Fuels-C

D 2.1. Feedstock and RES available for biofuels production

Feedstock database

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1. Introduction

The Fuels-C project envisions the development of a pioneering platform for the conversion of biogenic residues, including organic wastes and CO_2-rich gases, into advanced biofuels, suitable for use in transportation applications. A versatile combination of technologies (Figure 1) is proposed to ensure the conversion capacity of a variety of **biodegradable** and **non-biodegradable feedstocks** in an efficient manner, **using renewable energy** as a driving force. Fuels-C will first perform a feedstock mapping exercise, to define the baseline scenario for Fuels-C concept validation.

Two main conversion routes are then envisaged according to feedstock composition. On one hand, a route for **biodegradable wastes** intended to produce biomethane and ammonia (NH_3) as target fuels, using a combination of biotechnological processes operating under mild conditions (low-energy requirements, low pressure, low temperature). The initial conversion step of organic wastes will be carried out by a combination of anaerobic digestion (AD) and bioelectrochemical systems (BES) (AD+BES), offering higher performance compared to conventional AD, releasing biogas and a liquid digestate. The electromethanogenesis (EMG) process will be responsible for biogas upgrading to biomethane, by converting the residual carbon dioxide (CO_2) from the biogas. NH_3 will recover from the liquid digestate by an innovative BES process, allowing the direct recovery of ammonia (NH_3) ready to use in fuell cell (FC) and also reducing potential problems with digestate management. On the other hand, **non-biodegradable organic matter and CO_2-rich gases** will be employed as feedstocks for ethanol and formic acid production. Firstly, gasification of complex organic matter will be done to produce syngas. The solid fraction from gasification, biochar, will be considered as an amendment for BES processes contributing to the zero-waste approach of the Fuels-C platform. Syngas, together with CO_2, will then be fed to the conversion technologies. Formate (FA) production will go beyond conventional CO_2 electro-reduction to FA, by directly producing FA in a single reactor and also using syngas. Ethanol will be derived from CO_2 and syngas through a microbial electrosynthesis platform (BES) using enriched microbial communities.

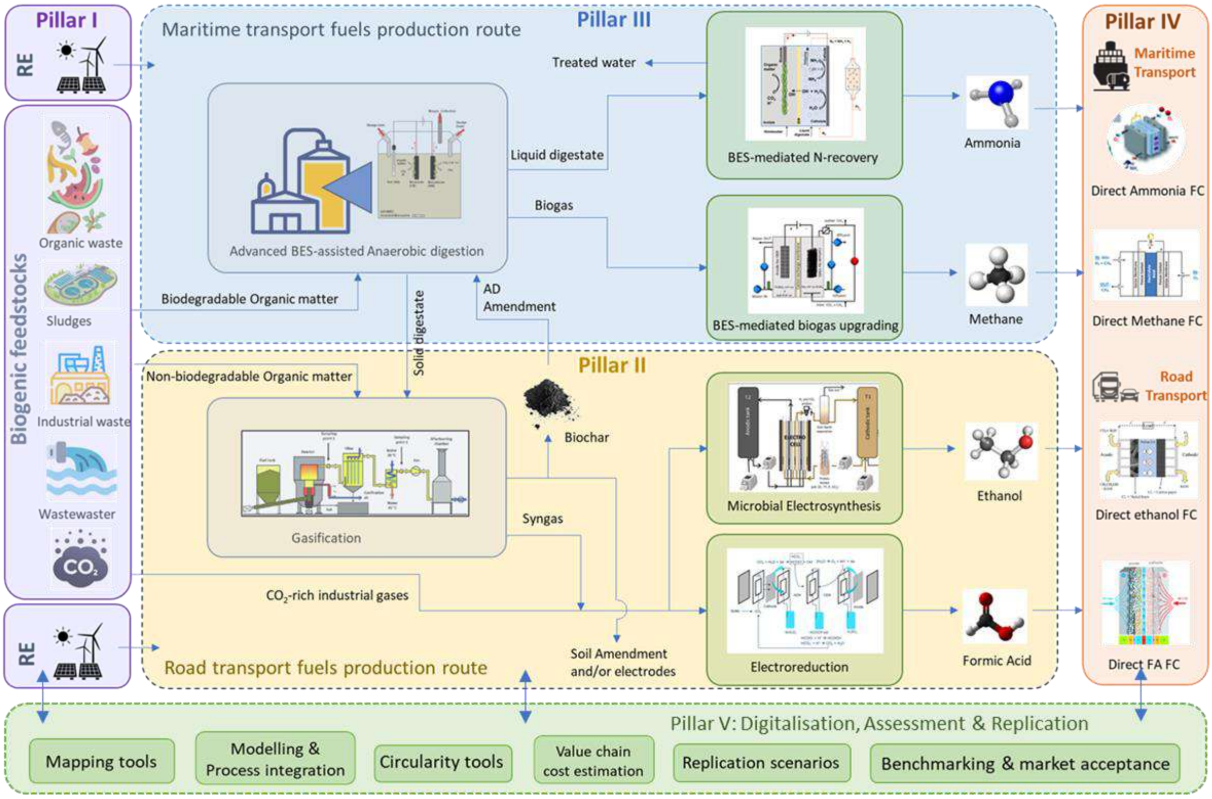


Figure 1. Overall Fuels-C Concept

The identification of renewable feedstock is crucial to developing new technologies able to transform them into the target biofuels. The feedstock must not compete with food production (second or third generation) and their logistics must imply low Greenhouse gas (GHG) emissions and low transportation cost. In this sense, the feedstocks (excluding CO2) for advanced biofuels must be based on biogenic residues. These can include different typologies and origins, but all of them are characterized by organic matter (source of carbon (C) and nitrogen (N)) in their structure. The main differences between them are related to their biodegradability degree. Depending on this biodegradability, different technologies are available for their conversion into biofuels. In general, biological technologies are applied to high biodegradable biogenic residues while thermo-chemical technologies are used for low biodegradability residues.

As a first step to develop the Geographical Information System (GIS) feedstock mapping, a database with the compilation of the different existing biogenic residues at European regions in terms of amount availability, seasonality and logistics was elaborated. These feedstock databases have been used as a decision tool to select four representative European regions to analyze the Fuels-C model for advanced biofuels production and to select three non-biodegradable and three biodegradable feedstocks to research the new technologies to produce the different advanced biofuels. The methodology and results obtained from this study are described in this deliverable. In addition, the identification of the potential of renewable energy in the 4 European regions and the methodology developed to quantify the availability of the selected feedstocks in the 4 European regions selected are included in the deliverable.

2. Objectives

The main objective of this deliverable was to select 4 European regions for analyzing the Fuels-C model, which focusses on producing advanced biofuels using different and innovative technologies. Additionally, it aimed to select the most interesting feedstocks for studying and evaluating the performance of the proposed technologies at laboratory scale.

To carry out the main objective of the study, several specific objectives were defined:

I. Identification of seven criteria to select the feedstocks to use in the gasification and anaerobic digestion technologies.

II. Identification of a list of non-biodegradable and biodegradable feedstocks for use in the Fuels-C technologies.

III. Classification of the identified feedstocks into several typologies and their analysis considering multiple aspects (seasonality, composition, production, origin, possible conditioning, storage time, etc.).

IV. Selection of three biodegradable and three non-biodegradable feedstocks considering the database and the criteria definition.

V. Selection of the 4 European areas based on the elaborated database and the criteria definition.

VI. Identification of available renewable energy potential in the 4 European areas.

3. Methodology

Figure 2 shows a scheme of the methodology applied to select the feedstocks and 4 European regions.

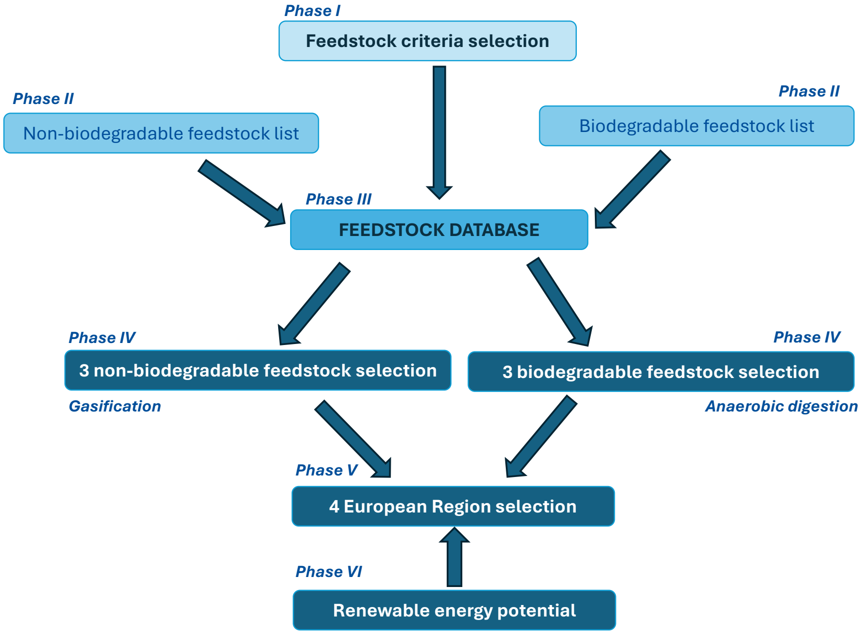


Figure 2. Methodology applied to select 4 European regions and feedstocks

4. Results

4.1. Feedstock criteria selection

The feedstocks are classified in different categories (urban, forestry, agriculture, and industrial (food and beverage)) and a qualitative analysis of each one was carried out analyzing several aspects to compare among them. Based on this analysis, the three more interesting feedstocks for gasification technology and three feedstocks for the anaerobic digestion technology were selected. The analyzed aspects were:

- The European areas where these feedstocks are mainly generated.
- The approximate production potential of each one, at EU level.
- The production seasonality (during all year or in a specific period of the year). This is important to consider possible pretreatment and storage systems of these feedstocks.
- The qualitative composition in terms of kind of matter on their structure (lipids, carbohydrates, proteins).
- The humidity ranges, in case of non-biodegradable feedstocks.
- The physico-chemical characteristics (total solids (TS), volatile solids (VS), total Kjeldahl nitrogen (TKN), ammonia concentration (NH_4^+-N) of the biodegradable feedstocks.
- The possible pretreatment applied to the feedstocks to use in the gasification or in anaerobic digestion technologies.

4.2. Feedstock list

Figure 3 shows a list of interesting feedstocks that can be used in gasification technology (high lignocellulosic composition, low humidity, more slowly biodegradable, etc.). The feedstocks were classified in different categories in function of their origin: urban, forestry, agricultural and food and brewery industry. Figure 4 shows a list of biodegradable feedstocks that can be used in anaerobic digestion technologies. In this case, the feedstocks were classified in urban, animal farms and food and brewery industry.

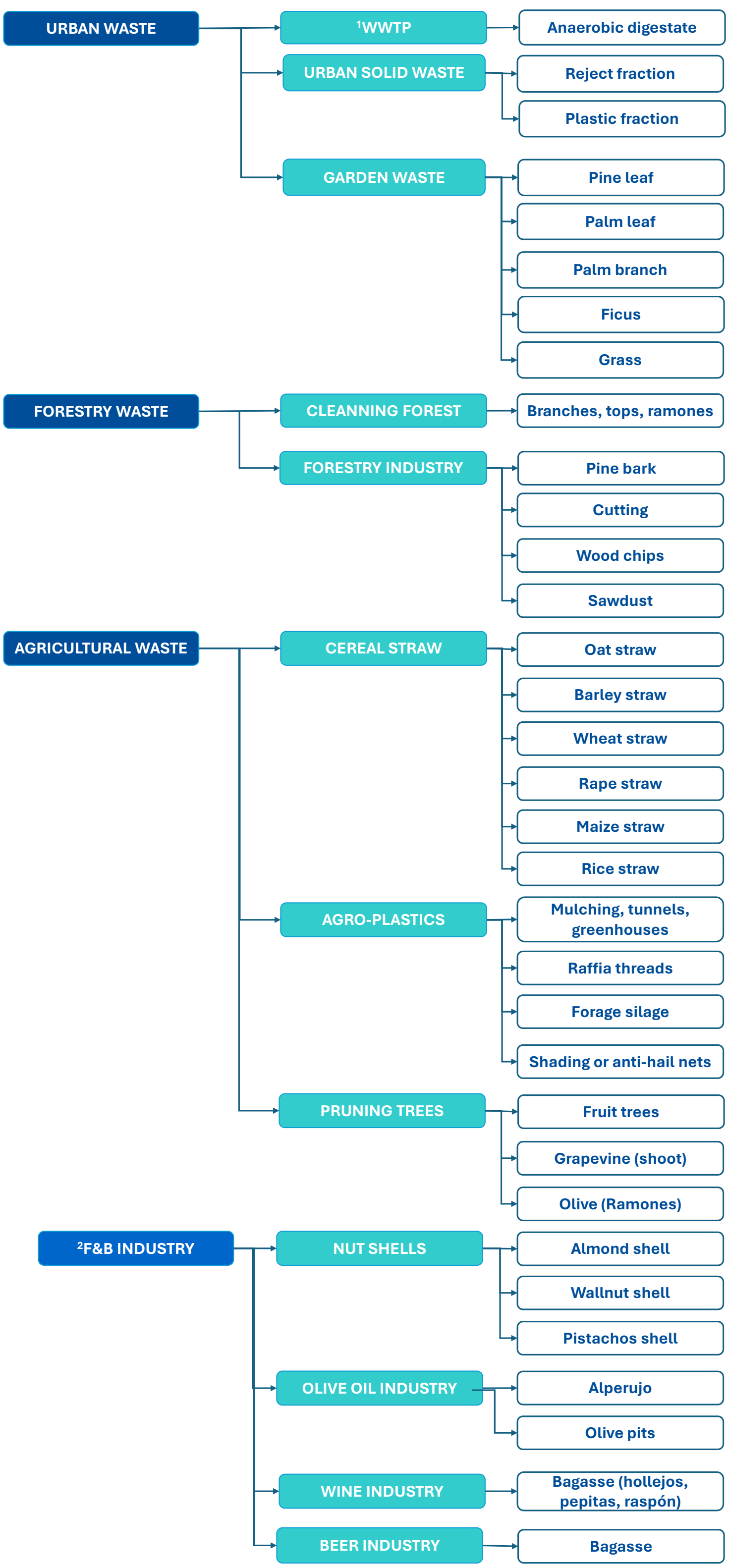


Figure 3. Possible feedstocks identified to use in gasification technology; 1WWTP: Wastewater Treatment Plant; 2F&B: Food and beverage

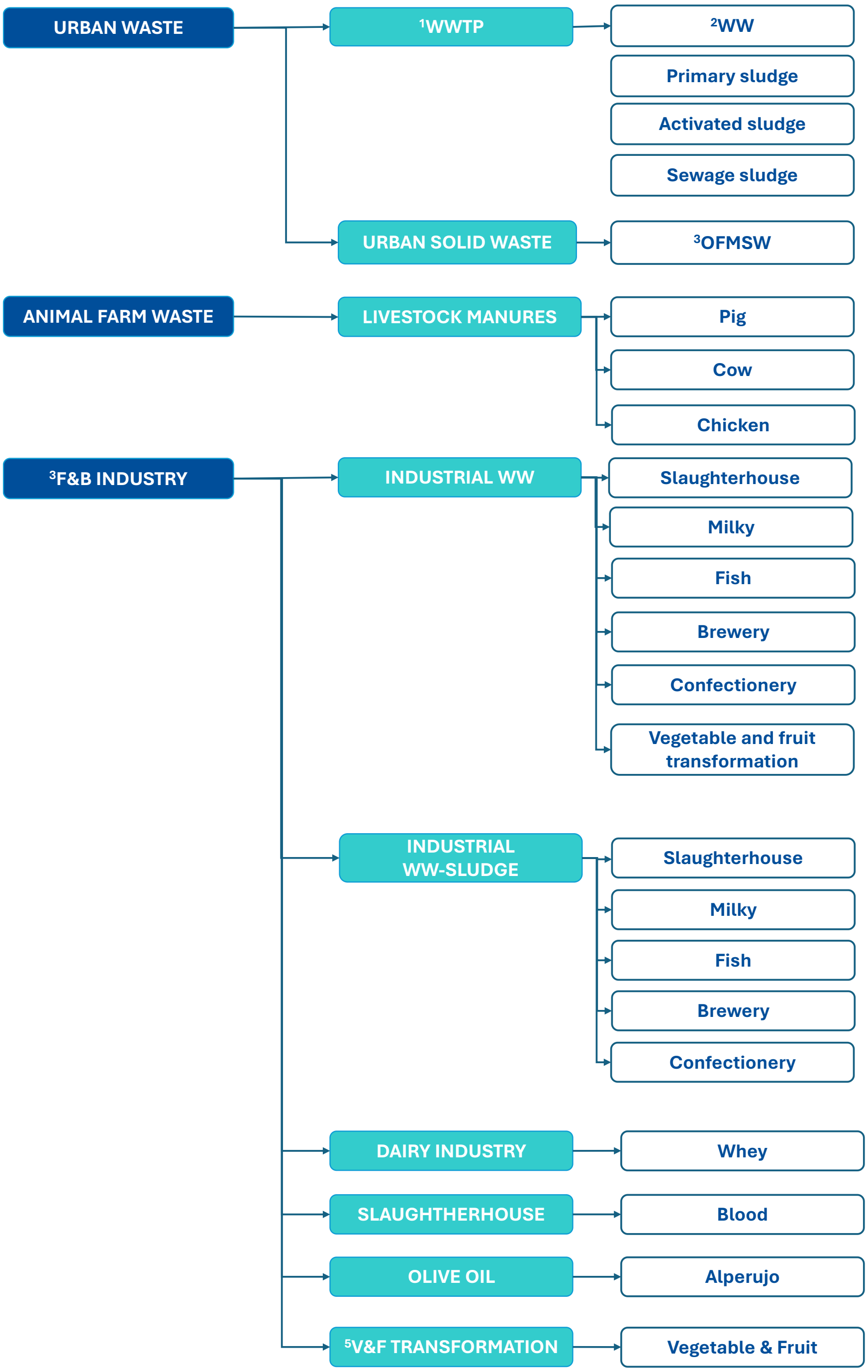


Figure 4. Feedstocks list identified to use in anaerobic digestion technology; [1]WWTP: Wastewater treatment plant; [2]WW: wastewater; [3]OFMSW: Organic fraction of municipal solid waste; [4]F&B: Food and beverage; [5]V&F: Vegetable and fruits

4.3. Feedstock database

Tables 1 and 2 show the feedstock database for use in gasification process (non-biodegradable feedstock) and in anaerobic digestion (biodegradable feedstock), respectively. EU production is estimated as maximum potential production based on several studies and reports of the EU commission.

Table 1. Feedstock database for gasification technology

FEEDSTOCK	ORIGIN	EUROPEAN AREAS	EU PRODUCTION (MT/year)	SEASONALITY	STORAGE	COMPOSITION	HUMIDITY (%)	PRETREATMENT
MUNICIPAL WASTE			**64**					
WWTP			**6**					
Anaerobic digestate dehydrated	*Sludge anaerobic digestion treatment*	*All*	*6*[1]	*Daily*	*20-30 days*	*Biological (proteins, bacteria, lignocellulosic)*	*15-25*	*Dewatering*
MUNICIPAL SOLID WASTE			**27**					
Rejected fraction	*Mechanical separation*	*All*	*13*[2]	*Daily*	*10 days*	*Organic matter (34%); plastics (18%); paper (12%); textile (7%); metals (3%); glass (3%)*	*20-70*	*Palletisation (solar drying, shredding, screening, size reduction)*
Plastic fraction	*Mechanical separation*	*All*	*14*[3]	*Daily*	*-*	*Polyethylene*	*90-100*	*Shredding*
GARDEN WASTE (BIOWASTE)			**31**					
Pine leaf	*Garden areas*	*All*	*31*[4]	*Pruning season (1-2 times year)*	*1 year*	*Lignocellulosic*	*80-100*	*Shredding*
Palm leaf	*Garden areas*	*Mediterranean countries*		*Pruning season (1-2 times year)*	*1 year*	*Lignocellulosic*	*80-100*	*Shredding*
Palm branch	*Garden areas*	*Mediterranean countries*		*Pruning season (1-2 times year)*	*1 year*	*Lignocellulosic*	*80-100*	*Shredding*
Ficus	*Garden areas*	*All*		*Pruning season (1-2 times year)*	*1 year*	*Lignocellulosic*	*80-100*	*Shredding*
Grass	*Garden areas*	*North-Centre Europe*		*Pruning season (1-2 times year)*	*1 year*	*Lignocellulosic*	*80-100*	*Shredding*
FORESTRY WASTE			**290**					
MAINTENANCE AND CLEANING FORESTS			**224**					

Branches, tops, ramones, non-timbering plants, etc.	*Forests*	*Finland, Sweeden, Austria, Germany; Poland*	*224*[5]	*Annually (1 times per year)*	*-*	*Lignocellulosic*	*80-100*	*shredding*
WASTE FORESTY INDUSTRY			**66**		**-**			
Pine bark	*Sawmill*	*Finland, Sweeden, Austria, Germany*	*66*[6]	*Daily-Temporary*	*-*	*Lignocellulosic*	*80-100*	*-*
Cuttings	*Sawmill*	*Finland, Sweeden, Austria, Germany*		*Daily-Temporary*	*-*	*Lignocellulosic*	*80-100*	*-*
Wood chips	*Sawmill*	*Finland, Sweeden, Austria, Germany*		*Daily-Temporary*	*-*	*Lignocellulosic*	*80-100*	*-*
Sawdust	*Sawmill*	*Finland, Sweeden, Austria, Germany*		*Daily-Temporary*	*-*	*Lignocellulosic*	*80-100*	*-*
AGRICULTURAL WASTE			**103**					
CEREAL WASTE			**55**					
Oat straw	*Crop fields*	*Poland, Finland, Spain, Germany, Sweden*	*1.73*[7]	*Harvest time*	*1-3 year*	*Lignocellulosic*	*80-100*	*Shredding/bales*
Barley straw	*Crop fields*	*France, Germany, Spain, Denmark, Poland*	*14.05*[8]	*Harvest time*	*1-3 year*	*Lignocellulosic*	*80-100*	*Shredding/bales*
Wheat straw	*Crop fields*	*France, Germany, Poland, Romania, Bulgaria*	*36.68*[9]	*Harvest time*	*1-3 year*	*Lignocellulosic*	*80-100*	*Shredding/bales*
Rape straw	*Crop fields*	*France (24.5%); Germany (23.1%), Poland (12.4%)*	*5.69*[10]	*Harvest time*	*1-3 year*	*Lignocellulosic*	*80-100*	*Shredding/bales*
Corn stover	*Crop fields*	*France, Poland, Romania, Italy, Germany*	*80.84*[11]	*Harvest time*	*1-3 year*	*Lignocellulosic*	*80-100*	*Shredding/bales*
Rice straw	*Crop fields*	*Italy (59%), Spain (25%), France (5.5%), Portugal (5%); Greece (4.5%)*	*1.97*[12]	*Harvest time*	*1-3 year*	*Lignocellulosic*	*80-100*	*Shredding/bales*
AGRICULTURAL PLASTICS			**1**		**-**			
Mulching, tunnels and greenhouses	*Crop fields*	*Spain, Portugal, Italy, Greece*	*1*[13]		*-*	*Mainly Polyethylene*	*80-100*	*Shredding*
Raffia threads	*Crop fields*	*Spain, Portugal, Italy, Greece*			*-*	*Mainly Polyethylene*	*80-100*	*Shredding*
Forage silage	*Crop fields*	*Spain, Portugal, Italy, Greece*			*-*	*Mainly Polyethylene*	*80-100*	*Shredding*
Shading or anti-hail nets	*Crop fields*	*Spain, Portugal, Italy, Greece*			*-*	*Mainly Polyethylene*	*80-100*	*Shredding*

WOODY TREE PRUNING WASTE			**47**					
Fruit trees	*Crop fields*	*Spain (33%), Italy (22%) , Poland (13%)*	25[14]	*Harvest time*	-	*Lignocellulosic*	80-100	*Shredding*
Grapevine (shoot)	*Crop fields*	*Spain, France, Italy (75%)*	*9.6*[15]	*Harvest time*	-	*Lignocellulosic*	80-100	*Shredding*
Olive (Ramones)	*Crop fields*	*Italy , Spain*	7[16]	*Harvest time*	-	*Lignocellulosic*	80-100	*Shredding*
FOOD INDUSTRY			**16**					
NUT SHELL			**0.27**					
Almond shell	*Agro-industry*	*Spain, Italy*	0.03[17]	*Daily-Temporary*	-	*Lignocellulosic*	95-100	*Crushed*
Walnut shell	*Agro-industry*	*Romania, France, Spain, Italy*	0.004[18]	*Daily-Temporary*	-	*Lignocellulosic*	95-100	*Crushed*
OLIVE OIL PRODUCTION			**8**					
Alperujo	*Agro-industry*	*Spain, Italy, Greece, Portugal*	6.42[19]	*Temporary*	1-2 month	*Lignocellulosic, proteins, fats*	60-80	-
Olive pits & hojín	*Agro-industry*	*Spain, Italy, Greece, Portugal*	1.90[20]	*Temporary*	-	*Lignocellulosic*	80-100	*Crushed*
WINE PRODUCTION			**3.30**					
Bagasse (hollejos, pepitas, raspón)	*Agro-industry*	*Spain, France, Italy (75%)*	3.30[21]	*Daily-Temporary*	1-2 month	*Lignocellulosic, proteins, fats*	60-80	-
BEER PRODUCTION			**1.72**					
Bagasse	*Agro-industry*	*Germany (22.5%); Spain (11.5%); Poland (11%), Netherlands (7.5%), France (5.9%)*	1.72[22]	*Daily*	1-2 month	*Lignocellulosic*	60-80	-

[1] *WW production EU: 39,785 Mm^3/year [1]; sewage sludge yield (wet basis):0.0039 m^3/m^3 WW; Anerobic digestate TS (2%); Dewatered anaerobic digestate TS (20%).*

[2] *Municipal Waste: 513 kg/hab. year [2]; recycled fraction: 48% [2]; EU habitants: 448 Mhab. [3]*

[3] *Municipal Waste: 513 kg/hab. year [2]; recycled fraction: 48% [2]; EU habitants: 448 Mhab. [3]; Plastic fraction recycled municipal waste: 13% [4]*

[4] *Municipal Waste: 513 kg/hab. year [2]; EU habitants: 448 Mhab [3]; Garden Waste: 13.6% of the MSW [5]*

[5] *EU Maintenance and cleaning biomass from forest production [6]*

[6] *EU Waste forestry industry production [7]*

[7] *Oat cultivation area EU: 2 Mha/year [2]; Oat straw yield: 0.87 T/ha [10]*

[8] *Barley cultivation area EU: 10.32 Mha/year [8]: Barley straw yield: 1.36 T/ha [12]*

[9] *Whet cultivation area: 22.83 Mha/year [13]; Whet straw yield: 1.61 T/ha [9]*

[10] *Rape cultivation area: 5.69 Mha/year [11]; Rape straw yield: 1 T/ha*

[11] *Corn cultivation area: 8.60 Mha/year [12]; Corn stover: 9.40 T/ha [13]*

[12] *Rice cultivation area: 0.39 Mha/year [14]; Rice straw yield: 5 T/ha [15]*

[13] *European Agricultural Plastics [16]*

[14] *European fruit tree pruning waste production [17]*

[15] *Grapevine cultivation area: 3.2 Mha/year [18]; Shoot (Sarmiento) yield:3T/ha [19]*

[16] *Olive cultivation area: 4 Mha/year [2]; Ramones yield: 1.75 T/ha [20]*

[17] *Almond production: 147,700 T/year [2]; Almond shell weight: 20% [21]*

[18] *Walnut production: 20,000 T/year [2]; Walnut shell weight: 20% [21]*

[19] *Oil production: 1.78 MT/year [23]; Alperujo yield: 3.21T/T oil [20]*

[20] *Oil production: 1.78 MT/year [23]; Olive pit & hojín: 0.95T/T oil [20]*

[21] *Wine production: 16.5 Mm^3/year [24]; Bagasse yield: 200 Kg/m^3 wine [25]*

[22] *Beer production: 34.3 Mm^3/year [2]: Bagasse yield: 0.05 T/m^3 beer [26]*

Table 2. Feedstock database for anaerobic digestion technologies

FEEDSTOCK	ORIGIN	EUROPEAN AREAS	EU PRODUCTION (Mm^3/year)	SEASONALITY	STORAGE	COMPOSITION	[19]TS (%)	[20]VS (%)	[21]TKN (g/L)	NH_4^{+-}N(ppm)	PRETREATMENT
MUNICIPAL WASTE			39,966								
WWTP			**39,940**								
Wastewater	*WWTP*	*All*	*39,785*[1]	*Daily*	*1-2 days*	*Mix*	*0.13*[22]	*0.05*[22]			-
Primary sludge	*After 1° decanter*	*All*	*107*[2]	*Daily*	*1-2 days*	*Mix*	*3.00*[22]	*1.34*[22]			*Liquid addition to reduce the TS*
Secondary sludge	*Biological treatment*	*All*	*48*[3]	*Daily*	*1-2 days*	*Biological*	*3.04*[22]	*1.20*[22]			*Liquid addition to reduce the TS*
Sewage sludge	*Mix primary and secondary*	*All*	*155*[4]	*Daily*	*1-2 days*	*Mix-Biological*	*3.20*[23]	*2.3*[23]	*2*[23]	*841*[23]	*Liquid addition to reduce the TS*
URBAN SOLID WASTE			**26**								
OFMSW	*Origin separation*	*All*	*26*[5]	*Daily*	*1-2 days*	*Mix*	*42.2-25.9*[24]	*30.0-22.0*[24]	*6-7.5*[24]	*1400-800*[24]	*Shredding*
ANIMAL FARM WASTE			**741**								
LIVESTOCK SLURRY			**741**								
Pig slurry	*Farms*	*Spain (20.8%), Germany (17.8%): France (9.3%) Denmark (8.5%)*	*200*[6]	*Daily*	*1-2 weeks*	*Mix (proteins)*	*62*[25]	*42*[25]	*6*[25]	*4540*[25]	*Filtration*
Cow slurry	*Farms*	*France (22%); Germany (14.7%); Poland (8.6%)*	*481*[7]	*Daily*	*1-2 weeks*	*Mix (proteins)*	*49*[26]	*33*[26]	*3*[26]	*1435*[26]	*Filtration* *Liquid addition to reduce the TS*
Chicken slurry	*Farms*	*Poland (17%), France, Spain, Germany, Italy*	*60*[8]	*Daily*	*1-2 weeks*	*Mix (proteins)*	*48*[27]	*34* [27]	*5*[27]	*800*[27]	*Filtration* *Liquid addition to reduce the TS*
FOOD INDUSTRY			**1,222**								
INDUSTRIAL WASTEWATER			**1,096**								
Slaughterhouse industry	*Agro-industry*	*Spain, France, Germany, Irland, Italy, Poland*	*366*[9]	*Daily*	*1-2 days*	*Mix (proteins-lipids)*	*1164*[28] *mg/L (TSS*[38]*)*	*4*[28] *g/L (COD*[39]*)*	*0.43*[28] *g/L (TN*[40]*)*		*No*

Milky industry	Agro-industry	Germany (22%); France (16.6%); Netherlands (9.6%); Italy (9.0%); Poland (8.8%)	193[10]	Daily	1-2 days	Mix (protein-lipids)	2/0.3[29] % (TSS)	27[29] g/L (COD)	0.62[29] g/L (TN)		No
Fish canned industry	Agro-industry	France, Greece, Spain, Italy (67% aquiculture); processing industry Spain (26%); Poland (12%); Italy (8%)	6[11]	Daily	1-2 days	Mix (proteins-lipids)	0.55[30] % (TSS)	47[30] g/L (COD)			No
Brewery industry	Agro-industry	Germany (22.5%); Spain (11.5%); Poland (11%), Netherlands (7.5%), France (5.9%)	172[12]	Daily	1-2 days	Mix (carbohydrates)	0.3-0.05[31]	1.1-0.04[31]	0.01-0.28[31] g/L (TN)	-	No
Confectionery industry	Agro-industry	Germany, Italy and France (64%)	31[41]	Daily	1-2 days	Carbohydrates	2.5-20[32] g/L (COD)	0.4-8[32] g/L (BOD)	32	28.5-120[32]	
Vegetable and fruit transformation industry	Agro-industry	Spain (33%), Italy (22%) , Poland (13%)	359[13]	Daily	1-2 days	Carbohydrates		13[33] g/L (COD)	0.18[33]		No
INDUSTRIAL SLUDGE			**3.60**								
Slaughterhouse	Agro-industry	Spain, France, Germany, Irland, Italy, Poland	1.43	Daily	1-2 days	Mix (proteins-lipids)	-	-	-	-	No
Milky	Agro-industry	Germany (22%); France (16.6%); Netherlands (9.6%); Italy (9.0%); Poland (8.8%)	0.75	Daily	1-2 days	Mix (protein-lipids)	-	-	-	-	No
Fish	Agro-industry	France, Greece, Spain, Italy (67% aquiculture)	0.02	Daily	1-2 days	Mix (proteins-lipids)	-	-	-	-	No
Brewery	Agro-industry	Germany (22,5%); Spain (11,5%); Poland (11%), Netherlands (7,5%), France (5,9%)	0.67	Daily	1-2 days	Carbohydrates	-	-	-	-	No
Confectionery	Agro-industry	Germany, Italy and France (64%)	0.12	Daily	1-2 days	Carbohydrates	-	-	-	-	No
Vegetable and fruit transformation	Agro-industry	Spain (33%), Italy (22%) , Poland (13%)	1.40	Daily	1-2 days	Mix (carbohydrates)	-	-	-	-	No
DAIRY INDUSTRY			**92**								
Whey	Agro-industry	Germany (22%); France (19%); Italy (12%)	92[15]	Daily	1 week	Carbohydrates	8.19[34]	7.44[34]	21.4[34]	-	No
SLAUGHTERHOUSE			**1.8**								

Blood	*Agro-industry*	*Spain, France, Germany, Irland, Italy, Poland*	*1.8*[16]	*Daily*	*1 week*	*Proteins*	*16.2*[35]	*16.2*[35]	*68*[35]	*1767*	*No*
OLIVE OIL			**6.42**								
Alperujo	*Agro-industry*	*Spain, Italy, Greece, Portugal*	*6.42*[17]	*season (October-March)*	*2 weeks*	*Lignocellulosic*	*25.8*[36]	*19.8*[36]			*Filtration Liquid addition to reduce the TS*
VEGETABLE AND FRUIT TRANSFORMATION			**22.54**								
Vegetable and fruit	*Agro-industry*	*Spain (33%), Italy (22%) , Poland (13%)*	*22.54*[18]	*Season*	*1 week*	*Carbohydrates/lignocellulosic*	*4.4*[37]	*3.9*[37]	*1*[37]		*Shredding/dilution/filtration*

[1] *EU Urban Wastewater (WW) production: 109 Mm^3/day [1]*

[2] *EU Urban Wastewater (WW) production: 109 Mm^3/day [1]; Primary sludge ratio: 0.0027 m^3/m^3WW (wet basis).*

[3] *EU Urban Wastewater (WW) production: 109 Mm^3/day [1]; Secondary sludge ratio: 0.0012 m^3/m^3WW (wet basis).*

[4] *EU Urban Wastewater (WW) production: 109 Mm^3/day [1]; Primary sludge ratio: 0.0027 m^3/m^3WW; Secondary sludge ratio: 0.0012 m^3/m^3WW (wet basis)*

[5] *Municipal waste production: 513Kg/hab year [2]; EU habitants: 448 Mhab [3]; Recycled fraction: 48% [2]; Food/kitchen waste: 27% MSW [4]*

[6] *EU pigs' heads: 133 Mheads/year (closed circuit:13 Mheads/year; Feedlot farms: 13 Mheads/year: piglets:72 Mheads/year) [2]; "closed circuit" manure production: 3 m^3head/year; "Feedlot" manure production: 2.15 m^3head/year; "Piglets" manure production: 0.41 m^3head/year [27]*

[7] *EU Bovine heads: 74 Mheads/year [2]; Average bovine manure: 6.52 m^3 head/year [27]].*

[8] *EU Chicken heads: 1,630 Mheads/year [2]; Chicken manure: 0.037 m^3/head year [27]].*

[9] *WW meet industry production: 9 m^3/T meat [28]; EU meet production: 40.7 MT/year [2]*

[10] *European milky industry wastewater production [29]*

[11] *Fish WW production: 30 m^3/h; Capacity production: 100 T fish/h [31]: Fish processed:1,913 T/year [32].*

[12] *Beer WW production: 5 L/Lbeer [30]; EU beer production: 34.3 Mm^3/year [2].*

[13] *EU Vegetable and fruit processing industry: 7.18 MT/year [33]; V&F WW production: 50 m^3/T [34].*

[14] *Industrial WW sludge: 0.0039 m^3 sludge/m^3WW (similar ratio obtained from Urban Wastewater).*

[15] *Whey yield: 9 L/Kg Cheese [37]; Cheese production: 11 MT/year [2].*

[16] *Animal by-products (ABP): 20 MT/year [35]; Blood component on ABP: 9% [36].*

[17] *Oil production: 1.78 MT/year [23]; Alperujo yield: 3.21T/T oil [20]*

[18] *EU Vegetable and fruit (V&F) production: 60.1 MT/year [2]; V&F discharge ratio: 37.5% [37]*

[19] *TS: Total solids.*

[20]VS: Volatile solids.

[21]TKN: Total Kjeldahl nitrogen

[22][40]; [23][41]; [24] [42]; [25][43]; [26][44]; [27][45]; [28][46]; [29][47], [30][48], [31][49], [32][50], [33][51], [34][52], [35][53],[36] [54],[37][55], [38]TSS: Total suspended solids; [39]COD: carbon oxygen demand; [40]TN: Total nitrogen; [41]EU chocolate, biscuit and confectionary production: 13.3 MT/year [38]; Confectionary water consumption: 0.0023 m^3/kg [39]

4.4. Feedstocks selection

4.4.1. Non-Biodegradable feedstocks

The non-biodegradable feedstocks selected to study the gasification process at laboratory scale are:

1. Anaerobic digestate. FACSA manages this kind of waste in several Wastewater Treatment Plants (WWTPs). This is a typical waste that is produced across the EU. Digestate is a nutrient-rich by-product from organic waste anaerobic digestion but can contribute to environmental pollution due to the presence of microcontaminants, heavy metals, antibiotics, microplastics and/or pathogens. The most suitable use of this kind of feedstock depends on their composition. Currently, EU rules promote the use of digestate in agriculture but regulate this use to prevent harmful effects on soil, vegetation, animals and people. The directive of sewage sludge (Council Directive 86/278/EEC of 12 June 1986 on the protection of the environmental, and particular of the soil, when sewage sludge is used in agriculture), only sets limits for the concentration of seven heavy metals for agricultural use, but it expected that their agricultural use would be more and more restricted, with the aim to avoid the contamination of soils with this kind of contaminants. Therefore, the anaerobic digestate use like feedstock for the gasification could be an interesting option in specific cases that the anaerobic digestate cannot use in agriculture in the future.

2. Not-recycled plastic fractions of urban waste. The plastic fraction collected from urban waste is recycled and classified into different kinds of plastics. The non-recycled plastic fraction could be an interesting feedstock to use in gasification technology. The non-recycled plastic fraction is usually incinerated. The composition of this plastic fraction is very varied, the main plastic materials are the film and PET. Other compounds like steel, aluminum, or wood are in its composition. Therefore, it is important to analyze their suitability like an interesting feedstock for the gasification technology.

3. Fruit tree pruning is an interesting feedstock to use in the gasification technology due to the high potential production in different European regions. Fruit tree pruning is a lignocellulosic material rich on lignin and therefore interesting like a feedstock for gasification technology.

4.4.2. Biodegradable feedstocks

Three feedstocks were selected for studying the different AD technologies to produce several biofuels. The selection was carried out considering several criteria described in section 4.1. The three feedstocks selection were:

1. Urban sewage sludge (USS): The USS is generated during the treatment of urban wastewater. The USS is a mixture of primary sludge and secondary sludge. Primary sludge is generated in the primary settler. The organic compounds in primary sludge constated mainly of 40% carbohydrates, 23% lipids and 21% proteins (Abdelrahman et a´, 2023). Activated sludge consisting of suspended flocs of active bacteria. The organic pollutants are used for growth by bacteria and thereby are transformed into water, CO_2 and new cell material. The sewage sludge is generated in all European countries and regions. Therefore, it is an interesting feedstock to produce biofuels. The sewage sludge has a high production potential in comparison with other feedstocks analyzed.

2. Industrial wastewater from F&B industry: Industrial wastewater from food and beverage industry is another interesting feedstock to use in the AD technologies studied in the FUELS-C project. The F&B WW shows high organic matter concentrations, and it is generated in different European areas. The food and beverage industry WW composition varied depending on the type of industry. Slaughterhouses, milky and fish WW is characterized by WW with high fat and protein concentrations while the brewery, V&F and confectionary industry the WW contains more carbohydrates and sugars concentration. For the AD technologies analyzed in Fuels-C it is more interesting to use WW with high sugar concentration. Among the wastewater with high sugar content, water from candy manufacturing was selected. FACSA had this substrate in its facilities to provide it to LEITAT for the study of anaerobic digestion technologies.

3. Pig manure. Pig manure is the main biodegradable feedstock available in the Region I selected to study the Fuels-C model to produce innovative biofuels. Pig manure is characterized by high proteins content and ammonia concentration and pig manure shows high production potential at EU level.

Therefore, we selected three feedstocks from different origins (municipal, farm and industry) with different composition (biological, proteins, carbohydrates). These feedstocks will be analyzed to produce alternative biofuels using gasification technology (WP4) or anaerobic digestion technologies (WP3). The feedstocks will be tested alone or using mixtures of the different feedstocks with the aim of identifying the best performance of the technologies studied.

4.5. European Union regions selection

The objective is to select 4 European regions (Figure 5) where the main feedstocks available will be different among them. Considering the feedstocks selected for the project and the EU production potential, the four regions were selected.

- **Region I**, corresponding with a region in the **north-east of Spain**. This region was selected at the proposal phase. In this region there are high density of animal farms, mainly pig farms, therefore it is a region with high pig manure availability. The selection of the area was carried out considering the livestock density. This region covers the provinces of **Castelló**, **Tarragona**, **Barcelona**, **Lleida**, **Girona** and **Huesca**.

- **Region II** was selected considering the forest biomass availability. The forest biomass is an interesting and available feedstock for gasification technology. **Centre Poland** is a region with high density of forest biomass in Europe, therefore, this region could be interesting to analyze the Fuels-C solution. This region covers the voivodeships of **Greater Poland**, **Kuyavian-Pomeranian** and **Lodz´**.

- **Region III** was selected considering municipal waste as the main feedstock available in the region. **Ile de France** (Paris) is the region with most population density in Europe, therefore the municipal waste density in the region will be high. This region covers the departments of **Paris**, **Hauts-de-Seine**, **Seine-Saint Denis**, **Val-d´Oise**, **Seine-et-Marne**, **Essonne**, **Yvelines**.

- **Region IV** was selected considering the pruning waste from fruit trees. **Apulia (Italy)** is an area with high presence of fruit trees. This region covers the provinces of the Metropolitan **City of Bari**, **Lecce, Foggia**, **Taranto**; **Barletta-Andria-Trani** and **Brindisi**.

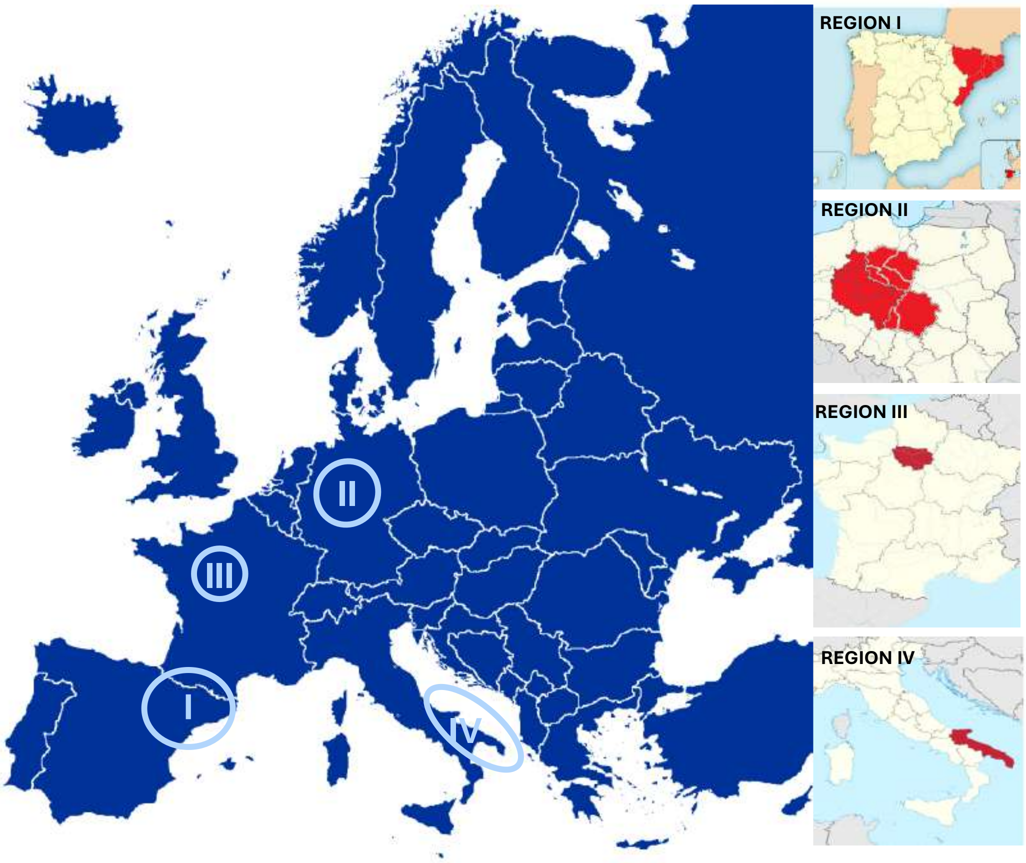


Figure 5. European Regions selected to analyze the FUELS-C solution

N.º	EU REGION	COUNTRY	FEEDSTOCKS (MAIN)	EXTENSION	POPULATION Habitants	DENSITY Habitants/Km^2
I	**NORTH-WEST SPAIN**	SPAIN	LIVESTOCK MANURE	53,746 km^2	8,899,144	166
II	**CENTRE POLAND**	POLAND	FOREST BIOMASS	66,014 km^2	8,085,782	122
III	**ILE DE FRANCE**	FRANCE	MUNICIPAL WASTE	12,011 km^2	12,140,526	1,011
IV	**APULIA**	ITALY	PRUNNING WASTE FRUIT TREES	19,541 km$_2$	3,895,352	199

Table 3. EU regions selected

4.6. Renewable energy potential in the 4 selected European Areas

Fuels-C processes could need an input of energy in terms of:

- Thermal energy (to guarantee temperature for the different processes).
- Electric energy (to guarantee operability of electro-driven equipment present along the process).

In general, it is important to assess the potential of both thermal renewables and electrical renewables, while also considering the possibility to efficiently exploit this electric input to drive heat pumps or electric heaters to provide heat to the processes.

A more detailed assessment (e.g. temperature levels, continuous/batch energy provision of each Fuels-C process and therefore potential integration of energy storage) could be realized once the overall Fuels-C fuel production processes are duly defined.

Nevertheless, a first assessment of Renewable Energy potential in the four reference European regions has been performed by BER.

Such an assessment of renewable sources is mostly targeted:

- Solar irradiation for electric conversion through photovoltaic technology as well as for solar thermal energy production.
- wind speed for electric conversion through wind turbine farms;
- geothermal power;
- biomass residues availability for thermal energy production purposes;
- waste heat as a renewable source of heat.

The renewable sources availability in the selected regions comes from the following European databases:

- PVGIS: Photovoltaic Geographical Information System [56]
- NEWA: New European Wind Atlas [57]
- GEODH: Geothermal District Heating [58]
- Waste Heat [59]
- Biomasses residues [60]

Data is based on average values for the regions. The paragraph reports for each region an assessment on renewable energy availability, also considering the present renewable energy infrastructure status and the available data on renewable production of the actual installed capacity.

4.6.1 Solar irradiation and Photovoltaic generation

Solar energy photovoltaics (PV) technologies convert sunlight into energy as electricity. Solar is the fastest growing energy source in the EU. Solar energy is cheap, clean and flexible.

The cost of solar power decreased by 82% between 2010-2020, making it the most competitive source of electricity in many parts of the EU. PV generators can be installed on free surfaces on roof top without requiring new land, although they provide energy only on sunny days during daytime, and with significant season variation of delivered energy (winter/summer), they can work together with energy storage system, like battery energy storage (BESS) for more flexible performance.

The energy produced by 1 kWp of PV module installed on a roof with tilt angle: 15 deg, and orientation south, is the benchmark for the assessment of each region respect this technology.

- **Region I (Northeast Spain). SPAIN** has a Solar potential amongst the best in Europe, if not the best, the northeast region of the country shows excellent performance with over 1,300 equivalent hours of production per year per kW installed.
- **Region II (Centre Poland). Poland** shows the lower values for solar irradiation, anyway, roof installed PV generator can operate about 1,000 hours per year at its nominal power.
- **Region III (Ille de France)**. Ile de France shows value of about 1, 000 hours/year of production per kW installed.
- **Region IV (Apulia). Italy** in Apulia region has solar irradiation values that allows a PV generator to operate at its nominal power more than 1,300 hours per year.

PV energy is a convenient renewable source, although it requires free surfaces for installation (about 600 square meters for 100 kWp) and production decreases significantly in winter season. Southern regions like Spain and Italy show good production average also in the winter season, but northern regions PV production falls with average values below the 20% of the summer season ones.

Reported PV production values could be a good reference also to evaluate the solar thermal energy potential in the proposed areas. What is relevant to highlight is that, in case of Solar Thermal production, thermal panels are usually tilted with an angle close to the value of the latitude of the location.

The following values of Global Solar Irradiation are typical of the four Fuels-C reference areas, in the following figures irradiation values from PVGIS database:

- Region I (Northeast Spain, Spain): 1,600-1,800 kWh/m^2
- Region II (Central Poland, Poland): 1,000-1,200 kWh/m^2
- Region III (Ile-de-France, France) : 1,100-1,300 kWh/m^2
- Region IV (Apulia, Italy): 1,500-1,700 kWh/m^2

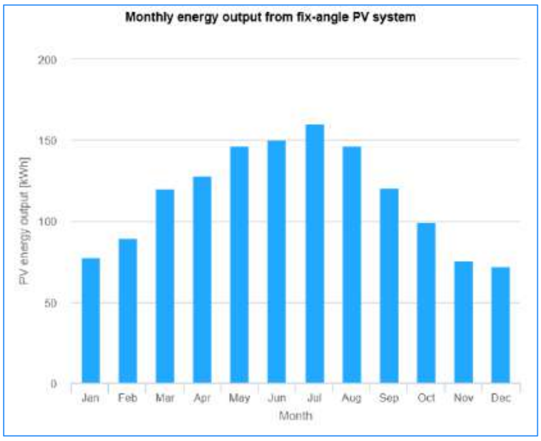


Figure 6.REGION I SPAIN PV average monthly production

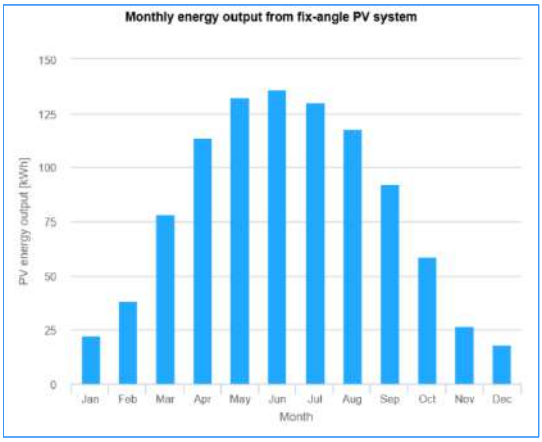


Figure 7.REGION II POLAND PV average monthly production

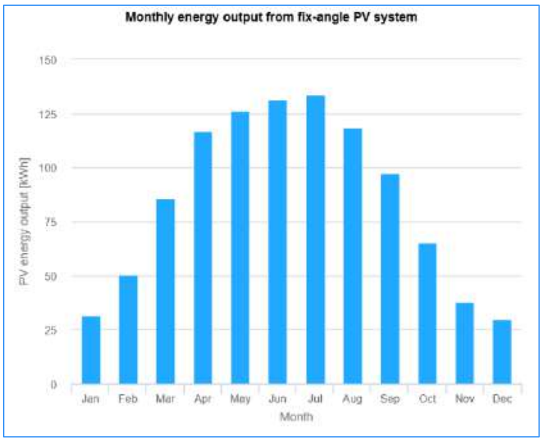


Figure 8. REGION III France PV average monthly production

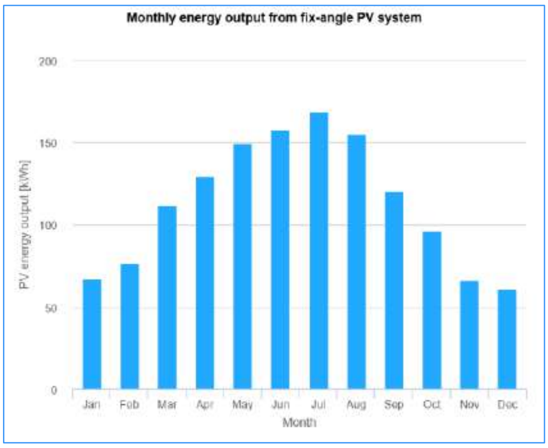


Figure 9. REGION IV Italy Apulia 1kWp PV average monthly production

4.6.2 WIND

Wind power has played an important part in the growth of renewable energy in Europe and will be key to achieving the EU's renewable energy targets and to reach carbon neutral by 2050.

Continued improvements in manufacturing and design of wind turbines, combined with improved capacity factors (more electricity generated per turbine), due to more performant turbines and/or better localization, have driven down the costs of wind power and reaffirmed its position as a key driver of the clean energy transition.

According to Eurostat, wind accounted for over one-third (37.5%) of the total electricity generated from renewable sources in the EU in 2022 [61]

Nevertheless, wind farms require availability of land, wind resource is more available in remote areas far enough from the built environment, and the urban areas, so installations need accurate evaluation and environmental impact assessments.

Wind speed is a first indication of possible exploitation of the resource. Average speed higher than 6 m/s are typical values for exploitable wind energy sites, although the wind resources must be carefully assessed locally for the optimal design of the park and the estimation of production profiles. Data of wind speed available from the New European Wind Atlas [62] are shown in the following figures: the maps show the average speed of the wind at 50 m of height from the ground, for the selected regions. Data of existing wind farms operating in the selected region are provided in the following paragraphs to complete the context.

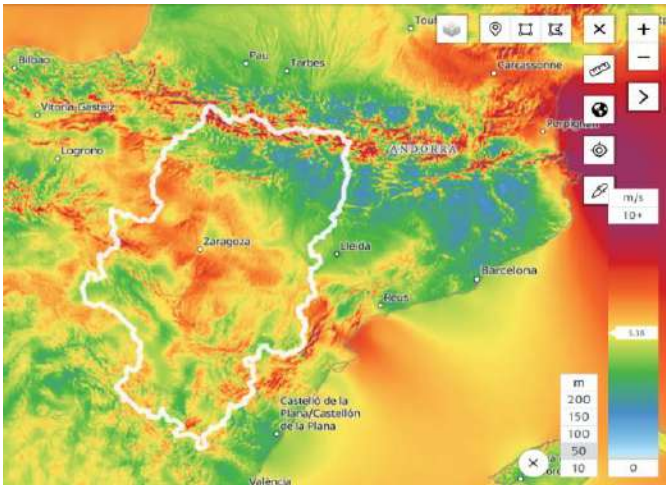


Figure 10. REGION I Northeast Spain, wind speed average values at 50 m

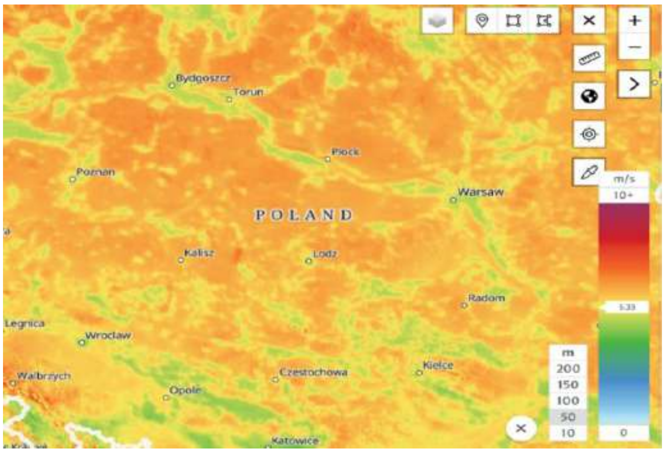


Figure 11. REGION II Central Poland, Poland, wind speed average values at 50 m

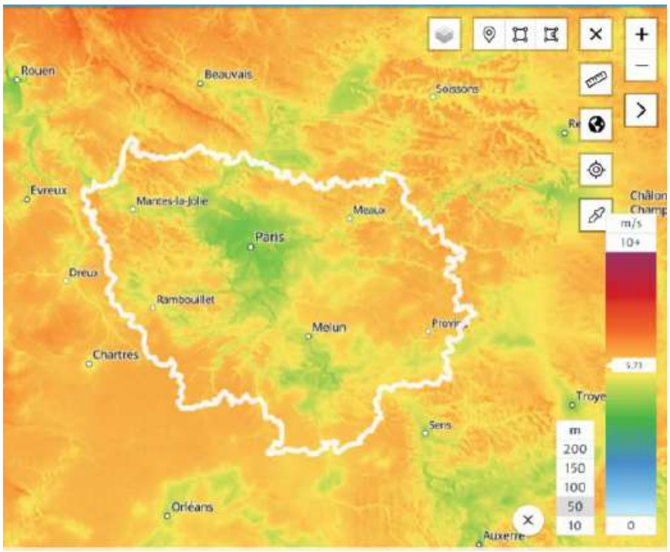


Figure 12. REGION III Ile-de-France, France, wind speed average values at 50 m

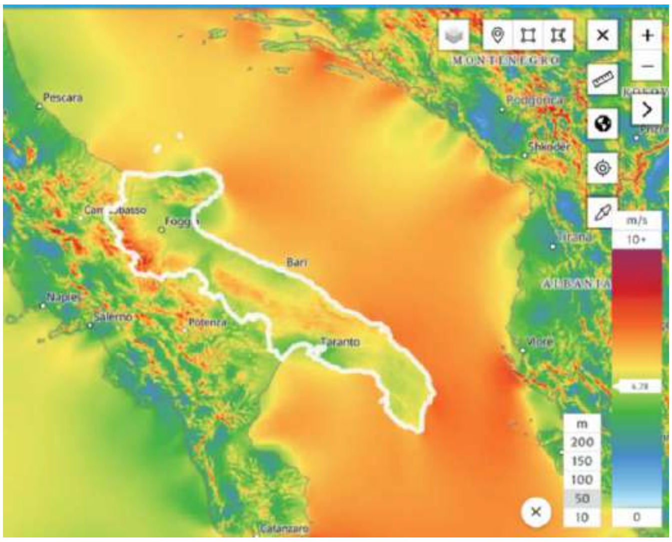


Figure 13. REGION IV Apulia, Italy, wind speed average values at 50 m

REGION I Northeast Spain (Spain)

Aragon, in the northeast of Spain, is one of the regions with **higher potential for wind generation in Europe** with annual average wind speeds around 6.5 m/s and greater at 80-m height. **Sites in the region of Zaragoza register more than 7.5 m/s as average wind speed.** Aragon ranks as the second Spanish region in terms of the installed wind power (5,246.3 MW). According to reports by Red Eléctrica, Aragon produced from renewable sources a total of **22,235 GWh** in 2023, in 2023 the region boasted the highest wind power share in its energy generation mix among all autonomous communities, and it ranked second in terms of electricity generated from wind power (12,004 GWh) [63].

REGION II Centre Poland (Poland)

Poland intends to unlock wind energy development - draft new regulations introduce greater flexibility in spatial planning for wind farms. The reduction of restrictions on the distance of turbines from buildings is expected to result in an increase in the scale of RES projects, which is reflected in the government's ambitious new plans for renewable energy growth targets.

According to PWEA, the Polish Wind Energy Industry's development potential by 2030 may range from 21.3 GW to 26.6 GW (12.7-18 GW onshore and 8.6 GW offshore), which would account for 4.26% to 5.32% of installed capacity in the EU. In 2020 the installed capacity was 6.294 MWp with a production of 155.800 GWh in the year.

REGION III Ile de France (FRANCE)

The region of Ile de France hosts 7 wind parks for an installed capacity of about 140 GW. A total of 42 turbine is in service in Essonne, Seine and Marne and in the Yvelines Two of the parks are both on the Ile de France and in the neighboring department (Eure et Loire and Loiret). The production from wind energy in the year 2023 for the region of Ile de France was about 380 GWh [64].

REGION IV Apulia (ITALY)

Wind power in Italy is predominantly concentrated in Southern regions of the country. According to data from the Energy Services Manager (GSE), Puglia alone is responsible for 25% of the national electricity produced from wind power, followed by Sicily with 18%, Campania with 14%, Basilicata with 13% and Calabria and Sardinia with 10%.

In 2023, wind power on Italian territory generated 23.4 TWh, a record for the technology, which last year covered 7.6% of the country's electricity demand (9.1% of national production). The Apulia region installed capacity is about 3.1 GWp, with annual production in 2023 of about 6000 GWh.

Thermal renewables sources for the selected reference European regions

Thermal RES assessment analyzed three potential sources:

- Geothermal heat (looking at the possibility to upgrade it via heat pumps – potentially driven by electric RES)
- Availability of Waste Heat
- Residual biomass or the production of thermal energy

In order to assess the local geothermal potential, the geothermal district heating (GeoDH) database [65] was used. Such database presents data about the European cities with an operating district heating network, in that locations opportunities for accessible renewable thermal energy must be considered.

There are over 5,000 district heating systems in Europe, including more than 240 Geothermal District Heating systems. The first regions to install GeoDH were those with the best hydrothermal potential, however with new technologies and systems, an increasing number of regions are developing geothermal DH. Systems can be small (from 0.5 to 2 MWth), and larger, with capacity of 50 MWth. Some new District heating schemes that utilize shallow geothermal resources are assisted by large heat pumps.

GeoDH systems in areas of high urban density improve project economics, as both resources and demand need to be geographically matched. Based on currently available information in terms of geological data, already operational district heating systems, and heat demand, it shows the potential in the 14 project countries: **Italy, France**, Germany, Netherlands, Ireland, United Kingdom, Slovakia, Slovenia, Czech Republic, Romania, Bulgaria, **Poland**, Denmark, and Hungary.

For the assessment of available geothermal heating sources, maps for the selected regions are provided, highlighting existing district heating network for possible connection, or development, and the availability of underground heating power. While specific area in the Spanish and Italian regions show potential for geothermal underground source, it is interesting to see the opportunities to exploit the existing district heating networks largely available in the Ile de France and Poland region.

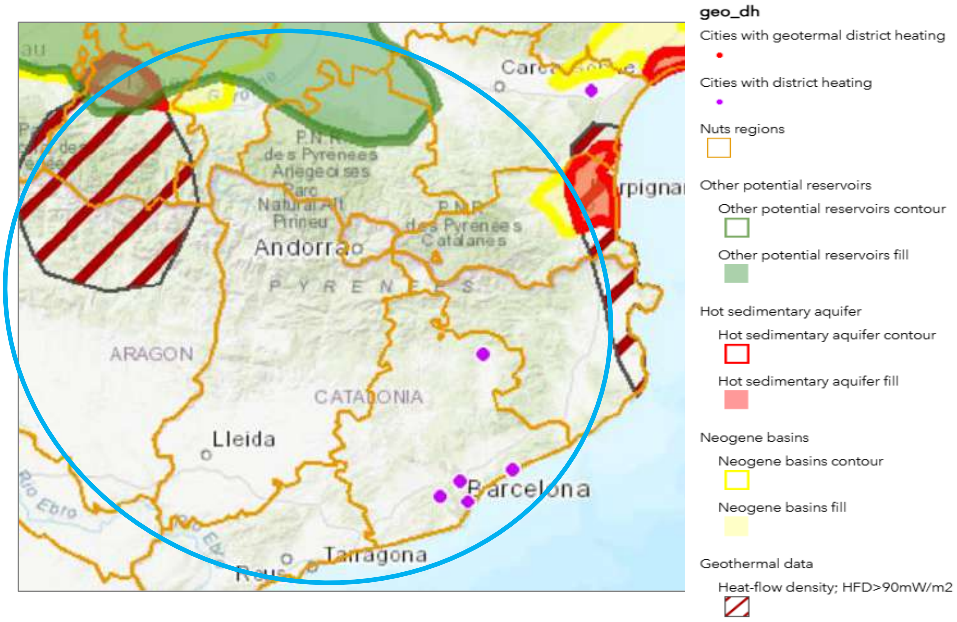


Figure 14. REGION I Northeast Spain, renewable heating resources from GeoDH database

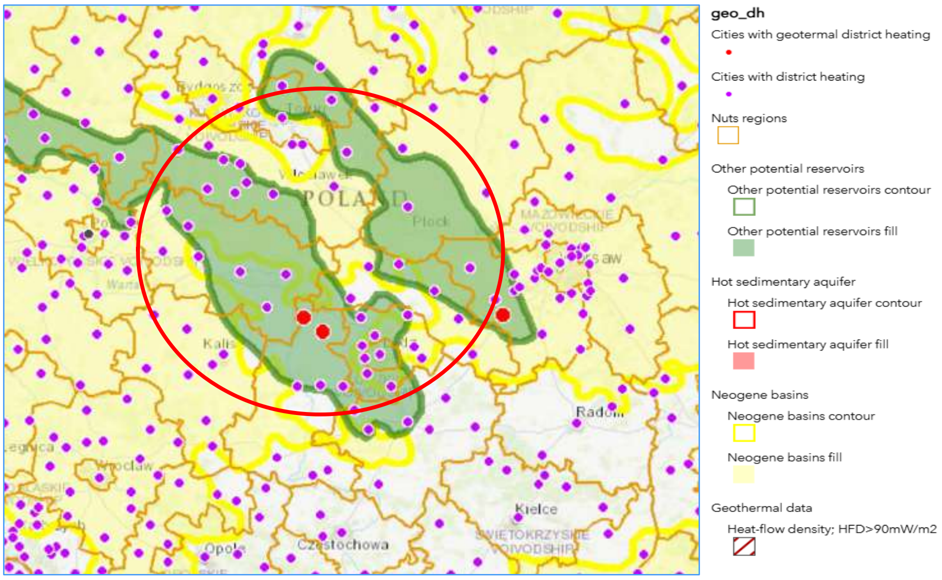


Figure 15. REGION II Centre Poland (Poland), renewable heating resources from GeoDH database

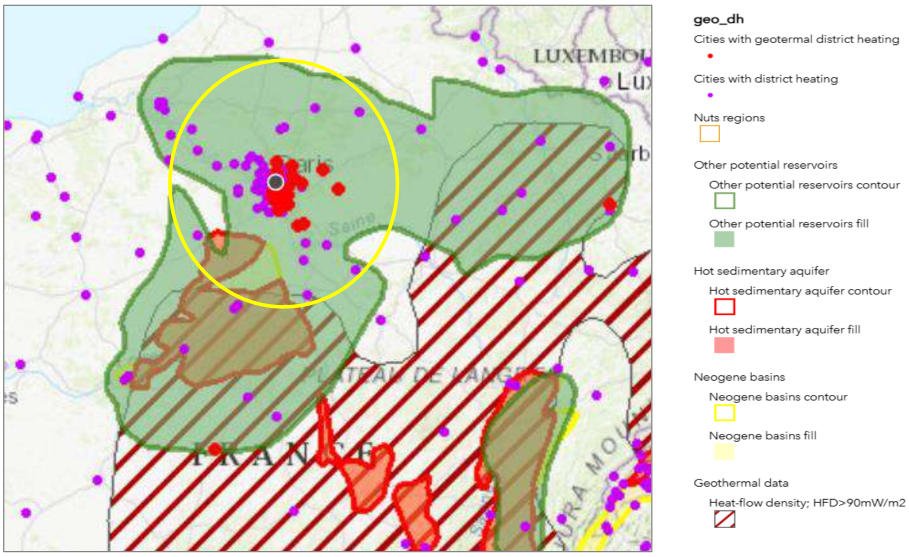


Figure 16. REGION III Ile-de-France (France=, renewable heating resources from GeoDH database

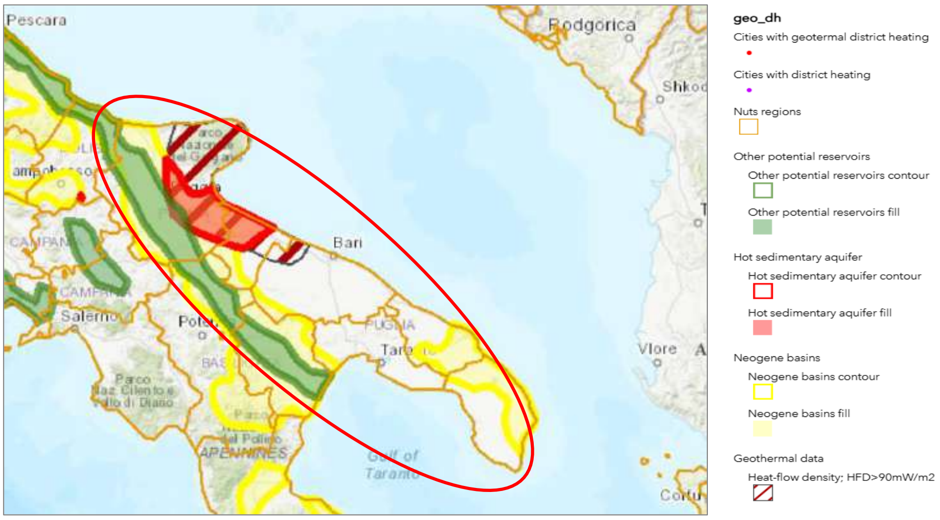


Figure 17. REGION IV Apulia Italy, renewable heating resources from GeoDH database

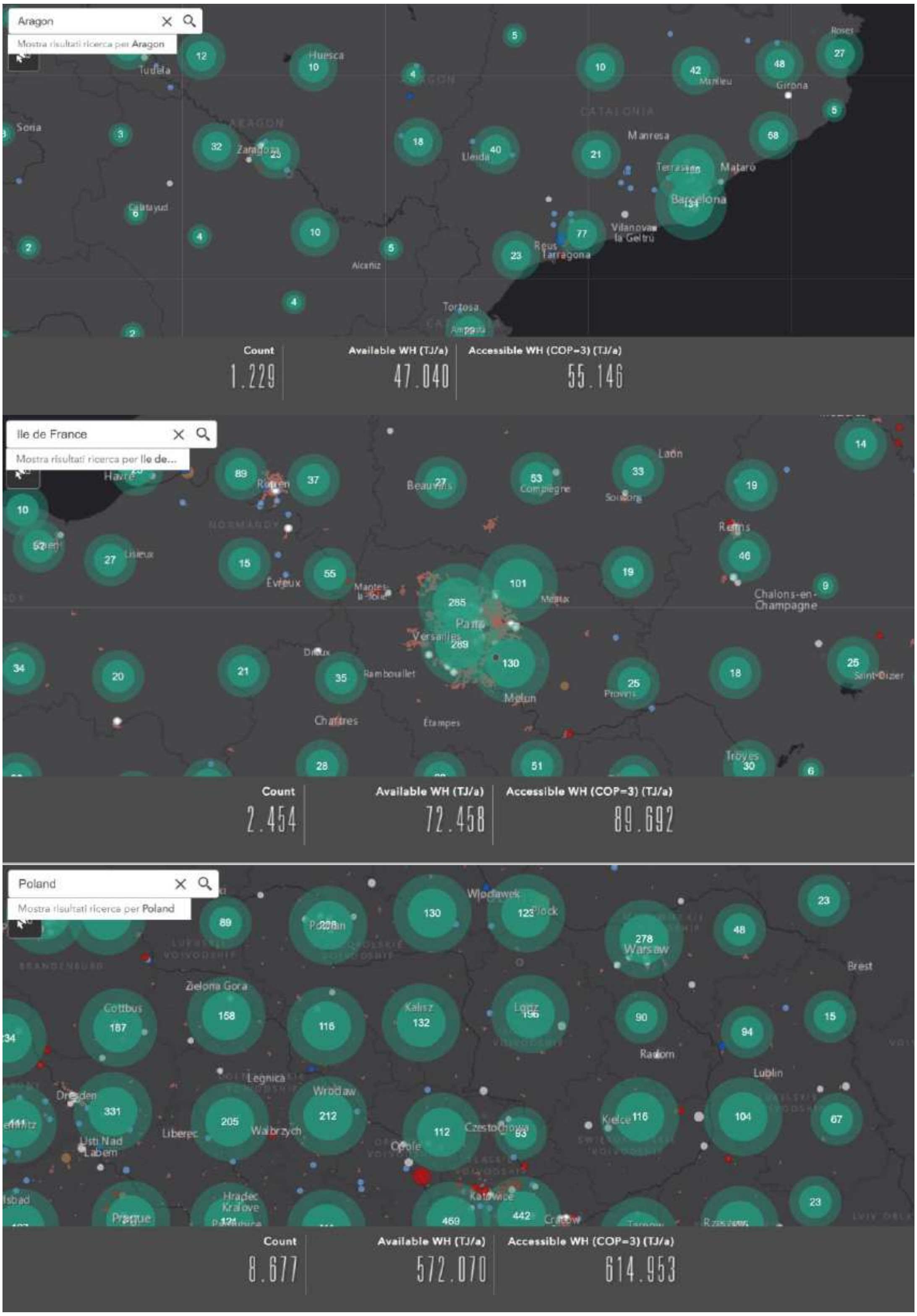
4.6.3 Waste heat Mapping: The Reuse Heat project

Waste heat occurs in almost all thermal and mechanical processes. Sources of waste heat include hot combustion gases discharged to the atmosphere, heated water released into the environment, heated products exiting industrial processes, and heat transfer from hot equipment surfaces.

The most significant amounts of waste heat are being lost in industrial and energy generation processes. The exact amount of industrial waste heat is difficult to quantify, but various studies have estimated that as much as 20 to 50 percent of industrial energy consumption is ultimately discharged as waste heat, and that between 18 and 30 percent of this waste heat could be utilized.

The **ReUseHeat** project has mapped European Union’s urban waste heat potential in a new map. This unique tool [66] displays all low-grade heat sources available in all European Union countries (UK included) and includes also industrial waste heat and heat from waste incineration plants [67].

For the assessment of the waste heat available to support a Fuels-C process it is possible to investigate the specific site and retrieve data about industrial waste heat sources, and their energy potential.



Aragon

Mostra risultati ricerca per Aragon

Count	Available WH (TJ/a)	Accessible WH (COP=3) (TJ/a)
1.229	47.040	55.146

Ile de France

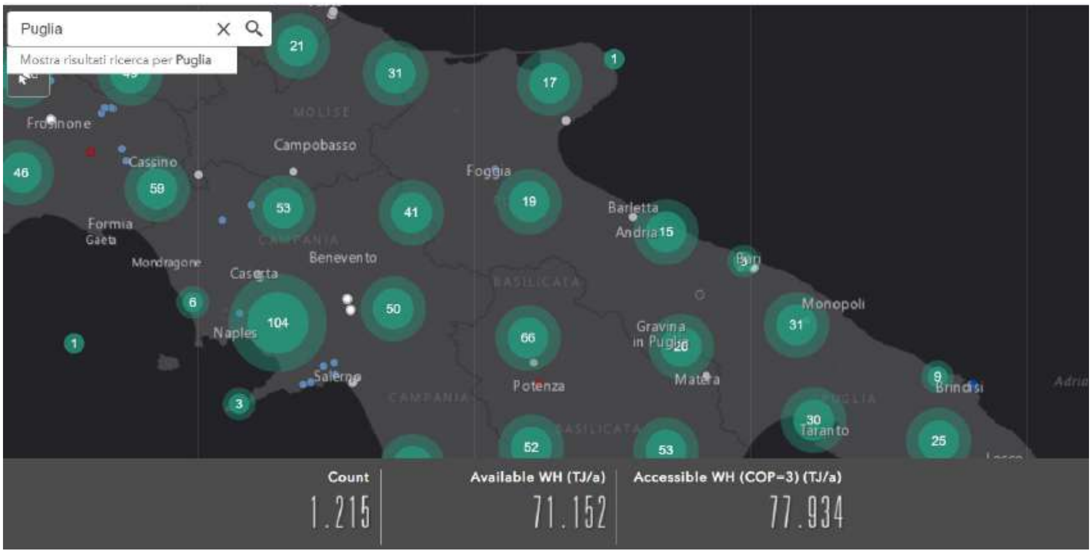
Mostra risultati ricerca per Ile de...

Count	Available WH (TJ/a)	Accessible WH (COP=3) (TJ/a)
2.454	72.458	89.692

Poland

Mostra risultati ricerca per Poland

Count	Available WH (TJ/a)	Accessible WH (COP=3) (TJ/a)
8.677	572.070	614.953



Count 1.215

Available WH (TJ/a) 71.152

Accessible WH (COP=3) (TJ/a) 77.934

Figure 18. Waste heat available on an annual basis according to the Reuse heat database for the selected regions

Sources of waste heat recovery considered by the REUSEHEAT tool include:

- WH from an industrial site
- WH from the data center
- WH recovery from the cooling towers in a hospital
- WH from sewage network
- WH from metro network (subways) recovery .

In the project, analyses of replicability and scalability were performed of the ReUseHeat demonstrators The urban heat recovery potential is large, it can meet 10% of the European heat demand for buildings. The largest excess heat volumes of the ReUseHeat sources comes from sewage water, the lowest from the food industry.

To identify accessible waste heat volumes and quality is important for Fuels-C processes. The utilization of urban excess heat can both reduce costs and the need for primary energy supplies and detailed study must be done based on the specific site identified.

4.6.4 Biomasses residues Mapping

An important resource that can be used not only to drive Fuels-C bio-fuel production processes, but that can also deliver relevant thermal energy inputs to improve the sustainability and efficiency of Fuels-C processes is the biomass residues, that can be available and contribute to the thermal need of the FUELS-C processes. Here in addition to the specific assessment of the feedstock suitable for the Fuels-C processes of the previous paragraph, is provided a further tool for the assessment of the biomasses residues available for thermal energy conversion.

The **S2Biom project** developed a tool that helps the assessment of such an energy source. The project aim is to support the sustainable delivery of non-food biomass feedstock at local, regional and pan European level through developing harmonized data sets for EU28, Western Balkans, Ukraine, Moldova and Turkey that can be accessed via this S2BIOM tool set.

The tools enable the user to interact with the results by making sub-selections for data of interest; or to design own biomass delivery chains and evaluate the performance; or to obtain the-point information on specific issues of relevance for developing biomass delivery chains.

In the following tables the potential contribution of biomasses in terms of energy per land surface (GJ/km^2) is reported for the 4 regions of interest (Northeast Spain, Ile de France, Poland Centre, Italy Apulia). Contribution of different residues are considered for each region.

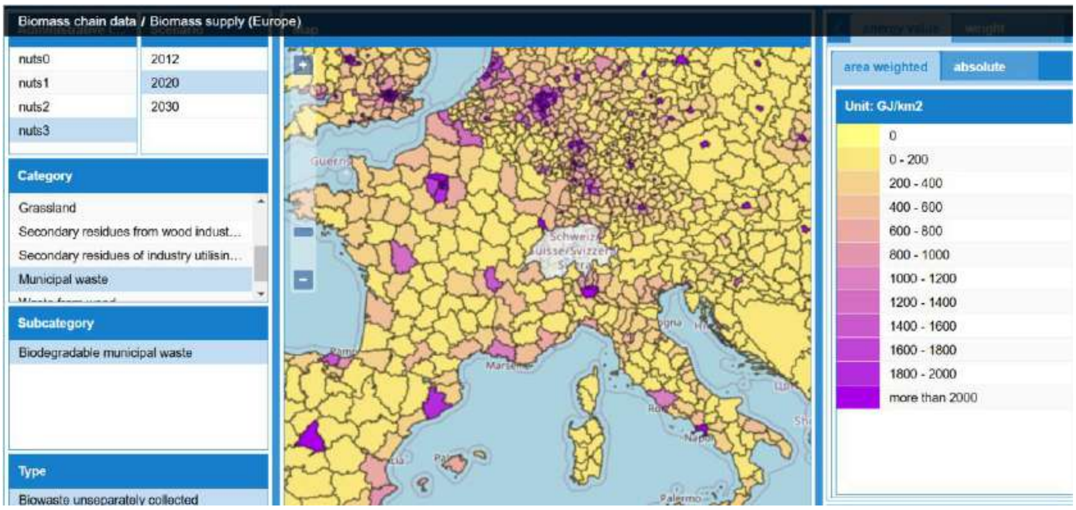


Figure 19. Biomass residues mapping tool S2Biom assessment of available biomasses for thermal energy

Table 4. Assessment of available biomasses for thermal energy

European Region	NorthEast Spain	Ile de France	Centre Poland	Italy Apulia
Units	GJ/km^2	GJ/km^2	GJ/km^2	GJ/km^2
Primary Residues from forest	20	80	40	10
Agricultural residues	400	1000	1000	50
Secondary residues from wood industry	20	30	40	20
Waste from wood	50	80	40	50
Municipal waste	500	2000	200	400
TOTAL	**990**	**3190**	**1320**	**530**

4.6.5 Renewable sources availability summary

Wrapping up the previous “source per source assessment”, it has been possible to recap the local RES potential as reported in the table below.

Table 5. Renewable energy potential availability for power and heating in the selected regions

Renewable nergy availability	PV roof 1 MWp MWh/y	Wind 1 MWp MWh/y	Geothermal available -	Biomasses for heat GJ/km^2
Region I Northeast Spain	1386	2000	yes	990
Region II Centre Poland	960	>2000	yes	3190

Region III Ile de France	1020	>2000	yes	3190
Region IV Apulia, Italy	1360	1800	yes	530

As previously introduced, a more detailed assessment (e.g. also looking at temperature levels, continuous/batch energy provision of each Fuels-C process and therefore potential integration of energy storage) could be realized once the overall Fuels-C fuel production processes are duly defined.
What is for sure relevant to highlight is that both looking at thermal and electric RES, all analyzed regions could have access to a proper amount of renewable energy sources. However, to effectively exploit them, it is important to make some considerations at general and at “case per case level”.

Looking at local Waste heat potential analyzed by REUSEHEAT tool as well as by S2BIOM biomass availability potential, it is important to underline that such values are based on high level estimation processes that do not fully take into account the real exploitability and constraints/barriers that could hinder the exploitation of such sources, as well as the real operating performances of such sources (e.g. temperature, easiness of access, continuity of delivery…).

Looking at wind potential analyzed by wind atlas, it is important to underline that such values are based not on real punctual wind monitoring campaign, but more on “wind generation/presence models”, thus the only way to effectively evaluate the wind potential of a spot is to conduct an anemometric campaign. Furthermore, such atlases do not consider physical constraint (natural or artificial related to urbanization or presence of civil infrastructure) to the effective realization of wind plants

Looking at geothermal potential, it is important to underline that such values do not consider the local ground stratification thus the real possibility to dig and install boreholes in the area.

Looking at residual biomass potential, it is important to underline that such values are not considering local regulatory constraints for the use of biomass for energy purposes or the presence of Natural Heritage areas as well as the need of “biomass regeneration” pathways and timing.

5.Conclusions

The selection criteria for selecting raw materials for Fuels-C technologies are key to selecting those that are most representative of the European Union, have great production potential and have no or a few recovery routes or recovery routes that provide little value and may even affect the environment.

The selection criteria identified as most important were the availability around different European regions and areas, their production potential and their physical-chemical characteristics.

The feedstocks for the gasification study were anaerobic digestate from WWTP, the plastic waste fraction from recycling plastic fraction from municipal waste, and woody remains from pruning fruit trees. For the case of anaerobic digestion, pig manure, WWTP sludge and wastewater from a candy industry were selected. In this way, raw materials of different origins and different composition have been selected, which will allow obtaining a wider range of results regarding the technology but will also allow studying the technical-economic viability of the Fuels-C solution in different conditions of raw material availability

The four European regions selected to analyze the techno-economic impact of the Fuels-C solution have been selected considering different boundary conditions related to feedstocks availability in the area. The main selection criterion was the type of raw material that is most abundant in each of the areas and that this was different between them. Region I corresponds to the north-eastern area of Spain where there is a high density of pig farms and therefore high availability of pig manure. Region II corresponds to the central area of Poland where there is a high density of forests and high production of forest biomass. The third region corresponds to Ille de France. Ille de France is a small area with high population density. This means that it has a high potential for raw materials of urban origin, such as urban wastewater and sludge, and municipal waste. The fourth region is Apulia, Italy, where there is a high concentration of woody biomass from the pruning of fruit trees. This selection therefore allows us to identify four areas in different European geographical points with different social, economic and climatic conditions. The study of the potential use of Fuels-C technology in these four very different regions will allow us to identify the best business and economic model for the Fuels-C solution according to the different conditions of specific European regions.

Respect to the assessment of renewable energy potential to support the Fuels-C project processes the selected regions show opportunity both for thermal and electric energy sources.

Looking at the reference cases identified by Fuels-C it is important to highlight some aspects per each of them:

- **ILE DE FRANCE**: being a quite urbanized area, it could complicate to get allowed to setup large scale ground-based PV or wind farms, thus the RES potential calculated via atlases should be somehow validated also looking at local land use maps.

- **APULIA:** recent Italian normative, limit the possibility to use agricultural areas for the setup of large-scale ground-based PV plants, thus the solar potential calculated via atlas should be somehow validated also looking at local cadastral and land use maps.

- **CENTRAL POLAND:** considering that the area is full of forests, the possibility of fully exploiting the local biomass potential must be counterchecked with local National Natural Heritage regulatory framework.

- **ARAGON:** the region is quite “Grid congested” from a RES integration point of view, thus the possibility to setup further large-scale RES electric power plants should take into account the eventual integration of energy storage at plant level.

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