NNFCC

The Bioeconomy Consultants

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NNFCC is a leading international consultancy with expertise on the conversion of biomass to bioenergy, biofuels and bio-based products.

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1 Background

The recent Bioenergy Strategy highlighted the importance of bioenergy delivering significant GHG emissions reduction, and that reductions would need to tighten over time to reflect the UK's ambitions to 2020 and 2050. However, the responses to the RO Banding Review consultation from industry set out that any changes to the GHG target would need to be stepwise, realistic and agreed well in advance.

In September 2012 DECC released a consultation on biomass electricity and combined heat and power plants – ensuring sustainability and affordability which included the proposals to enhance the sustainability criteria for the use of biomass feedstocks under the RO. The proposals included formally linking criteria with eligibility for support, tightening the GHG target for new dedicated biomass from 2013 and tightening the GHG targets for all biomass electricity from 2020. The consultation proposed the following GHG trajectories, subject to the ability of the supply chain to deliver the future reductions:

- New dedicated biomass at 240 $kgCO_{2eq}$/MWh, potentially reducing to 200 $kgCO_{2eq}$/MWh in 2020,
- Existing dedicated biomass accredited before April 2013 at 285.12 $kgCO_{2eq}$/MWh, potentially reducing to 200 $kgCO_{2eq}$/MWh in 2020, and
- Coal plants converting to or co-firing with biomass at 285.12 $kgCO_{2eq}$/MWh reducing to 240 $kgCO_{2eq}$/MWh in 2020.

The consultation requested evidence to inform the setting of the GHG emissions target between 2020 and 2025, specifically data relating to potential improvements in transport, harvesting and processing, energy use, innovation in feedstock type and performance, fertiliser use, and generation efficiencies at power plant. The Government expects that between 2020 and 2037 GHG targets may be further tightened to reflect the 2050 pathway.

1.1 Scope

NNFCC are providing technical support for the development of a GHG trajectory for biomass electricity to assist DECC in forming its consultation response. The aim of this project was to:

- Evaluate the range of life cycle GHG emissions for current feedstocks used in the UK,
- Assess the potential for future improvements in GHG savings, and
- Analyse the possible impacts on industry if more stringent standards are introduced.

2 Methodology

NNFCC were asked to assess the impact of tightening the GHG emissions trajectory for biomass electricity in 2020, 2025 and potentially 2030, subject to sufficient data being available. The main tasks necessary to achieve this were as follows:

- Task 1: Evaluate the range of lifecycle GHG emissions for current feedstocks used in the UK
- Task 2: Assess the potential for future improvements in GHG savings
- Task 3: Analyse possible impacts on industry if more stringent standards are introduced

This summary report presents GHG emissions ranges for a number of priority biomass supply chains in 2012, comparing the default biomass supply chains modelled in the UK Solid and Gaseous Biomass Carbon Calculator (BCC) with data provided by industry stakeholders, and estimates the potential GHG emissions reductions which may be achieved in 2020 and 2030. It presents specific findings for coal plant conversions and dedicated biomass plants based on consultation responses, discussions with project developers and supported by the scenario analysis.

2.1 Priority biomass supply chains

A list of priority biomass supply chains is presented in Table 1. This feedstock list is based on the Ofgem Sustainability Report for biomass electricity generation in 2011/12[1], and on NNFCC and DECC's understanding of other feedstocks likely to be important over the next 20 years.

Forest resides include branches, tops, bark, and small diameter whole trees removed during forest thinning activity. As residues, the GHG emissions associated with the establishment and cultivation of the forest are excluded from the lifecycle GHG emissions calculation. For the purpose of this analysis all forest residues are approximated to one supply chain, as the industry data received does not provide sufficient detail to distinguish between these different sources it is therefore appropriate to make this grouping.

Round wood may be sourced from short rotation or long rotation forestry. Short rotation forestry refers to fast-growing species harvested on 8 to 20 year rotations, where the species is dependent on the region. Long rotation forestry refers to conifer or broadleaf forest with an average age of greater than 20 years. Long

[1] Ofgem, Sustainability Report on biomass fuelled generating stations for 2011-12 obligation period dataset, available at http://www.ofgem.gov.uk/Pages/MoreInformation.aspx?docid=366&refer=Sustainability/Environment/RenewablObl/FuelledStations/ro-sustainability

rotation forestry would typically be harvested for a range of markets, including sawlogs for timber production, not entirely for biomass feedstock.

The BCC includes default values for the establishment of short rotation forests, but not for long rotation forestry. The forest establishment inputs, including fertiliser use are referenced to CONCAWE, JRC, and REAP, Canada. Forest establishment default values for long rotation forestry may be included in subsequent versions of the BCC, however, consultation responses and discussions with industry have highlighted the difficulty in gathering data on forest establishment and highlights that these estimates should be made on a regional basis and default values are the only practical way forward if these are to be included. Due to the available information, we have approximated round wood to short rotation forestry. The supply chains labelled as short rotation forestry (SRF) refer to round wood and whole trees not classed as forest residues or forest thinnings.

It should be noted that, information gathered from project developers emphasises forest residues as the primary feedstock.

Table 1: Priority biomass supply chains

Form	Biomass type	Origin
Wood chip	• Forest residues • Round wood	• North America • Europe • UK • Brazil
Wood pellet	• Forest residues • Round wood	• North America • Europe • UK • Brazil
Wood briquettes	• Forest residues	• Europe • UK
Bales	• Straw	• UK
Chips	• Miscanthus • SRC	• UK
Pellets	• Miscanthus • SRC	• UK
Pellets	• Olive cake • Palm Kernel Expeller	• Europe • Malaysia

2.2 Task 1: Current life cycle GHG emissions

The BCC, data supplied by industry stakeholders, and other references, were used to identify the supply chain parameters with greatest impact on lifecycle GHG emissions. This has informed the scenario analysis which provides range estimates for appropriate feedstock categories for coal plant conversions and dedicated biomass plants. The assumptions, input data, and results have been supplied to DECC as a spreadsheet. The results are presented in Section 3.1

2.3 Task 2: The potential for future improvements in GHG savings

A review of previous research into supply chain improvements and potential innovations in transport emissions, including in shipping and inland transport has been completed to identify possible measures for reducing lifecycle GHG emissions. Assumptions relating to the carbon intensity of supply chain parameters in 2020, 2025 and 2030 have been made (Annex 1), and the GHG emissions estimated for each priority biomass supply chain in 2020, 2025 and 2030.

2.4 Task 3: Possible impacts on industry

NNFCC have reviewed consultation responses and discussed directly with project developers the risks associated with a tightening GHG emissions trajectory, strategies to mitigate the associated risks, and the impact on project development for coal plant conversions and dedicated biomass plants. These observations are summarised in Section 3.3

2.5 Headline assumptions

The headline assumptions used for the GHG calculations within this task:

- Biomass power generation: The conversion efficiency for biomass electricity is modelled at 30 – 37%, with a central value of 33%, in line with the expected performance of UK biomass power plants, including dedicated and co-firing.

The following factors are excluded from the scope of this report:

- Land use change: No land use change emissions are included as it is assumed that any additional biomass resource will be grown on land of low carbon stock.
- Indirect land use change: Under the RO biomass power generators are not required to include iLUC emissions in the GHG emissions reporting. iLUC factors are not included within the analysis, although the EC are developing methods for including iLUC impacts.
- Carbon debt: A number of consultation responses referred to the methodology for accounting lifecycle GHG emissions for biomass, stating that the current methodology fails to account for the length of time taken for carbon dioxide emissions released when biomass is burnt to be removed from the atmosphere by new biomass growth. This issue is not discussed with in the report.

3 Results

3.1 Task 1: Current lifecycle GHG emissions

The lifecycle GHG emissions for the default biomass supply chains embedded in the BCC are presented in Table 2 for each of the priority biomass supply chains. Figure 1 illustrates the contribution of each stage of the supply chain to lifecycle GHG emissions per tonne of wood pellet.

Lifecycle GHG emissions are lowest for UK derived feedstocks. For these supply chains the greatest contribution is potentially drying when this is fuelled by fossil fuels. Compared to biomass drying, fossil fuel drying adds 45 – 77 $kgCO_{2eq}$/tonne for forest residue pellets, and up to 276 $kgCO_{2eq}$/tonne for short rotation forestry pellets, due to the higher energy input for short rotation forestry. For biomass supply chains utilizing biomass drying, the greatest contribution to life cycle GHG emissions is forest establishment, in the case of short rotation forestry, and harvesting in the case of forest residues, the next greatest contribution is from pelleting. Total lifecycle GHG emissions for these supply chains are calculated to be 105 $kgCO_{2eq}$/tonne, equivalent to 82 $kgCO_{2eq}$/MWh, at 33% plant conversion efficiency.

For European pellets, drying is also potentially the greatest contribution to life cycle GHG emissions, with fossil fuel drying adding up to 79 $kgCO_{2eq}$/tonne for forest residue pellet and up to 283 $kgCO_{2eq}$/tonne for short rotation forestry pellet. For biomass drying supply chains, post processing transportation to the UK is a significant contributor, assuming road transport. Other significant contributions come from harvesting in the case of forest residues and forest establishment in the case of short rotation forestry, and pelleting. For supply chains with biomass drying, lifecycle GHG emissions are calculated to be 148 – 154 $kgCO_{2eq}$/tonne, equivalent to 115 – 119 $kgCO_{2eq}$/MWh, at 33% plant conversion efficiency.

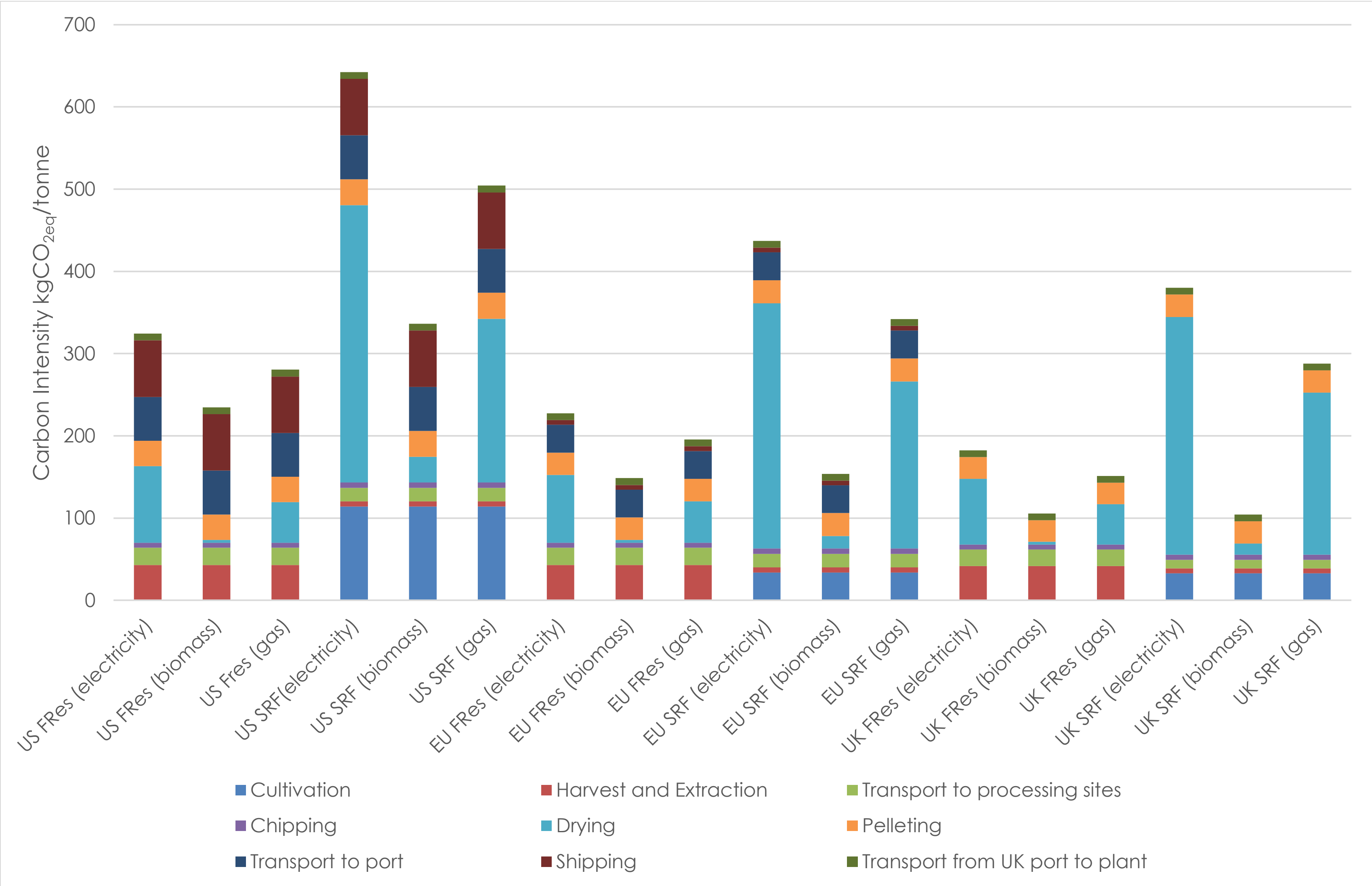
For US supply chains, drying is again the greatest contributor to lifecycle GHG emissions where fossil fuel fired drying is employed, electrical drying is particularly high due to the high carbon intensity of the electricity grid. For supply chains employing biomass drying, the greatest contributor to life cycle GHG emissions is post-processing transportation of pellets to the UK, accounting for 122 $kgCO_{2eq}$/tonne. For these supply chains lifecycle GHG emissions are estimated at 235 – 336 $kgCO_{2eq}$/tonne, equivalent to 182 – 261 $kgCO_{2eq}$/MWh. Notably the GHG emissions associated with SRF establishment are higher than in Europe, this is due to the assumed fertilizer inputs based on REAP Canada references for 1999. The Nitrogen application rates are more than three times that assumed for the UK.

Table 2: Carbon intensity of biomass electricity based on the default supply chains included in the Solid and Gaseous Biomass Carbon Calculator, reference year 2012

Feedstock type	Feedstock type	Origin	Drying	Fuel carbon intensity kg CO_{2eq}/tonne	Electricity carbon intensity kg CO_{2eq}/MWh		
					30%	33%	37%
Woodchip	Forest residues	North America	Natural drying	192	199	181	162
Woodchip	Forest residues	Europe	Natural drying	97	101	92	82
Woodchip	Forest residues	UK	Natural drying	63	65	59	53
Woodchip	Short rotation forestry	North America	Natural drying	246	256	232	207
Woodchip	Short rotation forestry	Europe	Natural drying	89	93	84	75
Woodchip	Short rotation forestry	UK	Natural drying	43	44	40	36
Pellet	Forest residues	North America	Woodchip	235	201	182	163
Pellet	Forest residues	North America	Natural gas	280	239	217	194
Pellet	Forest residues	North America	Electricity	324	277	251	224
Pellet	Forest residues	Europe	Woodchip	148	126	115	102
Pellet	Forest residues	Europe	Natural gas	195	166	151	135
Pellet	Forest residues	Europe	Electricity	227	194	176	157
Pellet	Forest residues	UK	Woodchip	106	90	82	73
Pellet	Forest residues	UK	Natural gas	151	129	117	104
Pellet	Forest residues	UK	Electricity	182	155	141	126
Pellet	Short rotation forestry	North America	Woodchip	336	287	261	233
Pellet	Short rotation forestry	North America	Natural gas	504	430	391	349
Pellet	Short rotation forestry	North America	Electricity	642	548	498	444
Pellet	Short rotation forestry	Europe	Woodchip	154	131	119	107
Pellet	Short rotation forestry	Europe	Natural gas	342	292	265	237
Pellet	Short rotation forestry	Europe	Electricity	437	373	339	302
Pellet	Short rotation forestry	UK	Woodchip	104	89	81	72

Pellet	Short rotation forestry	UK	Natural gas	228	195	177	158
Pellet	Short rotation forestry	UK	Electricity	380	324	295	263
Briquette	Forest residues	North America	Woodchip	268	229	208	185
Briquette	Forest residues	North America	Natural gas	314	268	244	217
Briquette	Forest residues	Europe	Woodchip	178	152	138	123
Briquette	Forest residues	Europe	Natural gas	225	192	175	156
Briquette	Forest residues	UK	Woodchip	135	115	105	93
Briquette	Forest residues	UK	Natural gas	180	154	140	125
Briquette	Short rotation forestry	North America	Woodchip	369	315	286	255
Briquette	Short rotation forestry	North America	Natural gas	537	458	417	372
Briquette	Short rotation forestry	Europe	Woodchip	183	156	142	127
Briquette	Short rotation forestry	Europe	Natural gas	371	317	288	257
Briquette	Short rotation forestry	UK	Woodchip	126	108	98	87
Briquette	Short rotation forestry	UK	Natural gas	172	147	133	119

Figure 1: Lifecycle GHG emissions per tonne of wood pellet, from each stage of the supply chain, based on default supply chains included in the Solid and Gaseous Biomass Carbon Calculator, reference year 2012



Through consultation responses and engaging directly with project developers, we have assessed the default values in the BCC. The number of detailed responses received has been very limited. However, some major discrepancies have emerged that have significant impact on the lifecycle GHGs.

The main impacts are:

- The majority of biomass supply chains use biomass drying
- The energy demand for pelleting is much higher than is assumed in the BCC
- Logistics from forest or field to processing plant
- Transport mode from port to biomass power plant

Data received primarily related to wood pellets from various locations including USA, Canada, Brazil, Europe, and Baltic States. Limited data was received relating to wood chips from several locations including the UK. Some submissions had used the BCC whilst others had used other lifecycle GHG calculation tools. Submissions varied in the number of default values used versus actual values. No data was received relating to energy crops or agricultural residues.

Default supply chains within the BCC most frequently assume that land transportation of feedstock is performed using the road network. However, it is clear from stakeholder feedback collected by NNFCC that biomass feedstock is expected to be transported via rail whenever this is feasible.

A sensitivity analysis was therefore undertaken comparing the impact of a modal shift from road to rail for all post-processing land transportation within biomass supply chains (Table 3). Modal shift had least impact on UK pellet supply chains, contributing to a less than 5% reduction in overall supply chain emissions. The benefit was greater for woodchip sourced from UK forestry in light of the greater estimation in transport distance attributed to this feedstock in the carbon calculator.

Greatest reductions in emissions as a result of modal shift were estimated for European supply chains. Use of rail could reduce supply chain emissions 17-24% as a consequence of long land transport distances in relation to those for sea. Modal shift could also substantially benefit US supply chains, reducing emissions 11-17%, and Brazilian supply chains, reducing emissions 12-14%.

Based on discussions with developers we have identified a number of specific regions for sourcing biomass feedstocks. The default supply chains from the BCC have been edited to estimate the carbon intensity of fuels from these regions, modifying transport distances and modes. The information received has been used to establish three scenarios for each biomass supply chain for coal plant conversions and for dedicated biomass plants (Tables 4 & 5). The scenario analysis includes forest residue pellets, saw mill residue pellets, SRF pellets, and for dedicated biomass plants also includes forest residue wood chips, SRC pellets, Miscanthus pellets, straw bales and straw pellets.

Figure 2 illustrates the GHG emission ranges for electricity generated from wood pellets at converted coal plants, assuming 33% conversion efficiency. The labelled series represents the central scenario. UK derived feedstocks achieve the lowest GHG emissions, followed by European pellets and short rotation forestry pellets from Brazil. Brazilian feedstocks perform well in part due to the low carbon intensity of the Brazilian electricity grid, such that even in high scenarios with very high electricity consumption, the Brazilian feedstocks achieve relatively low GHG emissions in comparison to North American feedstocks.

All feedstocks modelled can meet the current target of 285.12 $kgCO_{2eq}$/MWh, with the exception of short rotation forestry pellets, that are not classed as forest residues. Under central supply chain assumptions, short rotation forestry pellets will not meet the current target. Under high supply chain assumptions, with longer and more carbon intensive transport modes, and higher electricity demand, North American pellets derived from forest residues may also fail to meet the current GHG emissions target.

Figure 3 illustrates the GHG emissions associated with a range of wood chips and wood pellet supply chains, and UK energy crops and agricultural residues. Under the central supply chain assumptions there are a wide range of UK, European, Brazilian and North American feedstocks achieving GHG emissions of below 285.12 $kgCO_{2eq}$/MWh. North American pellets from short rotation forestry may find it difficult to meet the current target. Under high supply chain assumptions, both wood chips and pellets from North American forest residues may not meet the current target.

Compared to the GHG emissions estimates included in DECC's Impact Assessment, the GHG emissions associated with energy crop pellets are lower in this analysis, due to the assumption that biomass drying is employed. Straw feedstocks were assumed to be an agricultural reside, and therefore the crop establishment inputs are not allocated to the straw, as outlined in the RED GHG calculation methodology.

Table 3: Impact of a modal shift from road to rail for all land based transport on lifecycle GHG emissions

Supply Origin	Feedstock		Reduction	Carbon Intensity kg CO_{2eq}/MWh
North America	Forest residues	Woodchip	16.5 %	151
North America	Forest residues	Pellet	16.0 %	153
North America	SRF	Woodchip	12.9 %	202
North America	SRF	Pellet	11.2 %	232
Europe	Forest residues	Woodchip	22.3 %	72
Europe	Forest residues	Pellet	17.4 %	95
Europe	SRF	Woodchip	24.3 %	64
Europe	SRF	Pellet	16.7 %	100
Brazil	SRF	Woodchip	12.0 %	180
Brazil	SRF	Pellet	13.6 %	152
UK	Forest residues	Woodchip	13.2 %	51
UK	Forest residues	Pellet	4.7 %	78
UK	SRF	Pellet	4.6 %	79

Table 4: Scenarios for wood pellet supply to converted coal plants

		Low	Central	High
North America	Pellet energy	360 MJ/tonne, 0.062 kgCO_{2eq}/MJ	530 MJ/tonne, 0.145 kgCO_{2eq}/MJ	860 MJ/tonne, 0.062 kgCO_{2eq}/MJ
	Transport to port	320 km, rail	630km, rail	630km, road
	Shipping	3,000 N miles, panamax	5,000 N miles, panamax	9,000 N miles, panamax
	Transport to plant	100km, rail	100km, rail	100km, road
Europe	Pellet energy	360 MJ/tonne, 0.128 kgCO_{2eq}/MJ	530 MJ/tonne, 0.128 kgCO_{2eq}/MJ	860 MJ/tonne, 0.128 kgCO_{2eq}/MJ
	Transport to port	160km, rail	400km, rail	400km, road
	Shipping	200 N miles, panamax	1,000 N miles, panamax	1,500 N miles, panamax
	Transport to plant	100km, rail	100km, rail	100km, road
UK	Pellet energy	360 MJ/tonne, 0.131 kgCO_{2eq}/MJ	530 MJ/tonne, 0.131 kgCO_{2eq}/MJ	860 MJ/tonne, 0.131 kgCO_{2eq}/MJ
	Transport to plant	100km, rail	100km, rail	100km, road
Brazil	Pellet energy	360 MJ/tonne, 0.022 kgCO_{2eq}/MJ	530 MJ/tonne, 0.022 kgCO_{2eq}/MJ	860 MJ/tonne, 0.022 kgCO_{2eq}/MJ
	Transport to port	500 km, rail	500km, rail	500km, road
	Shipping	3,000 N miles, panamax	5,000 N miles, panamax	5,000 N miles, panamax
	Transport to plant	100km, rail	100km, rail	100km, road

Table 5: Scenarios for wood and energy crop chips and pellets to dedicated biomass plants

Wood Pellets		Low	Central	High
North America	Pellet energy	360 MJ/tonne, 0.062 $kgCO_{2eq}$/MJ	530 MJ/tonne, 0.145 $kgCO_{2eq}$/MJ	860 MJ/tonne, 0.062 $kgCO_{2eq}$/MJ
	Transport to port	320 km, rail	630km, rail	630km, road
	Shipping	3,000 N miles, panamax	5,000 N miles, handymax	9,000 N miles, handymax
	Transport to plant	0	0	0
Europe	Pellet energy	360 MJ/tonne, 0.128 $kgCO_{2eq}$/MJ	530 MJ/tonne, 0.128 $kgCO_{2eq}$/MJ	860 MJ/tonne, 0.128 $kgCO_{2eq}$/MJ
	Transport to port	160km, rail	400km, rail	400km, road
	Shipping	200 N miles, panamax	1,000 N miles, handymax	1,500 N miles, handymax
	Transport to plant	0	0	0
UK	Pellet energy	360 MJ/tonne, 0.131 $kgCO_{2eq}$/MJ	530 MJ/tonne, 0.131 $kgCO_{2eq}$/MJ	860 MJ/tonne, 0.131 $kgCO_{2eq}$/MJ
	Transport to plant	100km, rail	100km, road	100km, road
Brazil	Pellet energy	360 MJ/tonne, 0.022 $kgCO_{2eq}$/MJ	530 MJ/tonne, 0.022 $kgCO_{2eq}$MJ	860 MJ/tonne, 0.022 $kgCO_{2eq}$/MJ
	Transport to port	500 km, rail	500km, rail	500km, road
	Shipping	3,000 N miles, panamax	5,000 N miles, handymax	5,000 N miles, handymax
	Transport to plant	0	0	0
Wood Chips		**Low**	**Central**	**High**
North America	Extraction and baling	100MJ diesel/tonne	330 MJ diesel/tonne	330 MJ diesel/tonne
	Processing			additional heat treatment
	Transport to port	320 km, rail	630km, rail	630km, road
	Shipping	3,000 N miles, panamax	5,000 N miles, handymax	9,000 N miles, handymax
	Transport to plant	0	0	0
Europe	Extraction and baling	100MJ diesel/tonne	330 MJ diesel/tonne	330 MJ diesel/tonne
	Processing			additional heat treatment
	Transport to port	160km, rail	400km, rail	400km, road
	Shipping	200 N miles, panamax	1,000 N miles, handymax	1,500 N miles, handymax
	Transport to plant	0	0	0
UK	Extraction and baling	100MJ diesel/tonne	330 MJ diesel/tonne	330 MJ diesel/tonne
	Processing			additional heat treatment
	Transport to plant	100km, rail	100km, road	100km, road
Brazil	Processing			additional heat treatment
	Transport to port	500 km, rail	500km, rail	500km, road
	Shipping	3,000 N miles, panamax	5,000 N miles, handymax	5,000 N miles, handymax
	Transport to plant	0	0	0
Energy crop pellets		**Low**	**Central**	**High**
UK	Pellet energy	360 MJ/tonne	530 MJ/tonne	860 MJ/tonne
	Transport to plant	100km, rail	100km, road	100km, road

Figure 2: GHG emissions ranges for biomass supply chains based on coal plant conversion scenarios in 2012. Feedstock sourced from North America (Red), Europe (Blue), UK (Brown) and Brazil (Green)

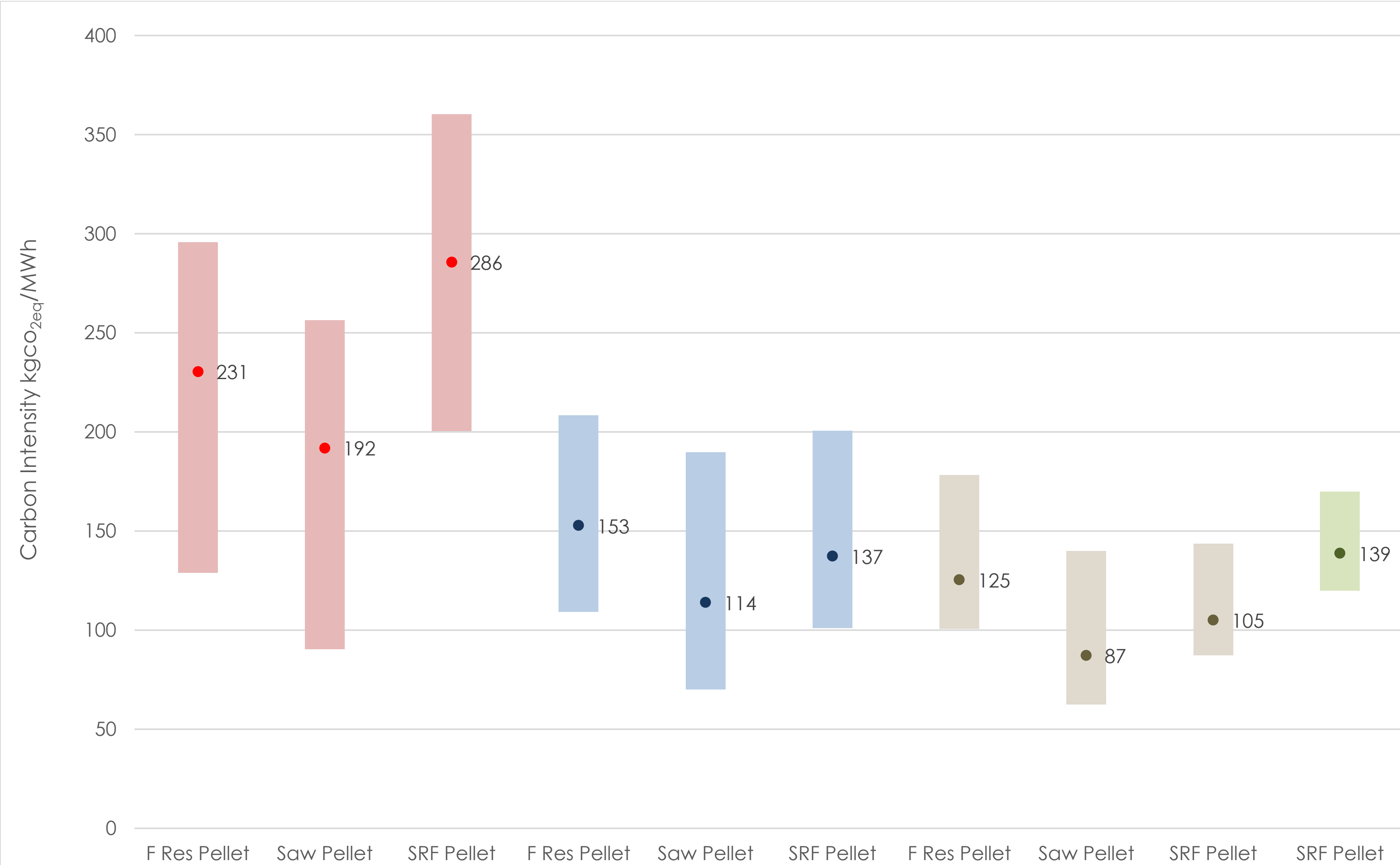
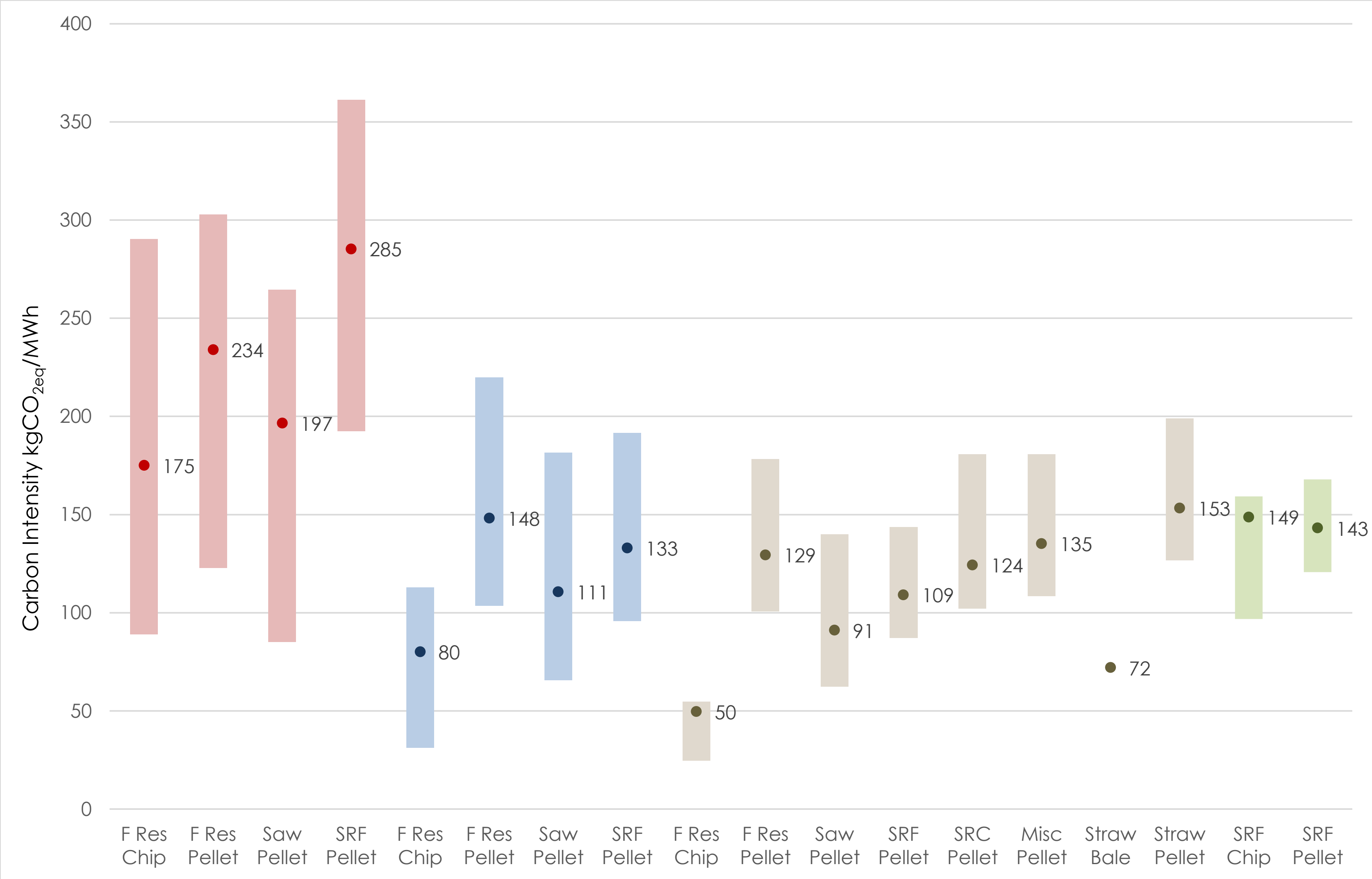


Figure 3: GHG emissions ranges for biomass supply chains based on dedicated biomass plant scenarios in 2012. Feedstock sourced from North America (Red), Europe (Blue), UK (Brown) and Brazil (Green)



3.2 Task 2: The potential for future improvements in GHG savings

Consultation responses and further industry engagement has given a clear indication that the majority of solid biomass used in electricity generation in the UK is likely to be imported wood pellets, much of which is expected to be sourced from North America. For these priority biomass supply chains, Task 1 highlighted the following supply chain stages as major contributors to the lifecycle GHG emissions:

- Shipping
- Inland transport
- Pelleting

Estimates of the potential GHG emissions reductions that may be achieved for priority biomass supply chains between 2020 and 2030, have therefore focused on these supply chain stages. The detailed results of the evidence review are included in Annex 1.

Mandates to be implemented by the International Maritime Organisation (IMO) are set to decarbonize the international shipping industry through both improved vessel design and improved management practices. The adopted regulations were estimated to reduce shipping GHG emissions by 20% by 2020, and 30% by 2030.

The rail industries, in UK and US, are yet to be governed by emission standards but are expected to reduce GHG emissions in the forthcoming years. Over the past three decades, the energy efficiency of rail freight has improved steadily such that freight may now be carried twice as far per unit of fuel than in 1980. The potential for cost-effective design and operational improvements are likely to continue this trend, such that a 15% reduction in rail emissions may be achieved by 2020 and a 30% reduction achieved by 2030.

Table 6: Projected estimates of GHG emission reductions in the maritime and rail industries

	2020 CO_{2eq} reduction	2025 CO_{2eq} reduction	2030 CO_{2eq} reduction
Shipping	20%	25%	30%
Rail	15%	22.5%	30%

Emissions associated with pellet production are largely due to electricity consumption and therefore dependent on regional electricity grid carbon intensity. Trajectories for the decarbonisation of national electricity grids are calculated from national plan estimates for future generation mixes and potential efficiency improvements for fossil electricity generation (Table 7). A 30% to 40% reduction in national grid carbon intensity was estimated for the US, Canada and the EU by 2030 whereas in the UK, emissions may be reduced by up to 80%. In contrast, Brazil is unlikely to see any significant improvement in the carbon intensity of electricity generation.

Table 7: Estimated electricity grid carbon intensities for key regions, $kgCO_{2eq}/MWh$

	2010	2020	2025	2030	2035
USA	520	439	398	358	317
Canada	180	148	132	117	101
Brazil	94	92	91	90	89
EU	350	282	247	213	179
UK	540	320	210	100	-

Based on these assumptions, the GHG emissions of priority biomass supply chains were estimated for 2020 and 2030 using as a baseline the coal plant conversion and dedicated biomass plant scenarios developed in Task 1. The results of each scenario are presented in Tables 8 & 9. The following figures present the results of the central supply chain scenarios.

By 2020, significant emission reductions for biomass supply chains with feedstock sourced from the EU, US and Brazil may be achieved (Figures 4 & 5). For the majority of these supply chains an overall emissions saving of between 10% and 30% is estimated compared to the baseline year 2012, with greater relative GHG emission savings for some saw mill residues. Actual GHG emission reductions range from 18 – 35 $kgCO_{2eq}/MWh$ for imported wood pellets. Supply chains with feedstock sourced from the UK are likely to see a lesser improvement.

By 2030, further GHG emission reductions for all biomass supply chains may be achieved (Figures 6 & 7). Compared to 2012, the carbon intensity of electricity from imported pellets may reduce by 18 – 56%, an actual GHG emission reduction of 28 – 58 $kgCO_{2eq}/MWh$.

Figure 4: Potential GHG emission reductions for 2020 biomass supply chains based on converted coal plant scenarios using central scenario assumptions. Feedstocks from the North America (Red), Europe (Blue), UK (Brown) and Brazil (Green)

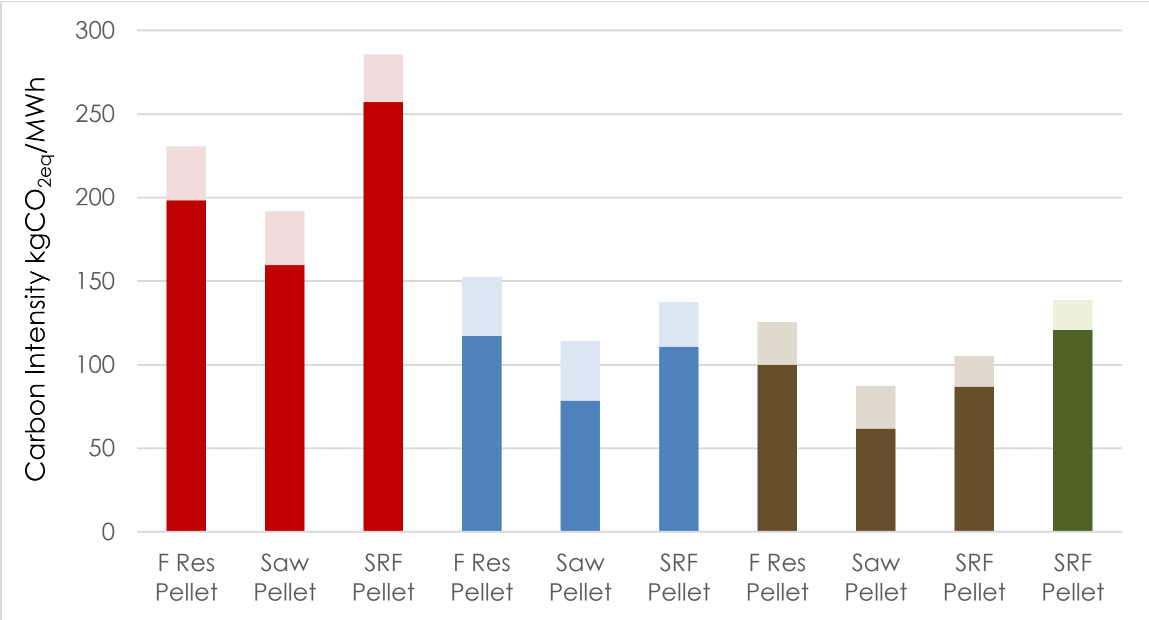


Figure 5: Potential GHG emission reductions for 2020 biomass supply chains based on dedicated biomass plant scenarios using central scenario assumptions. Feedstocks from the North America (Red), Europe (Blue), UK (Brown) and Brazil (Green)

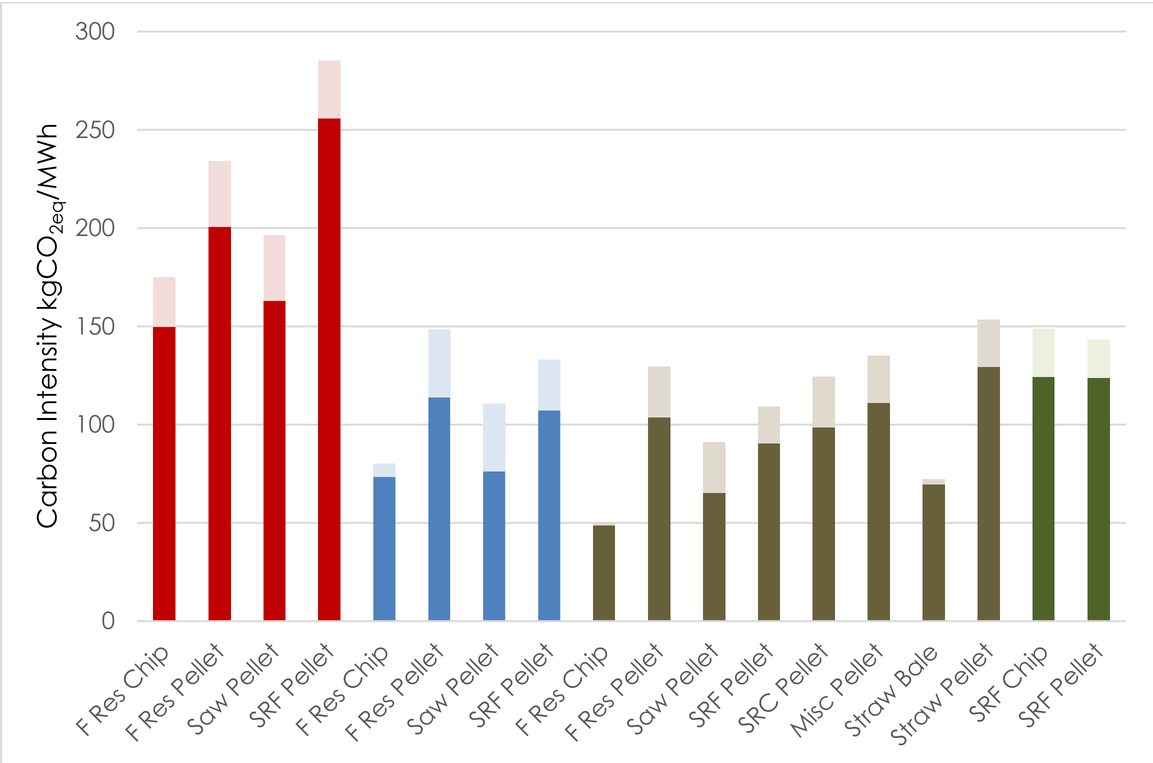


Figure 6: Potential GHG emission reductions for 2030 biomass supply chains based on coal conversion plant scenarios using central scenario assumptions. Feedstocks from the North America (Red), Europe (Blue), UK (Brown) and Brazil (Green)

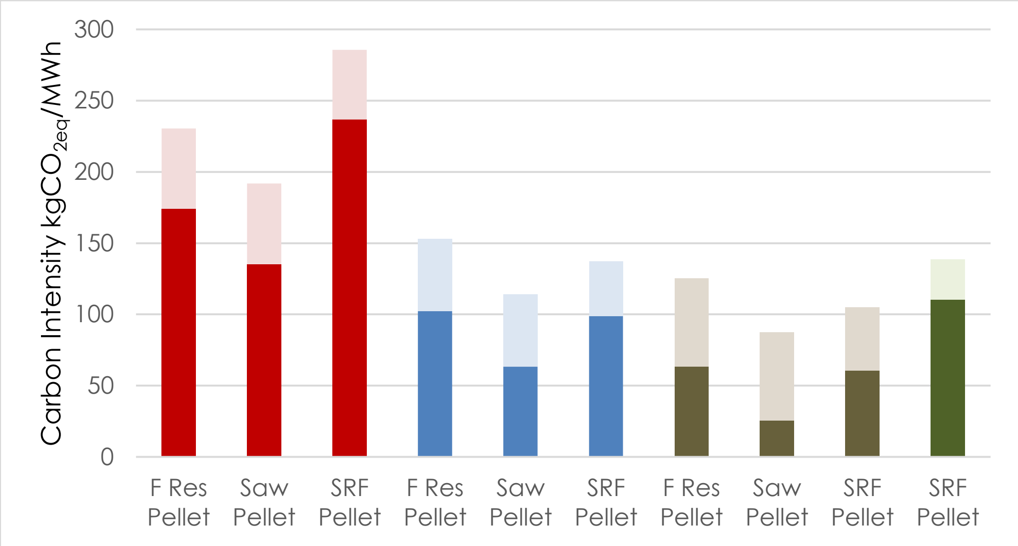


Figure 7: Potential GHG emission reductions for 2030 biomass supply chains based on dedicated biomass plant scenarios using central scenario assumptions. Feedstocks from the North America (Red), Europe (Blue), UK (Brown) and Brazil (Green)

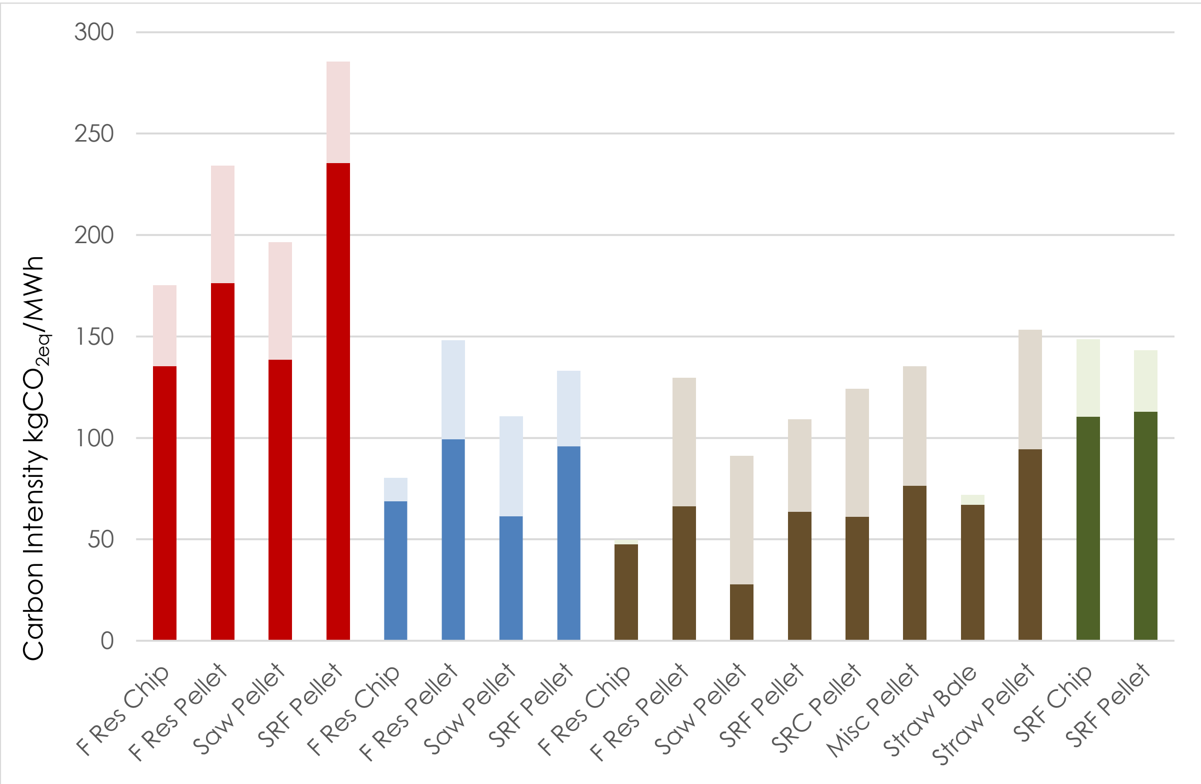


Table 8: Results of scenario analysis: Carbon intensity of electricity generation in coal plants converted to biomass in 2020 and 2030, $kgCO_{2eq}/MWh$

			2020			2030		
			30%	33%	37%	30%	33%	37%
North America	Forest Residues	Low	126	114	102	114	104	93
		Mid	218	198	177	192	174	155
		High	248	225	201	219	199	177
	Saw Mill Residues	Low	83	75	67	72	65	58
		Mid	176	160	142	149	135	121
		High	205	187	166	176	160	143
	SRF	Low	205	187	166	195	177	158
		Mid	283	257	229	260	237	211
		High	320	291	260	294	268	239
Europe	Forest Residues	Low	96	87	78	86	78	70
		Mid	129	117	105	113	102	91
		High	149	136	121	123	112	100
	Saw Mill Residues	Low	53	48	43	43	39	34
		Mid	86	79	70	70	63	56
		High	129	117	105	103	94	84
	SRF	Low	93	85	76	86	78	69
		Mid	122	111	99	109	99	88
		High	156	141	126	135	123	110
UK	Forest Residues	Low	92	83	74	64	58	52
		Mid	110	100	89	70	64	57
		High	147	133	119	81	74	66
	Saw Mill Residues	Low	50	45	40	22	20	18
		Mid	68	62	55	28	25	23
		High	105	95	85	39	36	32
	SRF	Low	82	75	67	62	57	51
		Mid	96	87	77	67	61	54
		High	121	110	98	75	68	61
Brazil	SRF	Low	115	105	94	106	96	86
		Mid	133	121	108	122	111	99
		High	139	127	113	128	117	104

Table 9: Results of scenario analysis: Carbon intensity of electricity generation in dedicated biomass plants in 2020 and 2030, $kgCO_{2eq}/MWh$

				2020			2030		
				30%	33%	37%	30%	33%	37%
North America	Chip	Forest Residues	Low	84	76	68	76	69	61
North America	Chip	Forest Residues	Mid	165	150	134	149	135	121
North America	Chip	Forest Residues	High	245	223	199	220	200	178
North America	Pellets	Forest Residues	Low	120	109	97	109	99	89
North America	Pellets	Forest Residues	Mid	221	201	179	194	176	157
North America	Pellets	Forest Residues	High	258	234	209	228	207	185
North America	Pellets	Saw Mill Residues	Low	78	71	63	68	61	55
North America	Pellets	Saw Mill Residues	Mid	179	163	145	152	139	124
North America	Pellets	Saw Mill Residues	High	216	197	175	186	169	151
North America	Pellets	SRF	Low	197	179	160	188	171	152
North America	Pellets	SRF	Mid	282	256	228	259	235	210
North America	Pellets	SRF	High	324	295	263	297	270	241
Europe	Chip	Forest Residues	Low	33	30	26	31	28	25
Europe	Chip	Forest Residues	Mid	81	73	65	76	69	61
Europe	Chip	Forest Residues	High	96	87	78	89	81	73
Europe	Pellets	Forest Residues	Low	91	83	74	81	74	66
Europe	Pellets	Forest Residues	Mid	125	114	102	109	99	89
Europe	Pellets	Forest Residues	High	165	150	133	140	127	113
Europe	Pellets	Saw Mill Residues	Low	49	44	40	39	36	32
Europe	Pellets	Saw Mill Residues	Mid	84	76	68	68	62	55
Europe	Pellets	Saw Mill Residues	High	123	112	100	98	89	80
Europe	Pellets	SRF	Low	88	80	72	81	74	66
Europe	Pellets	SRF	Mid	118	107	96	105	96	85
Europe	Pellets	SRF	High	148	135	120	129	118	105
UK	Chip	Forest Residues	Low	27	24	22	26	24	21
UK	Chip	Forest Residues	Mid	53	49	43	52	47	42
UK	Chip	Forest Residues	High	59	54	48	58	53	47
UK	Pellets	Forest Residues	Low	92	83	74	64	58	52
UK	Pellets	Forest Residues	Mid	114	104	92	73	66	59
UK	Pellets	Forest Residues	High	150	137	122	84	77	68
UK	Pellets	Saw Mill Residues	Low	50	45	40	22	20	18
UK	Pellets	Saw Mill Residues	Mid	72	65	58	31	28	25
UK	Pellets	Saw Mill Residues	High	108	98	88	42	38	34
UK	Pellets	SRF	Low	82	75	67	62	57	51
UK	Pellets	SRF	Mid	99	90	81	70	63	57
UK	Pellets	SRF	High	125	114	101	78	71	63

	Pellet	SRC	Low	93	85	76	66	60	53
			Mid	108	98	88	67	61	55
			High	153	139	124	87	79	71
	Pellet	Miscanthus	Low	102	92	82	76	69	62
			Mid	122	111	99	84	76	68
			High	156	142	127	95	86	77
	Bale	Straw	Mid	77	70	62	74	67	60
	Pellet	Straw	Low	122	111	99	96	87	78
			Mid	142	129	115	104	95	84
			High	176	160	143	115	104	93
Brazil	Chip	SRF	Low	91	83	74	82	74	66
			Mid	137	124	111	122	111	99
			High	129	118	105	116	105	94
	Pellet	SRF	Low	116	105	94	106	96	86
			Mid	136	124	110	124	113	101
			High	142	130	116	131	119	106

3.3 Task 3: Possible impacts on industry

3.3.1 Coal plant conversions

The consultation proposed that coal plants converting to or co-firing with biomass would have to achieve carbon intensity equal to or less than 285.12 kg CO_{2eq}/MWh from October 2013, reducing to 240 kg CO_{2eq}/MWh in 2020. The majority of stakeholder feedback received under the consultation states that the 2020 target was achievable, but would restrict the availability of wood pellets for consumption in the UK. It was broadly recognised that requiring each individual consignment to meet the GHG target would pose considerable risk where, due to unforeseen circumstances, changes in the supply chain logistics may result in additional GHG emissions, different approaches to this risk are outlined in the consultation responses.

Figures 2 & 4 illustrate the carbon intensity of electricity generated by coal plant conversions in 2012 and 2020 respectively. There are a wide range of wood pellet supply chains from the UK, Europe and Brazil that achieve GHG emissions below the 2013 target of 285.12 kgCO_{2eq}/MWh. The majority of sawmill and forest residue derived pellets from North America are also expected to meet this target according to the assumption made in this analysis. North American pellets sourced from round wood or whole trees that are not classed as forest residues or forest thinnings may not meet the 2013 threshold.

Considering the potential supply chain emission reductions that may be achieved by 2020, the majority of supply chains modelled would meet the proposed 2020 target of 240 $kgCO_{2eq}$/MWh, under the central scenario assumptions. Again, North American pellets sourced from round wood or whole trees that are not classed as forest residues or forest thinnings may not meet the 2020 threshold.

Figure 6 illustrates the carbon intensity of electricity generated by coal plant conversions in 2030, under the central scenario assumptions. Scenario analysis estimates that electricity generated from North American sawmill and forest residue pellets at 33% conversion efficiency may achieve GHG emissions of 65 – 199 $kgCO_{2eq}$/MWh in 2030 (Table 8).

The supply chains emissions illustrated in Figures 4 and 6 represent ideal logistics. However, there is a risk that due to unforeseen circumstances individual consignments may depart from the ideal logistics where for example shipments arrive in smaller vessels or are transported longer distances due to adverse weather conditions, or road haulage is used in the event of rail disruptions. Bioenergy generators are seeking to mitigate against the risk of failing to meet RO GHG emission standards, and the associated loss of income, by contracting biomass supply chains that expect to exceed the GHG emissions targets by a substantial margin (also referred to as the headroom). Project developers have indicated that the margin required between target GHG emissions and contracted supply chain values is between 10 and 25% to accommodate these risks.

3.3.2 Dedicated biomass plants

The consultation proposed that new build dedicated biomass plants would have to achieve carbon intensity less than or equal to 240 $kgCO_{2eq}$/MWh from October 2013, reducing to 200 $kgCO_{2eq}$/MWh. Feedback received under the consultation for dedicated biomass power has been mixed. All feedback has agreed that a limit of 200 $kgCO_{2eq}$/MWh would severely limit the availability of biomass feedstocks, particularly imports. Some developers suggest a target of 240 $kgCO_{2eq}$/MWh would allow a wider range of feedstocks to be used, and that the 200 $kgCO_{2eq}$/MWh target would be too high risk for projects to proceed. Dedicated biomass developers also express concern over the requirement for each individual consignment to meet the GHG emissions target, stating that this would add considerable risk.

Figures 3 & 5 illustrate the carbon intensity of electricity generated by dedicated biomass plants in 2012 and 2020 respectively. There are a wide range of wood and energy crop chips and pellets from the UK, Europe and Brazil that achieve GHG emission below the tighter 2013 target of 240 $kgCO_{2eq}$/MWh. Supply chains from North America may be constrained, forest residues wood chips and sawmill residue pellets are likely to meet the target under central scenario assumptions, but forest residue pellets and pellets from round wood and whole trees not classed as forest residues or forest thinnings may not meet the 2013 threshold.

In 2020, considering the potential supply chain emission reductions that may be achieved, a range of supply chains modelled would meet the proposed 2020 target of 200 $kgCO_{2eq}$/MWh, under the central scenario assumptions. However, North American pellets sourced from forest residues may not meet the 2020 threshold. Scenario analysis estimates that North American wood chips from forest residues may achieve GHG emission of 76 – 236 $kgCO_{2eq}$/MWh in 2020, and wood pellets from saw mill and forest residues achieve GHG emission in the range of 71 – 234 $kgCO_{2eq}$/MWh. Developers seeking to use imported wood pellets may find that the GHG emission target constrains the availability of suitable feedstocks, whilst those utilising UK and European feedstocks may comfortably achieve the proposed targets.

The estimated carbon intensity of electricity from dedicated biomass plants under the central scenario assumptions in 2030 is illustrated in Figure 7. Scenario analysis estimates that sawmill and forest residue derived pellets from North America may achieve GHG emissions of 61 – 207 $kgCO_{2eq}$/MWh in 2030, wood chips would also be within this range (Table 9).

Dedicated biomass generators indicated the margin required to accommodate the risk associated with unavoidable changes in biomass supply chain logistics and the impact on GHG emissions, for imported biomass feedstocks were between 10 and 25%.

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