ROLE OF NATIONAL FOSSIL FUEL COMPARATORS IN THE NOMINAL EMISSION SAVINGS THROUGH BIOENERGY UNDER THE RED - CASE STUDY IN SIX EU COUNTRIES

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ABSTRACT: As part of the energy transition efforts, most bioenergy policies are strongly driven by the ambition to reduce greenhouse gas (GHG) emissions and substitute fossil fuels. The challenge is to properly select the fossil fuel “baseline” comparators for each form of bioenergy for any given national context. Based on existing literature as well as data and experiences gathered within EU co-funded research projects the paper presents the methodological approach for discussing the effect on nominal GHG emissions savings due to bioenergy under RED rules taking into consideration the national fossil fuels comparators. The paper assesses this effect in the 3-bioenergy markets (electricity, heating/cooling and transport) in Finland, Germany, Italy, Lithuania, the Netherlands and Poland. The paper assesses this effect for each sector separately without trying to compare them showing that project-specific and/or national fossil fuels comparators in the calculation of nominal GHG emission savings from bioenergy can have a more stimulating effect than generic EU comparators and the GHG reduction can be more accurately estimated depending on specific conditions in a country. The paper suggests that for including any other effects than CO_2 emissions, it is relevant to select appropriate indicators and use adequate comparators, with enough reference data, for those effects.
Keywords: bioenergy, climate-effectiveness, greenhouse gases, sustainability, energy transition, fossil fuel comparator, life cycle analysis

1 INTRODUCTION

The ‘Paris Agreement’ [1], signed at the 2015 Paris Climate Conference (COP21-CMP11) shows the international community’s commitment to combat climate change. The agreement aims at a global temperature increase remaining below 2oC and preferably even below 1,5oC. While the agreement is considered historic, it is also the starting point of a long transition process. Mitigation actions in the world’s energy systems require not only massive investments in energy efficiency and renewable energy, but also require substantial divestments in the fossil fuels sector, the goal of which is to eventually fully phase-out the use of fossil energy. In fact, to meet the climate objectives, several regions in the world would need to leave a certain share of their fossil fuel reserves ‘in the ground’; as suggested by [2]: “a third of oil reserves, half of gas reserves and over 80% of current coal reserves should remain unused from 2010 to 2050 in order to meet the target of 2oC.”

Climate change mitigation is one of the key drivers of renewable energy deployment in the EU. However, particularly in the use of biomass for energy there is an ongoing debate about its sustainability. Aside from the GHG emission impact, deployment of bioenergy can also cause harm to the environment and society in other ways than only the greenhouse gas effects. Hence, other negative impacts or trade-offs like food versus fuel, land use change, biodiversity impacts, need to be considered where possible, also depending on the availability of data for the reference cases. On the other hand, positive impacts or co-benefits provide a synergy for climate change action. The desire to enlarge the scope of climate change mitigation activities to sustainable development is still ongoing. The 17 UN Sustainable Development Goals (SDGs) of the 2030 Agenda for Sustainable Development are one of the most recent recognitions that climate change mitigation is linked to a wide range of other development objectives. The specific SDG on climate action is “Take urgent action to combat climate change and its impacts” (goal 13). The adoption of the Renewable Energy Directive (RED I) [3] in 2009 introduced a set of sustainability criteria on liquid and gaseous biofuels towards their contribution in the EU renewable energy targets. A threshold of GHG emission savings for biofuels and bioliquids in comparison with fossil fuels was set. The changes coming with RED II [4] extended the existing EU sustainability criteria for bioenergy to cover biomass and biogas for heating and cooling and electricity generation. The aim is to reach an 80% GHG savings versus the fossil fuel equivalent, applied to biomass used in heating/cooling and electricity sectors after 2021.

The reduction of GHG emissions has become one of the major political goals in environmental policy in recent years. To mitigate the effects of climate change, the EU has developed a set of policy initiatives. Under the EU’s 2020/2030 energy and climate policy frameworks [5], [6], and the 2016 Winter Package [7] each Member State committed to a binding target to limit GHG emissions.

The fossil fuel comparator is a critical variable for setting GHG reduction targets. The RED I guided the EU countries in the calculations of the impact of renewables in the GHG emission saving as well as the default and typical fossil fuels comparators. The calculation of this indicator assumes that energy generated from renewable energy sources would otherwise have been provided by a fossil energy mix showing the difference between assumed fossil emissions and the actual emissions. For the calculation of GHG emission savings by bioenergy the Commission recommended the EU countries to apply the same approach which has been set at the report from the Commission on the sustainability requirements on solid biomass and biogas in electricity and heating/cooling [8]. The use of default EU fossil fuel comparator has its benefits in terms of ease of use and monitoring and reporting. On the other hand, the use of national fossil fuel comparators or more project-specific fossil comparators both needs considerably more detailed information.

The main aim of this paper is to put under the same assessment basis the default and the national/specific fossil fuels comparators for different bioenergy pathways in electricity, heating/cooling and transport in countries as Germany, Italy, Lithuania, Netherlands, Poland and Finland. These countries have been part of an EU project called Bioteam, co-funded by the Intelligent Energy Europe from 2013 to 2016. The project was focused on 'Optimizing Pathways and Market Systems for Enhanced Competitiveness of Sustainable Bioenergy and Technologies in Europe' [9]. One of the outputs of this project was the creation of a short list of sustainability indicators. GHG emissions are ranked in the first position in the list of environmental indicators. According to RED I, in order to meet sustainability criteria, the GHG emissions from production of biofuels shall be less than fossil comparator.

There are three sets of fossil fuels comparators involved in this paper: (i) the EU fossil fuel comparators according to RED I and [8]; (ii) the national fossil fuel comparators according to [10] and [11]; the project specific comparators sourced by the European project Bioteam. The paper assesses the effect of these comparators for each sector separately not including any comparison. This paper aims also on seeing how results from the BIOTEAM project can be used to redefine and compile fossil fuel comparators from regional to the national level.

The paper is structured to present a short description on (i) the methodology approach followed by the EU countries to calculate their GHG emission savings due to renewables; (ii) the methodology and bioenergy pathways applied in this paper to discuss the climate-effectiveness of bioenergy and selection of fossil comparators. The paper presents and discusses specific results ending with some conclusions and recommendations.

2 BIOENERGY DEPLOYMENT IN SELECTED EU COUNTRIES

Italy and Finland have already exceeded their 2020 planned bioenergy use. Germany leads with nearly 19 Mtoe in 2017 (Table I). In the same year bioenergy in Italy reached almost 11 Mtoe, exceeding by 11.3% its 2020 plan. Over period 2010-2017 the fastest deployment of bioenergy among Bioteam countries took place in Lithuania with a CAGR of 4.7%. Netherlands followed with a CAGR of 2.5% together with Finland with a CAGR of 2.3%.

Table I: Bioenergy progress in selected EU countries (2010-2017) & 2020 plans (ktoe) – Source [12]

	DE	IT	LT	NL	PL	FI
2010	18501	9884	936	1711	6018	7424
2011	17701	7883	929	1838	6449	7032
2012	19775	9962	1015	1892	6692	7471
2013	20024	10501	1040	1837	6708	7828
2014	18658	9719	1101	1885	6449	8240
2015	18792	10612	1191	1926	6532	8138
2016	18561	10302	1227	1864	6467	8350
2017	18774	10930	1290	2033	6559	8727
2020	210801	9815	1295	3785	8280	8280

Solid biomass used for electricity and heating/cooling is the main source of bioenergy in Bioteam project countries with a share of 94% in Lithuania and Finland in 2017. Biogas has deployed faster in Germany with a share of 24% in its bioenergy in the same year. In Netherlands' bioenergy the share of biogas for electricity and heating/cooling had a share of 12.3%. In other countries the share of biogas in their bioenergy use stood at 9% in Italy, 3% in Poland, 1.6% in Lithuania and only 1% in Finland.

3 GHG EMISSION SAVINGS USING RENEWABLES IN SELECTED EU COUNTRIES

Since the entry into force of the Renewable Energy Directive (RED I) and the related national renewable energy action plans (NREAPs), renewables have already provided a strong overall contribution to GHG reduction.

The evidence on the role that renewables play in the reduction of GHG emissions are provided at each EU country progress reports. Fig. 1 illustrates the 2016 Bioteam countries ranking on the overall GHG emission savings using renewables sourced by their four sets of biennial progress reports.

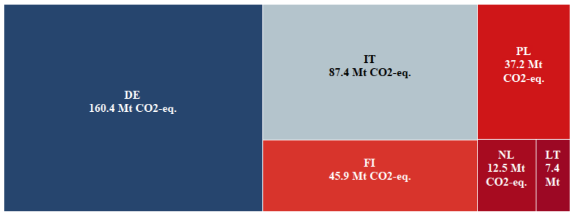

Figure 1: GHG emission savings using renewables, 2016 Source [13]

In 2016, the equivalent of 716 Mt CO2-eq was avoided for the EU area, using renewables. In this year, the countries included in the following analysis (Germany, Italy, Finland, Poland, Netherlands and Lithuania) have covered nearly 50% (350.5 Mt CO2-eq) of the overall EU GHG emission savings due to renewables. Germany remained the main contributor in the reduction of GHG emissions using renewables in three sectors.

As shown in Figure 2 renewable electricity deployment is the main source of GHG emission savings in Germany, Italy and Netherlands. The deployment of renewables in heating/cooling sector remains dominant for GHG emission savings in Finland, Poland and Lithuania.

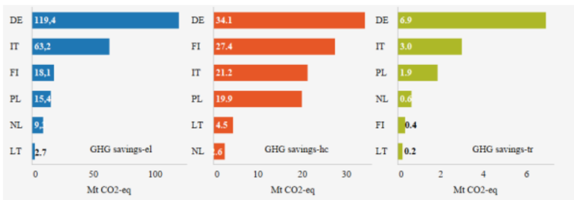

Figure 2: Breakdown upon sectors of GHG emission savings using renewables in selected countries Source [13]

In Germany the use of bioenergy brought in 2016 a GHG emission savings by 64.2 Mt CO2-eq, equal to 40% of overall GHG savings through renewables. The role of biomass was more distinguee in heating/cooling sector, covering 48% of overall GHG emission savings using bioenergy [14]. Some EU countries proved also a breakdown of these saving for each sector. For example, in Italy the role of biomass in reduction of GHG emissions in electricity sector almost three-folded between 2009 and 2016 (using the Life-cycle assessment (LCA) method). Biogas electricity almost 4-folded its contribution in the reduction of GHG emissions in Italian electricity sector, from 1 Mt CO_2-eq in 2009 to 3.8 Mt CO_2-eq in 2016. GHG emission savings using solid biomass electricity were estimated to have changed from 2.3 Mt CO_2 eq in 2009 to 3.5 Mt CO_2 eq. in 2016. In the heating and cooling, the role of solid biomass has been dominant in the reduction of GHG emissions from the use of biomass, changing from 8.8 Mt CO_2 eq. to 9.8 Mt CO_2 eq. (LCA method) [15].

The RED I firstly and then the RED II (recast) approaches are designed to facilitate the reporting on GHG savings through renewables considering to a range of factors. According the requirements set in the RED I the EU countries report on how the deployment of renewable energy impact the reduction of GHG emissions. The fossil fuel comparator is a very important variable for the calculation of GHG reduction targets.

The RED I defined how the EU countries had to proceed in the calculation of net GHG emission saving using renewables. The methodology suggested by RED I is as the following:

• For biofuels: In accordance with Article 22(2) of RED.
• For electricity and heat: It is suggested to use the EU wide fossil fuel comparators as set out in the report on sustainability requirements for the use of solid and gaseous biomass sources in electricity and heating/cooling.

If a Member State chooses not to use the suggested methodology for estimating the net greenhouse gas emission savings, please describe what other methodology has been used to estimate these savings. In several cases, the Member States did not report which methodology they applied: seven Member States did not report the methodology applied for electricity, heating and cooling and eight Member States did not report the methodology applied for biofuels. Most Member States decided to develop and apply their own methodology for the calculation of net GHG emission savings in electricity (17 Member States out of 28) and heating and cooling (15 out of 28) sectors. In the case of biofuels, only 11 Member States developed a different methodology of what was suggested in the RED I [10].

Table II shows if any of six EU countries under the analysis in this paper has followed the suggested or its own methodology to calculate its GHG emission savings through renewables.

Table II: Countries methodologies to calculate GHG emission savings due to RES (2009 – 2016)

		DE	IT	LT	NL	PL	FI
El.	COM(2010)11					X	
	MS Method	X	X		X		X
HC	COM(2010)11					X	
	MS Method	X	X		X		X
Tr	Annex V RED		X			X	X
	MS Method	X			X		

In Italy the emission factors of the upstream phase of bioenergy's have been obtained from the standard values shown in Annex V of RED for the different types of bioliquids (including biofuels) and from the standard values listed in UNI-TS-11435 for the different types of biogas and for solid biomass. Germany and Netherlands apply their own methods (owns fossil fuels comparators) to calculate the GHG emission savings through renewables in all sectors. Lithuania does not provide any information on the choice of the method used for the calculation of GHG emission savings through renewables. Poland follows the suggested RED I method for these calculations whereas Finland applies the Annex V fossil fuels comparators only in transport sector [10], [11].

4 METHODOLOGY – BIOENERGY PATHWAYS

Assessing the role of bioenergy (or other forms of renewable energy) in the GHG emission savings requires a transparent quantification of these emissions that: a) are created in the process and b) avoided through substitution of fossil fuels. For a bioenergy project the GHG emissions related to the production process (e.g. biomass cultivation or biomass transport) are subtracted from the GHG emissions saved from the avoided use of fossil fuels. The selection of an appropriate 'fossil comparator' (or baseline) is crucial for this.

The debate on proper selection and monitoring of a fossil baseline is not new. There exists a wide-array of reports and guidebooks on baseline determination, -monitoring and –standardization [16], [17], [18]. The range of methodological approaches for baseline determination (e.g. project-specific baselines, multi-project baselines, performance standards), suggests that this is a choice variable. Standardized baselines (or default comparators) are typically used to minimize the transaction costs (e.g. monitoring, accounting and verification). Table III presents the fossil fuels comparators for biomass sources (solid, gas and liquid) as defined in Annex V of RED I (and RED II) and [8].

Table III: Fossil fuels comparators liquid, solid and gaseous biomass (Mt CO_2-eq./MJ)

	Annex V RED I & COM (2010) 11		Annex V RED II	
	Liquids biomass	Solid & gaseous biomass	Liquid biomass	Solid & gaseous biomass
Transport	83.8	-	94	
Electricity	91	198		183
Heating	77	87		80
Cogeneration	85	-		
Cooling	-	57		

For the analysis presented in this paper the three fossil comparators described previously are used to discuss the potential variance in the climate-effectiveness of different bioenergy pathways for electricity, heating and transport. Table IV shows the three sets of fossil fuels comparators for the six EU countries in the three sectors used in our analysis. Only fossil fuel comparators for solid and biogas biomass in electricity and heating/cooling sectors and biofuels in transport sector are used in the analysis presented in this paper.

Table IV: Fossil fuel comparators for bioenergy in electricity, heating/cooling and transport (gCO2-eq. / MJ)

Electricity	DE[26]	IT[27]	LT[25]	NL[28]	PL[29]	FI[24]
EU comparator	198	198	198	198	198	198
MS PRs comparator[1]	164-216	156-169	n.a	163.9	198	95.1-81
Project specific[2]	342	135.3 -187	90.8	271.4	225.6	93.1
Heating Cooling	DE	IT	LT	NL	PL	FI
EU comparator	87	87	87	87	87	87
MS PRs comparator	48-84	n.a	n.a	63	87	74
Project specific[2]	95.2	48-99 (86.3)	108.6	58	96.8-123.4	93.7-94.7
Transport	DE	IT	LT	NL	PL	FI
EU comparat	83.8	83.8	83.8	83.8	83.8	83.8
MS PRs comparator	38[3]-40[4]					
Project specific [2]	(110[5]/112[6])	84.3[6]	99[6]/72.9[5]	89.1[5]/87.1[6]	84.3[5]/78.9[6]/62.6[7]	84.3[6]

The first set of fossil fuels comparators is taken from Annex V of RED I and [8]. The fossil fuels comparators are calculated by using data reflecting the average mix of fossil fuels used in the entire EU to produce one kWh electricity, one GJ of heat, etc. It is assumed that using renewable energy sources for these purposes are fully carbon neutral and do thus not affect the emissions per kWh, per GJ heat, etc.

The second set of fossil fuel comparators is taken from a JRC research report [10], an assessment based on data reported by EU countries in their 1st and 2nd set of biennial progress reports covering period 2009-2012, and the 3rd and 4th sets of EU countries progress reports. These fossil fuels comparators will be referred here as EU Member States progress report comparators (abbreviated as EU MS PRs comparators). The fossil fuel comparators on the national level, as provided by the EU Member States, most often reflect a country-specific value. To report the GHG savings from renewable energy source (RES) deployment, EU countries were given some degree of flexibility in selecting the fossil comparator for various renewable energy options for heating, electricity and transport (see section 2).

The third set of fossil comparators taken from the Bioteam project in which a series of Life Cycle Analyses (LCAs) for bioenergy for electricity, heating and transport in six EU countries was conducted based on a common methodology [19].

The following bioenergy pathways in the Bioteam countries are selected:

Germany

- Solid pathway - Wood pellets for domestic heating and biomass CHP plant using as Fossil energy baseline the natural gas and German electricity mix;
- Liquid pathway - Biodiesel from rape and, bioethanol from crop and sugar beet using as Fossil energy baseline the fossil diesel and fossil gasoline;
- Gas pathway - Biogas from maize and biomethane from maize using as Fossil energy baseline the natural gas and German electricity mix.

Italy

- Solid pathway - Heat production from small-scale wood chip boilers; Wood-based district heating; Pyro-gasification of wood chips and CHP using as Fossil energy baseline the natural gas and gasoil;
- Liquid pathway - Second generation bioethanol from wheat straw using as Fossil energy baseline the fossil gasoline;
- Gas pathway - Biogas from manure and maize silage for electricity and biogas from municipal solid waste for CHP using as Fossil energy baseline the natural gas.

Lithuania

- Solid pathway - Wood-based CHP and wood pellets for household heating using as Fossil energy baseline the natural gas;
- Liquid pathway - Bioethanol from grain and biodiesel from rapeseed using as Fossil energy baseline the fossil gasoline and fossil diesel;
- Gas pathway - Industrial and agricultural residues for biogas and wastewater sludge for biogas using as Fossil energy baseline the natural gas.

Netherlands

- Solid pathway - Imported wood pellets for electricity prod. in co-firing power plants and wood chips for district heating using as Fossil energy baseline the hard coal and natural gas;
- Liquid pathway - Used cooking oil for biodiesel production and biomethanol production from glycerin using as Fossil energy baseline the fossil diesel and fossil gasoline;
- Gas pathway - Agro-food residues for biomethane and mono-manure digestion for biomethane using as Fossil energy baseline the natural gas.

Poland

- Solid pathway - Wood pellets for domestic heating and biomass CHP plant using as Fossil energy baseline the light fuel oil and Polish electricity mix and coal;
- Liquid pathway - Biodiesel from rapeseed and bioethanol from maize using as Fossil energy baseline the fossil diesel and fossil gasoline;
- Gas pathway - Biogas from maize for CHP and compressed biomethane for transport from landfills using as Fossil energy baseline the natural gas and Polish electricity mix and coal.

Finland

- Solid pathway - Wood-based district heating and wood-based CHP plant using as Fossil energy baseline the light fuel oil and heavy fuel oil;
- Liquid pathway - Bioethanol from barley and

bioethanol from straw using as Fossil energy baseline the fossil gasoline;

- Gas pathway - Biogas from wastes and residues and municipal waste-based biogas using as Fossil energy baseline the Finnish electricity mix and the heavy fuel oil.

5 RESULTS

The net impact in the GHG emissions is calculated as a difference between the selected bioenergy pathway GHG emissions and the GHG emissions that would have been released by the fossil fuels substituted by the bioenergy feedstocks' or the fossil fuel comparator.

Net GHG impact = Pathway GHG emissions – GHG emissions of avoided fossil energy (comparator)

The following sections show the net GHG impacts (expressed in gCO2-eq./MJ of final energy) for selected bioenergy pathways for electricity, heating/cooling and transport.

5.1 Bioenergy net GHG impact in electricity sector

The comparison shows that depending on the fossil comparator used, the net GHG savings effect of a standard biomass-to-electricity option could be three times higher in one country relative to another. To determine the climate-effectiveness of bioenergy, it is important to specify the type of fossil fuels that is going to be substituted and thus defining which comparator will be the most appropriate. The assessment of the climate-effectiveness of bioenergy does not result in generally applicable results. Given that EU countries typically have a differently structured electricity system, with a different energy mix and electricity grid configuration, therefore also the location of the substituted fossil fuel matters. To build on this notion, an European (international) strategy that aims for a high level of climate effectiveness (i.e. high net GHG savings) could, for example, be tailored to trigger market operators to first phase out the use of the most GHG intensive forms of fossil fuels in the most polluting facilities in the EU. Such a strategy requires a coordinated effort at the EU level to pro-actively phase-out fossil-fuels from the energy mix, instead of maintaining a dynamic mix with fossil fuels included.

Table V illustrates the fossil fuels comparators for chosen bioenergy pathways in Germany electricity sector: EU average comparator; Germany's fossil fuel comparators as reported in its 2013 progress report and Bioteam project fossil fuel comparators.

Table V: Fossil fuels comparators for chosen pathways in Germany (gCO2-eq. / MJ)

Pathway	EU comparator	MS PRs comparator	Project specific comparator
DE1-wood chips biomass CHP	198	216	342
DE2- biogas from maize	198	194	342

Figure 3 illustrates the impact of selected fossil fuel comparators for chosen bioenergy pathways in Germany's electricity sector. The Bioteam fossil fuel comparator assumes that less lignite will be used for electricity production in Germany resulting in higher net GHG emission savings using this comparator. The use of the other two fossil fuel comparators is based on avoiding the use of respectively an EU mix and national mix of fossil fuels for electricity production, resulting so in a lower calculated net GHG impact.

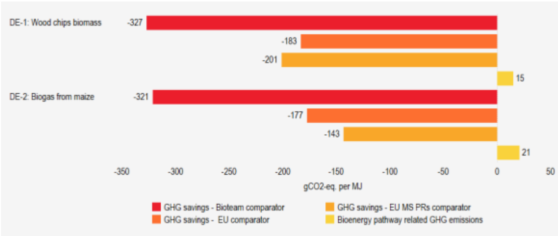

Figure 3: The impact of selecting an appropriate fossil comparator for electricity in Germany (gCO2-eq./MJ)

Table VI shows the three sets of fossil fuels comparators used in the following assessment. As shown by the table Poland is applying the suggested methodology to calculate the GHG emission saving using RES, whereas Netherlands and Finland apply their own national fossil fuels comparators. In the cases of Poland and Netherlands the Bioteam fossil fuels comparators are higher than other two sets of comparators.

Table VI: Fossil fuels comparators for chosen pathways in Poland, Netherlands and Finland, (gCO2-eq. / MJ)

Pathway	EU comparator	MS PRs comparator	Project specific comparator
PL1-wood chips CHP electricity	198	198	225.6
PL2- biogas from maize CHP electricity	198	198	225.6
NL1- imported wood pellets cofired	198	163.8	271.4
FI1-Biogas from waste and residues	198	95.1	93.1

Figure 4 shows for illustration purposes the net GHG impact of a selection of biomass to electricity pathways in Finland, Poland and the Netherlands.

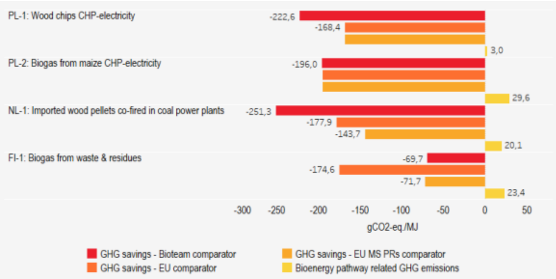

Figure 4: The impact of an appropriate fossil fuel comparator in Finland, Poland and the Netherlands (gCO2-eq./MJ)

As shown in both Figure 3 and 4 and as expected, the largest net GHG savings arise when the project specific fossil comparators are used. The figures show that implementing bioenergy options that come at the expense of using lignite (i.e. less use of lignite) have the highest GHG benefits. Knowing that the two German bioenergy pathways are considered to reduce the use of lignite, it is not surprising to observe that the highest climate-benefits can be achieved here. Also, for the Dutch bioenergy pathway, the used wood pellets come at the expense of the use of imported hard coal (anthracite) in a relatively old (and therefore less efficient) coal-fired power plant.

Observed net GHG saving variations are considerably lower when the EU default comparator is used. Hence, when using this comparator, from a GHG perspective the EU internal energy market is essentially indifferent where phase-out occurs first, and which type of fossil energy (e.g. lignite coal, anthracite coal, domestic natural gas, imported natural gas) is phased-out first, whilst there is considerable scope and reason to begin fossil phase-out with the most polluting types of fossil energy and the most inefficient electricity production facilities. The results show that within the EU there is enough potential to maximize the GHG emission reduction efforts, and hence the climate-effectiveness of EU renewable energy policies by adopting an EU level strategy aiming for a phase-out the most polluting forms of fossil energy and shut down the most inefficient installations.

5.2 Bioenergy net GHG impact in heating/cooling sector

Table VII illustrates the fossil fuel comparators used for chosen Polish bioenergy pathways. Since Poland applies the suggested methodology for the calculation of GHG emission savings from renewables, the fossil fuel comparators used are those of EU and BIOTEAM project.

Table VII: Fossil fuels comparators for chosen pathways in Polish heating sector, (gCO2-eq. / MJth)

Pathway	EU comparator	Project specific comparator
PL1-wood chips CHP heat	198	225.6
PL2- biogas from maize CHP heat	198	225.6
PL3- wood pellets for domestic heating	198	271.4

Figure 5 illustrate the impact of using the three sets of fossil fuels comparators in the selected bioenergy pathways.

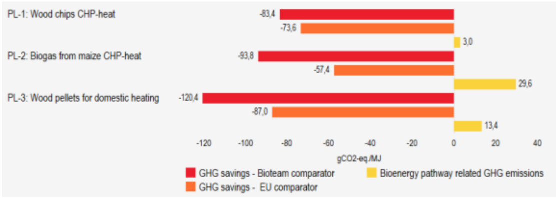

Figure 5: The impact of an appropriate fossil fuel comparator for heating in Poland (gCO2-eq./MJth)

For Poland, the project-specific comparator (123.4 gCO2-eq./MJ) implies the highest GHG reduction for bioenergy for heat options, while it is the lowest for the Netherlands and Italy (resp. 58.01 and 48 gCO2-eq./MJ).

The variation in GHG saving potential when using the other fossil comparators (EU default or EU MS PRs) is much lower. The project-specific comparator assumes that less coal will be used for heat production and therefore results in the highest GHG emission savings.

When the use of the EU comparator is applied it is assumed that a certain mix of fossil fuels for heat production, including also natural gas, takes place. Figure 6 shows the net GHG impact of a sample of biomass to heat pathways for Germany, Finland, Poland and the Netherlands.

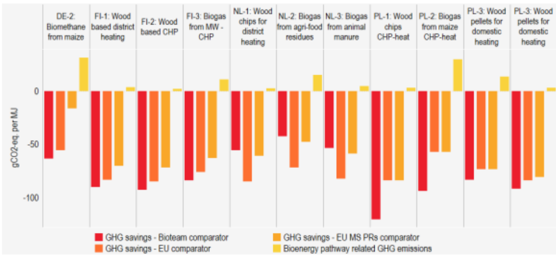

Figure 6: The impact of an appropriate fossil fuel comparators in some EU countries (gCO2-eq./MJth)

The large variation in net GHG savings for heating shows that throughout the EU there is enough scope for enhancing the climate-effectiveness of biomass for heating options. The largest net GHG savings are typically achieved when bioenergy substitutes coal or fuel oil for heating. This is the case for Poland and Finland. It is interesting to observe that the project-specific comparator for example for the Netherlands is lower than the EU (default) or the EU MS PRs comparator. This is mainly because in the Netherlands natural gas is substituted and this has a more moderate GHG impact compared to coal or fuel oil.

5.3 Bioenergy net GHG impact in transport sector

Table VIII illustrates the fossil fuel comparators for biofuels pathway in Netherlands. The calculation of GHG emissions saved as a result of using biogasoline and biodiesel in the Dutch transport sector have been calculated from a combination of data from the energy statistics of CBS and data from the Dutch Emissions Authority (NEa) on GHG performance of biogasoline and biodiesel placed on the market.

Table VIII: Fossil fuels comparators for chosen pathways in Netherlands transport sector, (gCO2-eq. / MJ)

Pathway	EU comparator	Project specific comparator
NL1-biodiesel from UCO	83.8	89.1
NL2-Biomethanol from glycerine	83.8	87.1

The NEa received these data from companies that supply biogasoline and biodiesel under the laws and regulations on renewable energy for transport and the laws and regulations on fuels and air pollution [20].

It must be noted that in most cases the EU MS PRs comparator was equivalent to the EU default comparator.

For reporting the GHG savings of the transport sector at the national level many EU countries appear to have chosen to use the EU default comparator values rather than to calculate a country-specific comparator [10]. The variance between the EU default and BIOTEAM fossil comparator values shows that there is enough scope to stimulate the market to phase out fossil fuel-based transport fuels of more polluting origin. In the Dutch case, the project specific comparator results in a higher GHG savings for biofuels for transport both for diesel and gasoline. Fig. 7 illustrates the impact of selected fossil fuels comparators in Netherlands transport sector for the chosen bioenergy pathways.

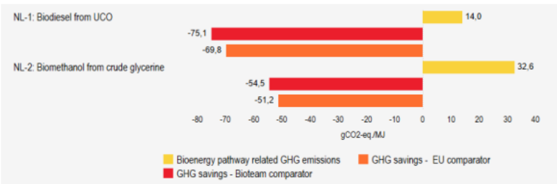

Figure 7: The impact of an appropriate fossil comparator for transport in the Netherlands (gCO2-eq./MJ).

6 DISCUSSIONS

It is expected (hypothesis) that national comparators can have a more stimulating effect on GHG savings more than generic EU comparators. With national level fossil fuel comparators, instead of EU level comparators, the GHG reduction can be more precisely calculated depending on specific conditions in a country such as the efficiency of power production. The impact on emissions does not consider soil carbon depletion, or indirect effects such as ILUC, or carbon debt, and does not evaluate climate impact. Any other impacts than direct GHG emission savings will be considered in the discussion section.

6.1 Future changes of fossil fuel composition

Determining the project-specific comparator for transportation fuels is largely depending on the type of fossil fuel involved. It matters for the GHG emissions savings, whether diesel or gasoline is used, although these differences are rather small: about 4 gCO2-eq./MJ (section 4.3). However, those differences are significant when compared to the differences observed in the sections on electricity and heating (section 4.1 and 4.2).

Furthermore, new fossil fuels are coming on the market. These fuels could be more polluting, especially for fuels produced from unconventional oil reserves, like shale-based transport fuels, tar sands, imported natural gas from unconventional sources (e.g. fracking) or imported LNG and so more specific fossil fuel comparators for transport are likely to be needed in the near future.

The EC proposal for calculation methods and reporting requirements to the quality of petrol and diesel fuels [21], already incorporates a more differentiated approach for establishing fossil comparators for transport, as listed in Table IX, acknowledges that more differentiation in terms of comparators is needed to properly reflect the real GHG impact of a given fossil fuel.

Table IX: Life cycle GHG intensity of fossil fuels (gCO_2-eq./MJ)

Raw material source and process	Fuel or energy type placed on the market	Life cycle GHG intensity	Weighted life cycle unit GHG intensity
Conventional crude		93.2	
Natural Gas-to-Liquid		94.3	
Coal-to-Liquid	Petrol	172	93.3
Natural bitumen		107	
Oil shale		131.3	
Conventional crude		95	
Natural Gas-to-Liquid		94.3	
Coal-to-Liquid	Diesel or gasoline	172	95.1
Natural bitumen		108.5	
Oil shale		133.7	

Such a default comparator is typically far from reality, as in Germany for example the energy mix is different than in Portugal. Effectively the EU comparator ensures that the same biogas (e.g. manure co-digestion with maize) project in Germany has the same ‘climate performance’ as in Spain or Italy. Of course, given the different energy mixes in these countries we know that the climate performance of that biogas plant is different. What might be wanted is that the higher the climate performance of the bioenergy project, the more investments it attracts. For this one needs more context specific comparators (either national ones or project specific ones).

6.2 Any other effects than GHG emissions

The UN's 13th Sustainable Development Goal is "take urgent action to combat climate change and its impact". Next to GHG emissions, other negative impacts or trade-offs like food versus fuel, land use change, biodiversity impacts, need to be considered where possible, depending on the availability of data for the reference cases. So far, the focus of substituting fossil fuels by renewables is on the GHG effects, putting less attention to other non-climate factors. While the need and urgency for highly climate-effective development strategies is widely recognized, there is also a wide-range of other 'non-climate' impacts related to implementing renewable energy and phasing out fossil fuels. Such social, economic or environmental impacts can aid or frustrate the transition process.

Substantial anticipated employment losses can be considered a barrier or trade-off for countries to proactively phase-out coal, oil or gas. Also, the net effect of the transition on emissions of local pollutants to air, water soil and other non-climate impacts can influence the social acceptance of specific mitigation technologies.

For example, a bioenergy plant that is 'only' good for saving GHG emissions, but is causing an increase in air polluting emissions, could face serious public opposition.

Also, an expected increase in local noise levels (e.g. more traffic movements due to biomass transport) or odour emissions (e.g. biomass storage) can result in a poor social acceptance at the local level of a given mitigation option. Furthermore, a recent research [22] shows that the water footprint for bioenergy production is strongly depending on the type of biomass used. This is relevant nowadays, considering that many renewable energy projects face implementation difficulties for example due to poor social acceptance [23]. Proper appreciation of co-benefits and trade-offs will aid both local and national actors in deciding which options best contribute to the sustainable development objectives in their own region.

7 CONCLUSIONS

This paper explores the 'climate-effectiveness' using three different type of fossil comparator. The net GHG savings performance of various bioenergy options for electricity, heating, and transport is compared when considering (i) an EU default comparator, (ii) a national comparator and (iii) a project-specific comparator.

The results clearly show that a more project-specific comparator tends results in the highest net GHG savings.

Particularly those bioenergy options that result in a substitution of coal (e.g. lignite or anthracite), or fuel oils can obtain high net GHG savings. Other fossil comparators tend to be based on energy mixes (e.g. grid average) and hence do not always trigger market operators to stimulate a phase-out of the most GHG intensive forms of fossil energy.

There are some drawbacks of not using an EU-default comparator to calculate GHG savings of a renewable energy initiative. Firstly, a more project or country specific approach typically puts a higher burden of proof on the entity claiming the GHG savings performance (i.e. higher transaction costs). Proper monitoring, reporting and verification (MRV) needs to be in place to be able to make a credible claim that a specific fossil fuel is substituted. Setting up a reliable MRV program at the project level is often more costly, relative to GHG related MRV being done at the aggregate EU level.

Using a project or country initiative's net GHG savings as the single most important proxy for a projects' performance generally does not do full justice to its real contribution to other development ambitions (e.g. employment creation, local regional development, air quality or other Sustainable Development Goals within the EU (e.g. (SWD(2016) 390 , 2016c)).

Based on the Bioteam project efforts considering the experience of participated countries on compiling their national fossil comparators we conclude the following:

- Within the EU it is needed to have the existing fossil fuel comparators for the calculation of GHG emission reduction redefined from the EU level to at least the national level. Applying national level (or project-specific) fossil fuel comparators, instead of EU level default comparators, the GHG reduction can be more accurately estimated depending on specific conditions in a country such as the efficiency of power production. This is because the real substitution effect can be more accurately determined.
- The above analysis showed that national and project-specific comparators can have a more stimulating effect on GHG savings more than generic EU comparators, especially in areas with more GHG intensive energy systems that run on coal, oil and natural gas.
- The costs related to estimating, monitoring and verifying the fossil comparator are expected to increase proportionately when a more case-specific fossil comparator to the project is applied.
- Depending on the fossil comparator used, the net GHG savings effect of a standard biomass-to-electricity option could be three times higher in one country relative to another.
- The large variation in net GHG savings in heating/cooling sector shows that throughout the EU there is enough scope for enhancing the climate-effectiveness of biomass for heating options. The analysis shows that there is sufficient scope to stimulate the market to phase out fossil fuel-based energy of more polluting origin.
- The results for electricity and heating/cooling sectors depend heavily on the specific fossil and nuclear fuels that the renewable energy sources replace. The emissions balance for the use of biomass also depends on the nature and provenance of the raw materials.

8 NOTES

(1) [10]; [11]
(2) [24]; [25]; [26]; [27]; [28]; [29]
(3) Biodiesel
(4) Bioethanol
(5) Diesel
(6) Gasoline
(7) Compressed Natural Gas (CNG)

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