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SCREENING OF BIOGENIC RESIDUES AND SETTING UP SUSTAINABLE SCENARIOS FOR COMMERCIAL BIOREFINERIES AROUND EUROPE

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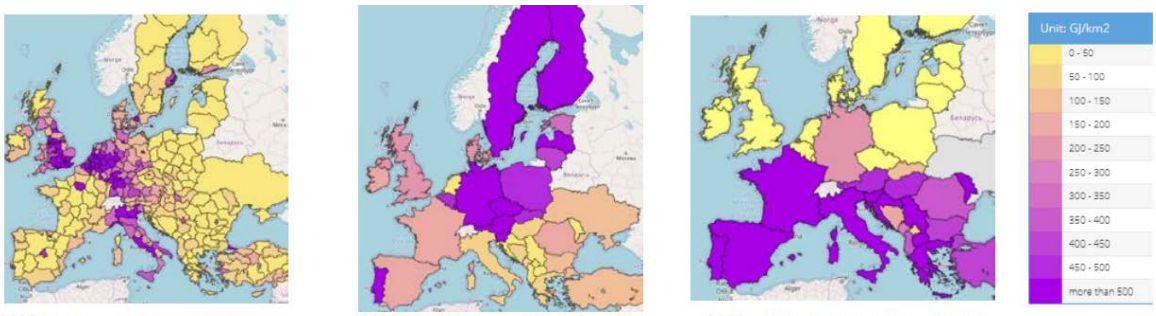
ABSTRACT
This paper presents a methodology for the development of commercial biorefinery case studies across Europe by implementing sustainable supply chains based exclusively on biogenic residues. An extended screening of biogenic residues around Europe was carried out, utilizing various available platforms and web tools and a general feedstock placement in terms of capacities has been performed. At least four types of feedstock that comply with the overall requirements (availability, sustainability, technical performance, market competitiveness) are selected and characterized. Based on the selected feedstock types four sustainable real-case scenarios were developed. Key factors for each developed case study were initially the strategic identification of suitable candidate locations for a commercial plant establishment and subsequently the calculation of an average feedstock supply cost. After, the mentioned case studies have been formed, it was investigated the impact of potential involvement of biogenic wastes as feedstock on the developed scenarios and in particular how the average feedstock price will be set. Wastes are considered as a very economical feedstock option, which is mainly attributed to the charged gate-fees that usually cover any required pre-treatment and logistics costs.
Keywords: Residual Biomass, Gasification, Biorefinery, Case-Studies, Biofuels

1. INTRODUCTION
In recent years, the interest for biofuels has increased concerning the global needs for sustainable energy. Gasification of biogenic residues becomes an attractive option for syngas production that can be utilized for subsequent biofuels production. Biogenic residues, such as agricultural residues, may be lower quality carbon sources compared to the sugar-, starch- and oil plants used for conventional liquid biofuels, but they do not come in conflict with food production and tend to avoid land use restrictions. Moreover, they are aligned with the EU's biofuels policy documented in the RED II directive, mentioning the promotion of residue based biofuels, or so-called advanced biofuels.

2. FEEDSTOCK SCREENING AND SELECTION
2.1. Screening of Biogenic Residues around Europe
An extended screening of biogenic residues capacities around Europe took place, utilizing the S2BIOM database (https://www.s2biom.eu/) and a general feedstock placement around Europe was performed. An attempt has been made to involve the most promising types of feedstock from each residual biomass category (forestry residues, agricultural residues, municipal wastes). In particular, the Mediterranean countries, always in respect of their size, present accumulations of both olive tree prunings and olive stones. A fact quite expectable, since Spain, Italy and Greece consist the top three olive producers in the world. Furthermore, these countries also specialized in the wine sector and this is the reason why the residues from vineyards come up with high numbers. Finally, the Mediterranean countries show particular fertility in the long season cultivations especially in wheat, barley, oats, rye and maize. One of the main reasons is the microclimate that prevails in these areas and ultimately creates these vast amounts of cereal straw (along with the cereal bran which in essence is a basic by-product of the food and fruit processing industry). Countries of Scandinavia and the Nordic Region are offered ideally for forest valorization. Forestry residues as well as residues from the wider wood industry (e.g. sawdust) are sourced in a potentially sustainable way. On the other hand, the grain sector is not as competitive as it is for the Mediterranean countries. The productivity of agricultural land differs somewhat from European growing conditions due to northerly location. Moreover, the productivity of agricultural land is weaker and the growing season is clearly shorter (Figure 1).



2030-Biodegradable municipal waste – Biowaste separately collected

2030-Primary residues from forests – Logging residues from final fellings & thinnings – conifer trees

2030 - Agricultural residues – Woody pruning & orchards residues – vineyards

Figure 1. 2030 technical potential energy value- area weighted (https://www.s2biom.eu/)

2.2. Feedstock Selection

The feedstock selection was based on the fulfilment of three main prerequisites: availability/sustainability i.e. capacities for large-scale applications, favorable technical characteristics (e.g. moisture, ash, heating value, etc.) and market competitiveness. Aiming to involve the widest possible spectrum of biogenic residues, and on the other hand, to maximize the territorial impact of the study by handling different feedstock and supply chains all around Europe the following types of feedstock have been selected:

- Olive and vineyard prunings from Greece & Spain respectively
- Cereal straw from Italy
- Forest residues from Finland
- Biogenic wastes all around Europe

Samples from each mentioned category were secured and characterized as presented in Table 1.

Table 1. Proximate analysis, Ultimate analysis and Calorific value - Olive and vineyard prunings, cereal straw and forest residue (d.b.: dry basis, N.D.: Not Detected)

Sample		Olive prunings (Greece)	Vineyard prunings (Spain)	Cereal straw (Italy)	Forest residue (Finland)
Parameter	**Units**	**Measured values**		**Given values**	
Ash	**% (d.b.)**	4.20	3.70	4.50	2.60
C	**% (d.b.)**	49.05	48.47	47.51	52.20
H	**% (d.b.)**	7.78	5.99	7.39	5.70
N	**% (d.b.)**	0.36	0.84	0.10	0.50
O	**% (d.b.)**	38.55	40.85	40.36	38.96
S	**% (d.b.)**	0.06	0.08	0.06	0.04
CL	**% (d.b.)**	N.D.	0.07	0.08	N.D.
High Heating Value	**MJ/Kg (d.b.)**	19.42	18.99	18.08	20.80
Low Heating Value	**MJ/Kg (d.b.)**	17.74	17.69	16.48	19.64

3. CASE STUDIES & FEEDSTOCK SUPPLY CHAIN DEFINITION

3.1. Methodological framework

The case studies, that are developed within this study, were largely based on the feedstock screening and selection presented in section 2. The first prerequisite for the development of the case studies is the tracking of locations that could potentially ensure the required feedstock capacities. The case studies were based on the hypothetical establishment of a 200 MWth plant, that corresponds to feedstock annual needs of

around 250 kt/year (considering LHV of 18-20 MJ/kg and annual operational time of 7500 h) (IFC 2017). It has to be mentioned that coastal areas have been preferred since they are easily accessible for low-cost massive feedstock transport (shipping) and strengthen the potential for synergies between different countries as well as future more sophisticated scenarios than those developed in the present document, which involve exclusively local road transport within the selected region. After electing the suitable locations with the required potential capacities, then an average feedstock supply cost should be estimated for each case study targeting an average cost of <10 €/MWh. The collecting/harvesting costs as well as the transportation costs are the two costs that basically form the final average feedstock price which will be used within the developed scenarios and are obtained with the assistance of BIORAISE GIS platform (http://bioraise.ciemat.es/Bioraise/). For the reliability of the results, these values are validated against literature data (Tzelepi 2020),(https://phyllis.nl/). After the mentioned case studies have been formed, it was investigated the impact of potential involvement of biogenic wastes as feedstock on the developed scenarios and in particular how the average feedstock price will be set. Wastes are considered as a very economical feedstock and this is mainly due to the gate-fees which are the fees charged by the operators of waste management facilities for disposal of received waste and usually cover any required pre-treatment cost (European Commmision 2020)

3.2 Scenarios development

The region of Peloponnese from Greece, a region in the south-east of Spain, a region of northern Italy as well as a part of south-west Finland have been identified as locations suitable to host a commercial BioSFerA-based biorefinery (Figure 2). The deep green coloring indicates that the mentioned regions ensure the required feedstock capacities (i.e. 250 kt/year). The case study of Greece was based on olive tree prunings. Peloponnese seems to be the biggest olive region in Greece and capable of covering the required amounts of feedstock. For the case of Italy, it was decided to focus on straw-derived residual biomass. It can be observed that the higher straw quantities can be found in areas of northern Italy, where the expansion of Po Valley (Pianura Padana) facilitates the cultivations. In particular, the sub-regions of Udine, Venezia, Pordenone were chosen to form the selected region for the Italian case study. For the case of Spain, it was selected to take advantage of the variety of permanent crops that are present in this country and mix prunings. In particular, the Spanish case study will be based on olive, vineyard and orchard prunings as well. The coastal territories of Granada, Almeria and Murcia offer great feedstock potential and favorable location. The case of Finland was based on logging and wood residues (e.g. bark, sawdust). The coastal areas of Satakunta, Varsinais-Suomi and Helsinki were preferred since their location let them 'communicate' with the Baltic states and in general have greater potential for synergies with central Europe rather than areas of central or north Finland.

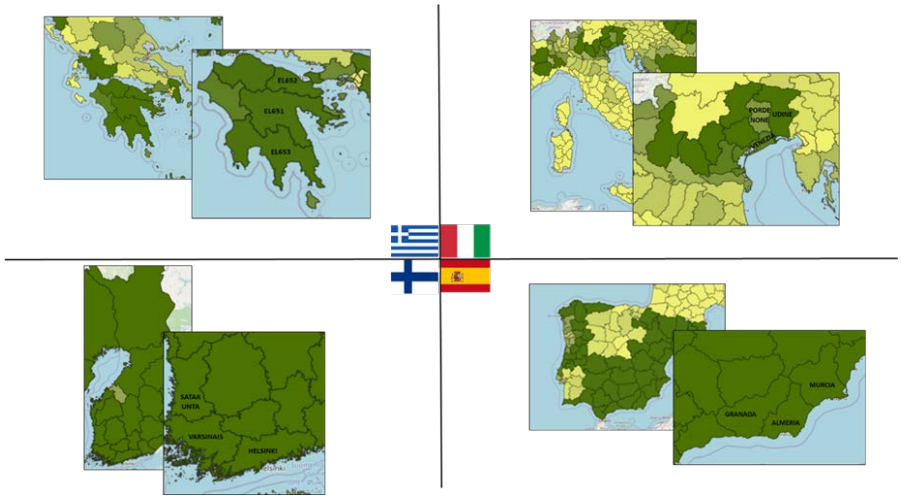
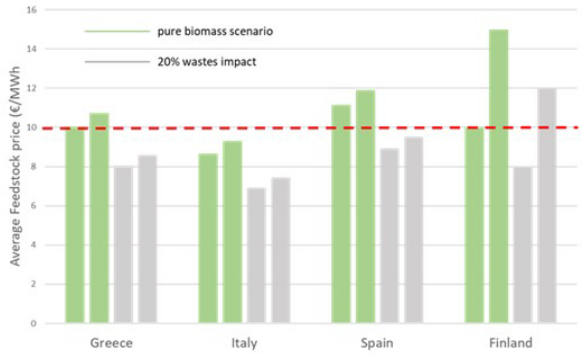


Figure 2. Identification of suitable candidate locations in terms of feedstock capacities according to 2030 expectations

4. RESULTS AND DISCUSSION

In order to ensure the financial sustainability of the assumed scenarios, the target of <10 €/MWh has been set for the average feedstock price of each case study. It can be observed in the following (Figure 3) that even with the most conservative predictions for the biogenic wastes (i.e. only 20% involvement & zero cost), the average feedstock price range of almost all the case studies falls below 10 €/MWh. Only the case of Finland remains a question mark, since the Finland biomass market is more mature and active in comparison to the other selected countries involving more stakeholders and consequently presenting higher feedstock price and demand.



Country	Greece	Italy	Spain	Finland
Feedstock	Olive prunings	Straw (cereal, maize stover)	Prunings (olive, vineyard)	Logging & wood residues
Region	Peloponnese	Udine	Granada	Helsinki
Estimated average feedstock price (€/MWh)	10.04 – 10.73	8.66 – 9.31	11.14 – 11.90	10 - 15
Average feedstock price with 20% biogenic wastes involvement (€/MWh)	8.03 – 8.58	6.93 - 7.45	8.91 – 9.52	8 - 12

Figure 3. Wastes effect in the average feedstock price of the developed scenarios

5. CONCLUSIONS

Within this study, an extended screening of biogenic residues across Europe was carried out and their ability to support a commercial plant (biorefinery) was assessed. The elected countries were Greece, Italy, Spain and Finland. Each assumed commercial scenario contained for each country the identification of suitable candidate locations in terms of feedstock capacities to host a 200 MWth plant as well as the calculation of an average feedstock cost for the selected region. The calculated feedstock costs for each case study were all around 10 €/MWh. Only the case of Finland can be characterized relatively unpredictable and this is due to the fact that Finland biomass market is more mature and involves more stakeholders in comparison to the other selected countries. However, in general the results can be regarded as encouraging and the biogenic wastes involvement seems able to further facilitate the economics of feedstock supply chains.

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