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FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

Waste2GridS

DELIVERABLE

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Duration	18 months
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Deliverable Number	D1.2
Deliverable Name	Future available wastes in selected RES-dominated zones
Lead beneficiary	ENEA
Authors (beneficiary)	Vincenzo Motola (ENEA), Yi Zong (DTU), Shi You (DTU)
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Summary

This report, delivered by ENEA and DTU, assesses Municipal Solid Waste MSW and Agro-forestry potential residues, current potential and 2030 waste (biomass) streams scenario, within and around the zones dominated by renewable energy sources RES-Dominated zones defined in WT1.1, both in Denmark and Italy.
For Italy the RES dominated zones are identified in the southern regions: Molise, Basilicata, Puglia and Calabria with the nearby Campania region included as area of possible waste collection to balance the RES dominated zones, Denmark is divided in 3 zones DK1, DK2 and Bornholm Island.
The main waste streams available on the Italian regions come from Agricultural Residues (straw and pruning), Forestry Sustainable above ground increment, MSW fractions organic, paper and wood. For Denmark waste stream are aggregated in 3 main categories: Agriculture Residues, Forest, Bio-Waste. The year 2030 sustainable Waste base potential is calculated with constraints defined by Renewable Energy Directive REDII 2018/2001/EU and Directive (EU) 2018/851 on waste.
The agricultural residues, forestry and Bio-Waste are explicit spatially allocated on CORINE Land Cover 2018 with a resolution of 100 m and NUTS EU Zones, the Geodatabase obtained is mapped using QGIS geographical information system software, with the aim to obtain digital and interactive mapping and interoperability dataset capability.

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Acronym

AIEL	Italian Association Agroenergy
BDI	Baltic Dry Index
BEE	Biomass Energy Europe
CAP	Common Agricultural Policy
CLC	Corine Land Cover
CONOE	Italian National Consortium Used Vegetable Oil Recovery
COPERNICUS	European Earth Observation Programme
CREA	Council for Agricultural Research and Economics
EFSOS	European Forest Sector Outlook Study
ENAMA	Italian National organization mechanization in Agriculture
GIS	Geographical Information System
GSE	Italian Energy Service Agency
ILUC	Indirect Land Use Change
ISPRA	Italian Environmental Protection Agency
ISTAT	Italian National Statistics Institute
LHV	Low Heating Value
MSW	Municipal Solid Waste
MWe	Megawatt Electrical
NREAP	National Renewable Energy Action Plan
NUTS	Nomenclature of territorial units for statistics
PV	Photovoltaic
REDII	Renewable Energy Directive 2018/2001/EU
RES	Renewable Energy Source
SOC	Soil Organic Carbon
SQL	Standard Query Languages
TOE	Tons Oil Equivalent
UN SDGs	Sustainable Development Goals United Nations
UNFCCC	United Nations Framework Convention on Climate Change
WP	Work Package
WT	Work Task

1. Introduction

1.1 Background and task description

The Renewable Energy Directive REDII 2018/2001/EU [1] refers to biomass as the 'biodegradable fraction of products, waste and residues from a biological origin, from agriculture (including vegetal and animal substances), forestry and related industries (including fisheries and aquaculture), as well as the biodegradable fraction of industrial and municipal waste. The directive establishes a series of binding targets, such as the obligation for the Member States to collectively ensure that the share of energy from renewable sources in the Union's gross final consumption of energy in 2030 is at least 32%, and the obligation on fuel suppliers to ensure that the RES share within the final energy consumption in the transport sector is at least 14% by 2030.

The revised EU legislative framework on waste [2] entered into force in July 2018, It sets clear targets for reduction of waste and also tracks long-term path for waste management and recycling, key elements of the revised waste proposal include a common EU target for recycling 65% of municipal waste by 2035, with some specific target for specific packaging materials: minimum recycling rate of Paper and Cardboard set at 85 %, minimum recycling packaging Wood set at 30 %.

A binding landfill target to reduce landfill to maximum of 10% of municipal waste by 2035, early obligations, separate collection, are strengthened and extended to hazardous household waste (by end 2022), bio-waste (by end 2023), textiles (by end 2025). Prevention objectives are largely reinforced, in particular, requiring Member States to take specific measures to tackle food waste and marine litter as a contribution to achieving EU commitments to the UN SDGs [3] (United Nation Sustainable Development Goals).

This project task will assess low-grade waste (MSW, fruit trees pruning, cereal straw, forestry residues, Bio-Waste), building the GIS (Geographical Information System) geodatabase for the W2G project, which spatially covers the areas identified as RES-dominated power-generation zones in Italy and Denmark. This GIS geodatabase will be used as input data to design the waste supply chain to evaluate the feasibility of the W2G plants, which are considered part of technology solutions to reach renewable energy and recycling waste target in 2030, accordingly with REDII EU [1] directive and EU Circular economy package [4].

The proposed biomass classification schemes and methodology applied, in compliance with EU projects like BEE [5], S2Biom [6], BIOMASS FUTURE [7]. The biomass source potential in and around RES-dominated zones in Italy and Denmark are elaborating taking into account national inventories, with photo-interpretation of satellite data and making a spatially explicit assessment. For Denmark, regional waste data are taken by the S2Biom project database.

1.2 Deliverable structure

The document has been divided into different chapters to present the results of the different steps taken. Specifically, chapter 2 highlights the renewable energy contest in Italy and the methodology used for the biomass assessment. Chapter 3 presents the assessment of waste stream current and projected in 2030 for RES dominated zones in Italy and Denmark. Chapter 4 presents conclusions, final remarks, and perspectives.

1.3 Scope and utilization of this report

The scope of this report is the quantification of organic waste stream potentially available in 2030, in and around the RES dominated zones, defined by the WT1.1 in Italy and Denmark. The waste converted to syngas or biogas is intended to be provided as feedstocks to fuel cells or natural gas grid. The biomass quantification is used to size the future plants with the scope of grid balancing, accordingly to the targets set by REDII EU directive and EU Circular Economy package.

2. Overview of RES projections according to REDII Directive

2.1 The proposed NREAP Italy and RES projection 2030

The EU RES (Renewable Energy Sources) target is to reach at least 32% of gross final energy consumption until 2030 (directive EU 2018/2001). Every Member State could set its own plan to reach the targets. Italy has issued NREAP [8] (National Energy and Climate Plan) with 30% RES target until 2030, which considers 33 Mtoe (tons of oil equivalent) energy from RES as a share of gross total energy consumption of 111 Mtoe.

The Italian RES target 2030 by sectors are 55.4% RES share for electric sector, 33% RES share thermal sector (heating and cooling), 21.6% RES share transport sector (obligation criteria RED II).

According to the proposed Italian NREAP [8], the generation electricity mix deeply change because of the phase-out of coal to power until 2025, and the promotion of RES.

Most RES contribution is planned to come from the electricity sector, which will reach 16 Mtoe of RES generation in 2030, equal to 187 TWh from the 119 TWh produced in 2017. The planned penetration of PV (photovoltaic) and wind power, will cover 55.4% final gross electricity with RES, versus 34.1% in 2017, with solar adding 50 TWh and wind 23 TWh capacity. Thanks to the reduction of the cost of these technologies, PV production is expected to be tripled and wind energy more than doubled by 2030 as shown in Figure 1.

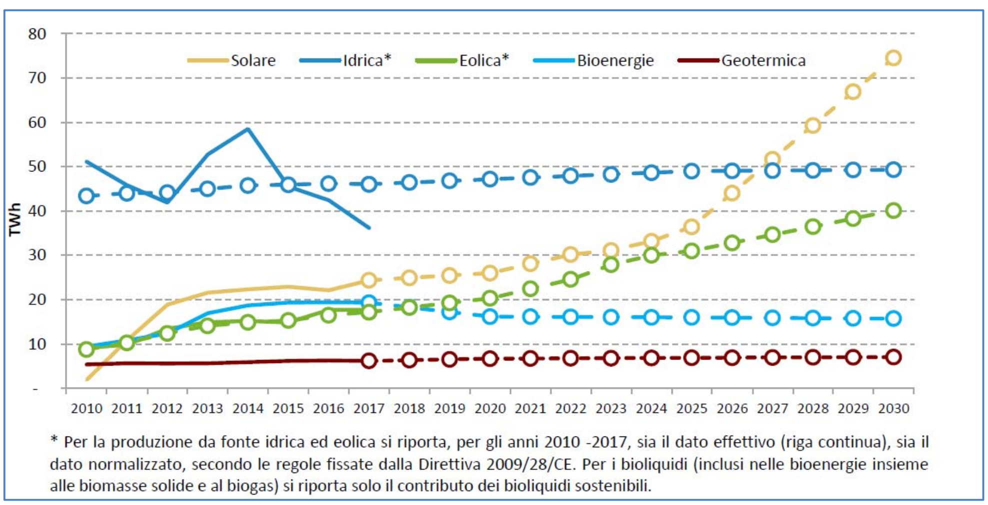


Figure 1 Italy Electric Energy Mix, source: Proposed Energy and Climate Plan REDII 2018/2001/EU.

For the thermal sector (Heating & Cooling), the RES share planned to reach 14.7 Mtoe until 2030, with a sharp increase in the installation of heating pumps. While bioenergy remaining to be the predominant source will remain steady, as given in Figure 2.

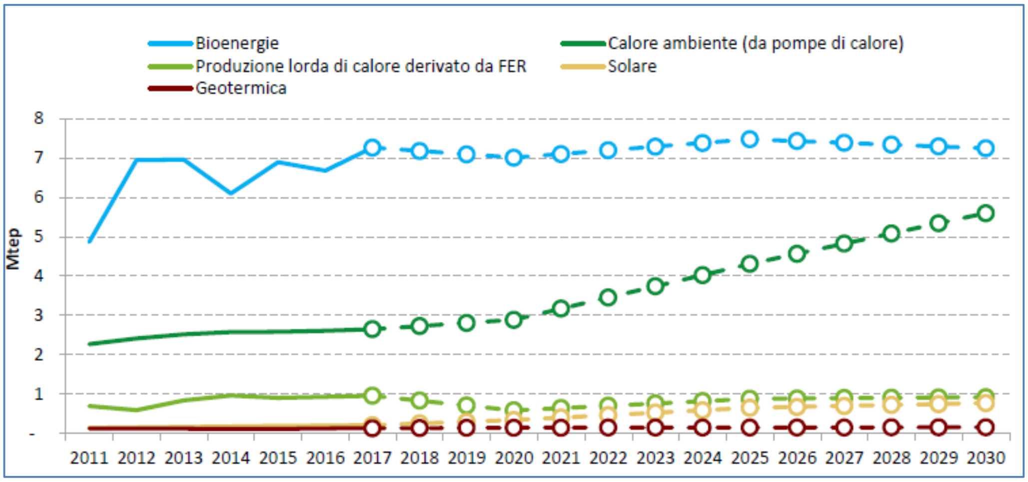


Figure 2 Italy Thermal Energy Mix, source: Proposed Energy and Climate Plan REDII 2018/2001/EU.

The RED II directive has a specific target 2030 for the transport sector equal to 14% RES share. Italy's challenging target of 30% final gross RES consumption from RES, requires the contribution of the transport sector much more than 14% minimum requirements, and it is planned to reach 21.6%. The transport sources mix trajectories are shown in Figure 3.

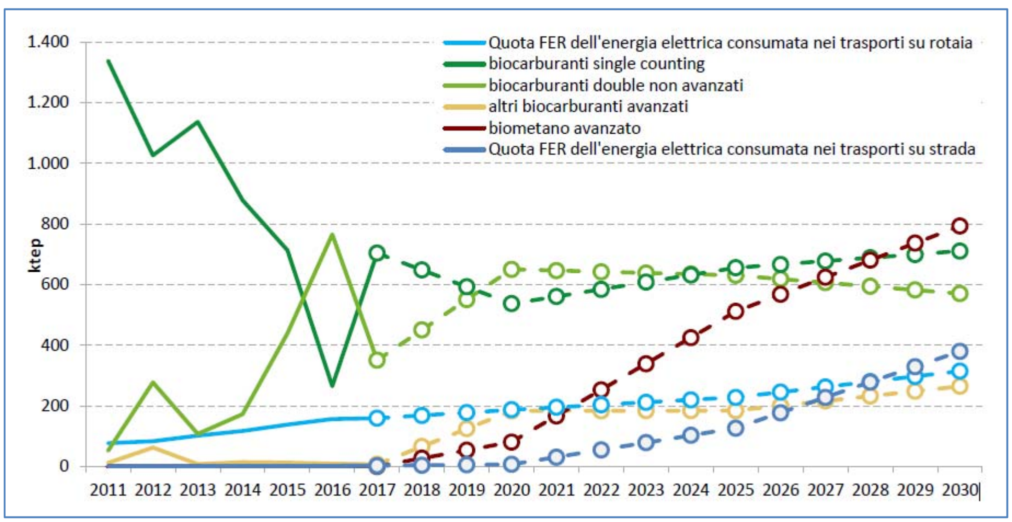


Figure 3 Italy Transport Energy Mix, source: Proposed Energy and Climate Plan REDII 2018/2001/EU.

Concerning the biogas production in Italy, there are 2116 facilities with nominal power installed of 1443 MW in 2017 (source GSE [9] and Terna [10]) with also associated heating production at around 11191 TJ in 2019 (source GSE [9] and Terna [10]). The direct bio-methane injection into the grid is 178 TJ equivalent to 4.3 ktoe in 2017 (GSE [9] and Terna [10]) and is planned to reach 800 ktoe year (NREAP) until 2030.

3. Biomass definitions and data source assessment

3.2 Biomass classification and characterization

There are many classification schemes on biomass classification worldwide. The project BEE [5] had the scope to harmonize the methodologies for biomass resource assessments for energy purposes in Europe and its neighboring countries. General classification scheme on biomass categories could be resumed as follow:

- **Energy crops:** wood energy crops (short rotation forestry, i.e. willow, eucalyptus, poplar), grass energy crops(miscanthus, hemp), oilseed crops (rape, linseed, sunflower), hydroponics (lake weed, kelp algae);
- **Wood, wood residues and by-products:** wood and wood branches from forest, wood residues from the industrial sector (sawmills, construction, furniture);
- **Agricultural residues:** wheat or barley straw, corn stover, pruning (fruit, vineyard);
- **Livestock:** pig and cattle slurry, sheep manure, grass silage, poultry litter;
- **Agro-industrial residues:** residues and wastes from various processes in the distillery, dairy, meat, fish, oils, fruit and vegetable sectors;
- **Waste:** sewage sludge, organic fraction of MSW (Municipal Solid Waste).

For the purpose of the project, the categories assessed are (1) **agricultural residues** including cereal straw, fruits tree pruning; (2) **Forest wood** including forestry above ground wood increment, forestry residues; (3) **Waste** including MSW fractions organic, wood and paper and other Bio-Waste. Table 1 provides the biomass characterization for the W2G project.

Table 1 Characteristics of Agriculture Residues and Dedicated Energy Crops, Source: AEBIOM 2009 [11] and IRENA 2012 [12]

Feedstock	Dry mass yield (a) (t/ha-year)	LHV (MJ/kg)	Energy produced (GJ/ha)	Water harvest (%)	Ash content (%)
Agriculture residues					
Straw (b)	2-4	15-18.1 (b)	35-70	14.5	5.0
Herbaceous crops					
Miscanthus	8-32	17.5-18.1	140-560	15.0	3.7
Switchgrass	9-18	16.8-18.6	n/a	15.0	6.0
Giant reed	15-35	16.3	245-570	50.0	5.0
Woody crops					
Willow	8-15	16.7-18.5	280-315	53.0	2.0
Poplar	9-16	18.7	170-300	49.0	1.5
Black locust	5-10	18.5-19.5	100-200	35.0	n/a
Wood pruning	2-3	18.7	35-50	50.0	1-1.5
Corn stalks/stover 16.8-18.1 MJ/kgDM; sugarcane bagasse 15-17.9 MJ/kgDM; wheat straw 15.1-17.7 MJ/kgDM					

The MSW, LHV (Low Heating Value) of waste fractions (1 kcal = 4.186 kJ), are presented in Table 2

Table 2 MSW LHV for organic fractions [13].

Fraction	kcal/kg
Food waste	951
Green waste	1065
Paper and cardboard	2748
Wood	3500

3.2 Waste stream assessment data sources

3.2.1 Italy's waste stream Italy data sources

There are many factors influencing agricultural residues availability, i.e., climate, crop productivity, alternative use. ENEA (Italian National Agency for Energy, Innovation and Sustainable Development) [14] has carried out research considering these factors, using official statistical data sources on agriculture, on field research, and on sample residues assessment.

The first step has been the selection of most relevant crops and fruits production in the southern Italian regions, considered the RES dominated zones from WT1.1 (Abruzzo, Puglia, Molise, Basilicata, Calabria, more region Campania). The selected statistical data source was ISTAT (Italian National Statistic Agency) [15], which reports agriculture cultivated areas and agriculture production. The production of grains and fruits was converted in straw and pruning using grain-fruit residues ratio factors measured on sample fields [14].

Then, the calculated annual agricultural residues are spatially explicit distributed in GIS (Geographical Information System) using CORINE Land Cover [16] dataset 2018 with 100 m spatial resolution, downloaded by COPERNICUS (European Earth Observation Program) [16] project open access portal. It spatially distributes 13 different classes of forest species and forest type aggregations. Subsequently, the specific forest species increment at a regional level, evaluated from the Italian Forest Inventory [17], was associated with the tree species mapped in the CORINE dataset, obtaining the forest above-ground annual increment as a spatial explicit final geo data source.

The data source for MSW assessment was taken by the "Municipal Solid Waste Report" [18] issued by ISPRA (Italian Environmental Protection Agency), the national Italian agency for collection of waste statistics in Italy. From the whole MSW DB, the organic, wood and paper fractions were selected with data collected and then mapped at the municipality level.

3.2.2 Danish waste stream data sources

The Danish waste stream sources were collected from S2Biom [6] project database, selecting **the waste stream typology possible to be converted in biogas or syngas, aggregation Agriculture Residues, Forestry and Bio-Waste** since they are the feedstocks under the project interest.

4. Methodology

4.2 Methodology for agricultural residues assessment Italy

The agricultural residues considered are the cereals straw and the fruits trees pruning, due to the southern Italian regions were defined RES dominated zones in WT1.1. ISTAT [15] data warehouse reports every year the grains and fruits production and the cultivated areas. The regions under screening have a total area of 62531 Km², cereal crops cultivation cover around 17550 Km², fruit trees plantation cover 9962 km².

Overall, the steps followed for the straw and pruning assessment are

- Selection of cultivations with associated residues suitable to biogas-syngas conversion;
- Quantification of grains and fruits annually produced
- Quantification of residues (straw and pruning) using specific conversion factors derived from sample determination on the field,
- Spatially explicit distribution of residues quantification on CORINE Land Cover 2018

The quantification of potential collectable straw is performed as follow:

[annual straw] t.d.m.= [grain harvested] t. x [straw/grain factor] – [straw moisture]

The quantification of potential collectable pruning can be obtained as follow:

[annual pruning] t.d.m.= [fruits harvested] t. x [pruning/fruit factor] – [pruning moisture]

The annual straw and pruning computed, successively allocated on CORINE land Cover using QGIS software, obtain a geo dataset, raster format, with the aim to have a spatial explicit distribution with geographical cover, with the advantages to having data interoperability, SQL (Standard Query Language) query capabilities, and dynamic maps visualization. To identify the stream available for 2030, legal restrictions REDII, such as sustainability restrictions from current legislation, are considered. Agricultural farming practices include applying conservation of Soil Organic Carbon (SOC) (e.g. Cross Compliance issues of 'maintaining agricultural land in good farming and management condition' and avoiding soil erosion).

4.3 Methodology for forest increment assessment in Italy

The National Forest Service in cooperation with the Forest Monitoring and Management Research Unit of the Council for Agricultural Research and Economics (CREA) released the National Inventory of Forests and forest Carbon pools [19], with the scope not to intake the carbon pool role of the forest. In our analysis, we have considered only the annual forest increment, measured by the national forest inventory. It is evaluated at a regional level and it is tree specific. The forest increment factor is then distributed on CORINE land Cover using QGIS software, with the aim to have a spatial explicit distribution about forest increment, raster format, with geographical cover, and having the advantages of data interoperability, SQL query capabilities, and dynamic maps visualization. The final results are the geo dataset with 100 m resolution. On the derived geo dataset further application of sustainability criteria are applied, excluding for the year 2030 possible forestry collection on forest area with slope more than 30% (erosion, accessibility, soil protection), exclusion of forestry collection into the riparian areas (Soil and River Protection, Biodiversity, Habitat) [25] [26]

4.4 Methodology for waste assessment in Italy

The Italian Institute for Environmental Protection and Research, ISPRA (Istituto Superiore per la Protezione e la Ricerca Ambientale) is the public Italian body responsible for waste monitoring and has a role to produce yearly "the MSW report", with the database containing all the fractions of municipal solid waste at municipality level. For the scope of our WP, we selected 3 different MSW fractions: *organic, paper and wood* for the municipalities of RES dominated zones in Italy and Campania region. Then, we mapped the current waste production and the future 2030 waste stream based on demography projection and the goals contained in the Circular Economy Package Directive [4].

4.5 Methodology for waste assessment in Denmark

For Denmark, waste data have been elaborated by the S2Biom project, funded by the European Union's 7th Framework Programme for research, technological development and demonstration. The project aim was to support the sustainable delivery of non-food biomass feedstock at local, regional and pan European level and has produced database using harmonized datasets at local, regional, national and pan European level for EU28, Western Balkans, Moldova, Turkey and Ukraine.

The S2BIOM [6] project uses the BEE handbook [5] to determine biomass potentials for energy. Four types of biomass potentials are commonly distinguished in the BEE classification:

- **Theoretical potential**
- **Technical potential**
- **Economic potential**
- **Implementation potential**

The types of potentials differ with respect to the constraints that are considered including sustainability issues. Methodological details can be found in the project report with the general scheme given in Figure 4:

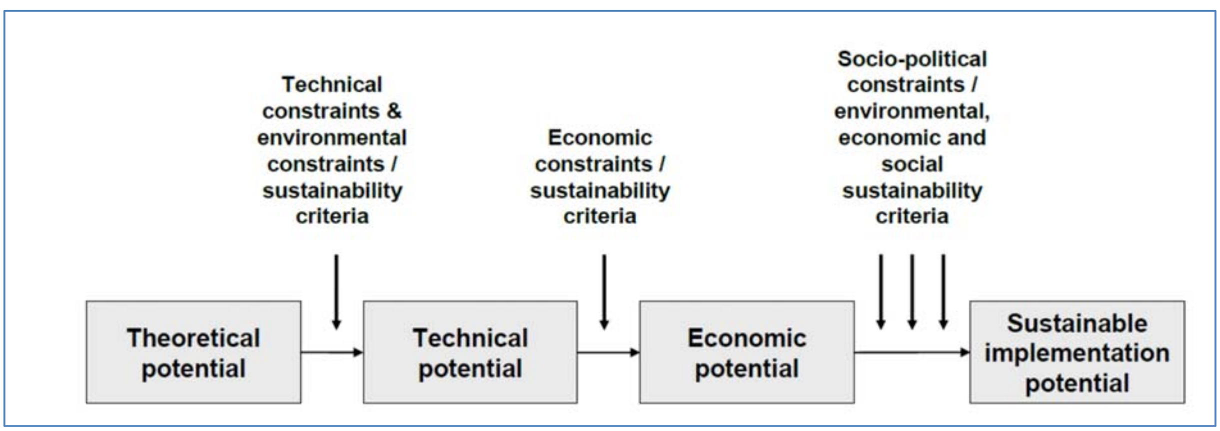


Figure 4 Biomass potential classification, source S2Biom Project

For the W2G project scope from the S2Biom DB, we consider the **Technical Potential** defined as follows:

- The absolute maximum amount of lignocellulosic biomass potentially available for energy use assuming the absolute minimum of technical constraints and the absolute minimum constraints by competing uses. This potential is provided to illustrate the maximum that would be available without consideration of sustainability constraints.

Then, we also use the **Base Potential** defined as follows:

- The base potential is thus considered as the **sustainable technical potential**, considering agreed sustainability standards in CAP (Common Agricultural Policy) for agricultural farming practices and land management and in agreed (national and regional) forestry management plans for forests (equivalent to current potentials described in EFSOS II) [20]. This also includes the consideration of legal restrictions such as restrictions from management plans in protected areas and sustainability restrictions from current legislation. Further restrictions resulting from RED (Renewable Energy Directive) and CAP are considered as restrictions in the base potential as well. CAP sustainable agricultural farming practices include applying conservation of Soil Organic Carbon (SOC) (e.g. Cross Compliance issues of 'maintaining agricultural land in good farming and management condition' and avoiding soil erosion).

The overall scheme considered by the S2BIOM project is reported in Figure 5.

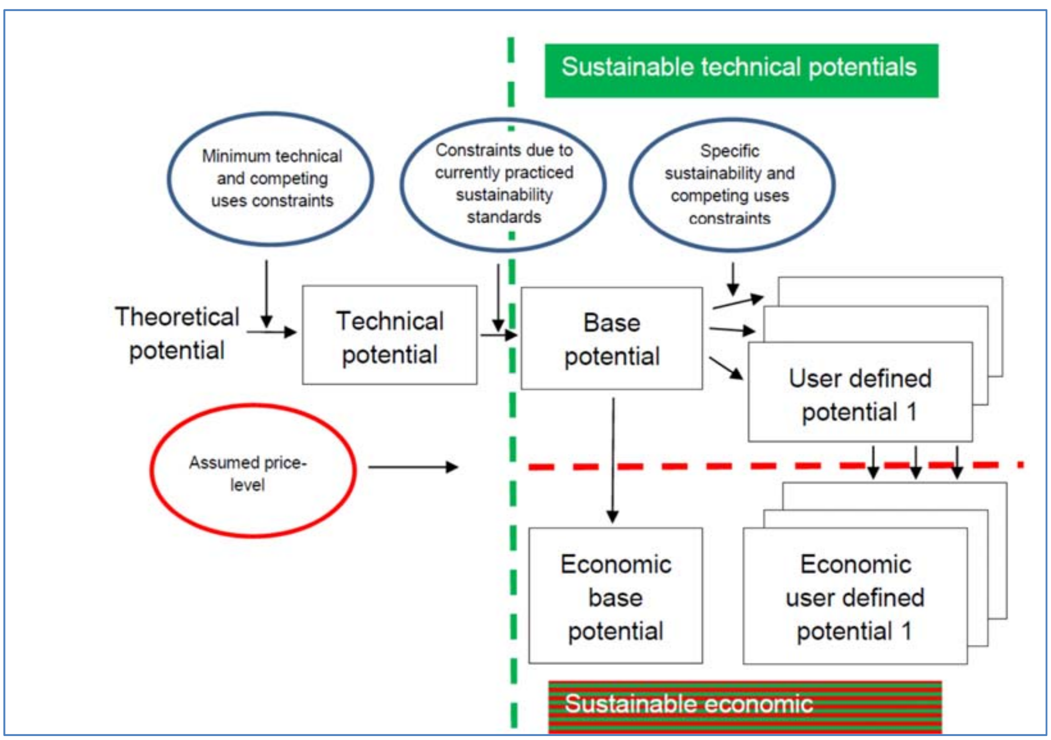


Figure 5 constraints for biomass potential evaluation, Source: S2BIOM project

Lignocellulosic biomass assessed by S2Biom includes biomass originating from the following:

- Primary residues from agriculture
- Dedicated cropping of lignocellulos biomass on agricultural area
- Wood production and primary residues from forests
- Secondary residues from wood industry
- Secondary residues of industry utilizing agricultural products
- Waste collection/ tertiary residues

Among all the biomass categories classified by S2Biom project, we have considered the aggregation Forest, Agriculture, Bio-Waste.

5. Biomass assessment results

5.2 Agricultural residues assessment Italy

The agricultural residues assessment for cereal straw and fruits trees pruning was dedicated to 6 Regions: Molise, Puglia, Basilicata, Calabria (NUTS2 EU) identified as RES dominated zones for Italy more the Campania region what has a resident population of 5,8 Million inhabitants. The combined Campania nearby regions: Puglia, Molise and Basilicata have 4,9 Million inhabitants, moreover Campania has the higher potential in terms of MSW produced compare the RES dominated regions on its border. The total area covered by these regions is 62531 km² out of total 301338 km² Italy's surface.

Figure 6 Biomass collection zones for RES dominated zones, Italy.

For the selected regions, we have investigated what are the most relevant cultivated agriculture produces in terms of area coverage and annual production, with the aim to quantify the straw and pruning potentially available. The selected data source is ISTAT [15] agricultural database, which reports annually the cultivation area and production, for the reference year 2018. For the regions under evaluation, the crops choice for the biomass assessment are *Wheat, Barley, Oat, Rice, Corn and horticulture*. These cultivation areas of 1755020 ha are then geographically allocated on the CORINE 2018 classes as shown in Figure 7. The maximum technical straw potential evaluated for the year 2018 is 2754612 t.d.m./year.

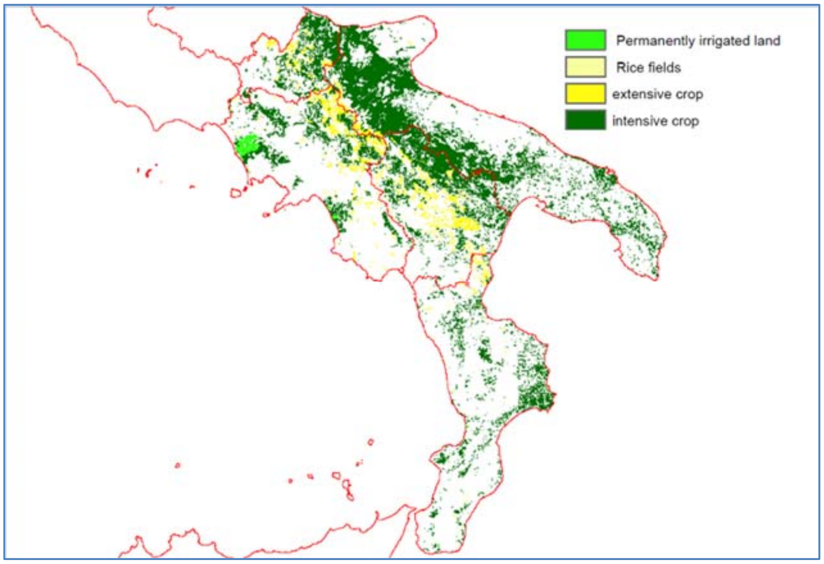


Figure 7 Crop spatial allocation on CLC 18.

The fruit trees with more relevant production in the selected regions are *olives, vineyard, peaches, apricot, cherries and oranges*, for the reference year 2018. The cultivation area is equal to 996234 ha with fruit trees cultivation geographically allocated on the CORINE classes as shown in Figure 8. The maximum technical pruning potential of year 2018 evaluated is 1356780 t.d.m./year.

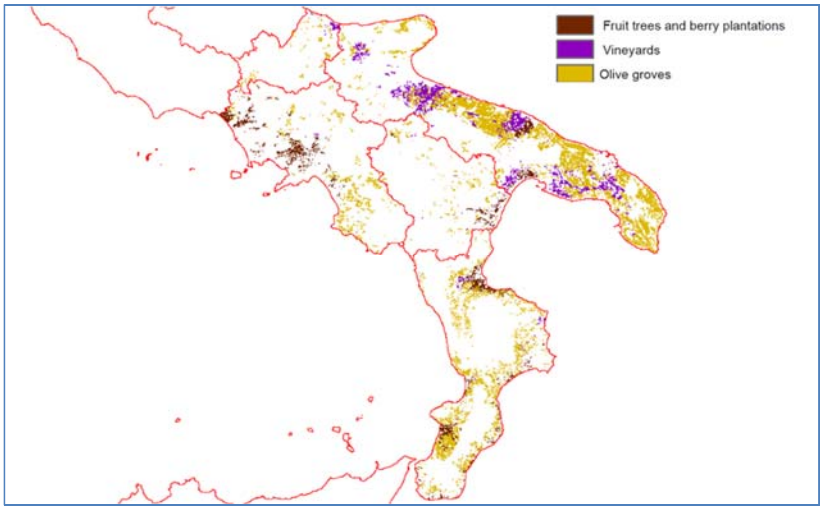


Figure 8 Fruit trees spatial allocation on CLC 18.

To derive the straw and pruning from the agricultural residues, the relation straw/grain and pruning/fruits factors are derived from the Italian research program [14]. These factors are strictly dependent on the type of cultivar, cultivation methods applied, slope and local climate. The investigation to derive the relation factors were carried on the field EU NUTS2 level [21].

To derive the 2030 agricultural residues stream, we consider environmental constraints: *leave the straw on field for SOC carbon preservation* [22], *market constraints as the straw is already used for livestock bedding*, *animal feed in perspective building biomaterial and 2nd generation biofuel* [23]. According to these studies, on average the straw potential has been reduced 70% with the total exploitable base potential in the year 2030 equal to 826383 t. d.m./year.

Fruit trees pruning currently have limited use due to its destination to conventional bioenergy use (low price), very high moisture content 60%, low density 2-4 t.d.m./ha, collection, bailing and transport cost. The pruning residues are only partially exploited. Currently pruning is mainly chopped and left in the fields, or taken away and burned to preserve fruits trees from infection ENAMA [23]. The real limitation for the year 2030 exploitability is the feedstock market price in case of pruning syngas conversion, as no major environmental constraints are present. For the year 2030, base potential is considered 90% of the calculated year 2018 potential, thus finally the year 2030 pruning exploitable base potential is estimated at 1221102 t. d.m./year.

Table 3 Straw and pruning technical and base potential in the southern Italian Regions.

Region	**2018 Straw Technical potential (t.d.m.)**	**2018 Pruning Technical potential (t.d.m.)**	**2030 Straw Base potential (t.d.m.)**	**2030 Pruning Base potential (t.d.m.)**
Abruzzo	249753	185135	74926	166621
Molise	186832	33209	56050	29888
Campania	383375	186763	115013	168087
Puglia	1302306	506938	390692	456244
Basilicata	447514	40680	134254	36612
Calabria	184832	404055	55450	363650
Total	**2754612**	**1356780**	**826384**	**1221102**

With the scope to have the straw and pruning potential projected with georeferenced and dynamically mapped, the potential is converted with the aid of QGIS software in Geodatabase and then mapped on NUTS regions, as shown in Figure 9 and 10.

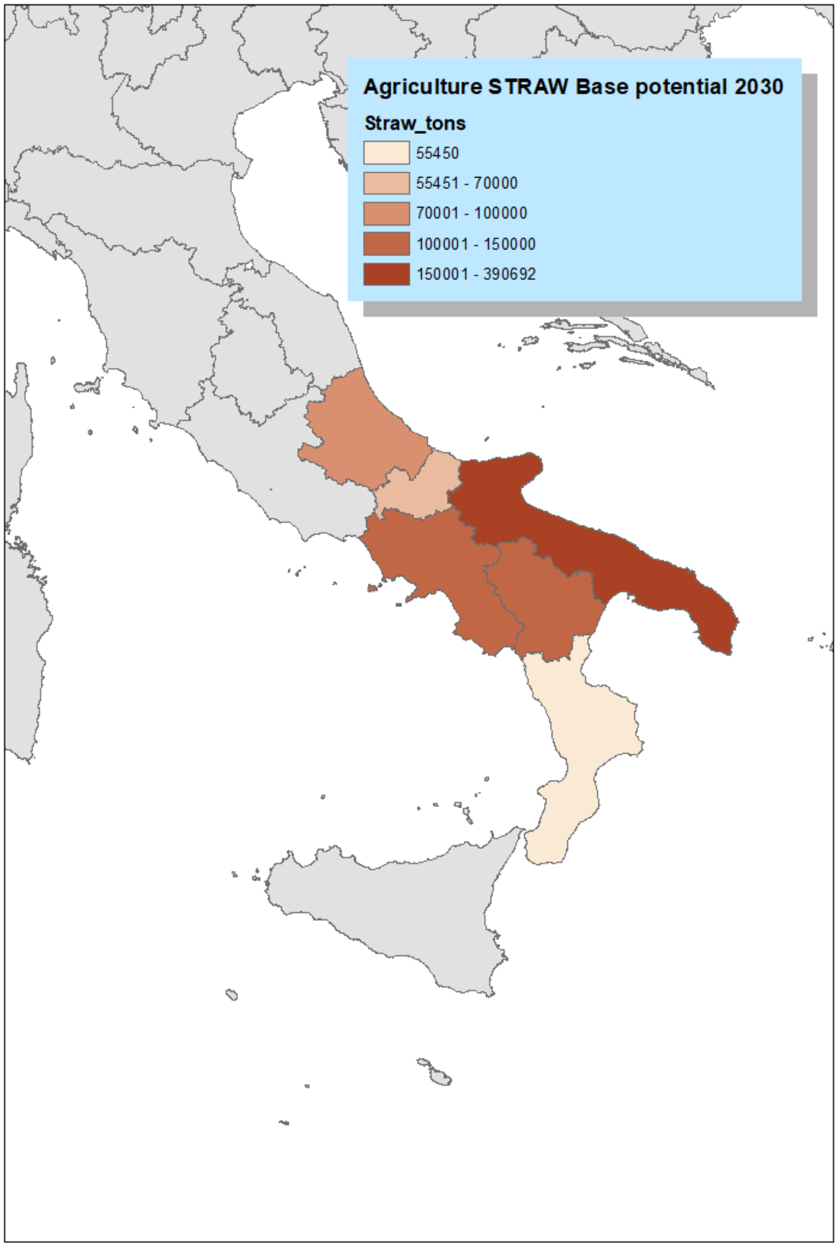


Figure 9 Straw base potential 2030, Italy's Southern Regions

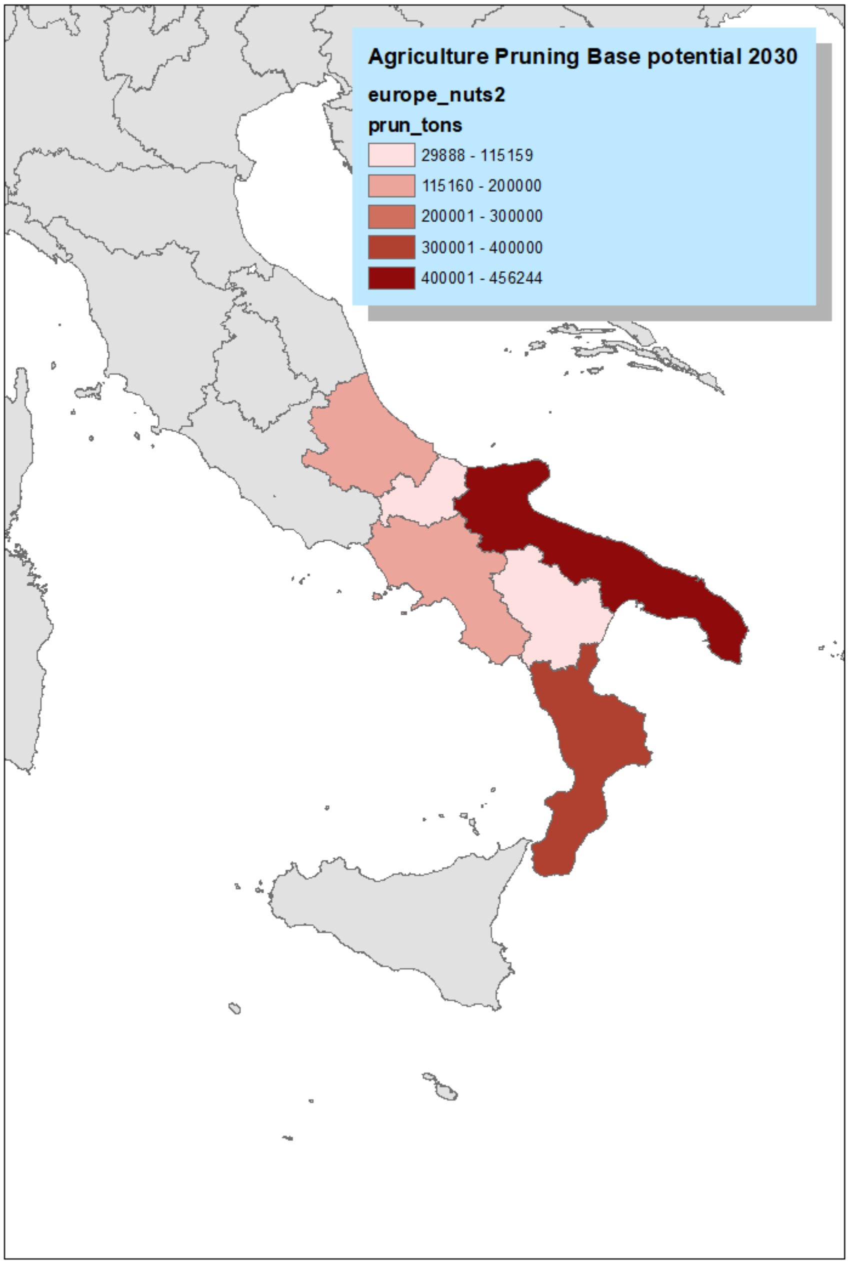


Figure 10 Pruning base potential 2030, Italy's Southern Regions

5.3 Forestry assessment Italy

Italy participates in The United Nations Framework Convention on Climate Change (UNFCCC) on an agreement between the industrialized countries listed in Annex I of the Convention. These states must report annually a National Greenhouse Gas Inventory of its anthropogenic emissions by sources and removals by sinks of greenhouse gases (GHGs). The fluxes generated by forest management and land-use changes into and from the forest are part of the carbon sink. With the scope to preserve the forest carbon sink role, the annual forest increment has been considered the maximum possible forestry collectable.

We use the Italian Forest Inventory, where the forest is classified into 4 main categories: *Stands, Coppices, Planta- tions and Protective Forests*. The *Stands* include tree species: *Norway spruce, silver fir, larches, mountain pines, Mediterranean pines, other conifers, European beech, turkey oak, other oaks, other broadleaves*. The *Coppices* mainly include *European beech, sweet chestnut, hornbeams, other oaks, turkey oak, evergreen oaks, other broadleaves, conifers*. The *Plantations* include *eucalyptuses coppices, other broadleaves coppices, poplar stands, other broadleaves stands, conifers stands, others*. The *Protective Forests* include *rupicolous forest, riparian forests, shrublands*.

For the purpose of the project, we identify the most predominant tree species, covered area, in the RES dominated zones, from the Italian national inventory dataset. We use the sources for the forest above ground annual increment, detailed at EU NUTS2 level, the data, tree specific, are then allocated on CORINE land Cover 2018, Figure 11.

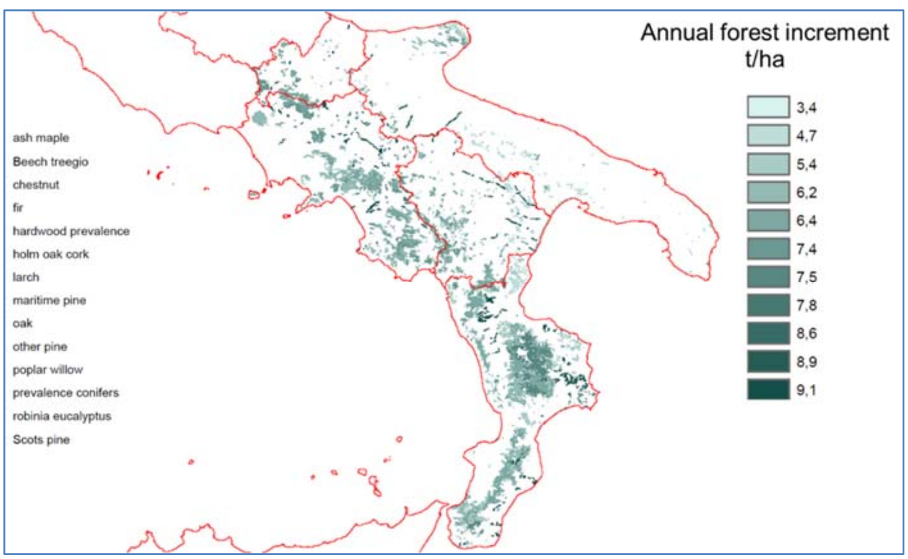


Figure 11 Above Ground Forest Increment, Italian National Forest Inventory, allocated on CLC 18.

The total forest increment is mapped at a spatial resolution of 100 m. The total forest cover area in 2018 for the RES dominated areas is 1464290 ha with the amount of above-ground forest wood annual increment of 7071709 t/year.

To derive the forest wood stream potentially available in 2030, some environmental and technical constraints have been considered: (1) avoid to collect wood above 30% slope as those areas are considered very sensitive to erosion [24], and (2) usually very cost-intensive for collection accessibility, harvesting and transport ENAMA [23]. Other exlusion areas for forestry collection in 2030 are the riparian zones COPERNICUS [17], as those areas are part of legal acts and policy initiatives, such as the EU Biodiversity Strategy to 2020 [25], the Habitats and Birds Directives [26] and the Water Framework Directive [27].

To apply the constraints, the forest increment dataset was processed in Q-GIS software. Using raster calculation function, the new distribution obtained is illustrated in Figure 12

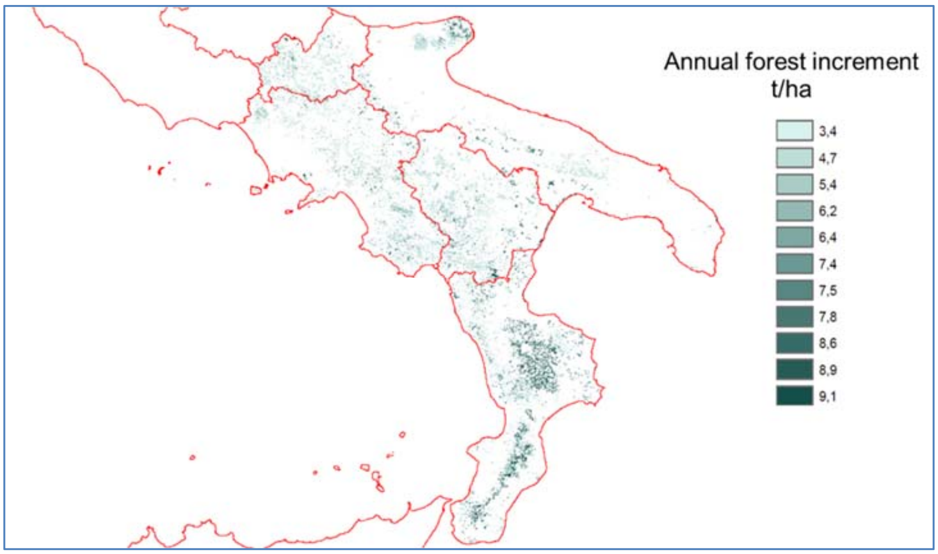


Figure 12 above ground forest increment, allocated on CLC 18, restrictions applied

The new dataset obtained with spatial resolution of 100 m. After applying the above mentioned contraints, the estimates are obtained for the RES dominated zones in Italy with a total forest maximum exploitable area in 2030 equal to 669.026 hectares and a total forest increment potentially exploitable of 3317461 t/year.

Table 4 Forest Increment RES DOM Regions: Campania, Molise, Basilicata, Puglia, Calabria, Italy

Forest area 2018 [Ha]	**Forest above ground increment 2018 [t/year]**	**Forest area 2030 Base potential scenario [Ha]**	**Forest above ground increment Base potential scenario 2030 [t/year]**
1464290	7071709	669026	3.317461

5.4 MSW assessment Italy

The Italian Agency for environmental protection ISPRA, publishes every year the Municipal Waste Report, and also publically provides MSW data on the online dashboard. We use as data source the ISPRA [18] MSW report 2018 (the reference year 2017) concerning municipal waste generation, separate collection and management at the municipality level, considering the organic fraction, paper and wood, waste landfilled and incinerated. The aggregated MSW for the RES dominated zones and Campania are evidenced in Table 5.

Table 5 MSW statistics, aggregation Molise, Campania, Puglia, Basilicata, Calabria, Source ISPRA [18]

MSW separated at origin			**MSW landfilled**	**MSW incinerated**
Organic fraction 2017 [t/year]	Wood 2017 [t/year]	Paper 2017 [t/year]	Landfilled 2017 [t/year]	Inceniration 2017 [t/year]
2433638	66371	630501	1493876	920194

With the aim to derive the long term waste potential 2030, the Directive (EU) 2018/851 [2] has been considered, the mandatory goals for the EU member states are following evidenced:

- *A common EU target for recycling 60% of municipal waste by 2030;*
- *A common EU target for recycling 75% of packaging waste by 2030;*
- *A binding landfill target to reduce landfill to a maximum of 10% of municipal waste by 2035;*

Many other actions are clearly stated and promoted :

- *ban on landfilling of separately collected waste;*
- *Promotion of economic instruments to discourage landfilling ;*
- *Simplified and improved definitions and harmonized calculation methods for recycling rates throughout the EU;*
- *Concrete measures to promote re-use and stimulate industrial symbiosis - turning one industry's by-product into another industry's raw material;*
- *Economic incentives for producers to put greener products on the market and support recovery and recycling schemes (eg for packaging, batteries, electric and electronic equipment, vehicles).*

The mandatory goals in the Directive (EU) 2018/851 are considered and applied to model the 2030 MSW management and quantification. The MSW in terms of separated fraction at origin to be in compliance with the directive is calculated. The comparison MSW separated year 2017 against future 2030 MSW (directive 2018/851) target is considered as potential 2030 waste stream available. Waste separation target 2030 is compared with the waste 2017 statistics. The results aggregated for the RES dominated zones in Italy are presented in Table 6.

Table 6 Additional Separated at origin MSW stream generated in 2030 compare to 2017

Additional Separated at origin MSW stream generated in 2030, according with EU directive 2018/851 minimum targets waste separation, difference year 2030 "projection" compare to year 2017 "measured" (2030-2017)		
Organic fraction 2030-2017 [t/year]	**Wood 2030-2017 [t/year]**	**Paper 2030-2017 [t/year]**
1.287.385	19.739	166.196

The computed potential MSW stream available in 2030 aggregated and visualized in Table 7, is the distributed at municipality level and converted in GEO Database, mapped in Figure 13.

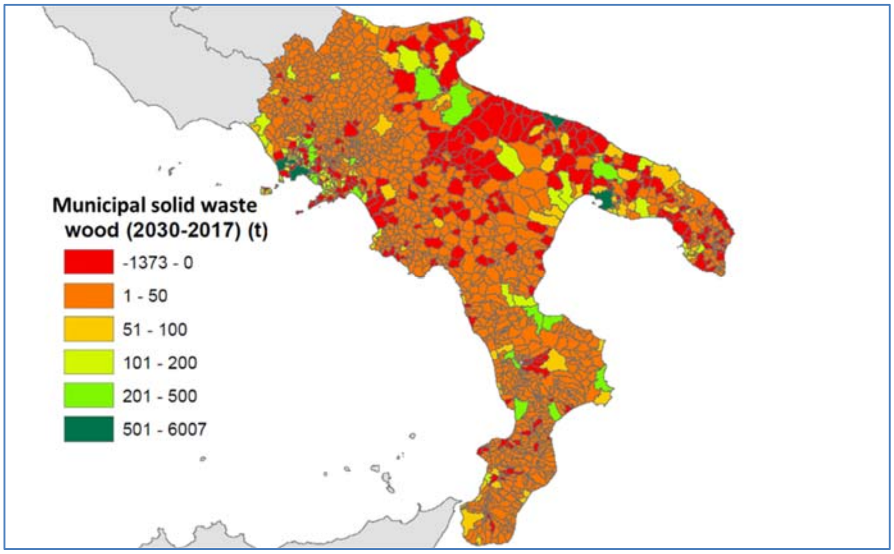


Figure 13 MSW wood, minimum target 2030 EU EU directive 2018/851, compared with 2017 wood separated at origin.

For the wood fraction of MSW, most of munipilaties have already reached in 2017 the set target for 2030. The main future potential stream is projected being available in larger cities like Napoli, Bari and Taranto.

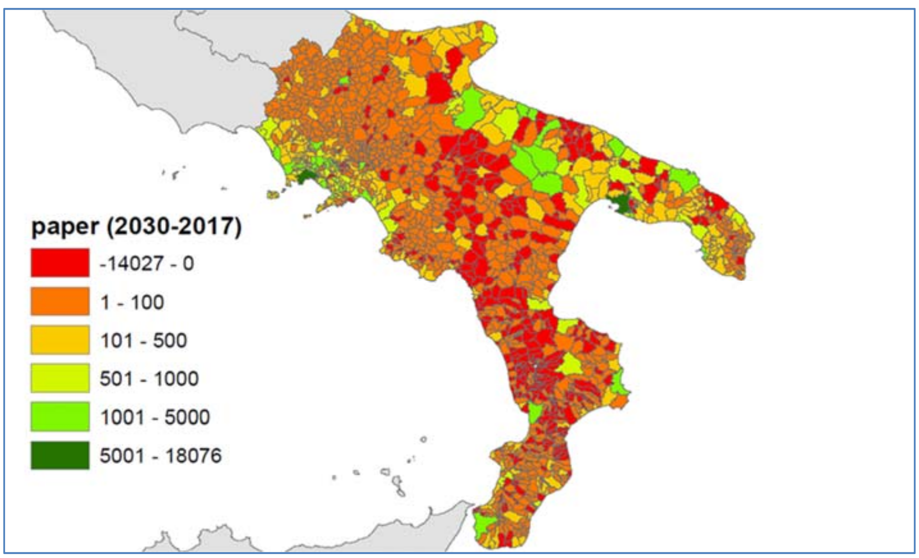


Figure 14 MSW paper, minimum target 2030 EU EU directive 2018/851, compared with 2017, paper separated at the origin.

The MSW paper fraction separated at the origin in 2017, is already mostly in line with the projected target in 2030. Napoli and Taranto are the cities where there is more waste stream coming to be in compliance with the waste package directive.

The organic fraction of MSW has the higher potential in terms of stream added in 2030 to be in compliance with the directive, but it is also the fraction with more competitive use, currently mainly compost, and future for biomethane. The MSW organic Fraction potential is mapped in Figure 15.

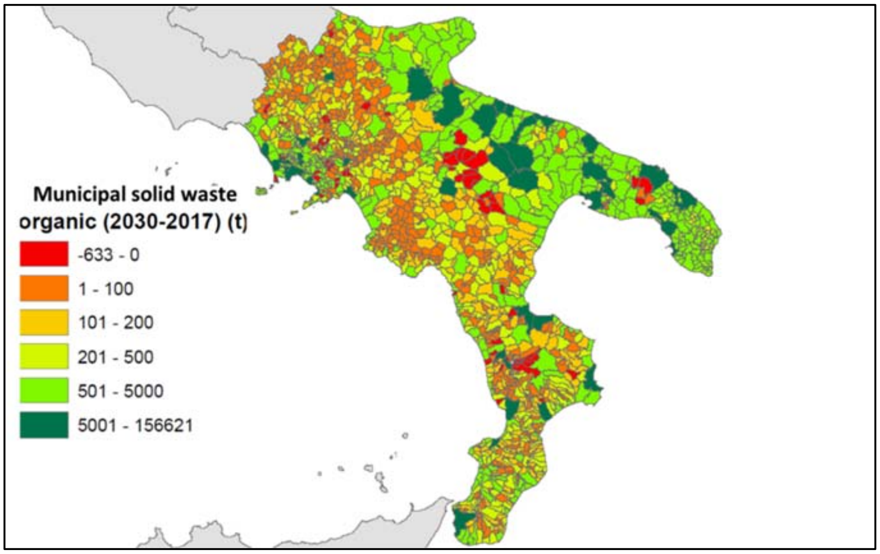


Figure 15 MSW organic fraction, the difference between minimum target 2030 EU directive 2018/851 and 2017 organic fraction separated at the origin.

5.5 Waste stream assessment Denmark

Waste assessment in Denmark is based on the S2BIOM project database. Several biomass categories of biomass evaluated by the project are grouped in three main classes: *Agriculture, Forest and Bio-Waste*, computed as "base potential year 2030" resume with also the RES-DOM label in Table 7.

Table 7 biomass base potential 2030 on Denmark Zones DK1, DK2 and Bornholm, Source S2Biom project

NUTS	Name	RES_ZONE	Forest [kt d.m./year]	Agriculture [kt d.m./year]	Biowaste [kt d.m./year]
DK050	Nordjylland	DK1	253	274	201
DK041	Vestjylland	DK1	241	249	148
DK042	Ostjylland	DK1	332	203	291
DK032	Sydjylland	DK1	305	299	248
DK031	Fyn	DK1	174	121	168
DK013	Nordsjaelland	DK2	93	49	155
DK012	Kobenhavns omegn	DK2	9	12	180
DK011	Byen Kobenhavn	DK2	0	6	244
DK021	Ostsjaelland	DK2	42	28	82
DK022	Vest- og Sydsjaelland	DK2	350	222	201
DK014	Bornholm	Bornholm	50	20	14
DK0	**Denmark**	**Total**	**1850**	**1484**	**1931**

The 3 aggregated tipologies of aggregated Danish biomass (Forest, Agriculture an Biowaste) base potential 2030 is georeferenced and then mapped on the 3 zones in Denmark (DK1, DK2 and Bornholm Island) defined by WT1.1. The biomass base potential Agriculture 2030, Forest and Bio-Waste is given in Figure 16,17 and 18.

Figure 16 Denmark Agricultural Residues Base potential 2030.

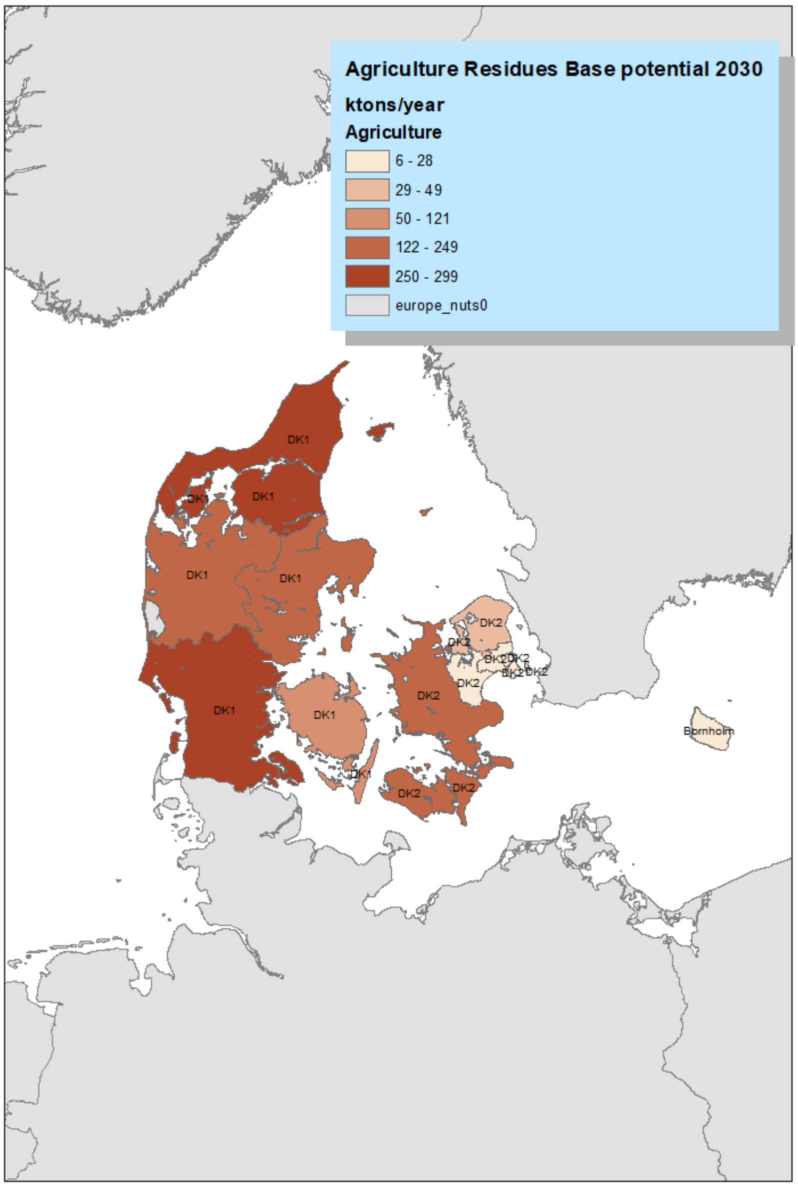


Figure 17 Denmark Foret Base potential 2030.

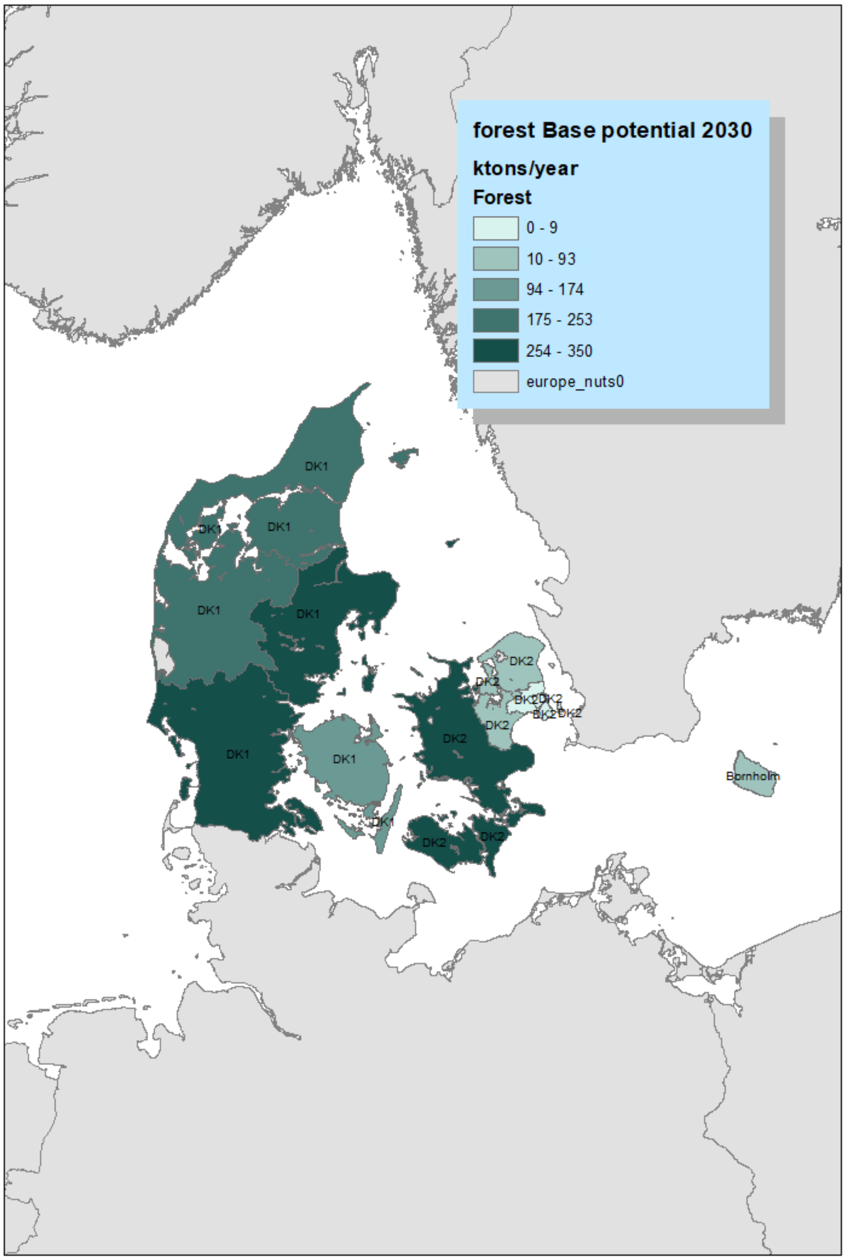
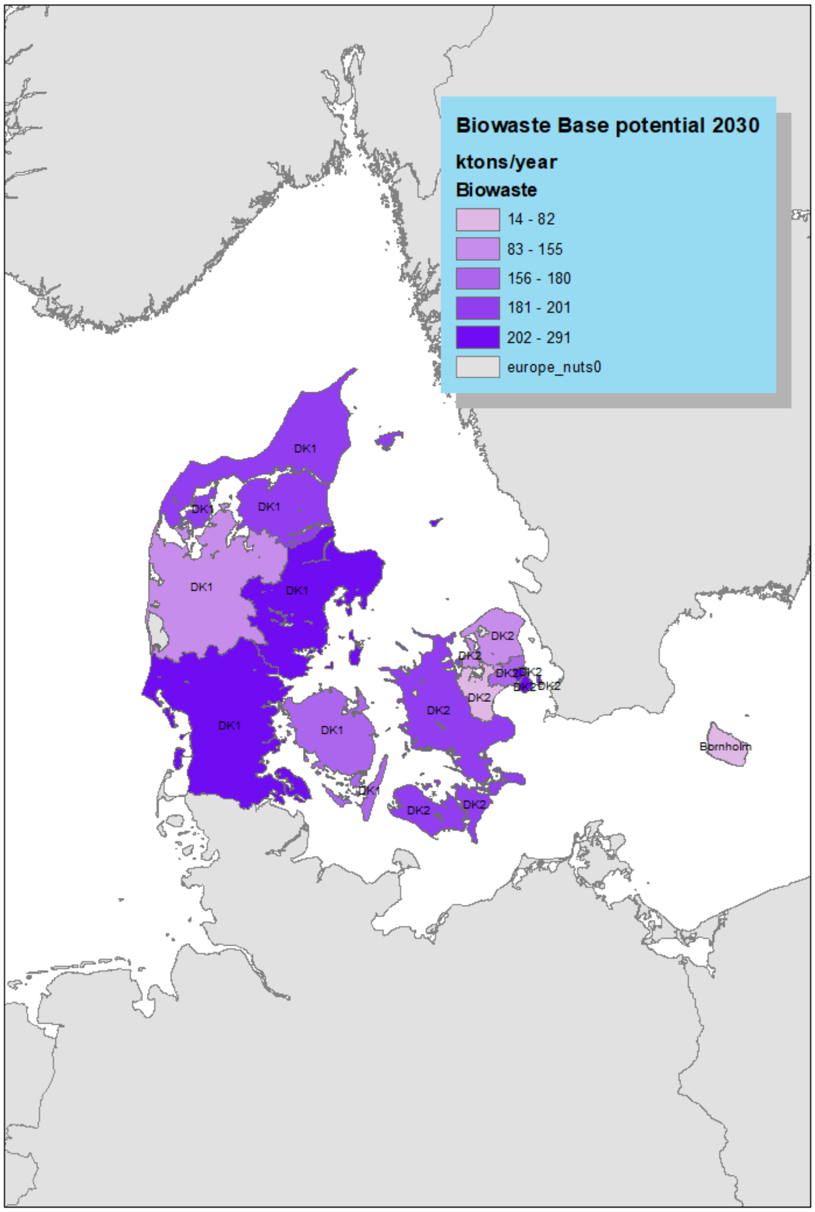


Figure 18 Denmark Bio Waste Base potential 2030.



6. Biomass price

6.2 Biomass price in Italy

Biomass factory gate-household price

For detailed monitor on biomass price, there are sectorial services available and constantly updated, for instance, the straw price can be found in the section Foraggi of "Borsa merci Modena" [28]. The market price of solid biomass fuel is available by payment service, provided by "Osservatorio Prezzi Camera Commercio Milano [29]. AIEL (the Italian Association for Agri-Forestry Energy) provides detailed market statistics for its members and makes available to the public some biomass market summary and statistical series:

Table 7 Biomass Fuel average price Italy 2018, Source: ENEA; ENAMA [23], CONOE [28]; AIEL[29]

Biomass	**price/cost (€/t)**
Cereal straw	45
Vine marc	22
Olive pomace	130
Fruits trees pruning	40
Nuts shell	175
Tomato peel	40*
Orange bark	30*
Used vegetable oil	180
**Cost: waste disposal*	

The prices in terms of cost per energy content for woody biomass and pellets are monitored by AIEL [29] and resumed in Table 8.

Table 8 Biomass Fuel average price Italy 2018, VAT included, Source: AIEL [29].

Biomass	price (€/MWh)
Chipped wood (M50)*	20
Cipped wood (M30)*	27
Fire wood (M20)*	41
Pellet (ENplus A1, 15 Kg bag)	65
*M: Moisture content %	

Table 9 Costs and characteristics of biomass collection systems, source ENAMA [23].

	Machinery Cost [euro]	**Productivity [m³/h]**	**Fuel Use [litres/h]**	**Operating Cost [euro/h]**
Manual	500-700	1-2.5	0.6-1	18-20
skidder	45k-60k	2.5-6	4-9	45-50
Forwarder	180-270	12-20	7-11	65-80
Tractor and trailer	45k-60k	5-12	5-10	40-50

Cable yarder	40k-120k	3-6	5-6	40-80

Biomass Harvesting Cost

In Italy, several harvesting experiments have been carried out by several institutes and companies. AIEL makes available some information about chipping cost and operational conditions of its campaigns in its reports and publications, with detailed comparison among several different harvesting technologies. AIEL calculates costs for various biomass harvesting techniques, like cable yarder, forwarder, skidder, tractor and trailer, cable crane. Some results are reported as a brief summary concerning the detected costs in Table 9.

Biomass Transport cost

Truck: Truck transport price in Italy is regulated by "Ministero Infrastrutture e Trasporti" [30] who publish the enterprise cost associated with various truck loads. As an example, in 2014 the cost for 26 tons load, a truck traveling 100 km was 2 Euro/Km [30].

Rail: The price rate is quoted per rail car; it is affected by the distance and value of transported material. In Italy, for 2016, Trenitalia, the largest national rail carrier, publishes the indicative cost for each rail car at 3.80 euro/km, 50 euro/km is reported for the whole train. The cost is affected by several factors and changes, detailed conditions are available on Trenitalia Cargo [31].

Ship: Shipping cost is quoted on-trade market. The reference is the Baltic dry index BDI. The Panamax shipping is quoted 5500 $/day in August 2016.

Detailed information on the market price on Baltic Index [32].

Table 10 Denmark Forest residues cost 2030, **€/Tons d.m.**, source S2Biom Project.

	Final fellings nonconifer	**Final fellings conifer**	**Thinnings nonconifer**	**Thinnings conifer**	**Logging residues final fellings nonconifer**	**Logging residues final fellings conifer s**	**Logging residues thinnings nonconifer**	**Logging residues thinnings conifer**	**Stumps final fellings nonconifer**	**Stumps final fellings conifer**
Byen Kobenhavn	32,83	48,47	54,12	21,24	38,20	45,74	48,37	25,79	46,70	60,75
Kobenhavns omegn	32,83	48,47	54,12	21,24	38,20	45,74	48,37	25,79	46,70	60,75
Nordsjaelland	32,84	48,25	46,53	21,24	38,43	46,04	46,62	25,79	46,70	61,79
Bornholm	33,14	50,17	45,95	21,24	40,17	46,16	48,69	25,79	48,71	63,47
Ostsjaelland	32,83	52,21	44,77	21,24	38,35	45,93	45,87	25,79	46,61	63,59
Vest- og Sydsjaelland	32,88	54,18	43,83	21,24	38,60	45,70	45,80	25,79	46,96	63,33
Fyn	32,89	52,56	42,48	21,24	38,66	45,69	45,27	25,79	46,98	62,59
Sydjylland	33,00	47,24	43,93	21,24	39,27	46,22	46,68	25,79	47,77	61,68
Vestjylland	33,09	46,44	52,49	21,24	39,74	46,41	50,20	25,79	48,39	61,59
Ostjylland	32,95	48,03	43,13	21,24	38,95	46,07	45,93	25,79	47,39	61,75
Nordjylland	33,07	48,40	45,62	21,24	39,65	46,18	47,87	25,79	48,21	62,40

6.3 Biomass price Denmark

The biomass cost for Denmark is derived from the S2BIOM project and it is referred to road-side cost. They are expressed in €/ton dry mass. The cost have only been calculated for the base potential and the cost have been kept constant between 2012, 2020 and 2030. The cost refers to road side cost of biomass based on the activities needed to produce, yield and forward the biomass to the road side. For secondary residues and waste the activity based cost are set at zero '0' and are therefore not included in the datasheets.

Table 11 Agriculture, Denmark Forest residues cost 2030, **€/Tons d.m.**, source S2Biom Project.

	Rice straw	**Cereals straw**	**Oil seed rape straw**	**Maize stover**	**Sugarbeet leaves**	**Sunflowe r straw**	**Residues fruit tree plantations**	**Road side verges (grassy)**
Byen Kobenhavn	57,78	36,86	30,80	33,70	95,98	42,72	232,10	96,29
Kobenhavns omegn	57,78	36,86	30,80	33,70	95,98	42,72	232,50	96,29
Nordsjaelland	57,78	36,86	30,80	33,70	95,98	42,72	233,70	96,29
Bornholm	57,78	36,86	30,80	33,70	95,98	42,72	274,20	96,29
Ostsjaelland	52,63	35,52	30,57	32,91	90,90	40,31	229,26	96,29
Vest- og Sydsjaelland	52,63	35,52	30,57	32,91	90,90	40,31	234,16	96,29
Fyn	51,83	35,58	30,90	33,14	89,72	40,11	256,69	96,29
Sydjylland	51,83	35,58	30,90	33,14	89,72	40,11	265,95	96,29
Vestjylland	52,65	35,53	30,57	32,92	90,93	40,32	882,78	96,29
Ostjylland	52,65	35,53	30,57	32,92	90,93	40,32	882,25	96,29
Nordjylland	51,87	35,56	30,82	33,08	89,84	40,12	273,81	96,29

7. Conclusion

The zones dominated by renewable energy sources RES-Dominated zones are defined in WT1.1 in Denmark and Italy. Low-grade waste (biomass) stream assessed for 2030, converted to Biogas-Syngas, is considered among the options to balance the grid. There are many classification schemes on biomass worldwide, the project BEE is used with the scope to harmonize methodologies for biomass resource assessments. Four different aggregations of Biomass have been evaluated: *Agriculture Residues (Straw and Pruning), Forest (net increment and residues), MSW (organic, wood and paper fraction) and Bio-Waste*. The data source used is national inventories, satellite-derived data COPERNICUS, EU project S2Biom. Using validated methodologies at the EU level, the year 2030 Biomass Base Potential (future waste stream) is derived. The Biomass Base potential considers legal restrictions such as constraints from management plans in protected areas and sustainability, restrictions from REDII (Renewable Energy and Climate Directive) and EU-Waste Directive.

Italy's southern regions ”in-around” RES Dominated zones, for 2030 have the annual base potential of 826.384 t.d.m straw, 1.221.102 t.d.m Prunings, 3.317.461 tons. of forest increment, an additional stream of 1.287.385 tons of MSW organic fraction, compared with the year 2017 separated at origin MSW organic fraction quantity.

Denmark is divided into 3 RES-Dominated zones with the 2030 biomass base potential for Forest residues being estimated at around 1850 k.t. d.m, Agriculture residues 1484 k.t. d.m, Biowaste 1931 k.t. d.m.

The evaluated Biomass potential is allocated on CORINE land Cover using QGIS software, to obtain a geo dataset with geo reference, shape and raster format, with the aim to have a spatial explicit distribution with geographical cover. The advantages are data interoperability with other software and geo portals, SQL (Standard Query Language) query capabilities, and dynamic maps visualization.

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