | tp | high | low | medium | tp | high | low | medium | tp |
| AL | | | | | 0 | 0 | 0 | 0 | 49 | 16 | 32 | 65 |
| AT | | | | | | | | | 259 | 86 | 173 | 346 |
| BA | | | | | | | | | 59 | 20 | 39 | 79 |
| BG | 3 | 1 | 2 | 4 | | | | | 199 | 66 | 133 | 266 |
| BL | | | | | | | | | 580 | 193 | 387 | 774 |
| CS | | | | | | | | | 131 | 44 | 87 | 174 |
| CY | | | | | 0 | 0 | 0 | 0 | 40 | 13 | 27 | 53 |
| CZ | | | | | | | | | 294 | 98 | 196 | 392 |
| DE | | | | | | | | | 2,572 | 857 | 1,715 | 3,429 |
| DK | | | | | | | | | 577 | 192 | 385 | 770 |
| EE | | | | | | | | | 44 | 15 | 29 | 58 |
| EL | 4 | 1 | 3 | 5 | 5 | 2 | 3 | 7 | 242 | 81 | 161 | 322 |
| ES | 15 | 5 | 10 | 19 | 42 | 14 | 28 | 56 | 1,643 | 548 | 1,095 | 2,190 |
| FI | | | | | | | | | 269 | 90 | 180 | 359 |
| FR | 2 | 1 | 1 | 2 | 0 | 0 | 0 | 0 | 2,473 | 824 | 1,648 | 3,297 |
| HR | | | | | 0 | 0 | 0 | 0 | 89 | 30 | 59 | 119 |
| HU | 0 | 0 | 0 | 0 | | | | | 267 | 89 | 178 | 357 |
| IR | | | | | | | | | 259 | 86 | 173 | 345 |
| IT | 201 | 67 | 134 | 267 | 5 | 2 | 3 | 6 | 1,086 | 362 | 724 | 1,448 |
| KO | | | | | | | | | 37 | 12 | 25 | 50 |
| LT | | | | | | | | | 126 | 42 | 84 | 169 |
| LV | | | | | | | | | 95 | 32 | 63 | 126 |
| MK | 5 | 2 | 3 | 7 | 0 | 0 | 0 | 0 | 47 | 16 | 31 | 62 |
| MO | | | | | | | | | 12 | 4 | 8 | 16 |
| MT | | | | | | | | | 8 | 3 | 5 | 10 |
| NL | | | | | | | | | 752 | 251 | 501 | 1,002 |
| NO | | | | | | | | | | | | |
| PL | | | | | | | | | 1,622 | 541 | 1,081 | 2,163 |
| PT | 4 | 1 | 2 | 5 | 1 | 0 | 1 | 1 | 141 | 47 | 94 | 188 |
| RO | 2 | 1 | 2 | 3 | | | | | 585 | 195 | 390 | 780 |

| | Rice husk (4201) | | | | Grape dregs (4202) | | | | Cereal bran (4203) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | high | low | medium | tp | high | low | medium | tp | high | low | medium | tp |
| SE | | | | | | | | | 302 | 101 | 202 | 403 |
| SI | | | | | | | | | 42 | 14 | 28 | 56 |
| SK | | | | | | | | | 110 | 37 | 73 | 147 |
| TR | 319 | 106 | 213 | 425 | 15 | 5 | 10 | 20 | | | | |
| UK | | | | | | | | | 1,617 | 539 | 1,078 | 2,156 |

Table A2 - 81 Biomass supply per country per year and scenario in 2050 for rice husk, grape dregs and cereal bran

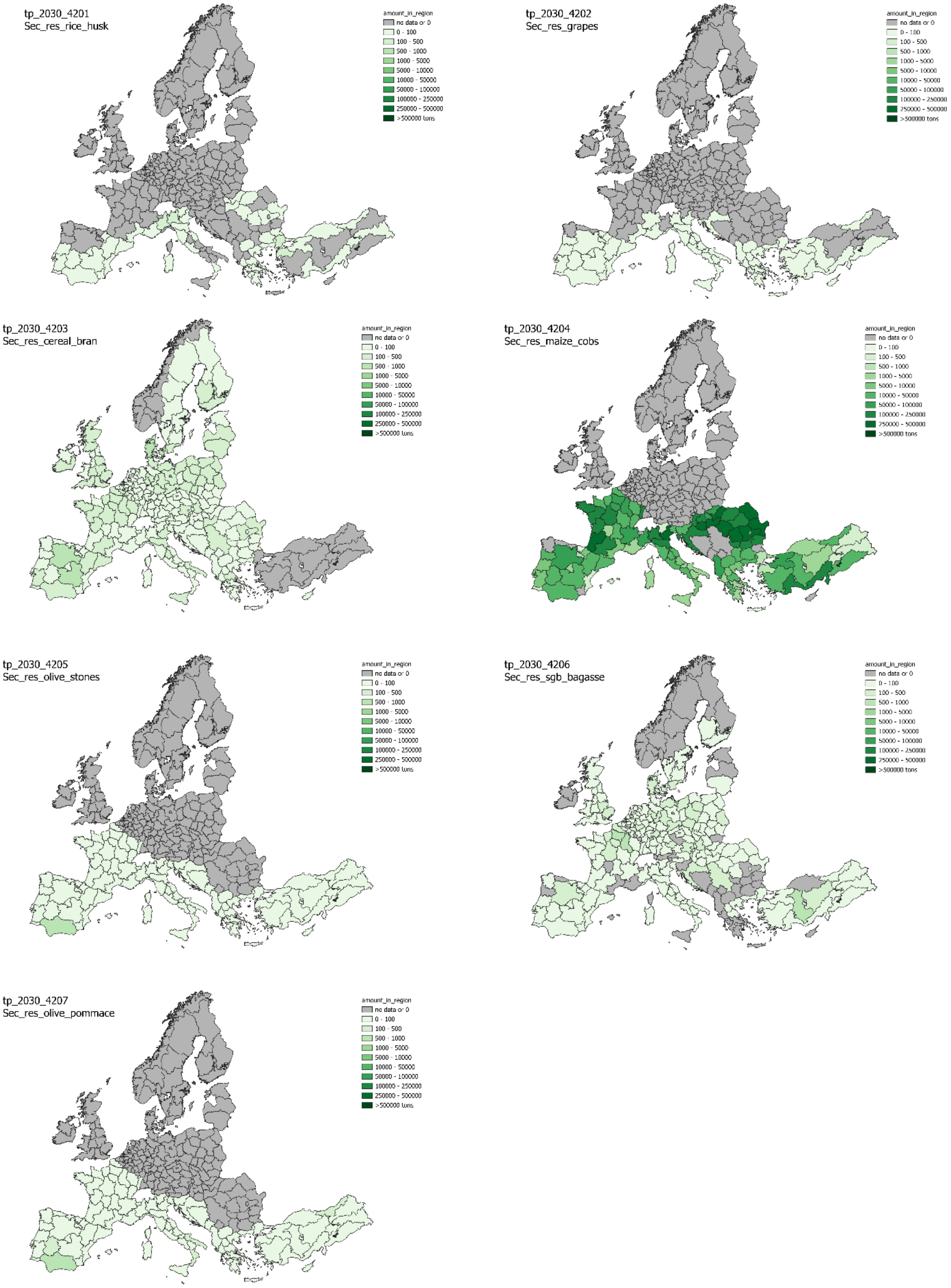
| | Maize cobs (4204) | | | | Olive stones (4205) | | | | Sugarbeet bagasse (4206) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | high | low | medium | tp | high | low | medium | tp | high | low | medium | tp |
| AL | 54,164 | 18,055 | 36,109 | 72,218 | 6 | 2 | 4 | 8 | | | | |
| AT | | | | | | | | | 374 | 125 | 249 | 499 |
| BA | | | | | 0 | 0 | 0 | 0 | | | | |
| BG | 393,278 | 131,093 | 262,185 | 524,371 | | | | | | | | |
| BL | | | | | | | | | 365 | 122 | 243 | 486 |
| CS | | | | | | | | | 185 | 62 | 124 | 247 |
| CY | | | | | 1 | 0 | 1 | 1 | | | | |
| CZ | | | | | | | | | 351 | 117 | 234 | 468 |
| DE | | | | | | | | | 1,943 | 648 | 1,295 | 2,590 |
| DK | | | | | | | | | 475 | 158 | 317 | 633 |
| EE | | | | | | | | | | | | |
| EL | 29,505 | 9,835 | 19,670 | 39,340 | 121 | 40 | 81 | 162 | 11 | 4 | 7 | 14 |
| ES | 32,997 | 10,999 | 21,998 | 43,997 | 735 | 245 | 490 | 980 | 218 | 73 | 146 | 291 |
| FI | | | | | | | | | 4 | 1 | 3 | 6 |
| FR | 1,296,812 | 432,271 | 864,541 | 1,729,082 | 3 | 1 | 2 | 3 | 2,362 | 787 | 1,575 | 3,149 |
| HR | 139,092 | 46,364 | 92,728 | 185,457 | 4 | 1 | 3 | 6 | 79 | 26 | 53 | 105 |
| HU | 869,226 | 289,742 | 579,484 | 1,158,968 | | | | | 69 | 23 | 46 | 92 |
| IR | | | | | | | | | | | | |
| IT | 138,053 | 46,018 | 92,035 | 184,070 | 210 | 70 | 140 | 281 | 1 | 0 | 1 | 1 |
| KO | | | | | | | | | | | | |

| | Maize cobs (4204) | | | | Olive stones (4205) | | | | Sugarbeet bagasse (4206) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **high** | **low** | **medium** | **tp** | **high** | **low** | **medium** | **tp** | **high** | **low** | **medium** | **tp** |
| LT | | | | | | | | | 113 | 38 | 75 | 150 |
| LV | | | | | | | | | | | | |
| MK | 37,248 | 12,416 | 24,832 | 49,664 | 0 | 0 | 0 | 1 | | | | |
| MO | | | | | 0 | 0 | 0 | 0 | | | | |
| MT | | | | | | | | | | | | |
| NL | | | | | | | | | 395 | 132 | 264 | 527 |
| NO | | | | | | | | | | | | |
| PL | | | | | | | | | 1,311 | 437 | 874 | 1,748 |
| PT | 5,232 | 1,744 | 3,488 | 6,976 | 55 | 18 | 37 | 74 | 0 | 0 | 0 | 0 |
| RO | 1,541,617 | 513,872 | 1,027,745 | 2,055,489 | | | | | 126 | 42 | 84 | 168 |
| SE | | | | | | | | | 207 | 69 | 138 | 276 |
| SI | 2,243 | 748 | 1,495 | 2,991 | 0 | 0 | 0 | 0 | | | | |
| SK | | | | | | | | | 99 | 33 | 66 | 132 |
| TR | 304,093 | 101,364 | 202,728 | 405,457 | 115 | 38 | 77 | 153 | 728 | 243 | 486 | 971 |
| UK | | | | | | | | | 910 | 303 | 607 | 1,213 |

Table A2 - 82 Biomass supply per country per year and scenario in 2050 for maize cobs, olive stones and sugarbeet bagasse

| | Olive pommace (4207) | | | |
|---|---|---|---|---|
| | high | low | medium | tp |
| AL | 10 | 3 | 6 | 13 |
| AT | | | | |
| BA | 0 | 0 | 0 | 0 |
| BG | | | | |
| BL | | | | |
| CS | | | | |
| CY | 1 | 0 | 1 | 2 |
| CZ | | | | |
| DE | | | | |
| DK | | | | |
| EE | | | | |
| EL | 209 | 70 | 139 | 278 |
| ES | 1,241 | 414 | 827 | 1,654 |
| FI | | | | |
| FR | 4 | 1 | 3 | 6 |
| HR | 8 | 3 | 5 | 10 |
| HU | | | | |
| IR | | | | |
| IT | 371 | 124 | 248 | 495 |
| KO | | | | |
| LT | | | | |
| LV | | | | |
| MK | 1 | 0 | 1 | 1 |
| MO | 0 | 0 | 0 | 1 |
| MT | | | | |
| NL | | | | |
| NO | | | | |
| PL | | | | |
| PT | 99 | 33 | 66 | 132 |
| RO | | | | |
| SE | | | | |
| SI | 1 | 0 | 0 | 1 |
| SK | | | | |
| TR | 174 | 58 | 116 | 232 |
| UK | | | | |

Table A2 - 83  Biomass supply per country and scenario for olive pomace in 2050




Map 1 Distribution over Europe

# Evaluation

**General observations**

Describe general observations on e.g. approach of assessment, scenario approach, results in numbers (amounts and price levels), spatial distribution, comparison with PRIMES

The general approach for the formulation of the scenarios is well established and appropriate for the purposes of the study.

A comparison with other results of other studies / literature is not available.

For the technical potential, it may be useful to include values also for a baseline, historical year (e.g. 2019) to see how the future evolution.

If possible, the underlying values for agricultural land or production of CAPRI BAU, as well as the main assumptions (e.g. impact of climate change, consumer behaviour, etc.) would help to explain the future variation in the technical biomass potential.

A comparison with PRIMES is not possible, since that model bundles secondary agricultural residues with forest residues and other types of soli waste.

**Strength**

Please indicate what you regard as a strength in the assessment of results

The methodology is easy to apply and follows a well-established logic.

The range of secondary agricultural residues considered is very extensive (only one relevant one missing, see below).

An effort has been made to provide clear references to studies for the residue factors; if assumptions are made (e.g. regarding moisture content), then they are logical.

**Weaknesses**

Please indicate what you regard as a weakness in the assessment

A weakness is that the current level of competing uses is not taken into consideration in the assessment as a benchmark. For example, around 50% or more (depending on efficiency) of the produced olive pomace is self-consumed by the olive pomace mills for the drying of the wet olive pomace and for the production of steam. The practice is likely to continue till 2050, since it makes sense on an economic basis.

Similarly, olive stones, if separated, are a high-quality solid biomass fuel and find their ways in local heating markets, for residential and small-scale commercial applications. To a high extent, such markets are expected to be active until 2050.

Beyond energy, other competing markets – primarily animal feed & input for organic fertilizer production – may be relevant for some of the biomass feedstocks evaluated in this session.

The physical characteristics of the feedstock, namely moisture content and density, as well as the dispersion of production (smaller vs. larger units) are also factors that influence the mobilization potential.

**Options for improvement?**

Please indicate what can or really needs to be improved.

Sunflower hulls (or husks) is a relevant assortment for several European countries (e.g. Bulgaria, Ukraine) but it is not considered in the evaluation. The AgroBioHeat guide "Agroindustrial residues to energy" (https://agrobioheat.eu/wp-content/uploads/2022/04/agrobioheat-guide-2022-EN-small.pdf) provides further information on this type of feedstock

The residue factor for deoiled pomace should be rechecked, since other publications suggest important differences.

## SWOT 10 – Brewer's spent grain (BSG) (4208)

### Description of approach

Brewer's spent grain is a biomass type that has not been quantified before in S2BIOM or Concawe.

Brewers' Spent Grain (BSG) is the main by-product from the production process of beer. The base data to calculate the potential from comes from Eurostat on beer made from malt in 2019. Per 100 liter of brewed beer, roughly 20 kg of BSG is produced as a by-product which has a moisture content of about 80%. For the extrapolation towards 2030 and 2050 Eurostat population projection data were used assuming beer production follows this same population development trend.

The assessment of the BSG potential is based on the following formula:

BSG availability = Total Beer Production x 0.2 x 0.2

*Where:*

BSG availability = total BSG available on NUTS-2 level produced as by-product from beer production for use in biofuels and competing uses.

Total Beer Production = total beer production in liters distributed over the NUTS-2 regions based on population numbers for present, 2030 or 2050.

0.2 = 0.2 kg of BSG produced as by-product per liter beer.

0.2 = 20% of BSG is dry-matter content.

| DI codes | Description of biomass category | Issue | Technical potential | Low mobilisation | Medium mobilisation | High mobilisation |
|---|---|---|---|---|---|---|
| 4208 | BSG | **Beer production** | As projected population development | 2030: 10% less<br>2050: 15% less beer consumption | As projected population development | 2030: 10% more<br>2050: 15% more beer consumption |
| | | **Wasted BSG** | 2030 10% more & 2050 15% more | 2030 20% less & 2050 25% less | As reported | 2030 10% more & 2050 15% more |
| | | **Competing use** | No competing use | 2030: 60%<br>2050: 70% | 2030: 40%<br>2050: 45% | 2030: 20%<br>2050: 25% |

Table A2 - 84 *Scenario assumptions*

### Results

Results of total potentials are presented in Table 2.

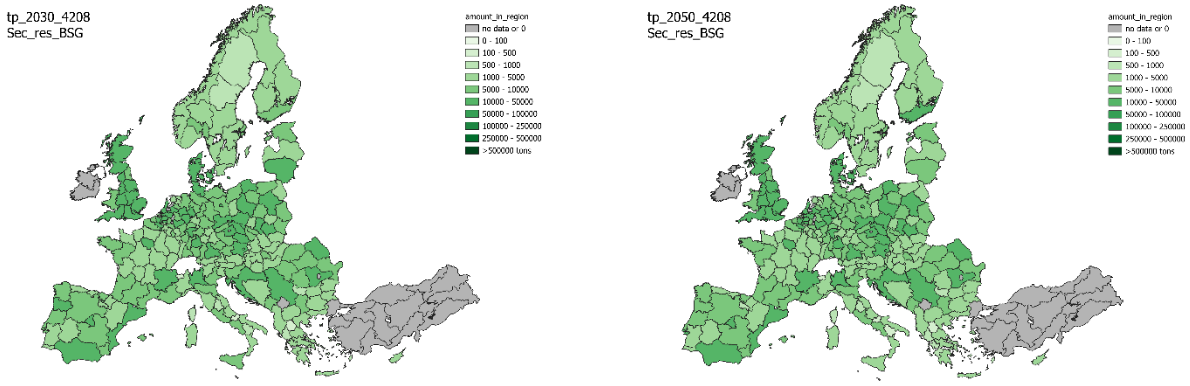
| | | 2030 | 2030 | 2050 | 2050 |
|---|---|---|---|---|---|
| | Technical | TP mln ton | %/total | TP mln ton | %/total |
| **4208** | BSG | 1.6 | 0.1% | 1.6 | 0.1% |
| | | 2030 | 2030 | 2050 | 2050 |
| | Low scenario | Low mln ton | %/total | Low mln ton | %/total |
| **4208** | BSG | 0.5 | 0.1% | 0.4 | 0.1% |
| | | 2030 | 2030 | 2050 | 2050 |
| | Medium scenario | Medium mln ton | %/total | Medium mln ton | %/total |
| **4208** | BSG | 1.0 | 0.1% | 0.9 | 0.1% |
| | | 2030 | 2030 | 2050 | 2050 |
| | High scenario | High mln ton | %/total | High mln ton | %/total |
| **4208** | BSG | 1.4 | 0.1% | 1.4 | 0.1% |

Table A2 - 85 Total Europe in 2030 and 2050 for technical, low, medium and high mobilisation scenario

| | BSG (4208) in 2030 | | | | BSG (4208) in 2050 | | | |
|---|---|---|---|---|---|---|---|---|
| | high | low | medium | tp | high | low | medium | tp |
| | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons |
| **AL** | 1,448 | 526 | 987 | 1,645 | 1,247 | 325 | 795 | 1,446 |
| **AT** | 29,998 | 10,908 | 20,453 | 34,088 | 30,083 | 7,848 | 19,183 | 34,879 |
| **BA** | 2,950 | 1,073 | 2,011 | 3,352 | 2,539 | 662 | 1,619 | 2,943 |
| **BG** | 15,728 | 5,719 | 10,723 | 17,872 | 13,610 | 3,551 | 8,679 | 15,780 |
| **BL** | 82,591 | 30,033 | 56,312 | 93,854 | 82,196 | 21,442 | 52,415 | 95,300 |
| **CS** | 19,042 | 6,924 | 12,983 | 21,639 | 15,797 | 4,121 | 10,074 | 18,316 |
| **CY** | 3,722 | 1,354 | 2,538 | 4,230 | 3,964 | 1,034 | 2,528 | 4,596 |
| **CZ** | 68,126 | 24,773 | 46,450 | 77,416 | 65,823 | 17,171 | 41,974 | 76,316 |
| **DE** | 283,489 | 103,087 | 193,288 | 322,146 | 275,046 | 71,751 | 175,392 | 318,894 |
| **DK** | 11,965 | 4,351 | 8,158 | 13,596 | 11,937 | 3,114 | 7,612 | 13,839 |
| **EE** | 4,885 | 1,776 | 3,331 | 5,551 | 4,597 | 1,199 | 2,931 | 5,329 |
| **EL** | 14,524 | 5,281 | 9,903 | 16,505 | 13,651 | 3,561 | 8,705 | 15,827 |
| **ES** | 139,791 | 50,833 | 95,312 | 158,853 | 140,017 | 36,526 | 89,286 | 162,338 |
| **FI** | 16,206 | 5,893 | 11,049 | 18,415 | 15,302 | 3,992 | 9,758 | 17,741 |
| **FR** | 89,105 | 32,402 | 60,753 | 101,256 | 88,962 | 23,207 | 56,729 | 103,144 |
| **HR** | 10,799 | 3,927 | 7,363 | 12,272 | 9,380 | 2,447 | 5,982 | 10,876 |
| **HU** | 19,917 | 7,243 | 13,580 | 22,633 | 18,862 | 4,921 | 12,028 | 21,870 |
| **IR** | | | | | | | | |
| **IT** | 58,803 | 21,383 | 40,093 | 66,822 | 56,098 | 14,634 | 35,773 | 65,041 |
| **KO** | | | | | | | | |
| **LT** | 10,131 | 3,684 | 6,907 | 11,512 | 8,242 | 2,150 | 5,256 | 9,556 |
| **LV** | 2,481 | 902 | 1,691 | 2,819 | 1,980 | 517 | 1,263 | 2,296 |
| **MK** | 2,957 | 1,075 | 2,016 | 3,360 | 2,676 | 698 | 1,706 | 3,102 |
| **MO** | 8,163 | 2,968 | 5,566 | 9,276 | 7,387 | 1,927 | 4,711 | 8,565 |
| **MT** | | | | | | | | |
| **NL** | 98,290 | 35,742 | 67,016 | 111,693 | 97,510 | 25,437 | 62,180 | 113,055 |
| **NO** | 14,366 | 5,224 | 9,795 | 16,325 | 15,536 | 4,053 | 9,907 | 18,013 |
| **PL** | 135,588 | 49,305 | 92,446 | 154,077 | 122,843 | 32,046 | 78,335 | 142,427 |
| **PT** | 27,541 | 10,015 | 18,778 | 31,296 | 25,346 | 6,612 | 16,163 | 29,387 |
| **RO** | 56,506 | 20,548 | 38,527 | 64,212 | 48,601 | 12,679 | 30,992 | 56,350 |

| | BSG (4208) in 2030 | | | | BSG (4208) in 2050 | | | |
|---|---|---|---|---|---|---|---|---|
| | **high** | **low** | **medium** | **tp** | **high** | **low** | **medium** | **tp** |
| | **Sum of tons** | **Sum of tons** | **Sum of tons** | **Sum of tons** | **Sum of tons** | **Sum of tons** | **Sum of tons** | **Sum of tons** |
| **SE** | 19,278 | 7,010 | 13,144 | 21,907 | 20,916 | 5,456 | 13,338 | 24,250 |
| **SI** | 8,200 | 2,982 | 5,591 | 9,318 | 7,798 | 2,034 | 4,973 | 9,041 |
| **SK** | 5,695 | 2,071 | 3,883 | 6,471 | 5,325 | 1,389 | 3,396 | 6,174 |
| **TR** | | | | | | | | |
| **UK** | 167,256 | 60,820 | 114,038 | 190,063 | 169,139 | 44,123 | 107,857 | 196,103 |

Table A2 - 86  Cost supply per country per year and scenario for brewers spent grain (BSG) 2030 and 2050




*Map 1 Distribution over Europe*

## Evaluation

### General observations

*Describe general observations on e.g. approach of assessment, scenario approach, results in numbers (amounts and price levels), spatial distribution, comparison with PRIMES*

For the reviewer it is difficult to judge the values of the type of biomass that has not been accessed before on a European level. In principle the approach sounds logical. Since not much data is available, population distributions and trends are the best to use.

### Strength

*Please indicate what you regard as a strength in the assessment of results*

The methodology to distribute over NUTS-2 and to extrapolate over the future.

### Weaknesses

*Please indicate what you regard as a weakness in the assessment*

### Options for improvement?

*Please indicate what <u>can</u> or <u>really needs</u> to be improved.*

## SWOT 11– Liquid whey permeate (LWP) (4209)

### Description of approach

Liquid whey permeate is produced in the cheese and casein manufacturing process and after drying can be used as whey permeate powder in biofuels.

For the quantification the main input data was the modelled CAPRI data 2020, 2030 and 2050 on cheese production. This is modelled information based on a simulation of the dairy sector. Results are modelled to regional (Nuts 2) level.

The assessment of the liquid whey permeate (dry-matter) potential is based on the following formula:

**Whey permeate (dry-matter) availability = total cheese production x 0.85 x 0.4 x 0.8 x 0.1**

*Where:*

**Whey permeate (dry-matter) availability** = total liquid whey permeate (dry-matter) available on NUTS-2 level produced as by-product from cheese production for use in biofuels and competing uses.

Total cheese production = total cheese production in tons on NUTS-2 level for present, 2030 or 2050.

0.85 = product-to-residue factor for cheese-to-raw liquid whey residue: 1 tonnes cheese produces 0.85 tonnes raw liquid whey (Bylund et al., 2015).

0.4 = product-to-residue factor for raw liquid whey-to-potential protein extraction residue: 1 tonnes raw liquid whey produces 0.4 tonnes potential protein extraction (Bylund et al., 2015).

0.8 = product-to-residue factor for potential protein extraction-to-raw liquid whey permeate residue: 1 tonnes potential protein extraction produces 0.8 tonnes liquid whey permeate (Bylund et al., 2015).

0.1 = 10% dry matter: 1 tonnes liquid whey permeate produces 0.1 tonnes of dry-matter whey permeate (EC, 2019).

Table 1 illustrates the three mobilization scenarios for the cheese production, the potential for whey permeate (dry-matter) and the competing use. Currently, 60% of the whey permeate (mainly dry-matter) is used in the animal feed sector which is the largest competing use of whey permeate (FEFAC, 2020). This known competition for the animal feed sector was used as an indication for the competing uses in the low mobilisation scenario and the competing use for the medium and high mobilisation was estimated accordingly.

| | Low mobilisation | | Medium mobilisation | | High mobilisation | |
|---|---|---|---|---|---|---|
| | **2030** | **2050** | **2030** | **2050** | **2030** | **2050** |
| **Cheese Production** | CAPRI | CAPRI | CAPRI | CAPRI | CAPRI | CAPRI |
| **Whey Permeate efficiency** | 5% less | 10% less | As reported | As reported | 10% more | 15% more |
| **Competing use** | 60% | 70% | 40% | 45% | 20% | 25% |

Table A2 - 87 Scenario assumptions

## Results

Results of total potentials are presented in Table 2.

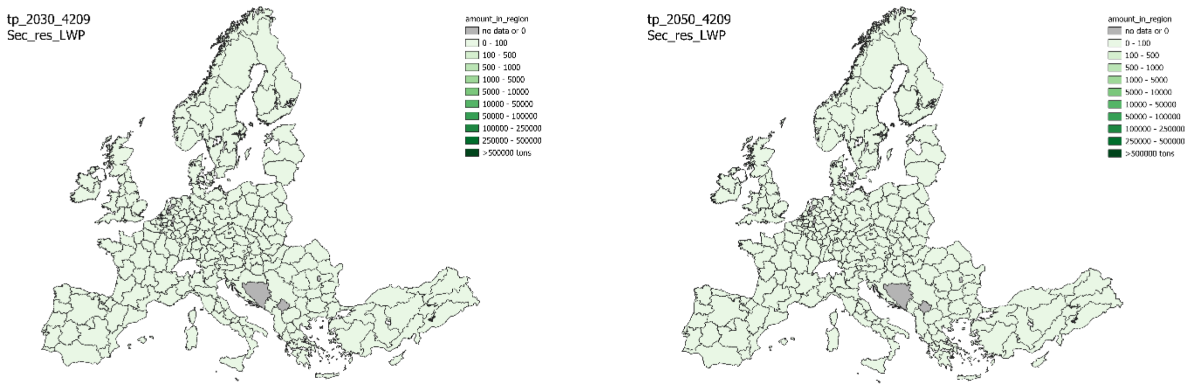
| | | 2030 | 2030 | 2050 | 2050 |
|---|---|---|---|---|---|
| | Technical | TP mln ton | %/total | TP mln ton | %/total |
| **4209** | LWP | 0.3 | 0.0% | 0.3 | 0.0% |
| | | 2030 | 2030 | 2050 | 2050 |
| | Low scenario | Low mln ton | %/total | Low mln ton | %/total |
| **4209** | LWP | 0.1 | 0.0% | 0.1 | 0.0% |
| | | 2030 | 2030 | 2050 | 2050 |
| | Medium scenario | Medium mln ton | %/total | Medium mln ton | %/total |
| **4209** | LWP | 0.2 | 0.0% | 0.2 | 0.0% |
| | | 2030 | 2030 | 2050 | 2050 |
| | High scenario | High mln ton | %/total | High mln ton | %/total |
| **4209** | LWP | 0.3 | 0.0% | 0.3 | 0.0% |

Table A2 - 88 Total (million tonnes) Europe in 2030 and 2050 for technical, low, medium and high mobilisation scenario

| | LWP (4209) in 2030 | | | | LWP (4209) in 2050 | | | |
|---|---|---|---|---|---|---|---|---|
| | high | low | medium | tp | high | low | medium | tp |
| | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons |
| **AL** | 317 | 137 | 216 | 360 | 273 | 85 | 174 | 316 |
| **AT** | 5,055 | 2,183 | 3,446 | 5,744 | 5,069 | 1,587 | 3,233 | 5,877 |
| **BA** | | | | | | | | |
| **BG** | 2,224 | 960 | 1,516 | 2,527 | 1,925 | 602 | 1,227 | 2,231 |
| **BL** | 2,812 | 1,214 | 1,917 | 3,195 | 2,798 | 876 | 1,784 | 3,244 |
| **CS** | 1,180 | 510 | 805 | 1,341 | 979 | 306 | 624 | 1,135 |
| **CY** | 833 | 360 | 568 | 946 | 887 | 278 | 565 | 1,028 |
| **CZ** | 3,241 | 1,399 | 2,210 | 3,683 | 3,131 | 980 | 1,997 | 3,630 |
| **DE** | 55,080 | 23,784 | 37,554 | 62,591 | 53,439 | 16,729 | 34,077 | 61,959 |
| **DK** | 11,167 | 4,822 | 7,614 | 12,690 | 11,141 | 3,487 | 7,104 | 12,917 |
| **EE** | 1,113 | 481 | 759 | 1,265 | 1,048 | 328 | 668 | 1,215 |
| **EL** | 4,862 | 2,099 | 3,315 | 5,525 | 4,570 | 1,430 | 2,914 | 5,298 |
| **ES** | 10,895 | 4,705 | 7,429 | 12,381 | 10,913 | 3,416 | 6,959 | 12,653 |
| **FI** | 2,005 | 866 | 1,367 | 2,279 | 1,894 | 593 | 1,207 | 2,195 |
| **FR** | 46,344 | 20,012 | 31,598 | 52,664 | 46,270 | 14,484 | 29,505 | 53,646 |
| **HR** | 763 | 330 | 520 | 867 | 663 | 208 | 423 | 769 |
| **HU** | 2,032 | 877 | 1,385 | 2,309 | 1,924 | 602 | 1,227 | 2,231 |
| **IR** | 7,384 | 3,189 | 5,035 | 8,391 | 8,170 | 2,557 | 5,210 | 9,472 |
| **IT** | 31,604 | 13,647 | 21,548 | 35,914 | 30,150 | 9,438 | 19,226 | 34,957 |
| **KO** | | | | | | | | |
| **LT** | 2,160 | 933 | 1,473 | 2,454 | 1,757 | 550 | 1,120 | 2,037 |
| **LV** | 1,086 | 469 | 740 | 1,234 | 867 | 271 | 553 | 1,005 |
| **MK** | 307 | 133 | 210 | 349 | 278 | 87 | 177 | 322 |
| **MO** | 41 | 18 | 28 | 47 | 38 | 12 | 24 | 43 |
| **MT** | | | | | | | | |
| **NL** | 23,549 | 10,169 | 16,056 | 26,761 | 23,363 | 7,314 | 14,898 | 27,087 |
| **NO** | 2,473 | 1,068 | 1,686 | 2,810 | 2,674 | 837 | 1,705 | 3,100 |
| **PL** | 20,280 | 8,757 | 13,827 | 23,045 | 18,373 | 5,752 | 11,716 | 21,303 |

| | LWP (4209) in 2030 | | | | LWP (4209) in 2050 | | | |
|---|---|---|---|---|---|---|---|---|
| | high | low | medium | tp | high | low | medium | tp |
| | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons |
| **PT** | 1,986 | 858 | 1,354 | 2,257 | 1,828 | 572 | 1,166 | 2,119 |
| **RO** | 2,131 | 920 | 1,453 | 2,422 | 1,833 | 574 | 1,169 | 2,125 |
| **SE** | 2,104 | 908 | 1,434 | 2,391 | 2,282 | 714 | 1,455 | 2,646 |
| **SI** | 380 | 164 | 259 | 432 | 362 | 113 | 231 | 419 |
| **SK** | 1,035 | 447 | 705 | 1,176 | 967 | 303 | 617 | 1,122 |
| **TR** | 5,140 | 2,220 | 3,505 | 5,841 | 5,672 | 1,775 | 3,617 | 6,576 |
| **UK** | 11,398 | 4,922 | 7,771 | 12,952 | 11,526 | 3,608 | 7,350 | 13,364 |

Table A2 - 89  Cost supply per country per year and scenario for liquid whey permeate (LWP) 2030 and 2050




*Map 1 Distribution over Europe*

# Evaluation

**General observations**

*Describe general observations on e.g. approach of assessment, scenario approach, results in numbers (amounts and price levels), spatial distribution, comparison with PRIMES*

The approach of the assessment is logical. The author did not make a comparison with literature, but observed, that some countries with a lot of cheese production (like FR, IT and NL) have high values. Comparison with PRIMES is not possible.

**Strength**

*Please indicate what you regard as a strength in the assessment of results*

The logic and ease of the methodology

**Weaknesses**

*Please indicate what you regard as a weakness in the assessment*

The weakness lies in the competing use. Currently whey is used as animal feed. The % competing use for the different scenarios and years are somewhat arbitrary.

**Options for improvement?**

*Please indicate what <u>can</u> or <u>really needs</u> to be improved.*

Maybe a quick scan to compare this with some national studies and see if comparable numbers come out.

## SWOT 12 – Alcoholic distillery residues and wastes (fusel oils) (4210)

### Description of approach

Alcoholic distillery residues (ADR) are from the alcoholic beverages production, excluding beer production as those residues fall under Brewers' Spent Grain. ADR can be used for bioethanol. They are also called 'fusel oil'and can be used as blending agent with gasoline but also for production of biochemicals.

*How is it quantified? Using what data and what conversion factors and assumptions?*

**Data used:**

- Current alcoholic distillery residues and waste for the EU are estimated at 5.5 million liters (Ardebili et al., 2020).
- EUROSTAT data on alcoholic production (in liters) on country level, excluding beer made from malt and non-alcoholic beer and beer containing <=0,5% by volume of alcohol.
- Eurostat, OECD and UN data on population projections 2030 and 2050 on NUTS-2 level where possible to assess future developments in alcohol distillery residues.

The assessment of ADR takes the total estimate of Ardebilli et al. (2020) and distributes this further over EU countries according to the Eurostat levels of alcoholic production (in liters) on country level. Every country takes a share of the total EU production and therefore a similar share of the alcoholic distillery residues.  To fill gaps in data for non-EU countries, the average per head ADR are taken and multiplied with population numbers in 2020 and in the future in 2030 and 2050.

*What scenarios for future development?*

Table 1 illustrates the three mobilization scenarios for the alcohol production and related residues and the competing use. Alcohol production and alcoholic distillery residues scenarios were assumed to deviate slightly from the technical potential (medium mobilisation) in the low and high mobilisation scenario. A small portion of alcoholic distillery residues and wastes is currently utilized for the competing use of low grade chemical applications. As the low grade chemical application can also be produced from other ethanol sources, this competing use will remain limited (Factsheet 'Assessment of the potential for new feedstocks for the production of advanced biofuels', DG-ENER ENER C1 2019-412 unpublished).

| | Low mobilisation | | Medium mobilisation | | High mobilisation | |
|---|---|---|---|---|---|---|
| | **2030** | **2050** | **2030** | **2050** | **2030** | **2050** |
| **Alcohol Production** | 10% less | 15% less | As reported | As reported | 10% more | 15% more |
| **Alcoholic distillery residues** | 20% less | 25% less | As reported | As reported | 10% more | 15% more |
| **Competing use** | 30% | 40% | 20% | 30% | 10% | 20% |

Table A2 - 90 Scenario assumptions

### Results

Results of total potentials are presented in Table 2.

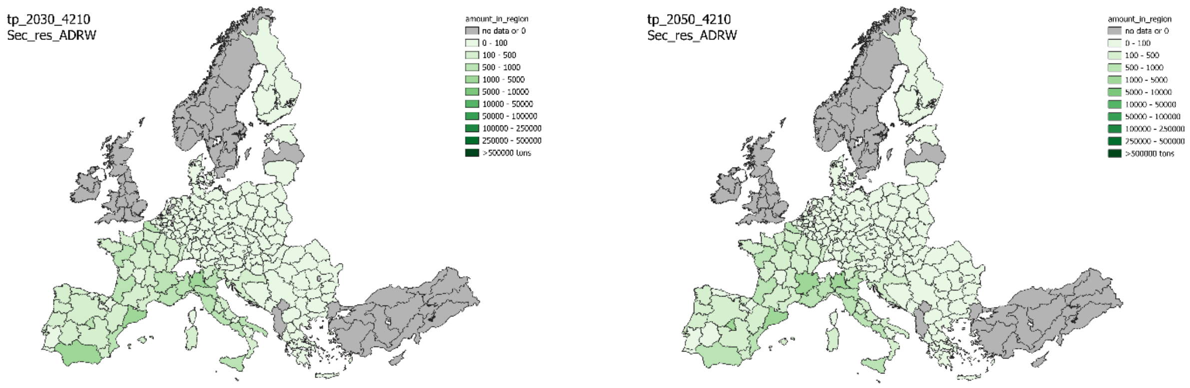
| | | 2030 | 2030 | 2050 | 2050 |
|---|---|---|---|---|---|
| | Technical | TP ton | %/total | TP ton | %/total |
| **4210** | ADR | 27,174 | 0% | 27,004 | 0% |
| | Low scenario | Low ton | %/total | Low ton | %/total |
| **4210** | ADR | 15,217 | 0% | 12,152 | 0% |
| | Medium scenario | Medium ton | %/total | Medium ton | %/total |
| **4210** | ADR | 21,739 | 0% | 18,903 | 0% |
| | High scenario | High ton | %/total | High ton | %/total |
| **4210** | ADR | 26,902 | 0% | 24,844 | 0% |

Table A2 - 91  Total biomass (tonnes dm) Europe in 2030 and 2050 for technical, low, medium and high mobilisation scenario

| | ADR (4210) in 2030 | | | | ADR (4210) in 2050 | | | |
|---|---|---|---|---|---|---|---|---|
| | high | low | medium | tp | high | low | medium | tp |
| | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons |
| **AL** | | | | | | | | |
| **AT** | 162 | 92 | 131 | 164 | 155 | 76 | 118 | 168 |
| **BA** | 10 | 6 | 8 | 10 | 8 | 4 | 6 | 9 |
| **BG** | 108 | 61 | 87 | 109 | 89 | 43 | 67 | 96 |
| **BL** | 32 | 18 | 26 | 32 | 30 | 15 | 23 | 33 |
| **CS** | 51 | 29 | 41 | 51 | 40 | 20 | 30 | 43 |
| **CY** | | | | | | | | |
| **CZ** | 181 | 103 | 147 | 183 | 166 | 81 | 126 | 181 |
| **DE** | 1,363 | 771 | 1,101 | 1,376 | 1,253 | 613 | 954 | 1,362 |
| **DK** | 8 | 5 | 7 | 8 | 8 | 4 | 6 | 8 |
| **EE** | 11 | 6 | 9 | 11 | 10 | 5 | 7 | 10 |
| **EL** | 247 | 140 | 200 | 250 | 220 | 108 | 168 | 239 |
| **ES** | 5,608 | 3,172 | 4,532 | 5,665 | 5,326 | 2,605 | 4,052 | 5,789 |
| **FI** | 89 | 50 | 72 | 90 | 80 | 39 | 61 | 86 |
| **FR** | 8,057 | 4,557 | 6,511 | 8,138 | 7,627 | 3,731 | 5,803 | 8,290 |
| **HR** | 159 | 90 | 128 | 160 | 131 | 64 | 99 | 142 |
| **HU** | 286 | 162 | 231 | 289 | 257 | 126 | 195 | 279 |
| **IR** | | | | | | | | |
| **IT** | 8,708 | 4,926 | 7,037 | 8,796 | 7,877 | 3,853 | 5,993 | 8,561 |
| **KO** | | | | | | | | |
| **LT** | 16 | 9 | 13 | 16 | 12 | 6 | 9 | 13 |
| **LV** | | | | | | | | |
| **MK** | 54 | 30 | 43 | 54 | 46 | 23 | 35 | 50 |
| **MO** | 10 | 5 | 8 | 10 | 8 | 4 | 6 | 9 |
| **MT** | | | | | | | | |
| **NL** | 60 | 34 | 48 | 61 | 56 | 28 | 43 | 61 |
| **NO** | | | | | | | | |
| **PL** | 225 | 127 | 182 | 227 | 193 | 95 | 147 | 210 |

| | ADR (4210) in 2030 | | | | ADR (4210) in 2050 | | | |
|---|---|---|---|---|---|---|---|---|
| | high | low | medium | tp | high | low | medium | tp |
| | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons |
| **PT** | 957 | 542 | 774 | 967 | 835 | 409 | 636 | 908 |
| **RO** | 388 | 219 | 313 | 392 | 316 | 155 | 241 | 344 |
| **SE** | | | | | | | | |
| **SI** | 49 | 28 | 40 | 50 | 44 | 22 | 34 | 48 |
| **SK** | 64 | 36 | 52 | 65 | 57 | 28 | 43 | 62 |
| **TR** | | | | | | | | |
| **UK** | | | | | | | | |

Table A2 - 92 Cost supply per country per year and scenario for alcoholic distillery residues (ADR) 2030 and 2050




*Map 1 Distribution over Europe*

**General observations**

*Describe general observations on e.g. approach of assessment, scenario approach, results in numbers (amounts and price levels), spatial distribution, comparison with PRIMES*

The total potential of this biomass type is very small. The total volume is difficult to judge, but is based on another literature source. The distribution over regions and the extrapolation to the future is logical.

**Strength**

*Please indicate what you regard as a strength in the assessment of results*

The logic of the approach

**Weaknesses**

*Please indicate what you regard as a weakness in the assessment*

**Options for improvement?**

*Please indicate what <u>can</u> or <u>really needs</u> to be improved.*

In the formula in the report the potential it is described that the amount of the product is in liters. It is not clear to the reviewer if the final potential is expressed in ton. Therefore the calculation should be checked and the conversion liter to ton should be mentioned.

## SWOT 13 – Bakery and confectionary residues (4211)

### Description of approach

The bakery and confectionary residues is waste generated during the production process of bakery (i.e. bread, pasta, wafer, dough) and confectionary (i.e. sweets) production. This residue is not fit anymore for the food and feed chain.

*How is it quantified? Using what data and what conversion factors and assumptions?*

Data used:

- The 2015 bread consumption per capita in individual countries across Europe was used as a proxy for the bakery and confectionary consumption per capita (International Association of Plant Bakers, 2015). For countries without available consumption levels, the consumption levels of bread per head of neighboring countries was taken as a proxy to fill the missing values.

- Population numbers and projections 2030 and 2050 were used (per NUTS-2 region where possible (from Eurostat, UN and OECD) to extrapolate the potenyials to the future.

**Conversion factors and assumptions:**

- The literature review of  Goryńska-Goldmann (2021) was used saying that 5% of bakery and confectionary produce is waste.

The assessment of the bakery and confectionary residue potential is based on the following formula:

**Bakery and confectionary residue availability = bread consumption per capita x population per NUTS-2 region x bakery and confectionary residue**

*Where:*

**Bakery and confectionary residue availability** = total bakery and confectionary residue available on NUTS-2 level produced as by-product from bread and confectionary production for use in biofuels and competing uses.

**Bread consumption per capita** = bread consumption per capita in kg per year on NUTS-2 level for 2015, 2030 or 2050.

**Population per NUTS-2 region** = population numbers per NUTS-2 region for present, 2030 or 2050.

**Bakery and confectionary residue** = 5% per kg bakery and confectionary goods is a residue (Goryńska-Goldmann et al., 2021).

*What scenarios for future development?*

Table 1 illustrates the three mobilization scenarios for the bread consumption, the potential for bakery and confectionary residues and the competing use. The bread consumption in the low and high mobilisation are modest estimations based on the expected increases/decreases of consumption patterns on country level as named in International Association of Plant Bakers (2015). For the bakery and confectionary residues the medium mobilisation assumes the estimated 5% residue for the medium mobilisation. The competing use was calculated based on the fact that there is limited competition for bakery and confectionary residues towards animal feed (10-25%) (Heuzé et al., 2018).

| | Low mobilisation | | Medium mobilisation | | High mobilisation | |
|---|---|---|---|---|---|---|
| | **2030** | **2050** | **2030** | **2050** | **2030** | **2050** |
| **Bread and confectionary consumption** | 2% less | 4% less | As reported | As reported | 2% more | 4% more |
| **Bakery and confectionary residues** | 20% less | 25% less | As reported | As reported | 10% more | 15% more |
| **Competing use** | 20% | 25% | 10% | 15% | 5% | 10% |

Table A2 - 93 *Assumptions per scenario*

## Results

Results of total potentials are presented in Table 2

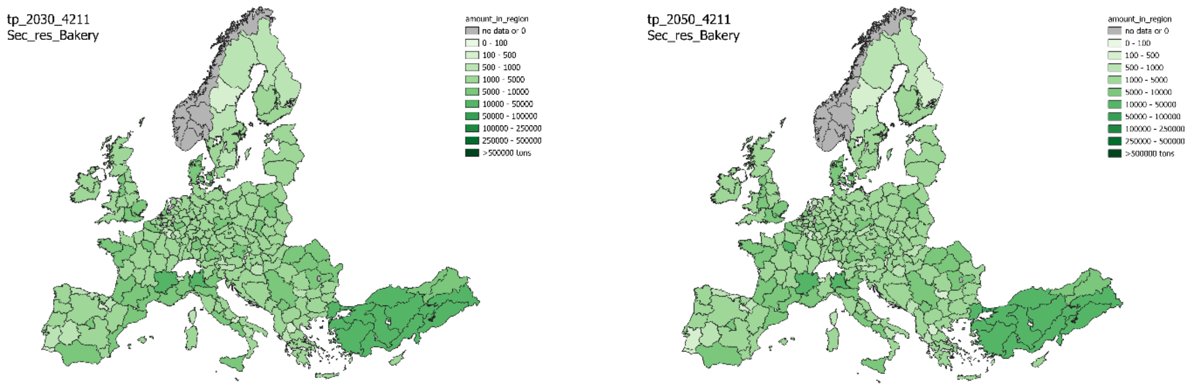
| | | 2030 | 2030 | 2050 | 2050 |
|---|---|---|---|---|---|
| | Technical | TP mln ton | %/total | TP mln ton | %/total |
| **4211** | BCR | 0.9 | 0.1% | 1.0 | 0.1% |
| | | 2030 | 2030 | 2050 | 2050 |
| | Low scenario | Low mln ton | %/total | Low mln ton | %/total |
| **4211** | BCR | 0.6 | 0.1% | 0.5 | 0.1% |
| | | 2030 | 2030 | 2050 | 2050 |
| | Medium scenario | Medium mln ton | %/total | Medium mln ton | %/total |
| **4211** | BCR | 0.8 | 0.1% | 0.8 | 0.1% |
| | | 2030 | 2030 | 2050 | 2050 |
| | High scenario | High mln ton | %/total | High mln ton | %/total |
| **4211** | BCR | 0.9 | 0.08% | 0.9 | 0.07% |

Table A2 - 94 Total biomass Europe (million tonnes dm) in 2030 and 2050 for technical, low, medium and high mobilisation scenario

| | BCR (4211) in 2030 | | | | BCR (4211) in 2050 | | | |
|---|---|---|---|---|---|---|---|---|
| | high | low | medium | tp | high | low | medium | tp |
| | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons |
| **AL** | 4,822 | 2,953 | 4,153 | 4,614 | 4,198 | 2,281 | 3,447 | 4,056 |
| **AT** | 13,501 | 8,268 | 11,627 | 12,919 | 13,682 | 7,436 | 11,236 | 13,219 |
| **BA** | 3,312 | 2,029 | 2,853 | 3,170 | 2,881 | 1,566 | 2,366 | 2,783 |
| **BG** | 15,776 | 9,662 | 13,587 | 15,097 | 13,796 | 7,498 | 11,330 | 13,330 |
| **BL** | 17,073 | 10,456 | 14,704 | 16,338 | 17,170 | 9,332 | 14,101 | 16,590 |
| **CS** | 6,818 | 4,175 | 5,872 | 6,524 | 5,715 | 3,106 | 4,694 | 5,522 |
| **CY** | 1,744 | 1,068 | 1,502 | 1,669 | 1,877 | 1,020 | 1,541 | 1,813 |
| **CZ** | 11,630 | 7,122 | 10,016 | 11,129 | 11,355 | 6,171 | 9,325 | 10,971 |
| **DE** | 121,974 | 74,702 | 105,050 | 116,722 | 119,587 | 64,993 | 98,212 | 115,543 |
| **DK** | 7,049 | 4,317 | 6,071 | 6,746 | 7,107 | 3,862 | 5,836 | 6,866 |
| **EE** | 1,917 | 1,174 | 1,651 | 1,834 | 1,823 | 991 | 1,497 | 1,761 |
| **EL** | 18,196 | 11,144 | 15,671 | 17,413 | 17,282 | 9,392 | 14,193 | 16,698 |
| **ES** | 47,192 | 28,902 | 40,644 | 45,160 | 47,766 | 25,960 | 39,228 | 46,151 |
| **FI** | 6,085 | 3,727 | 5,240 | 5,823 | 5,806 | 3,155 | 4,768 | 5,610 |
| **FR** | 102,817 | 62,969 | 88,550 | 98,389 | 103,732 | 56,376 | 85,191 | 100,224 |
| **HR** | 3,999 | 2,449 | 3,445 | 3,827 | 3,511 | 1,908 | 2,883 | 3,392 |
| **HU** | 10,476 | 6,416 | 9,023 | 10,025 | 10,026 | 5,449 | 8,234 | 9,687 |
| **IR** | 4,688 | 2,871 | 4,037 | 4,486 | 5,241 | 2,848 | 4,304 | 5,064 |
| **IT** | 79,773 | 48,856 | 68,704 | 76,338 | 76,904 | 41,796 | 63,158 | 74,303 |
| **KO** | 7,523 | 4,607 | 6,479 | 7,199 | 7,385 | 4,014 | 6,065 | 7,135 |
| **LT** | 3,785 | 2,318 | 3,260 | 3,622 | 3,112 | 1,691 | 2,555 | 3,006 |
| **LV** | 2,465 | 1,509 | 2,123 | 2,358 | 1,988 | 1,081 | 1,633 | 1,921 |
| **MK** | 3,590 | 2,199 | 3,092 | 3,436 | 3,283 | 1,784 | 2,696 | 3,172 |
| **MO** | 1,093 | 669 | 941 | 1,046 | 999 | 543 | 821 | 966 |
| **MT** | 1,085 | 664 | 934 | 1,038 | 1,236 | 672 | 1,015 | 1,194 |
| **NL** | 29,406 | 18,010 | 25,326 | 28,140 | 29,480 | 16,022 | 24,211 | 28,483 |
| **NO** | | | | | | | | |
| **PL** | 53,775 | 32,934 | 46,313 | 51,459 | 49,233 | 26,757 | 40,433 | 47,568 |

| | BCR (4211) in 2030 | | | | BCR (4211) in 2050 | | | |
|---|---|---|---|---|---|---|---|---|
| | high | low | medium | tp | high | low | medium | tp |
| | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons |
| **PT** | 9,827 | 6,019 | 8,464 | 9,404 | 9,139 | 4,967 | 7,506 | 8,830 |
| **RO** | 43,656 | 26,737 | 37,598 | 41,776 | 37,944 | 20,622 | 31,162 | 36,661 |
| **SE** | 12,339 | 7,557 | 10,627 | 11,807 | 13,528 | 7,352 | 11,110 | 13,070 |
| **SI** | 2,324 | 1,423 | 2,002 | 2,224 | 2,234 | 1,214 | 1,834 | 2,158 |
| **SK** | 5,951 | 3,645 | 5,126 | 5,695 | 5,623 | 3,056 | 4,618 | 5,433 |
| **TR** | 254,795 | 156,047 | 219,441 | 243,823 | 284,086 | 154,395 | 233,307 | 274,479 |
| **UK** | 58,228 | 35,661 | 50,149 | 55,721 | 59,504 | 32,339 | 48,868 | 57,491 |

Table A2 - 95  Cost supply per country per year and scenario for bakery and confectionary residues (BCR) 2030 and 2050




Map 1 Distribution over Europe

## Evaluation

### General observations

*Describe general observations on e.g. approach of assessment, scenario approach, results in numbers (amounts and price levels), spatial distribution, comparison with PRIMES*

The total potential of this type of biomass is rather modest. A comparison with PRIMES is not possible. The approach seems very logical.

### Strength

*Please indicate what you regard as a strength in the assessment of results*

The logic of the approach.

### Weaknesses

*Please indicate what you regard as a weakness in the assessment*

The total potential seems quite uncertain, since there is only one literature sources that is used for the waste factor (*…saying that 5% of bakery and confectionary produce is waste*). This 5% quite could be equally as well be 3% or 9%.

### Options for improvement?

*Please indicate what <u>can</u> or <u>really needs</u> to be improved.*

A quickscan to see if there are some country specific assessment, since the 5% factor might result in a high uncertainty.

## SWOT 14 – Dextrose Ultrafiltration retentate (4214)

### Description of approach

Dextrose Ultrafiltration retentate (DUR) is a residue from the sweetener High Fructose Corn Syrup 55 or Dextrose Monohydrate. It is mostly produced in Europe from grain corn and also concentrated in a few countries, especially France and the Netherlands. The two largest producers in France (Roquettes Freres and Tereos SA) are assumed to be in the dominant grain maize production regions. In the Netherlands the factory is based in the harbour of Rotterdam (Cargill).

From Statisa we derived figures on the current and forecasted volume of high fructose corn production for EU and this amounted to 550,000 tons per year in 2020 and is expected to grow towards 800,000 ton in 2030.

For the development in the future we applied two factors:

- 1) The growth trend. This could be a continuation of the trend between 2020 and 2030 as reported in Statisa and this would imply a growth trend of 3.83% per year (as in medium mobilisation scenario), or a smaller growth (as in Low mobilisation scenario) or an even higher growth (as in High and technical mobilisation) (See Table 1).

- 2) A competing use level for uses in other biochemical industries instead of in biofuels (see Table 1)

Table 1 illustrates the three mobilization scenarios

| | Technica | | Low mobilisation | | Medium mobilisation | | High mobilisation | |
|---|---|---|---|---|---|---|---|---|
| | 2030 | 2050 | 2030 | 2050 | 2030 | 2050 | 2030 | 2050 |
| Growth (%/yr) of High fructose Corn syrup production | 6% | 6% | 2% | 2% | 3.83% | 3.83% | 6% | 6% |
| Competing use | 0% | 10% | 50% | 60% | 25% | 30% | 0% | 10% |

Table A2 - 96 *Mobilisation scenario assumptions*

### Results

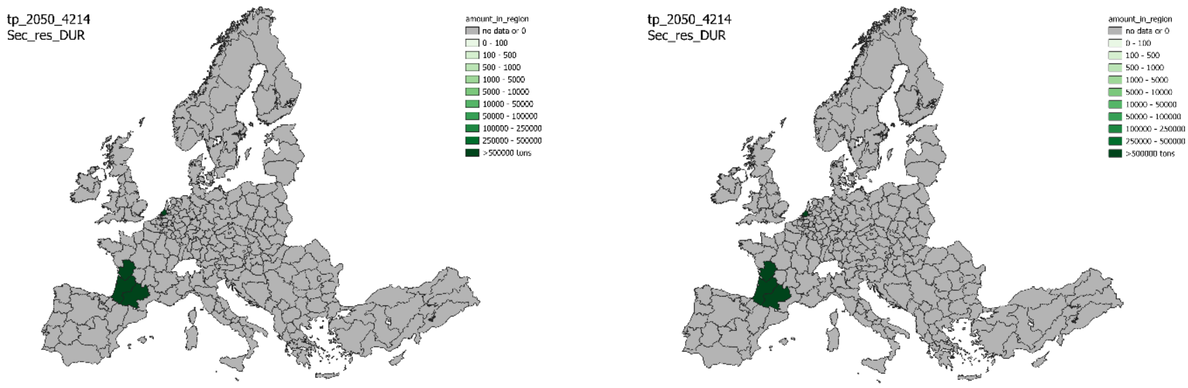
Results of total potentials are presented in Table 2

| | | 2030 | 2030 | 2050 | 2050 |
|---|---|---|---|---|---|
| | Technical | TP mln ton | %/total | TP mln ton | %/total |
| **4214** | DUR | 1.0 | 0.1% | 2.8 | 0.2% |
| | | 2030 | 2030 | 2050 | 2050 |
| | Low scenario | Low mln ton | %/total | Low mln ton | %/total |
| **4214** | DUR | 0.3 | 0.1% | 0.4 | 0.1% |
| | | 2030 | 2030 | 2050 | 2050 |
| | Medium scenario | Medium mln ton | %/total | Medium mln ton | %/total |
| **4214** | DUR | 0.6 | 0.1% | 1.2 | 0.2% |
| | | 2030 | 2030 | 2050 | 2050 |
| | High scenario | High mln ton | %/total | High mln ton | %/total |
| **4214** | DUR | 1.0 | 0.1% | 2.8 | 0.2% |

Table A2 - 97 Total Europe in 2030 and 2050 for technical, low, medium and high mobilisation scenario

| | BCR (4211) in 2030 | | | | BCR (4211) in 2050 | | | |
|---|---|---|---|---|---|---|---|---|
| | **high** | **low** | **medium** | **tp** | **high** | **low** | **medium** | **tp** |
| | **Sum of tons** | **Sum of tons** | **Sum of tons** | **Sum of tons** | **Sum of tons** | **Sum of tons** | **Sum of tons** | **Sum of tons** |
| **FR** | 787,973 | 268,179 | 480,000 | 787,973 | 2,274,423 | 318,800 | 951,122 | 2,274,423 |
| **NL** | 196,993 | 67,045 | 120,000 | 196,993 | 568,606 | 79,700 | 237,781 | 568,606 |

Table A2 - 98 Cost supply per country per year and scenario for bakery and confectionary residues (BCR) 2030 and 2050




*Map 1 Distribution over Europe*

## Evaluation

### General observations

*Describe general observations on e.g. approach of assessment, scenario approach, results in numbers (amounts and price levels), spatial distribution, comparison with PRIMES*

Overall, for the European countries assessed, this is a biomass type with a small potential since the potential is only available in two countries, FR and NL. For those two countries, the potential is non-negligible: around 10 PJ for FR and a few PJ for NL. Since this type of biomass can be pinpointed to a few specific plants, the spatial distribution is straightforward. A comparison with PRIMES can't be made.

### Strength

*Please indicate what you regard as a strength in the assessment of results*

Since there are only a few plant in Europe that have this type of biomass as residue, the potential and location are straightforward. The methodology is very clear.

### Weaknesses

*Please indicate what you regard as a weakness in the assessment*

### Options for improvement?

*Please indicate what <u>can</u> or <u>really needs</u> to be improved.*

## SWOT 15 – Animal fats cat. 1 and 2 (4216)

### Description of approach

Animal fats in categories 1 and 2 are fats from slaughtered animals and their consumption would present risks for human and animal health and therefore have little application possibilities. However, they could be used for biofuels.

*How is it quantified? Using what data and what conversion factors and assumptions?*

**Data used:**

- CAPRI data on pigs, cattle, sheep and poultry meat production (in thousand tonnes slaughtered) from 2015, 2020, 2030 and 2050 on regional level.
- EUROSTAT data on animal slaughtered (thousand heads) animals on individual country level.
- Fatty tissues percentage per animal obtained for cattle, sheep and pigs from Auvermann et al. (2004) and poultry from Murawska (2017).

The assessment of animal fats category 1 and 2 residue potential is calculated as follows. For pigs, cattle, sheep and poultry the animal fat cat. 1 and 2 is calculated separately and thereafter summed up to obtain the total animal fats cat. 1 and 2 per country. The distribution towards NUTS-2 regions is based on animal population size from CAPRI.

$$\textbf{Animal fats category 1 and 2 residue availability} = \frac{\boldsymbol{slaughtered\ meat}}{\boldsymbol{animal\ heads}} \times \boldsymbol{fatty\ tissue\ x\ animal\ fat}$$

*Where:*

**Animal fats category 1 and 2 residue availability** = total animal fat category 1 and 2 residues available on country level produced as by-product from animal slaughtering for use in biofuels and competing uses.

**Slaughtered meat** = meat production from pigs, cattle, sheep and poultry on country level in tonnes.

**Animal heads =** number of animals slaughtered (thousand heads) on regional level.

**Fatty tissue =** percentage of fatty tissue in pigs (30%), cattle (11%), sheep (22%) and poultry (13%).

**Animal fat** = Share of animal fat produced in one animal that is category 1 and 2: 17% is category 1 and 2 animal fat (EFPRA, 2020).

*What scenarios for future development?*

The meat production and animal fats category 1 and 2 for the three scenarios are based on CAPRI data of future meat production in 2030 and 2050. There are some competing uses from heat and power generation at rendering facilities, but as those are the only other uses of category 1 and 2 animal fats due to the high risk for humans and animals, the competing uses is assumed to remain low.

| | Low mobilisation | | Medium mobilisation | | High mobilisation | |
|---|---|---|---|---|---|---|
| | **2030** | **2050** | **2030** | **2050** | **2030** | **2050** |
| **Meat Production** | CAPRI | CAPRI | CAPRI | CAPRI | CAPRI | CAPRI |
| **Animal fats Cat1&2** | CAPRI | CAPRI | CAPRI | CAPRI | CAPRI | CAPRI |
| **Competing use** | 30% | 40% | 20% | 30% | 10% | 20% |

Table A2 - 99 *Mobilisation scenario assumptions*

## Results

Results of total potentials are presented in Table 2.

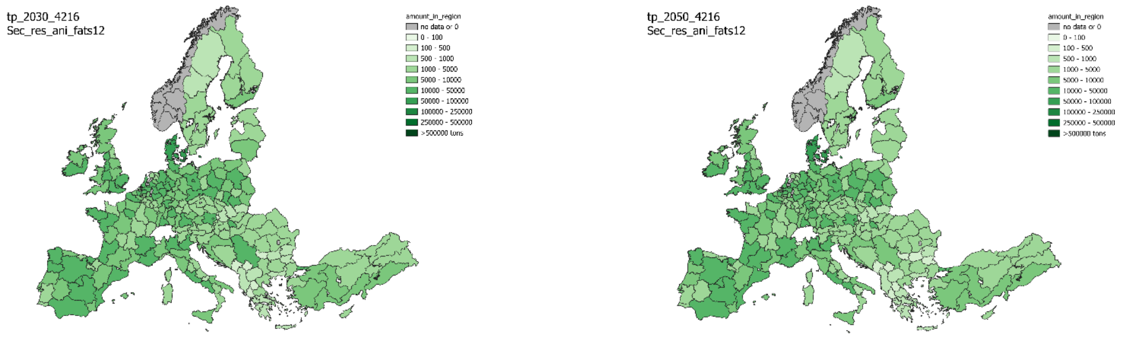
| | | 2030 | 2030 | 2050 | 2050 |
|---|---|---|---|---|---|
| | Technical | TP mln ton | %/total | TP mln ton | %/total |
| **4216** | Animal fats | 1.7 | 0.1% | 1.7 | 0.1% |
| | | 2030 | 2030 | 2050 | 2050 |
| | Low scenario | Low mln ton | %/total | Low mln ton | %/total |
| **4216** | Animal fats | 1.2 | 0.3% | 1.0 | 0.3% |
| | | 2030 | 2030 | 2050 | 2050 |
| | Medium scenario | Medium mln ton | %/total | Medium mln ton | %/total |
| **4216** | Animal fats | 1.5 | 0.2% | 1.4 | 0.2% |
| | | 2030 | 2030 | 2050 | 2050 |
| | High scenario | High mln ton | %/total | High mln ton | %/total |
| **4216** | Animal fats | 1.7 | 0.1% | 1.6 | 0.1% |

Table A2 - 100 Total biomass Europe (million tonnes) in 2030 and 2050 for technical, low, medium and high mobilisation scenario

| | Animal fats (4216) in 2030 | | | | Animal fats (4216) in 2050 | | | |
|---|---|---|---|---|---|---|---|---|
| | high | low | medium | tp | high | low | medium | tp |
| | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons |
| **AL** | 760 | 560 | 680 | 800 | 633 | 422 | 563 | 704 |
| **AT** | 31,169 | 22,966 | 27,888 | 32,809 | 30,164 | 20,109 | 26,812 | 33,515 |
| **BA** | 1,790 | 1,319 | 1,601 | 1,884 | 1,489 | 993 | 1,324 | 1,654 |
| **BG** | 4,857 | 3,579 | 4,346 | 5,113 | 4,034 | 2,689 | 3,586 | 4,482 |
| **BL** | 71,364 | 52,584 | 63,852 | 75,120 | 68,482 | 45,655 | 60,873 | 76,091 |
| **CS** | 9,502 | 7,002 | 8,502 | 10,003 | 7,620 | 5,080 | 6,773 | 8,466 |
| **CY** | 3,199 | 2,357 | 2,862 | 3,367 | 3,293 | 2,195 | 2,927 | 3,659 |
| **CZ** | 15,752 | 11,606 | 14,093 | 16,581 | 14,601 | 9,734 | 12,979 | 16,223 |
| **DE** | 326,857 | 240,842 | 292,451 | 344,060 | 305,870 | 203,914 | 271,885 | 339,856 |
| **DK** | 85,405 | 62,930 | 76,415 | 89,900 | 82,356 | 54,904 | 73,205 | 91,506 |
| **EE** | 2,224 | 1,639 | 1,990 | 2,341 | 2,023 | 1,349 | 1,798 | 2,248 |
| **EL** | 11,712 | 8,630 | 10,479 | 12,329 | 10,506 | 7,004 | 9,339 | 11,674 |
| **ES** | 242,336 | 178,563 | 216,827 | 255,090 | 231,641 | 154,427 | 205,903 | 257,379 |
| **FI** | 13,498 | 9,946 | 12,077 | 14,208 | 12,258 | 8,172 | 10,896 | 13,620 |
| **FR** | 175,046 | 128,981 | 156,620 | 184,259 | 168,454 | 112,302 | 149,737 | 187,171 |
| **HR** | 5,378 | 3,963 | 4,812 | 5,661 | 4,515 | 3,010 | 4,013 | 5,017 |
| **HU** | 30,314 | 22,337 | 27,123 | 31,909 | 27,678 | 18,452 | 24,602 | 30,753 |
| **IR** | 28,646 | 21,108 | 25,631 | 30,154 | 30,633 | 20,422 | 27,230 | 34,037 |
| **IT** | 115,399 | 85,031 | 103,251 | 121,472 | 105,995 | 70,664 | 94,218 | 117,773 |
| **KO** | 205 | 151 | 183 | 215 | 192 | 128 | 171 | 213 |
| **LT** | 5,615 | 4,138 | 5,024 | 5,911 | 4,416 | 2,944 | 3,925 | 4,906 |
| **LV** | 2,149 | 1,583 | 1,922 | 2,262 | 1,658 | 1,105 | 1,474 | 1,842 |
| **MK** | 687 | 506 | 615 | 723 | 601 | 401 | 534 | 668 |
| **MO** | 134 | 99 | 120 | 141 | 117 | 78 | 104 | 130 |
| **MT** | 444 | 327 | 397 | 467 | 484 | 323 | 430 | 538 |
| **NL** | 81,452 | 60,017 | 72,878 | 85,738 | 77,913 | 51,942 | 69,256 | 86,571 |
| **NO** | | | | | | | | |
| **PL** | 141,444 | 104,222 | 126,556 | 148,889 | 123,444 | 82,296 | 109,728 | 137,160 |

| | Animal fats (4216) in 2030 | | | | Animal fats (4216) in 2050 | | | |
|---|---|---|---|---|---|---|---|---|
| | **high** | **low** | **medium** | **tp** | **high** | **low** | **medium** | **tp** |
| | **Sum of tons** | **Sum of tons** | **Sum of tons** | **Sum of tons** | **Sum of tons** | **Sum of tons** | **Sum of tons** | **Sum of tons** |
| **PT** | 26,607 | 19,605 | 23,806 | 28,007 | 23,461 | 15,641 | 20,855 | 26,068 |
| **RO** | 23,408 | 17,248 | 20,944 | 24,640 | 19,389 | 12,926 | 17,235 | 21,544 |
| **SE** | 18,662 | 13,751 | 16,698 | 19,645 | 19,520 | 13,013 | 17,351 | 21,689 |
| **SI** | 2,870 | 2,114 | 2,568 | 3,021 | 2,638 | 1,759 | 2,345 | 2,931 |
| **SK** | 2,386 | 1,758 | 2,135 | 2,512 | 2,139 | 1,426 | 1,901 | 2,376 |
| **TR** | 56,754 | 41,819 | 50,780 | 59,741 | 60,527 | 40,352 | 53,802 | 67,253 |
| **UK** | 110,235 | 81,226 | 98,631 | 116,037 | 107,752 | 71,834 | 95,779 | 119,724 |

Table A2 - 101 Cost supply per country per year and scenario for animal fats category 1 & 2 2030 and 2050 (tonnes fat)




*Map 1 Distribution over Europe*

## Evaluation

### General observations

*Describe general observations on e.g. approach of assessment, scenario approach, results in numbers (amounts and price levels), spatial distribution, comparison with PRIMES*

The approach is based on the application of a straightforward equation data on future meat production, heads of animals slaughtered and fatty tissue percentage in different types of animals. The approach can produce results at regional levels.

The overall results seem to be about three times more than the current estimations for animal fats from Cat. 1 and 2 in the EU according to data from European Fat Processors and Renderers' Association (EFPRA) - quoted in the report here: https://www.transportenvironment.org/wp-content/uploads/2023/05/Cerulogy_Fat-of-the-land_May_23.pdf. Although a straightforward comparison is difficult since the geographical scopes are not perfectly aligned (EFPRA considers 23 member states + United Kingdom, Norway and Switzerland), the difference is more difficult to be explained.

A comparison with PRIMES is difficult at this stage, since it is not clear what other biomass types may be included **in the non-agricultural oils category.**

Strength

*Please indicate what you regard as a strength in the assessment of results*

The fact that the calculation is based on robust models for future meat production is positive.

### Weaknesses

*Please indicate what you regard as a weakness in the assessment*

It is not clear whether the calculation considers the total fatty tissue in an animal. It is expected that quantities of fat would remain with the meat sold, and hence would be non-recoverable for the purposes of this study.

The percentages considered for the different mobilization scenarios are ad hoc. At the moment, it seems that the amount of animal fats that go into heat production at rendering facilities remain very low and are probably not a big influence for future mobilization scenarios.

It is not clear how the calculation considers Category 3 animal fats that are used (or should be used) for other purposes.

### Options for improvement?

*Please indicate what <u>can</u> or <u>really needs</u> to be improved.*

The model could be adjusted and tuned to provide more accurate results for the current estimation for the industry regarding production of Cat.1 and Cat.2 animal fats.

COMMENT authors: The potential may be over-estimated as compared to current practices for 2 reasons:

- Current practices are rendering a small share of the cat- 2&3 animal fats
- To calculate the fat available this assessment took the total fat share in every animal, while large parts of the fat share are still consumed as part of meat consumption.

## SWOT 16 – Organic waste separately and separately collected (5101 and 5102)

### Description of approach

Organic waste consists of fractions that are separately collected and as part of mixed waste in the municipal solid waste (MSW) category. Eurostat reports the amount of waste produced per country on a yearly basis in waste production per head. The separately organic waste categories used are 'Animal and mixed food waste' and 'Vegetal waste'. In principle the organic waste amounts develop according to population development figures which were derived from Eurostat 2030 and 2050 population projections at regional level. However, differences in development of organic waste (separated and un-separated) are applied according to the mobilisation scenarios (see Table 1).

| | Technical | | Low mobilisation | | Medium mobilisation | | High mobilisation | |
|---|---|---|---|---|---|---|---|---|
| | 2030 | 2050 | 2030 | 2050 | 2030 | 2050 | 2030 | 2050 |
| Collection & Separation level organic waste | All separately collected waste + all organic waste in un-separated MSW | | All separately collected waste +<br>2030: already separated fraction in 2020 + extra up to 50% separated fraction<br>2050: already separated fraction in 2020 + extra up to 65% separated fraction | | All separately collected waste +<br>2030: already separated fraction in 2020 + extra up to 60% separated fraction<br>2050: already separated fraction in 2020 + extra up to 70% separated fraction | | All separately collected waste +<br>2030: already separated fraction in 2020 + extra up to 65% separated fraction<br>2050: already separated fraction in 2020 + extra up to 75% separated fraction | |
| Recycling & other uses | No recycling & other uses | | In 2030: 60% and in 2050: 70% recycling & other uses | | In 2030: 45% and in 2050: 55% recycling & other uses | | In 2030: 30% and in 2050: 40% recycling & other uses | |

Table A2 - 102 Scenario assumptions for Organic waste mobilisation

*For organic waste* the expectation for future development follows the Circular Economy Package[19] that 60% of municipal waste needs to be re-used and recycled by 2030, and 65% by 2035. These shares are reflected in the mobilisation scenarios where in the low mobilisation scenario the separation rates are reached in 2050, but has higher recycling levels, while in the medium and especially the high mobilisation scenario higher separation shares are reached with lower recycling and circular use rates.

### Results

Results of total potentials are presented in Table 2

| | | 2030 | 2030 | 2050 | 2050 |
|---|---|---|---|---|---|
| | Technical | TP mln ton | %/total | TP mln ton | %/total |
| **5101** | Organic waste separate | 30.9 | 1.9% | 31.6 | 1.7% |
| **5102** | Organic waste unseparate | 5.9 | 0.4% | 5.2 | 0.3% |
| | | 2030 | 2030 | 2050 | 2050 |
| | Low scenario | Low mln ton | %/total | Low mln ton | %/total |
| **5101** | Organic waste separate | 12.1 | 3.8% | 9.3 | 3.1% |
| **5102** | Organic waste unseparate | 2.7 | 0.8% | 1.8 | 0.6% |
| | | 2030 | 2030 | 2050 | 2050 |
| | Medium scenario | Medium mln ton | %/total | Medium mln ton | %/total |
| **5101** | Organic waste separate | 16.8 | 3.1% | 14.0 | 2.6% |
| **5102** | Organic waste unseparate | 3.4 | 0.6% | 2.5 | 0.5% |
| | | 2030 | 2030 | 2050 | 2050 |
| | High scenario | High mln ton | %/total | High mln ton | %/total |
| **5101** | Organic waste separate | 21.6 | 2.5% | 18.9 | 2.0% |
| **5102** | Organic waste unseparate | 4.1 | 0.5% | 3.1 | 0.3% |

Table A2 - 103 Total biomass (million ton d.m.) Europe in 2030 and 2050 for technical, low, medium and high mobilisation scenario

[19] https://ec.europa.eu/commission/presscorner/detail/en/IP_15_6203

| | Organic waste separate (5101) | | | | Organic waste unseparate (5102) | | | |
|---|---|---|---|---|---|---|---|---|
| | **Sum of high** | **Sum of low** | **Sum of medium** | **Sum of tp** | **Sum of high** | **Sum of low** | **Sum of medium** | **Sum of tp** |
| AL | 13,821 | 6,075 | 10,024 | 9,983 | 3,763 | 3,014 | 3,379 | 5,376 |
| AT | 371,449 | 212,257 | 291,853 | 530,642 | 26,706 | 15,261 | 20,983 | 38,151 |
| BA | 6,816 | 2,996 | 4,943 | 50,667 | 19,097 | 15,590 | 17,149 | 27,282 |
| BG | 296,198 | 169,256 | 232,727 | 423,139 | 22,120 | 12,640 | 17,380 | 31,600 |
| BL | 1,940,505 | 1,108,860 | 1,524,682 | 2,772,150 | 171,651 | 98,086 | 134,869 | 245,216 |
| CS | 4,854 | 2,134 | 3,520 | 43,740 | 9,922 | 5,669 | 7,795 | 14,174 |
| CY | 14,327 | 7,549 | 10,391 | 20,467 | 7,714 | 5,046 | 6,927 | 11,021 |
| CZ | 298,327 | 170,473 | 234,400 | 426,182 | 41,974 | 23,985 | 32,979 | 59,962 |
| DE | 3,027,077 | 1,729,758 | 2,378,418 | 4,324,395 | 592,963 | 338,836 | 465,900 | 847,090 |
| DK | 314,494 | 179,711 | 247,103 | 449,277 | 36,748 | 20,999 | 28,873 | 52,497 |
| EE | 53,855 | 30,774 | 42,315 | 76,936 | 5,935 | 3,392 | 4,663 | 8,479 |
| EL | 233,819 | 133,611 | 183,715 | 334,027 | 96,717 | 55,267 | 75,992 | 138,168 |
| ES | 1,949,463 | 1,113,979 | 1,531,721 | 2,784,947 | 245,734 | 140,420 | 193,077 | 351,049 |
| FI | 160,521 | 78,595 | 116,422 | 229,316 | 86,434 | 62,523 | 77,615 | 123,478 |
| FR | 2,085,277 | 1,191,587 | 1,638,432 | 2,978,967 | 698,346 | 399,055 | 548,700 | 997,637 |
| HR | 173,642 | 99,224 | 136,433 | 248,060 | 6,795 | 3,883 | 5,339 | 9,707 |
| HU | 204,693 | 116,967 | 160,830 | 292,418 | 87,870 | 50,212 | 69,041 | 125,529 |
| IR | 92,285 | 50,200 | 69,025 | 131,836 | 49,692 | 30,930 | 42,529 | 70,989 |
| IT | 994,879 | 468,112 | 721,560 | 1,421,255 | 535,704 | 406,507 | 481,040 | 765,291 |
| KO | 2,111 | 928 | 1,531 | 102,734 | 985 | 563 | 774 | 1,406 |
| LT | 98,077 | 56,044 | 77,061 | 140,110 | 15,211 | 8,692 | 11,952 | 21,730 |
| LV | 26,655 | 12,058 | 19,332 | 38,079 | 14,353 | 11,375 | 12,888 | 20,504 |
| MK | 6,988 | 3,129 | 5,068 | 16,294 | 5,261 | 3,006 | 4,133 | 7,515 |
| MO | 35,467 | 15,590 | 25,723 | 11,226 | 280 | 160 | 220 | 400 |
| MT | | | | | | | | |
| NL | 3,451,348 | 1,972,199 | 2,711,773 | 4,930,497 | 147,798 | 84,456 | 116,127 | 211,140 |
| NO | 158,096 | 69,493 | 114,663 | 225,851 | 85,128 | 69,493 | 76,442 | 121,612 |
| PL | 1,058,558 | 465,300 | 767,745 | 1,512,226 | 569,993 | 465,300 | 511,830 | 814,275 |
| PT | 69,218 | 36,896 | 50,732 | 98,882 | 37,271 | 23,955 | 32,937 | 53,244 |
| RO | 257,261 | 147,007 | 202,134 | 367,516 | 31,719 | 18,125 | 24,922 | 45,312 |

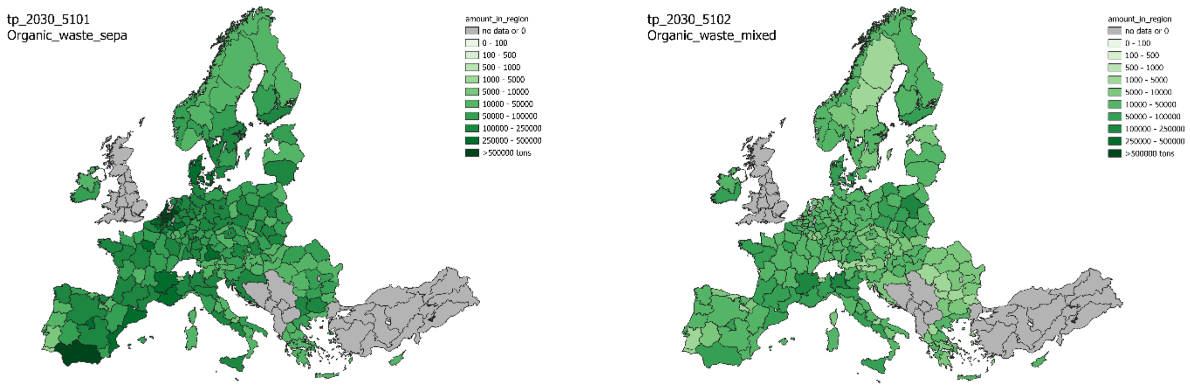
| | Organic waste separate (5101) | | | | Organic waste unseparate (5102) | | | |
|---|---|---|---|---|---|---|---|---|
| | Sum of high | Sum of low | Sum of medium | Sum of tp | Sum of high | Sum of low | Sum of medium | Sum of tp |
| SE | 578,038 | 330,307 | 454,172 | 825,768 | 73,269 | 41,868 | 57,569 | 104,670 |
| SI | 47,384 | 26,624 | 36,608 | 67,691 | 25,514 | 15,032 | 20,669 | 36,449 |
| SK | 258,979 | 147,988 | 203,483 | 369,970 | 17,868 | 10,210 | 14,039 | 25,526 |
| TR | 876,464 | 500,836 | 688,650 | 256,276 | 80,284 | 45,876 | 63,080 | 114,691 |
| UK | 2,481,027 | 1,417,730 | 1,949,378 | 4,420,992 | 291,605 | 166,631 | 229,118 | 416,578 |

Table A2 - 104 Biomass supply (tonnes dm) per country and scenario in 2030

| | Organic waste separate (5101) | | | | Organic waste unseparate (5102) | | | |
|---|---|---|---|---|---|---|---|---|
| | Sum of high | Sum of low | Sum of medium | Sum of tp | Sum of high | Sum of low | Sum of medium | Sum of tp |
| AL | 6,075 | 2,633 | 4,253 | 10,126 | 2,025 | 1,418 | 1,823 | 3,375 |
| AT | 325,235 | 162,617 | 243,926 | 542,058 | 23,383 | 11,692 | 17,537 | 38,972 |
| BA | 30,803 | 13,348 | 21,562 | 51,339 | 10,268 | 7,187 | 9,241 | 17,113 |
| BG | 222,582 | 111,291 | 166,936 | 370,970 | 16,623 | 8,311 | 12,467 | 27,704 |
| BL | 1,676,074 | 838,037 | 1,257,056 | 2,793,457 | 148,332 | 74,166 | 111,249 | 247,220 |
| CS | 22,214 | 11,107 | 16,660 | 37,023 | 7,198 | 3,599 | 5,399 | 11,997 |
| CY | 15,396 | 6,672 | 10,777 | 25,660 | 5,132 | 3,592 | 4,619 | 8,553 |
| CZ | 250,199 | 125,099 | 187,649 | 416,998 | 35,202 | 17,601 | 26,402 | 58,670 |
| DE | 2,562,933 | 1,281,467 | 1,922,200 | 4,271,555 | 502,044 | 251,022 | 376,533 | 836,740 |
| DK | 274,384 | 137,192 | 205,788 | 457,307 | 32,061 | 16,030 | 24,046 | 53,435 |
| EE | 44,320 | 22,160 | 33,240 | 73,866 | 4,884 | 2,442 | 3,663 | 8,141 |
| EL | 201,200 | 94,885 | 142,327 | 335,333 | 67,067 | 39,248 | 58,873 | 111,778 |
| ES | 1,685,961 | 842,980 | 1,264,471 | 2,809,935 | 212,519 | 106,260 | 159,390 | 354,199 |
| FI | 152,182 | 65,946 | 106,527 | 253,637 | 50,727 | 35,509 | 45,655 | 84,546 |
| FR | 1,817,750 | 907,813 | 1,361,719 | 3,029,584 | 605,917 | 304,021 | 456,031 | 1,009,861 |
| HR | 131,903 | 65,951 | 98,927 | 219,838 | 5,161 | 2,581 | 3,871 | 8,602 |
| HU | 181,259 | 84,546 | 126,881 | 302,098 | 60,420 | 36,294 | 54,378 | 100,699 |
| IR | 103,024 | 44,644 | 72,117 | 171,707 | 34,341 | 24,039 | 30,907 | 57,236 |
| IT | 953,979 | 413,391 | 667,786 | 1,589,966 | 317,993 | 222,595 | 286,194 | 529,989 |
| KO | 61,093 | 30,547 | 45,820 | 101,822 | 836 | 418 | 627 | 1,394 |
| LT | 69,782 | 34,891 | 52,337 | 116,304 | 10,823 | 5,411 | 8,117 | 18,038 |

| | Organic waste separate (5101) | | | | Organic waste unseparate (5102) | | | |
|---|---|---|---|---|---|---|---|---|
| | Sum of high | Sum of low | Sum of medium | Sum of tp | Sum of high | Sum of low | Sum of medium | Sum of tp |
| LV | 21,472 | 9,305 | 15,031 | 35,787 | 7,157 | 5,010 | 6,442 | 11,929 |
| MK | 9,893 | 4,514 | 6,925 | 16,488 | 3,298 | 2,082 | 2,968 | 5,496 |
| MO | 6,219 | 3,110 | 4,664 | 10,365 | 222 | 111 | 166 | 370 |
| MT | | | | | | | | |
| NL | 2,987,008 | 1,493,504 | 2,240,256 | 4,978,346 | 127,913 | 63,957 | 95,935 | 213,189 |
| NO | 172,246 | 74,640 | 120,572 | 287,076 | 57,415 | 40,191 | 51,674 | 95,692 |
| PL | 964,451 | 417,929 | 675,115 | 1,607,418 | 321,484 | 225,038 | 289,335 | 535,806 |
| PT | 63,717 | 27,611 | 44,602 | 106,196 | 21,239 | 14,867 | 19,115 | 35,399 |
| RO | 192,804 | 96,402 | 144,603 | 321,341 | 23,771 | 11,886 | 17,829 | 39,619 |
| SE | 547,021 | 273,511 | 410,266 | 911,702 | 69,338 | 34,669 | 52,003 | 115,563 |
| SI | 45,471 | 19,704 | 31,830 | 75,785 | 15,157 | 10,610 | 13,641 | 25,262 |
| SK | 210,006 | 105,003 | 157,505 | 350,011 | 14,489 | 7,245 | 10,867 | 24,149 |
| TR | 187,924 | 86,549 | 131,547 | 313,207 | 62,641 | 38,733 | 56,377 | 104,402 |
| UK | 2,736,893 | 1,368,446 | 2,052,670 | 4,561,488 | 257,890 | 128,945 | 193,417 | 429,817 |

Table A2 - 105  Biomass supply (tonnes dm) per country and scenario in 2050




*M*ap 1Distribution over Europe

## Evaluation

### General observations

*Describe general observations on e.g. approach of assessment, scenario approach, results in  numbers (amounts and price levels), spatial distribution, comparison with PRIMES*

The methodology is very logical: starting from Eurostat and following projections of population growth. Furthermore, bandwidths for collection and recycling have been assumed in line with the Circular Economy Package. A comparison with PRIMES is difficult to make, since PRIMES uses more aggregated categories. The reviewer compared current and projected use of the Netherlands with the results from this analysis and concluded that current and projected use all within the bandwidth of the current study.

### Strength

*Please indicate what you regard as a strength in the assessment of results*

**The methodology is very logical and has a solid starting point with Eurostat data**

Weaknesses

*Please indicate what you regard as a weakness in the assessment*

### Options for improvement?

*Please indicate what can or really needs to be improved.*

I do not see any point of improvement needed.

## SWOT 17 – Fruit and vegetable residues and waste not fit for use in the food and feed chain (5104)

### Description of approach

To estimate their potential we followed Mason-DÇroz et al (2019) who expected the amount of fruit and vegetable waste to be:

– 0.01378 kg/day/person by 2030 (assuming 8% dry mass)

– 0.01416 kg/day/person by 2050 (assuming 8% dry mass)

These figures were multiplied by the number of inhabitants as projected by Eurostat for European regions by 2030 and 2050 to generate the technical potential. For the additional assumptions made per mobilisation scenario, see Table 1.

*Overview of food waste factors copied from Mason-D'Croz, D., Bogard, J. R., Sulser, T. B., Cenacchi, N., Dunston, S., Herrero, M. and Wiebe, K. (2019). Gaps between fruit and vegetable production, demand, and recommended consumption at global and national levels: an integrated modelling study. The Lancet Planetary Health, 3 (7), E318-E329. https://doi.org/10.1016/S2542-5196(19)30095-6*

| | 1965 | 1990 | 2015 | 2050 | | |
|---|---|---|---|---|---|---|
| | | | | SSP1 | SSP2 | SSP3 |
| **East Asia and Pacific** | | | | | | |
| Fruit and vegetable availability (g/person per day) | 194 | 318 | 834 | 982 | 924 | 877 |
| Number of countries | 22 (5) | 22 (7) | 23 (12) | 23 (15) | 23 (15) | 23 (15) |
| Population (millions) | 1862 (144) | 3026 (271) | 2242 (1886) | 2173 (2105) | 2261 (2186) | 2352 (2266) |
| **South Asia** | | | | | | |
| Fruit and vegetable availability (g/person per day) | 167 | 198 | 326 | 1335 | 956 | 615 |
| Number of countries | 6 (0) | 6 (0) | 7 (0) | 7 (4) | 7 (3) | 7 (2) |
| Population (millions) | 637 (0) | 1133 (0) | 1747 (0) | 2108 (2025) | 2373 (1980) | 2720 (2032) |
| **Former Soviet Union*** | | | | | | |
| Fruit and vegetable availability (g/person per day) | 292 | 349 | 526 | 678 | 644 | 624 |
| Number of countries | 1 (0) | 1 (0) | 12 (10) | 12 (12) | 12 (11) | 12 (11) |
| Population (millions) | 230 (0) | 287 (0) | 281 (270) | 263 (263) | 278 (270) | 290 (279) |
| **Middle East and north Africa** | | | | | | |
| Fruit and vegetable availability (g/person per day) | 436 | 640 | 735 | 798 | 771 | 731 |
| Number of countries | 14 (7) | 14 (11) | 17 (15) | 17 (15) | 17 (15) | 17 (15) |
| Population (millions) | 145 (77) | 291 (251) | 499 (467) | 647 (594) | 716 (653) | 809 (732) |
| **Sub-Saharan Africa** | | | | | | |
| Fruit and vegetable availability (g/person per day) | 178 | 178 | 206 | 355 | 301 | 248 |
| Number of countries | 38 (0) | 38 (0) | 43 (1) | 43 (14) | 43 (5) | 43 (3) |
| Population (millions) | 233 (0) | 462 (0) | 956 (10) | 1542 (723) | 1767 (519) | 2055 (130) |
| **Latin America and Caribbean** | | | | | | |
| Fruit and vegetable availability (g/person per day) | 310 | 322 | 413 | 544 | 498 | 462 |
| Number of countries | 24 (6) | 24 (5) | 24 (13) | 24 (18) | 24 (16) | 24 (14) |
| Population (millions) | 250 (53) | 441 (21) | 616 (442) | 675 (555) | 742 (584) | 854 (628) |
| **Europe and North America*** | | | | | | |
| Fruit and vegetable availability (g/person per day) | 454 | 601 | 632 | 700 | 689 | 708 |
| Number of countries | 27 (11) | 27 (23) | 31 (30) | 31 (31) | 31 (31) | 31 (31) |
| Population (millions) | 665 (393) | 781 (757) | 905 (898) | 1053 (1053) | 1027 (1027) | 870 (870) |
| **Global** | | | | | | |
| Fruit and vegetable availability (g/person per day) | 252 | 335 | 546 | 862 | 732 | 608 |
| Number of countries | 132 (29) | 132 (46) | 158 (81) | 158 (109) | 158 (96) | 158 (91) |
| Population (millions) | 4019 (665) | 6419 (1298) | 7243 (3969) | 8457 (7314) | 9162 (7217) | 9946 (6934) |

Numbers in parentheses represent countries that have achieved fruit and vegetable availability greater than or equal to 400 g/person per day and their respective population. Food availability excludes consumer food waste. 1965 and 1990 values are taken from the FAOSTAT commodity balance sheets" and 2015 and 2050 values are projections from the International Model for Policy Analysis of Agricultural Commodities and Trade using three scenarios (SSP 1-3) using default diets (based on historical trends). SSP=Shared Socioeconomic Pathway. *The Baltic states are reported as part of the former Soviet Union up to 1990 and are included in Europe for all future projections.

**Table: Regional summary of fruit and vegetable availability and progress towards availability of 400 g/person per day**

| | Technical | | Low mobilisation | | Medium mobilisation | | High mobilisation | |
|---|---|---|---|---|---|---|---|---|
| | **2030** | **2050** | **2030** | **2050** | **2030** | **2050** | **2030** | **2050** |
| Consumption levels fruit and vegetables | As in 2020 | | 2030: 10% less<br>2050: 15% less<br>(compared to 2020) | | As in 2020 | | 2030: 10% more<br>2050: 15% more<br>(compared to 2020) | |
| Wasted | | | 2030: 20% less<br>2050: 25% less<br>(compared to 2020) | | As in 2020 | | 2030: 10% more<br>2050: 15% more<br>(compared to 2020) | |
| Competing use | No competing use | | 2030: 60%<br>2050: 70% to competing use (material) | | 2030: 40%<br>2050: 45% to competing use (material) | | 2030: 20%<br>2050: 25% to competing use (material) | |

Table A2 - 106 *Scenario assumptions*

## Results

Results of total potentials are presented in Table 2

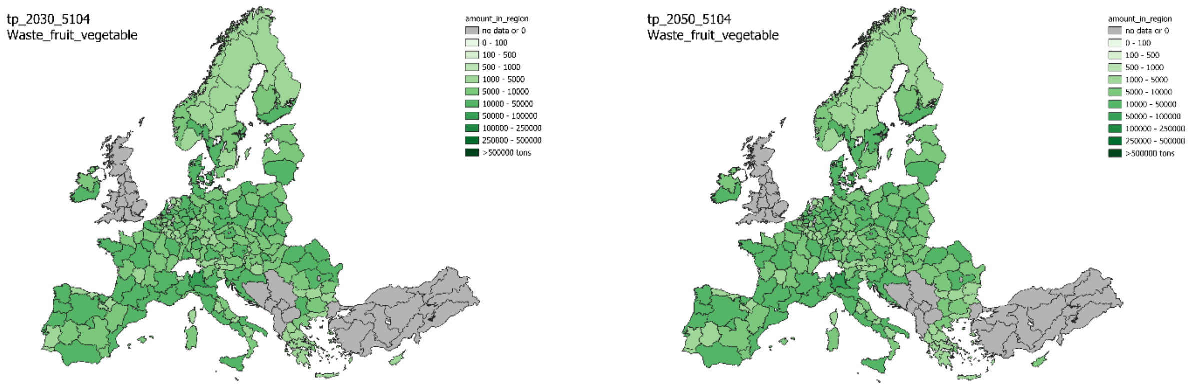
| | | 2030 | 2030 | 2050 | 2050 |
|---|---|---|---|---|---|
| | Technical | TP mln ton | %/total | TP mln ton | %/total |
| **5104** | Fruit & vegetable waste | 2.1 | 0.1% | 2.1 | 0.1% |
| | | 2030 | 2030 | 2050 | 2050 |
| | Low scenario | Low mln ton | %/total | Low mln ton | %/total |
| **5104** | Fruit & vegetable waste | 0.6 | 0.2% | 0.4 | 0.1% |
| | | 2030 | 2030 | 2050 | 2050 |
| | Medium scenario | Medium mln ton | %/total | Medium mln ton | %/total |
| **5104** | Fruit & vegetable waste | 1.3 | 0.2% | 1.2 | 0.2% |
| | | 2030 | 2030 | 2050 | 2050 |
| | High scenario | High mln ton | %/total | High mln ton | %/total |
| **5104** | Fruit & vegetable waste | 2.0 | 0.2% | 2.1 | 0.2% |

Table A2 - 107 Total Europe (million tonnes dm) in 2030 and 2050 for technical, low, medium and high mobilisation scenario

| | Fruit & vegetable waste (5104) in 2030 | | | | Fruit & vegetable waste (5104) in 2050 | | | |
|---|---|---|---|---|---|---|---|---|
| | high | low | medium | tp | high | low | medium | tp |
| | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons |
| **AL** | | | | | | | | |
| **AT** | 44,176 | 13,253 | 27,610 | 46,017 | 47,095 | 9,238 | 26,567 | 48,303 |
| **BA** | | | | | | | | |
| **BG** | 31,145 | 9,344 | 19,466 | 32,443 | 28,497 | 5,590 | 16,075 | 29,227 |
| **BL** | 53,434 | 16,030 | 33,396 | 55,660 | 56,486 | 11,080 | 31,864 | 57,934 |
| **CS** | | | | | | | | |
| **CY** | 4,649 | 1,395 | 2,906 | 4,843 | 5,272 | 1,034 | 2,974 | 5,407 |
| **CZ** | 51,965 | 15,590 | 32,478 | 54,131 | 53,064 | 10,409 | 29,934 | 54,425 |
| **DE** | 324,230 | 97,269 | 202,644 | 337,739 | 334,242 | 65,563 | 188,547 | 342,812 |
| **DK** | 24,764 | 7,429 | 15,478 | 25,796 | 26,307 | 5,160 | 14,840 | 26,981 |
| **EE** | 6,318 | 1,895 | 3,949 | 6,581 | 6,330 | 1,242 | 3,571 | 6,493 |
| **EL** | 38,771 | 11,631 | 24,232 | 40,386 | 38,313 | 7,515 | 21,612 | 39,295 |
| **ES** | 222,635 | 66,790 | 139,147 | 231,911 | 234,434 | 45,985 | 132,245 | 240,445 |
| **FI** | 26,650 | 7,995 | 16,656 | 27,760 | 26,661 | 5,230 | 15,039 | 27,345 |
| **FR** | 285,396 | 85,619 | 178,373 | 297,288 | 302,556 | 59,347 | 170,672 | 310,313 |
| **HR** | 18,484 | 5,545 | 11,552 | 19,254 | 17,096 | 3,353 | 9,644 | 17,534 |
| **HU** | 46,446 | 13,934 | 29,028 | 48,381 | 46,715 | 9,163 | 26,352 | 47,913 |
| **IR** | 26,578 | 7,973 | 16,611 | 27,685 | 31,309 | 6,141 | 17,662 | 32,112 |
| **IT** | 288,302 | 86,490 | 180,188 | 300,314 | 291,717 | 57,221 | 164,558 | 299,197 |
| **KO** | | | | | | | | |
| **LT** | 12,436 | 3,731 | 7,773 | 12,954 | 10,773 | 2,113 | 6,077 | 11,050 |
| **LV** | 8,270 | 2,481 | 5,169 | 8,615 | 7,030 | 1,379 | 3,966 | 7,210 |
| **MK** | | | | | | | | |
| **MO** | | | | | | | | |
| **MT** | | | | | | | | |

| | Fruit & vegetable waste (5104) in 2030 | | | | Fruit & vegetable waste (5104) in 2050 | | | |
|---|---|---|---|---|---|---|---|---|
| | **high** | **low** | **medium** | **tp** | **high** | **low** | **medium** | **tp** |
| | **Sum of tons** | **Sum of tons** | **Sum of tons** | **Sum of tons** | **Sum of tons** | **Sum of tons** | **Sum of tons** | **Sum of tons** |
| **NL** | 81,197 | 24,359 | 50,748 | 84,580 | 85,562 | 16,783 | 48,266 | 87,756 |
| **NO** | 27,838 | 8,351 | 17,399 | 28,998 | 32,004 | 6,278 | 18,054 | 32,825 |
| **PL** | 178,744 | 53,623 | 111,715 | 186,192 | 171,847 | 33,709 | 96,940 | 176,254 |
| **PT** | 46,394 | 13,918 | 28,996 | 48,327 | 45,066 | 8,840 | 25,422 | 46,222 |
| **RO** | 77,831 | 23,349 | 48,645 | 81,074 | 71,022 | 13,931 | 40,064 | 72,843 |
| **SE** | 53,592 | 16,078 | 33,495 | 55,825 | 61,751 | 12,113 | 34,834 | 63,334 |
| **SI** | 10,170 | 3,051 | 6,356 | 10,594 | 10,299 | 2,020 | 5,810 | 10,563 |
| **SK** | 26,271 | 7,881 | 16,419 | 27,365 | 25,938 | 5,088 | 14,632 | 26,603 |
| **TR** | | | | | | | | |
| **UK** | | | | | | | | |

Table A2 - 108  Cost supply per country per year and scenario for fruit and vegetal waste 2030 and 2050




Map 1 Distribution over Europe

## Evaluation

### General observations

Describe general observations on e.g. approach of assessment, scenario approach, results in numbers (amounts and price levels), spatial distribution, comparison with PRIMES

The approach is based on a simple calculation of waste generated per person multiplied by future projections of EU population per region. Different scenarios are formulated using different assumptions on mobilization potential and competing uses.

A comparison with PRIMES is not possible, since that model groups fruit and vegetable waste together with other approaches.

### Strength

Please indicate what you regard as a strength in the assessment of results

The calculation is easy to follow and can be cross-checked.

Future estimates of EU population are based on official projections.

### Weaknesses

Please indicate what you regard as a weakness in the assessment

The amount of fruit and vegetable waste generated per person is based on a single study; it is not clear whether there are other sources which possibly cite alternative factors.

It is unclear why the study of Kumar et al., (2020) assumes that the volume of waste per person increases from 2030 to 2050 when there should be expectations that food waste will be minimized.

The assumptions for the factors used in the various scenarios are ad hoc ones and are not based on any specific study.

### Options for improvement?

Please indicate what can or really needs to be improved.

More details on the assumptions behind the parameters used by Kumar et al., (2020) should be referenced – does the increasing volume of waste reflect for example the higher consumption of fruit and vegetables in the future?

Competing uses for fruit and vegetable waste should also consider animal feed, not only materials.

## SWOT 18 – Used Cooking Oil (5106)

### Description of approach

Used cooking oil is cooking oil from households and professional use that has been used for cooking and can still be used for biofuels.

To assess the UCO potential we used the following information as starting point:

- Current household and professional resource technical potential on country level was obtained from Greenea (2016).
- Estimated household and professional collection rates on country level obtained from Panoutsou et al. (2021).
  - 2030: Household rate 15%, Professional rate 90%
  - 2050: Household rate 45%, Professional rate 90%

As UCO potentials were not known for all countries, assumptions of missing values were made based on neighboring countries (see Table 1) based on the formula:

**UCO potential for country with missing data =**

$$\frac{Technical\ UCO\ potential\ proxy\ country}{Population\ proxy\ country} \times Population\ unkown\ country$$

| Country with missing data | Proxy country |
|---|---|
| Albania | Greece |
| Bosnia and Herzegovina | Croatia |
| Kosovo | Greece |
| Moldova | Romania |
| Montenegro | Greece |
| North Macedonia | Greece |
| Serbia | Hungary |
| Turkye | Bulgaria |
| Ukraine | Romania |

Table A2 - 109 Countries for which assumptions were made on UCO potential using the UCO/head production of neighbouring country

The UCO potential on country level was distributed to NUTS-2 region based on population size now and in the future based on population projection data per region in the EU and for non-EU countries other population projection data were used from national statistical offices and UN.

| | Low mobilisation | | Medium mobilisation | | High mobilisation | |
|---|---|---|---|---|---|---|
| | **2030** | **2050** | **2030** | **2050** | **2030** | **2050** |
| **UCO collection** | 10% household rate 90% professional | 30% household rate 90% professional | 15% household rate 90% professional | 45% household rate 90% professional | 20% household rate 90% professional | 60% household rate 90% professional |
| **Competing use** | 40% | 50% | 30% | 35% | 10% | 15% |

Table A2 - 110 Assumptions on collection rates determining future UCO availability in the three scenarios

## Results

Results of total potentials are presented in Table 3

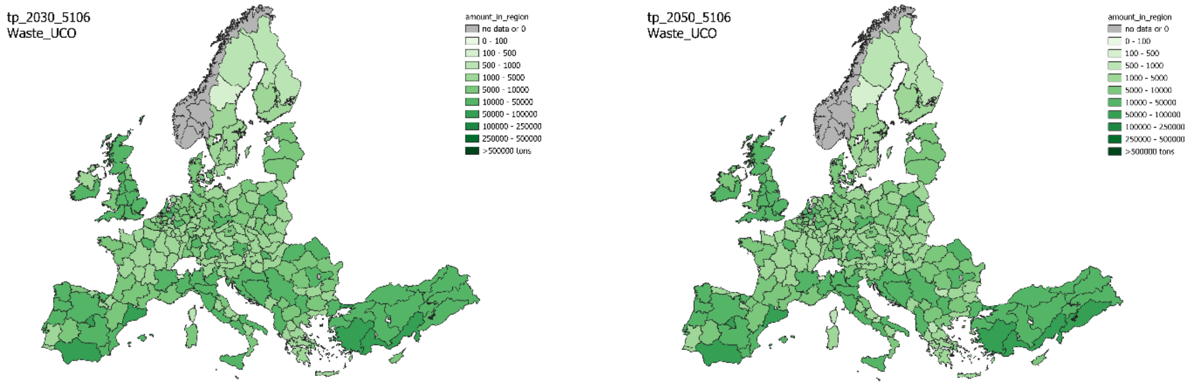
| | | 2030 | 2030 | 2050 | 2050 |
|---|---|---|---|---|---|
| | Technical | ton oil | %/total | TP ton oil | %/total |
| **5106** | UCO | 2.2 | 0.8% | 2.2 | 0.7% |
| | | 2030 | 2030 | 2050 | 2050 |
| | Low scenario | Low ton oil | %/total | Low ton oil | %/total |
| **5106** | UCO | 0.5 | 0.2% | 0.5 | 0.2% |
| | | 2030 | 2030 | 2050 | 2050 |
| | Medium scenario | Medium ton oil | %/total | Medium ton oil | %/total |
| **5106** | UCO | 0.6 | 0.1% | 0.7 | 0.1% |
| | | 2030 | 2030 | 2050 | 2050 |
| | High scenario | High ton oil | %/total | High ton oil | %/total |
| **5106** | UCO | 1.0 | 0.1% | 1.3 | 0.1% |

Table A2 - 111 Total Europe (million tons oil) in 2030 and 2050 for technical, low, medium and high mobilisation scenario

| | UCO (5106) in 2030 | | | | UCO (5106) in 2050 | | | |
|---|---|---|---|---|---|---|---|---|
| | high | low | medium | tp | high | low | medium | tp |
| | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons |
| AL | 6,402 | 3,297 | 4,112 | 11,943 | 6,463 | 2,684 | 3,697 | 10,498 |
| AT | 16,280 | 8,684 | 10,637 | 25,694 | 17,162 | 7,698 | 10,174 | 26,290 |
| BA | 7,022 | 3,616 | 4,510 | 13,098 | 7,081 | 2,941 | 4,051 | 11,502 |
| BG | 10,540 | 4,601 | 6,274 | 32,531 | 15,363 | 5,022 | 7,940 | 28,723 |
| BL | 29,732 | 15,853 | 19,422 | 47,047 | 31,156 | 13,958 | 18,460 | 47,772 |
| CS | 6,134 | 2,448 | 3,514 | 22,499 | 9,813 | 2,957 | 4,915 | 19,044 |
| CY | 1,660 | 705 | 977 | 5,426 | 3,113 | 990 | 1,592 | 5,895 |
| CZ | 13,515 | 6,702 | 8,526 | 29,227 | 16,929 | 6,557 | 9,389 | 28,811 |
| DE | 142,341 | 75,823 | 92,941 | 226,368 | 145,872 | 65,202 | 86,336 | 224,083 |
| DK | 5,329 | 2,859 | 3,491 | 8,167 | 5,487 | 2,494 | 3,273 | 8,313 |
| EE | 2,302 | 1,082 | 1,417 | 5,903 | 3,174 | 1,134 | 1,700 | 5,668 |
| EL | 24,148 | 12,436 | 15,511 | 45,045 | 26,594 | 11,043 | 15,212 | 43,196 |
| ES | 108,012 | 48,067 | 64,844 | 319,074 | 176,207 | 58,820 | 91,827 | 326,075 |
| FI | 4,588 | 2,399 | 2,968 | 7,996 | 4,853 | 2,080 | 2,817 | 7,703 |
| FR | 53,194 | 26,907 | 33,876 | 106,815 | 65,409 | 26,238 | 36,839 | 108,807 |
| HR | 5,096 | 2,265 | 3,058 | 15,100 | 7,226 | 2,409 | 3,764 | 13,382 |
| HU | 9,135 | 3,646 | 5,233 | 33,504 | 16,682 | 5,028 | 8,355 | 32,374 |
| IR | 12,966 | 7,093 | 8,578 | 17,732 | 13,810 | 6,605 | 8,444 | 20,015 |
| IT | 85,142 | 39,542 | 52,106 | 225,812 | 122,001 | 42,875 | 64,922 | 219,795 |
| KO | 4,343 | 2,236 | 2,789 | 8,100 | 4,943 | 2,053 | 2,827 | 8,029 |
| LT | 3,983 | 1,936 | 2,489 | 9,220 | 4,408 | 1,653 | 2,411 | 7,653 |
| LV | 2,829 | 1,392 | 1,778 | 6,287 | 2,985 | 1,141 | 1,646 | 5,120 |
| MK | 4,686 | 2,413 | 3,010 | 8,741 | 4,969 | 2,063 | 2,842 | 8,071 |
| MO | 1,403 | 723 | 901 | 2,617 | 1,488 | 618 | 851 | 2,417 |
| MT | 1,371 | 645 | 844 | 3,516 | 2,265 | 809 | 1,214 | 4,045 |
| NL | 59,912 | 32,665 | 39,570 | 83,598 | 57,916 | 27,454 | 35,258 | 84,618 |
| NO | | | | | | | | |

| | UCO (5106) in 2030 | | | | UCO (5106) in 2050 | | | |
|---|---|---|---|---|---|---|---|---|
| | high | low | medium | tp | high | low | medium | tp |
| | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons |
| **PL** | 41,467 | 20,743 | 26,268 | 86,878 | 47,644 | 18,733 | 26,597 | 80,309 |
| **PT** | 25,986 | 12,963 | 16,440 | 54,996 | 30,542 | 11,951 | 17,014 | 51,641 |
| **RO** | 28,349 | 13,486 | 17,541 | 70,202 | 34,824 | 12,646 | 18,786 | 61,607 |
| **SE** | 9,295 | 5,003 | 6,100 | 13,986 | 10,290 | 4,716 | 6,163 | 15,482 |
| **SI** | 3,981 | 2,011 | 2,533 | 8,042 | 4,682 | 1,873 | 2,634 | 7,803 |
| **SK** | 5,838 | 2,745 | 3,593 | 14,970 | 7,998 | 2,856 | 4,285 | 14,282 |
| **TR** | 146,220 | 63,826 | 87,036 | 451,298 | 271,729 | 88,834 | 140,437 | 508,041 |
| **UK** | 103,905 | 55,559 | 67,970 | 161,981 | 109,602 | 49,436 | 65,148 | 167,129 |

Table A2 - 112 Biomass supply (tonnes oil) per country per year and scenario




*Map 1 Distribution over Europe*

## Evaluation

### General observations

*Describe general observations on e.g. approach of assessment, scenario approach, results in numbers (amounts and price levels), spatial distribution, comparison with PRIMES*

The potentials are well in line with the values as used by PRIMES (they fall in the same range). Overall, the approach that is followed sounds logical. In general, earlier assessment has been re-used which is fine. Also, the energy conversion value used (ton to energy) uses a very similar factor as what the reviewer is using.

### Strength

*Please indicate what you regard as a strength in the assessment of results*

A consistent approach has been used for all countries. Data of countries that are missing, has been filled using a sensible approach.

### Weaknesses

*Please indicate what you regard as a weakness in the assessment*

The data source of the technical potential is somewhat old (2016). Also, it is not clear what the effect of double counting of UCO based biofuels was. Around 2016 this was very important and pulled a lot of UCO. Can we safely extrapolate this without double counting? Furthermore, it is not clear how the prices are determined.

### Options for improvement?

*Please indicate what <u>can</u> or <u>really needs</u> to be improved.*

It would be worthwhile to check if a more recent assessment of the technical potential has been done.

## SWOT 19 – Brown grease (5107)

### Description of approach

Brown grease is the oily material collected from grease traps that are used to segregate insoluble and gelatinous grease present in kitchen wastewater streams.

It is quantified based on the population size per NUTS-2 region and the brown grease production in Germany from 2019 (Umweltbundesamt, 2019):

- Brown grease (tonnes/capita/year) lower limit: 0.000015
- Brown grease (tonnes/capita/year) upper limit: 0.0051

The future potentials of brown grease production are based on the lower and upper limit estimates from Umweltbundesamt (2019) in tonnes/year of brown grease distributed to NUTS-2 region based on population size and population projections for 2030 and 2050 (see Table 1). There are limited competing uses of brown grease, therefore they were not taken into consideration for the scenarios.

| | Low mobilisation | | Medium mobilisation | | Technical and High mobilisation | |
|---|---|---|---|---|---|---|
| | **2030** | **2050** | **2030** | **2050** | **2030** | **2050** |
| **Brown grease production** | Lower limit | Lower limit | Between lower and upper limit | Between lower and upper limit | Upper limit | Upper limit |

Table A2 - 113 Scenario specifications

### Results

Results of total potentials are presented in Table 2

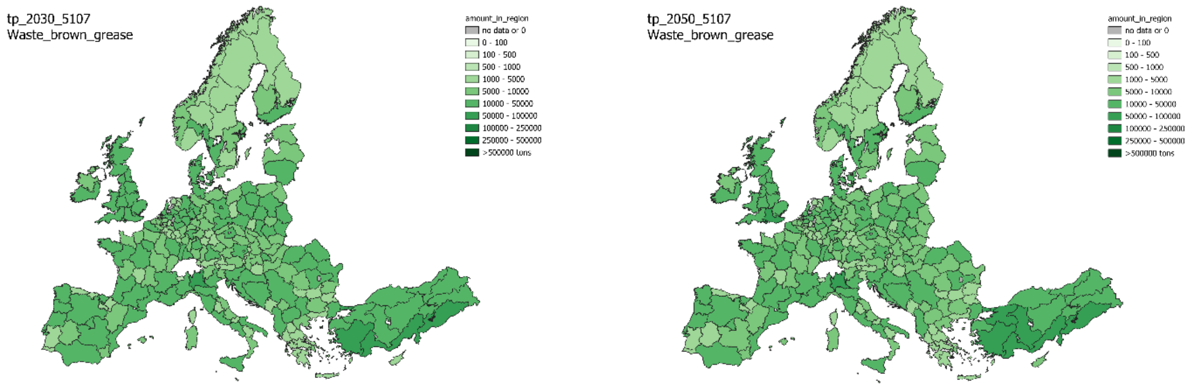
| | | 2030 | 2030 | 2050 | 2050 |
|---|---|---|---|---|---|
| | Technical | TP ton | %/total | TP ton | %/total |
| **5107** | Brown grease | 3.1 | 0.2% | 3.1 | 0.2% |
| | | 2030 | 2030 | 2050 | 2050 |
| | Low scenario | Low ton | %/total | Low ton | %/total |
| **5107** | Brown grease | 0.0 | 0.0% | 0.0 | 0.0% |
| | | 2030 | 2030 | 2050 | 2050 |
| | Medium scenario | Medium ton | %/total | Medium ton | %/total |
| **5107** | Brown grease | 0.9 | 0.2% | 0.9 | 0.2% |
| | | 2030 | 2030 | 2050 | 2050 |
| | High scenario | High ton | %/total | High ton | %/total |
| **5107** | Brown grease | 2.5 | 0.3% | 2.3 | 0.3% |

Table A2 - 114 Total Europe in 2030 and 2050 for technical, low, medium and high mobilisation scenario

| | Brown grease (5107) in 2030 | | | | Brown grease (5107) in 2050 | | | |
|---|---|---|---|---|---|---|---|---|
| | high | low | medium | tp | high | low | medium | tp |
| | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons |
| **AL** | 11,521 | 17 | 4,333 | 14,401 | 9,494 | 12 | 3,492 | 12,659 |
| **AT** | 37,726 | 57 | 14,190 | 47,158 | 36,129 | 44 | 13,288 | 48,172 |
| **BA** | 12,592 | 19 | 4,736 | 15,740 | 10,367 | 13 | 3,813 | 13,822 |
| **BG** | 26,598 | 40 | 10,004 | 33,247 | 21,861 | 27 | 8,040 | 29,148 |
| **BL** | 45,632 | 69 | 17,164 | 57,040 | 43,333 | 53 | 15,937 | 57,777 |
| **CS** | 26,524 | 40 | 9,977 | 33,155 | 21,048 | 26 | 7,741 | 28,063 |
| **CY** | 3,970 | 6 | 1,493 | 4,963 | 4,044 | 5 | 1,487 | 5,393 |
| **CZ** | 44,378 | 67 | 16,692 | 55,473 | 40,708 | 49 | 14,972 | 54,277 |
| **DE** | 276,890 | 420 | 104,149 | 346,113 | 256,413 | 311 | 94,303 | 341,884 |
| **DK** | 21,148 | 32 | 7,955 | 26,436 | 20,181 | 24 | 7,422 | 26,908 |
| **EE** | 5,395 | 8 | 2,029 | 6,744 | 4,856 | 6 | 1,786 | 6,475 |
| **EL** | 33,110 | 50 | 12,454 | 41,387 | 29,391 | 36 | 10,810 | 39,189 |
| **ES** | 190,129 | 288 | 71,515 | 237,661 | 179,845 | 218 | 66,143 | 239,794 |
| **FI** | 22,759 | 35 | 8,560 | 28,449 | 20,453 | 25 | 7,522 | 27,270 |
| **FR** | 243,727 | 370 | 91,675 | 304,659 | 232,105 | 282 | 85,363 | 309,473 |
| **HR** | 15,785 | 24 | 5,937 | 19,732 | 13,115 | 16 | 4,823 | 17,487 |
| **HU** | 39,664 | 60 | 14,919 | 49,580 | 35,837 | 43 | 13,180 | 47,783 |
| **IR** | 22,697 | 34 | 8,537 | 28,372 | 24,019 | 29 | 8,834 | 32,025 |
| **IT** | 246,208 | 373 | 92,608 | 307,760 | 223,790 | 272 | 82,305 | 298,387 |
| **KO** | 7,787 | 12 | 2,929 | 9,734 | 7,236 | 9 | 2,661 | 9,648 |
| **LT** | 10,620 | 16 | 3,995 | 13,275 | 8,265 | 10 | 3,040 | 11,020 |
| **LV** | 7,063 | 11 | 2,656 | 8,828 | 5,393 | 7 | 1,983 | 7,191 |
| **MK** | 8,399 | 13 | 3,159 | 10,498 | 7,270 | 9 | 2,674 | 9,694 |
| **MO** | 2,516 | 4 | 946 | 3,145 | 2,178 | 3 | 801 | 2,904 |
| **MT** | 2,287 | 3 | 860 | 2,858 | 2,467 | 3 | 907 | 3,289 |
| **NL** | 69,342 | 105 | 26,082 | 86,677 | 65,639 | 80 | 24,141 | 87,518 |

| | Brown grease (5107) in 2030 | | | | Brown grease (5107) in 2050 | | | |
|---|---|---|---|---|---|---|---|---|
| | high | low | medium | tp | high | low | medium | tp |
| | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons |
| **NO** | 23,773 | 36 | 8,942 | 29,717 | 24,552 | 30 | 9,030 | 32,736 |
| **PL** | 152,646 | 232 | 57,416 | 190,808 | 131,832 | 160 | 48,485 | 175,777 |
| **PT** | 39,620 | 60 | 14,903 | 49,525 | 34,572 | 42 | 12,715 | 46,097 |
| **RO** | 66,468 | 101 | 25,001 | 83,085 | 54,484 | 66 | 20,038 | 72,646 |
| **SE** | 45,767 | 69 | 17,215 | 57,209 | 47,372 | 57 | 17,422 | 63,162 |
| **SI** | 8,685 | 13 | 3,267 | 10,857 | 7,901 | 10 | 2,906 | 10,534 |
| **SK** | 22,435 | 34 | 8,439 | 28,044 | 19,898 | 24 | 7,318 | 26,531 |
| **TR** | 377,414 | 573 | 141,960 | 471,768 | 398,313 | 483 | 146,491 | 531,084 |
| **UK** | 283,075 | 429 | 106,475 | 353,844 | 273,817 | 332 | 100,704 | 365,089 |

Table A2 - 115 Biomass supply (tonnes grease) per country per year and scenario




Map 1 Distribution over Europe

## Evaluation

### General observations

*Describe general observations on e.g. approach of assessment, scenario approach, results in numbers (amounts and price levels), spatial distribution, comparison with PRIMES*

This type of biomass seems like a type that has hardly been investigated, since that potential is low, therefore the available data is very limited and it is also difficult to make a comparison. Using the limited available data, the approach that has been used seems logical. Not a meaningful comparison can be made with PRIMES data.

### Strength

*Please indicate what you regard as a strength in the assessment of results*

At least a data sources has been found for this relatively unknown type of biomass. The approach followed is logical.

### Weaknesses

*Please indicate what you regard as a weakness in the assessment*

It is unclear how the cost are determined. A generic cost of 440 €/ton is mentioned, but it is not clear where the difference between countries comes from.

### Options for improvement?

*Please indicate what <u>can</u> or <u>really needs</u> to be improved.*

The description how the cost have been accessed, in particular the differences between the countries.

## SWOT 20 – Organic fraction of sewage sludge (5108)

### Description of approach

The organic fraction of sewage sludge is derived from the sludge that remains when sewage water is cleaned. Part of the sludge that remains is organic.

For the assessment Eurostat that were used that reports the amount of sewage sludge produced per country on a yearly basis in production per head. The sludge amount in Eurostat is reported in dry mass. To determine what the organic fraction is we followed Sharma et al. (2022) who indicate that the dewatered sludge is composed of organic matter (50–70 %). For the assessment of the potential in this study a 60% organic matter content was assumed.

Like with the organic waste and several other categories of residual biomass sources, sludge is also assumed to develop according to population development figures which were derived from Eurostat 2030 and 2050 population projections at regional level within EU and several association countries. However, differences in development of sewage sludge are applied according to the mobilisation scenarios (see Table 1).

| | Technical | | Low mobilisation | | Medium mobilisation | | High mobilisation | |
|---|---|---|---|---|---|---|---|---|
| | **2030** | **2050** | **2030** | **2050** | **2030** | **2050** | **2030** | **2050** |
| Development of biomass | Growth according to population | Growth according to population | Growth according to population& -20% water use | Growth according to population& -40% water use | Growth according to population& -10% water use | Growth according to population& -20% water use | Growth according to population | Growth according to population |
| Competing use level for other than biofuels | 0% | 0% | 30% | 40% | 30% | 40% | 5% | 10% |

Table A2 - 116 *Assumptions for scenarios*

### Results

Results of total potentials are presented in Table 2

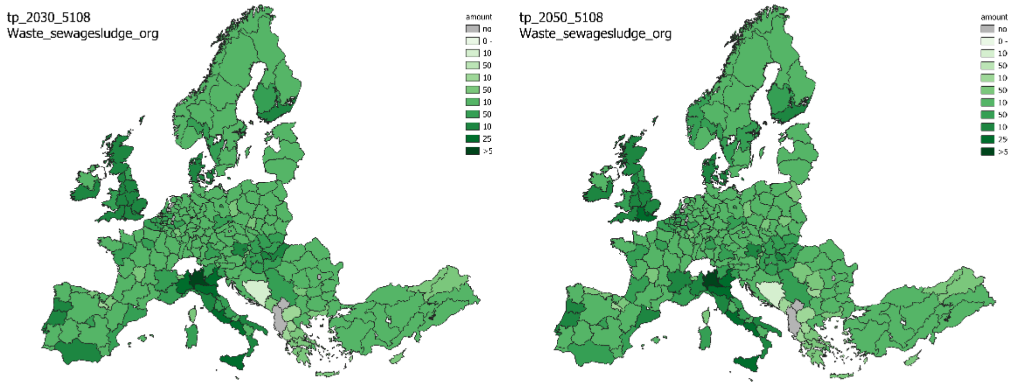
| | | 2030 | 2030 | 2050 | 2050 |
|---|---|---|---|---|---|
| | Technical | TP mln ton | %/total | TP mln ton | %/total |
| **5108** | Organic sewage sludge | 12.7 | 0.6% | 12.6 | 0.6% |
| | | 2030 | 2030 | 2050 | 2050 |
| | Low scenario | Low mln ton | %/total | Low mln ton | %/total |
| **5108** | Organic sewage sludge | 8.9 | 2.3% | 7.5 | 2.0% |
| | | 2030 | 2030 | 2050 | 2050 |
| | Medium scenario | Medium mln ton | %/total | Medium mln ton | %/total |
| **5108** | Organic sewage sludge | 10.8 | 1.5% | 10.1 | 1.4% |
| | | 2030 | 2030 | 2050 | 2050 |
| | High scenario | High mln ton | %/total | High mln ton | %/total |
| **5108** | Organic sewage sludge | 12.0 | 1.0% | 11.3 | 1.0% |

Table A2 - 117 Total Europe in 2030 and 2050 for technical, low, medium and high mobilisation scenario

| | Organic fraction of sewage sludge (5108) in 2030 | | | | Organic fraction of sewage sludge (5108) in 2050 | | | |
|---|---|---|---|---|---|---|---|---|
| | high | low | medium | tp | high | low | medium | tp |
| | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons |
| **AL** | | | | | | | | |
| **AT** | 250,773 | 184,780 | 224,376 | 263,972 | 242,686 | 161,790 | 215,721 | 269,651 |
| **BA** | 406 | 299 | 363 | 427 | 338 | 225 | 300 | 375 |
| **BG** | 110,194 | 81,196 | 98,595 | 115,994 | 91,523 | 61,016 | 81,354 | 101,693 |
| **BL** | 506,141 | 372,946 | 452,863 | 532,780 | 485,700 | 323,800 | 431,733 | 539,667 |
| **CS** | 71,036 | 52,342 | 63,558 | 74,774 | 56,962 | 37,975 | 50,633 | 63,292 |
| **CY** | 8,005 | 5,898 | 7,162 | 8,426 | 8,240 | 5,493 | 7,325 | 9,156 |
| **CZ** | 126,075 | 92,898 | 112,804 | 132,711 | 116,866 | 77,911 | 103,881 | 129,851 |
| **DE** | 926,178 | 682,447 | 828,686 | 974,925 | 866,711 | 577,807 | 770,410 | 963,012 |
| **DK** | 119,035 | 87,710 | 106,505 | 125,300 | 114,785 | 76,524 | 102,031 | 127,539 |
| **EE** | 32,613 | 24,031 | 29,180 | 34,329 | 29,664 | 19,776 | 26,368 | 32,960 |
| **EL** | 88,785 | 65,420 | 79,439 | 93,458 | 79,644 | 53,096 | 70,794 | 88,493 |
| **ES** | 514,258 | 378,927 | 460,126 | 541,325 | 491,564 | 327,709 | 436,945 | 546,182 |
| **FI** | 237,641 | 175,104 | 212,626 | 250,148 | 215,809 | 143,873 | 191,831 | 239,788 |
| **FR** | 775,825 | 571,660 | 694,159 | 816,657 | 746,607 | 497,738 | 663,650 | 829,563 |
| **HR** | 13,527 | 9,967 | 12,103 | 14,239 | 11,357 | 7,571 | 10,095 | 12,619 |
| **HU** | 696,879 | 513,490 | 623,523 | 733,556 | 636,270 | 424,180 | 565,573 | 706,967 |
| **IR** | 153,101 | 112,812 | 136,986 | 161,159 | 163,721 | 109,147 | 145,530 | 181,912 |
| **IT** | 3,380,251 | 2,490,711 | 3,024,435 | 3,558,158 | 3,104,814 | 2,069,876 | 2,759,834 | 3,449,793 |
| **KO** | | | | | | | | |
| **LT** | 28,522 | 21,016 | 25,520 | 30,023 | 22,430 | 14,953 | 19,938 | 24,922 |
| **LV** | 11,849 | 8,731 | 10,601 | 12,472 | 9,143 | 6,095 | 8,127 | 10,159 |
| **MK** | 2,379 | 1,753 | 2,129 | 2,505 | 2,081 | 1,388 | 1,850 | 2,313 |
| **MO** | 5,108 | 3,764 | 4,570 | 5,377 | 4,468 | 2,979 | 3,972 | 4,964 |
| **MT** | 7,708 | 5,680 | 6,897 | 8,114 | 8,402 | 5,602 | 7,469 | 9,336 |
| **NL** | 367,604 | 270,866 | 328,909 | 386,951 | 351,636 | 234,424 | 312,565 | 390,707 |
| **NO** | 171,865 | 126,637 | 153,774 | 180,910 | 179,363 | 119,575 | 159,434 | 199,292 |

| | Organic fraction of sewage sludge (5108) in 2030 | | | | Organic fraction of sewage sludge (5108) in 2050 | | | |
|---|---|---|---|---|---|---|---|---|
| | high | low | medium | tp | high | low | medium | tp |
| | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons | Sum of tons |
| **PL** | 323,586 | 238,432 | 289,525 | 340,617 | 282,406 | 188,270 | 251,027 | 313,784 |
| **PT** | 544,294 | 401,058 | 486,999 | 572,941 | 479,946 | 319,964 | 426,619 | 533,273 |
| **RO** | 103,528 | 76,283 | 92,630 | 108,976 | 85,756 | 57,171 | 76,227 | 95,284 |
| **SE** | 275,784 | 203,209 | 246,754 | 290,299 | 288,458 | 192,306 | 256,408 | 320,509 |
| **SI** | 19,616 | 14,454 | 17,551 | 20,648 | 18,031 | 12,021 | 16,028 | 20,035 |
| **SK** | 232,703 | 171,466 | 208,208 | 244,951 | 208,563 | 139,042 | 185,389 | 231,736 |
| **TR** | 219,753 | 161,924 | 196,621 | 231,319 | 234,363 | 156,242 | 208,323 | 260,404 |
| **UK** | 1,707,042 | 1,257,821 | 1,527,354 | 1,796,887 | 1,668,591 | 1,112,394 | 1,483,192 | 1,853,990 |

Table A2 - 118 Biomass supply (tonnes dm) per country per year and scenario




Map 1 Distribution over Europe

# Evaluation

### General observations

*Describe general observations on e.g. approach of assessment, scenario approach, results in numbers (amounts and price levels), spatial distribution, comparison with PRIMES*

The approach followed seems sensible. Eurostat statistics are combined with population growth and scenario's that have an effect on the amount (water use and competing use). The spatial distribution also makes sense, since the spatial distribution of population is used. Comparison with PRIMES is not well possible, since only a comparison with of gaseous biomass including manure is made, so no specific sewage sludge comparison can be made. The amounts in energy have been compared by the reviewer to numbers for the Netherlands. The energy values for 2030-2050 numbers from the current assessment are more than half lower than 2020/2021 statistics.

### Strength

*Please indicate what you regard as a strength in the assessment of results*

A logical approach is followed to determine the tonnes.

### Weaknesses

*Please indicate what you regard as a weakness in the assessment*

The conversion of the tonnes to energy. The conversion factor used is too generic and does not fit values that are probably more appropriate for sewage sludge.

### Options for improvement?

*Please indicate what <u>can</u> or <u>really needs</u> to be improved.*

Use of another conversion factor from mass to energy.

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The technical sustainable biomass potential available for energy markets in the EU27 and accession countries ranges from 310 to 836 million dry ton for 2030, and 294 - 892 million ton for 2050. The most significant biomass types, with the largest potential to be further mobilized are primary residues from arable crops, manure and stem wood and primary forestry residues. Towards 2050 the dedicated lignocellulosic crops and oil crops produced on unused degraded lands and as cover and intercrop in combination with food production also become more important.

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