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Review of Carbon Emissions from use of SIRF Pellets

Report for Waste Knot dated April 2022

Report prepared for:

Waste Knot Energy (Holding) Ltd

Prepared by:

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Checked and Approved by:

Joanne Wood – Senior Business Advisor

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Signature

Date 29th April 2022

Disclaimer

Monksleigh Ltd has taken due care and consideration in the preparation of this report to ensure that all the facts and analysis presented are as accurate as possible and within the agreed scope of the project. However, no assurance can be provided in respect of the evidence presented and Monksleigh Ltd is not responsible for the decisions or actions taken on the basis on the information contained therein.

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1. Executive Summary

In February 2021 SOL Environmental Ltd (SOL) produced a report for WKE assessing the carbon footprint of their SIRF Pellets, with a final report issued in May 2021. This report assessed the emissions associated with the production of the pellets, and the potential savings in emissions through diversion of from waste from landfill.

This report was commissioned by WKE to review the analysis undertaken by SOL and extend that analysis to assess the emission savings that might be realised by different industrial applications/users of the SIRF pellets.

The SOL report and its approach broadly corresponds with the approach that Monksleigh's LCA partner, AardvarkEM Ltd (AEM), would have used. Apart from some minor alterations around the detail of the assessment, the report has been assessed as a reasonable foundation from which to work.

In assessing the SOL report's use of emissions savings embedded in the SIRF Pellet, three key factors emerged when considering the use of the pellets in different applications:

- The emissions savings against landfill or incineration cannot be counted by a user as an emission benefit in their calculation of their emissions
- The emissions savings are therefore only in relation to the displaced fuel that would otherwise have been used but are replaced by the SIRF Pellets. In this instance it would include the emissions associated with the production of the pellets.
- In the case of cement and lime kilns the Substitute Fuel Protocol and EU ETS regime would allow for the emissions associated with the production of pellets to be ignored – the use of waste fuel allowing a zero emissions figure. Changing the SIRF Pellet to a non-waste 'product' would require the production emissions to be calculated by the user

When considering the potential use of the SIRF Pellets in industrial applications, the most beneficial use is in the substitution of coal, including coking coal, petroleum coke (pet coke) and industrial coal with emissions around x3.5 that of SIRF Pellets. This would naturally lead to the substitution in cement kilns, coal fired power stations and steel manufacturing as being of the greatest benefit.

Application to substitute natural gas, for example in brickmaking, would have lesser benefit than coking and pet coal replacement, but emissions are still around x2 that of SIRF Pellets.

Replacement of biomass energy fuels, such as wood chips, wood logs, wood pellets and grass/straw have no real benefit, with emissions around half that of the SIRF Pellets.

As an example of the replacement value of a 20MJ/kg SIRF pellet for pet coke in a cement plant (requiring 1.62kg of pellets for every tonne of pet coke replaced to maintain the thermal output):

- At 25% pet coke and 75% pellets with a zero-rated emissions pellet the substitution benefit/emissions savings would be 8.4 tonnes CO2e
- At the same parameters with a product emissions assumption of 0.68kg CO2e per kg of pellet used - the substitution benefit/emissions savings would be 5.8 tonnes CO2e

For replacement of industrial coal the ratio drops from 1.62 to 1.21 kg of pellets to 1kg of coal, and 1.44kg of pellets 1kg of coking coal.

For SIRF Pellets with a NCV outside of the target 20MJ/kg above, the lower the NCV the higher the emissions due to the requirement to burn more pellets to achieve the same thermal requirements.

Taking the above example of the 20MJ/kg SIRF pellet but applying different NCV assumptions:

- At the zero-rated emissions approach above, the changing NCV and amount of pellets used makes no difference to the assumed calculations
- An 18MJ/kg SIRF Pellet would require more pellets and lead to a saving of 5.5 tonnes CO2e in the product emissions assumption (i.e. 0.3 tonnes CO2e lower than the 5.5 tonnes CO2e above)
- A 22MJ/kg SIRF Pellet would require less pellets and lead to a saving of 6.1 tonnes CO2e in the zero-rated scenario (i.e. 0.6 more than the 5.5 tonnes CO2e above)

The overall carbon savings in a year for a Waste Knot plant would be 827,219 tonnes CO2e based on the following assumptions:

- The processing of c.350ktpa of waste (c. 300kt into a Waste Knot facility) to produce c. 244ktpa of pellets
- Pellet Energy content of 22MJ/kg and 55% carbon content
- Replacement of petroleum coke coal in a cement kiln for all pellets produced
- Includes the savings in CO2eq. of the diversion of waste from landfill (notwithstanding that no single party in the ‘process/user chain’ can utilise this benefit in their calculations)

2. Introduction

2.1 Overview

Waste Knot Energy (Holding) Ltd (WKE) are presently building their first plant in Middlesborough to produce their SIRF Pellets.

The SIRF Pellets are produced by refining, drying and pellitising Solid Recovered Fuel (SRF), which has been produced from the processing of primarily commercial and industrial wastes at other sites.

The delivered SRF from these other sites, whilst meeting a reasonably tight input specification, is manufactured into the SIRF Pellet to higher and more uniform quality substitute fuel, with a higher Net Calorific Value (NCV). This, in turn, is anticipated to enable it to be used in a far wider range of industrial applications, including cement manufacture, power generation, steel production and brickmaking.

The use of the SIRF Pellets in industrial applications is anticipated to replace carbon intensive fuels with a lower carbon option, further enhanced by virtue of the diversion of waste otherwise destined for landfill or incineration.

In February 2021 SOL Environmental Ltd (SOL) produced a report for WKE assessing the carbon footprint of their SIRF Pellets, with a final report issued in May 2021. This report assessed the scope 1, 2 and 3 emissions of the production of the pellets, and the potential savings for a user of the pellets through diversion from landfill.

This report was commissioned by WKE to review the analysis undertaken by SOL and extend that analysis to assess the carbon savings that might be realised by different industrial applications/users of the SIRF pellets.

In undertaking this work, Monksleigh worked with AardvarkEM Ltd (AEM) as their partner for LCA modelling and analysis.

2.2 Scope

The scope of work was to review the previous work undertaken by SOL (copy of report included in the appendix to this report) and extend the analysis to the benefits that could be realised using the SIRF Pellets in other industrial applications.

To maintain some flexibility in applying this analysis, the use of the SIRF Pellets was agreed with WKE to be considered against the alternative fuels used in different industrial applications and the potential substitution levels possible. This acknowledges that for practical and/or commercial reasons there may be a limit to the level of substitution possible of SIRF Pellets in an industrial process[1].

As part of this work, it also became apparent that the use of the SIRF Pellets in cement and lime kilns would be considered differently under the Substitute Fuels Protocol[2] and so the ramifications of this was added to the scope of the report.

2.3 Data Sources

The primary data sources for this report include:

- The SOL report dated February 2021 and appended to this report
- The BEIS Conversion Factors 2021[3]
- The Ecoinvent v3.8[4] database
- Chemical analysis provided by WKE by SGS laboratories[5]

[1] A practical example might include the capacity of the air conveyors used in a cement kiln, where the bulk density may affect the ability to introduce the fuel, and a commercial example may include the requirement to maintain a minimum biomass content in a waste wood plant benefitting from the Renewable Obligation Credits associated with burning primarily biomass material.

[2] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/291698/scho1207bnna-e-e.pdf

[3] https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2021

[4] https://ecoinvent.org/

[5] Report references MD22-00293; MD22-00317; MD21-01415; MD-01385.

3. Assessment of the SOL Report

3.1 Scope/Overview of Assessment

The SOL report sought to assess the 'carbon footprint' of the SIRF pellets by firstly calculating the emissions as a result of the production of the pellet, including:

- the processing of the residual commercial and industrial waste at a third-party site to the specification required by WKE,
- its transport to the WKE site,
- the energy used in the SIRF Pellets produced at the WKE site

These production emissions led to an assessed 128.87 kg CO2e per tonne of pellet.

In calculating the carbon footprint of the SIRF Pellets, SOL then considered the diverted emissions savings as if the commercial and industrial waste had gone to landfill, at -658.46kg CO2e per tonne of pellet.

By netting the diverted emissions savings against the production emissions the net emissions were assumed to be -529.6 kg CO2e per tonne of pellet used.

The scope of the report did not include the implications of the potential savings in emissions for users of the SIRF Pellet on a substitution basis.

3.2 Findings

The summary of the AEM findings is included in the appendix to this report. In summary, their findings are that the SOL report is a reasonable foundation from which to work. They have noted a number of minor points which could be addressed to refine the SOL work, all of which they believe would have a relatively minor impact if captured. These points, in brief, are:

- The assessment takes a broad-based approach and does not address the Well to Tank (WTT) emissions associated with the use of electricity in the SRF production and WKE production processes or the use of gas in the WKE drying process
- The transport assumptions between the SRF production facilities and the WKE production facility are broad-based haulage distance and load-weight assumptions that may benefit from more refinement
- The drying assumptions should have used a different metric of CO2e for natural gas, but the difference between that chosen and the correct metric is minor

In terms of the tonnage used in the report, it assumes 350,000 tonnes received at the SRF productions sites with 302,400 tonnes sent to the WKE production facility to produce 243,541 tonnes of SIRF Pellets[6].

The SOL report uses these proportions, with assumed losses through landfill and evaporation, to derive a ratio to apply to the benefit of diversion of waste from landfill (458.16kgCO2e of emissions per tonne of landfill avoided multiplied by 1.437 to derive a saving per tonne of SIRF Pellet of 658.38kgCO2e).

By then deducting the emissions produced in the overall production of the SIRF Pellet, the net carbon intensity has been calculated at -530kgCO2e per tonne of pellet produced. AEM have confirmed that these calculations are reasonable and capture the losses through the production processing, although have noted that the emission derived from converting the commercial and industrial waste to SRF are a default figure by reference to a 2015 report, and not the specifics of the actual processing facilities themselves.

3.3 Diverted Benefit from Incineration

The SOL report used the diverted saving against the alternative of landfill of commercial and industrial waste. This is generally the accepted default approach in most LCA analysis associated with waste.

Monksleigh and AEM have assessed the alternative option of using this commercial and industrial waste in a combustion process rather than landfill in order to evaluate the difference between the two and address the question of whether the material would be better going straight to combustion.

The Ecoinvent data suggests that the combustion of commercial and industrial waste results in emissions of 489.00kg CO2e vs the landfill assumption used in the BEIS data of 458.18kg CO2e.

Applying the ratios above results in emissions of 702.69kg CO2e or an additional 44.31kg of CO2e more in using combustion as the default vs using landfill as the default. In our opinion the primary reasons for this are:

- The assessment of the combustion of MSW via incineration (without heat recovery) in the Ecoinvent database focuses on the fossil-derived carbon only

[6] IN recent discussions with WKE the ratios may be closer to 250kt of pellets from 300kt of input material, which would change the ratios slightly if used.

- This results in a significant impact from the composition of hard and soft plastics, with no/little implication for other organic carbon
- The landfill assumptions assume slow degradation of organics, resulting in net emissions, but plastics are broadly assumed to be sequestrated in landfill, with no resultant emissions

Therefore the default position used by SOL, whilst being the standard approach used, is also a more conservative assumption in terms of kgCO2e than that of combustion in determining the diverted benefit of the SIRF Pellets.

4. Application of Carbon Savings for Users

4.1 Key Assumption

Whilst the carbon footprint modelled by the SOL report looks at the overall savings in emissions against the alternative of landfill, the user of the pellets cannot take such a carbon saving into consideration when calculating their emissions. As such they can only take into consideration the embedded emissions in the production of the pellet, and the diverted benefit of replacing the original fuel being used.

AEM have taken the production emissions of 0.13kg CO2e per tonne[7] of pellet and applied a 55% carbon content[8][9] to derive a total 0.68kg CO2e for every kg of SIRF Pellet used.

This base-line figure has then been compared to a range of other fuels to assess the relative benefits on a weight for weight and on a thermal basis.

4.2 Emissions Base-Line Assumptions

The following table summarises the different fuel uses that AEM have considered that can be used in a variety of industrial applications:

[7] The scope 3 analysis.

[8] The scope 1 analysis.

[9] The average of the four samples SIRF Pellets from the SGS laboratories provided by WKE was 54.98% carbon and 21.19MJ/kg NCV.

Table 1: Summary of Metrics Database Used by AEM in Assessment

Items	Metric	Unit	Scope	Source
Conversion MJ > kWh	0.278			BEIS Conversion Factors 2021
Conversion kWh > MJ	3.600			BEIS Conversion Factors 2021
Coal (Industrial)	0.341	kg CO2e/ kWh (Net CV)	1	BEIS Conversion Factors 2021
Coal (Industrial) WTT	0.056	kg CO2e/ kWh (Net CV)	3	BEIS Conversion Factors 2021
Coal (Industrial)	2,403.84	kg CO2e/ tonne	1	BEIS Conversion Factors 2021
Coal (Industrial) WTT	393.14	kg CO2e/ tonne	3	BEIS Conversion Factors 2021
Petroleum Coke	0.359	kg CO2e/ kWh (Net CV)	1	BEIS Conversion Factors 2021
Petroleum Coke WTT	0.042	kg CO2e/ kWh (Net CV)	3	BEIS Conversion Factors 2021
Petroleum Coke	3,386.86	kg CO2e/ tonne	1	BEIS Conversion Factors 2021
Petroleum Coke WTT	399.25	kg CO2e/ tonne	3	BEIS Conversion Factors 2021
Natural Gas	0.203	kg CO2e/ kWh (Net CV)	1	BEIS Conversion Factors 2021
Natural Gas WTT	0.035	kg CO2e/ kWh (Net CV)	3	BEIS Conversion Factors 2021
Coking coal	0.377	kg CO2e/ kWh (Net CV)	1	BEIS Conversion Factors 2021
Coking coal WTT	0.056	kg CO2e/ kWh (Net CV)	3	BEIS Conversion Factors 2021
Wood chips	0.015	kg CO2e/ kWh (Net CV)	1	BEIS Conversion Factors 2021
Wood chips WTT	0.008	kg CO2e/ kWh (Net CV)	3	BEIS Conversion Factors 2021
Wood logs	0.015	kg CO2e/ kWh (Net CV)	1	BEIS Conversion Factors 2021
Wood logs WTT	0.013	kg CO2e/ kWh (Net CV)	3	BEIS Conversion Factors 2021
Wood pellets	0.015	kg CO2e/ kWh (Net CV)	1	BEIS Conversion Factors 2021
Wood pellets WTT	0.037	kg CO2e/ kWh (Net CV)	3	BEIS Conversion Factors 2021
Grass/straw	0.013	kg CO2e/ kWh (Net CV)	1	BEIS Conversion Factors 2021
Grass/straw WTT	0.016	kg CO2e/ kWh (Net CV)	3	BEIS Conversion Factors 2021
Household residual waste (combustion)	0.021	kg CO2e/ kg	1	BEIS Conversion Factors 2021
Commercial and industrial waste - landfill	458.18	kg CO2e / tonne	1 & 3	BEIS Conversion Factors 2020
Commercial and industrial waste - combu	489.00	kg CO2e/ kWh (Net CV)	1	EcoInvent
Waste knot pellets - landfill	-2.648	kg CO2e per kWh		
Waste knot pellets - combustion	-2.869	kg CO2e per kWh		

The substitution levels of SIRF Pellet in relation to use in cement kilns replacing pet coke was also considered by AEM at a range of 18 to 22MJ/kg in order to demonstrate the replacement/substitution impact of changing NCV and the resultant savings in kgCO2e.

4.3 Relative Emissions

The relative emissions for each type of fuel are summarised in the table below per kg of fuel used (shown at the lowest level of pellet NCV of 21MJ/kg):

Table 2: Relative Emissions per kg of Fuel Used (SIRF Pellets at 21MJ/kg)

Fuel	Fuel Classification	Quantity of Fuel (kg)	Net Calorific Value (MJ/kg)	Energy Generated (kWh)
Waste Knot Pellets	Fuel	1	21	5.83
Coal (industrial)	Fossil Fuel	1	25	7.06
Coking Coal	Fossil Fuel	1	30	8.40
Petroleum Coke	Fossil Fuel	1	34	9.44
Natural Gas	Fossil Fuel	1	45	12.51
Wood Chips	Biofuel	1	14	3.78
Wood Logs	Biofuel	1	15	4.09
Wood Pellets	Biofuel	1	17	4.80
Grass/straw	Biofuel	1	13	3.74

Fuel	Scope 1 (kg CO2e)	Scope 3 (kg CO2e)	kg CO2e per kg fuel
Waste Knot Pellets	0.55	0.13	0.68
Coal (industrial)	2.40	0.39	2.80
Coking Coal	3.17	0.47	3.63
Petroleum Coke	3.39	0.40	3.79
Natural Gas	2.54	0.43	2.97
Wood Chips	0.06	0.03	0.09
Wood Logs	0.06	0.05	0.11
Wood Pellets	0.07	0.18	0.25
Grass/straw	0.05	0.06	0.11

Whilst this table considers the emissions on a kg equivalent basis, it does not adjust for the equivalence on a thermal basis. The second part of the table above can be adjusted as shown below to show the relative emissions on an equivalent thermal basis.

Table 3: Relative Emissions per kg of Fuel Used (adjusted on a thermal basis with SIRF Pellets at 21MJ/kg)

Fuel	kg of Pellets Required to Deliver Same NCV	Kg CO2e Emmited at Same NCV	Savings kg CO2e to Chosen Fuel	Ratio of Saving to Chosen Fuel
Waste Knot Pellets	1.00	0.68	0.00	
Coal (industrial)	1.21	0.82	-1.98	-2.91
Coking Coal	1.44	0.98	-2.66	-3.91
Petroleum Coke	1.62	1.10	-2.69	-3.96
Natural Gas	2.14	1.45	-1.52	-2.24
Wood Chips	0.65	0.44	0.35	0.52
Wood Logs	0.70	0.48	0.36	0.53
Wood Pellets	0.82	0.56	0.31	0.45
Grass/straw	0.64	0.44	0.33	0.48

When considering the potential use of the SIRF Pellets in industrial applications, the most beneficial use, as can be seen in the table, is in the substitution of coal, including coking coal, petroleum coke (pet coke) and industrial coal with emissions of these chosen fuels around x3 to x4 that of SIRF Pellets. This would naturally lead to the substitution in cement kilns, coal fired power stations and steel manufacturing as being of the greatest benefit.

Application to substitute natural gas, for example in brickmaking, would have lesser benefit than coking and pet coal replacement, but emissions are still around x2 that of SIRF Pellets.

Replacement of biomass energy fuels, such as wood chips, wood logs, wood pellets and grass/straw have no real benefit, with emissions around half that the SIRF Pellets

4.4 Substitution Level

The actual savings in kgCO2e on a substitution level is clearly has to acknowledge the differences in NCV in the fuels being considered.

The table below considers the replacement of pet coke with SIRF Pellets for a 100GJ load, for example in a cement kiln application, with varying degrees of substitution level from 0%, 25%, 50% and 75% to show the increasing benefit with higher substitution.

In addition it considers the impact of three NCV assumptions for the SIRF Pellets of 18, 20 and 22MJ/kg.

Table 4: Example of Emissions Savings Replacing Pet Coke with SIRF Pellets in a Cement Kiln

Cement Kiln							
Total Load	100	GJ					
Scenario A							
	Fuel Classification	**Fuel % Split**	**GJ**	**NCV (GJ/tonne)**	**Tonnes**	**Emissions kg CO2e**	
Petroleum coke	Fossil fuel	100%	100	34	2.94	11,144.79	
							Potential Emission Savings
Waste knot pellets	Fuel	0%	0	22	0.00	0	0
Waste knot pellets	Fuel	0%	0	20	0.00	0	0
Waste knot pellets	Fuel	0%	0	18	0.00	0	0
Scenario B							
	Fuel Classification	**Fuel % Split**	**GJ**	**NCV (GJ/tonne)**	**Tonnes**	**Emissions kg CO2e**	
Petroleum coke	Fossil fuel	75%	75	34	2.21	8,358.59	
							Potential Emission Savings
Waste knot pellets	Fuel	25%	25	22	1.14	771.2	2,015.04
Waste knot pellets	Fuel	25%	25	20	1.25	848.3	1,937.92
Waste knot pellets	Fuel	25%	25	18	1.39	942.5	1,843.67
Scenario C							
	Fuel Classification	**Fuel % Split**	**GJ**	**NCV (GJ/tonne)**	**Tonnes**	**Emissions kg CO2e**	
Petroleum coke	Fossil fuel	50%	50	34	1.47	5,572.40	
							Potential Emission Savings
Waste knot pellets	Fuel	50%	50	22	2.27	1,542.32	4,030.08
Waste knot pellets	Fuel	50%	50	20	2.50	1,696.55	3,875.85
Waste knot pellets	Fuel	50%	50	18	2.78	1,885.06	3,687.34
Scenario D							
	Fuel Classification	**Fuel % Split**	**GJ**	**NCV (GJ/tonne)**	**Tonnes**	**Emissions kg CO2e**	
Petroleum coke	Fossil fuel	25%	25	34	0.74	2,786.20	
							Potential Emission Savings
Waste knot pellets	Fuel	75%	75	22	3.41	2,313.48	6,045.12
Waste knot pellets	Fuel	75%	75	20	3.75	2,544.83	5,813.77
Waste knot pellets	Fuel	75%	75	18	4.17	2,827.58	5,531.01

At 20MJ/kg NCV for the SIRF pellet (with pet coke at 33.97MJ/kg NCV) with a 25% substitution of pellets in a 100GJ scenario would result in 1.25 tonnes of SIRF Pellet to 2.21 tonnes of pet coke and a saving of 2.8 tonnes of CO2e.

As an example of the replacement value of 75% of a 20MJ/kg SIRF pellet for pet coke in the above table (requiring 1.7kg of pellets for every tonne of pet coke replaced to maintain the thermal output) the substitution benefit/emissions savings would be 5.8 tonnes CO2e

5. Implications of Substitute Fuel Protocol

5.1 Background

As previously set out in this report, the use of the SIRF Pellets does not allow for the diverted benefit vs landfill in kgCO2e to be acknowledged by the user, but the production emissions and savings against the substituted fuel can be considered.

AEM, in their assessment of the ability of the end-user to acknowledge the embedded benefit, have pointed to the Substitute Fuels Protocol[10] where the SIRF Pellet, if considered a waste in the applications for cement kilns and lime kilns, could allow the user to consider the production emissions to be zero.

5.2 Consequence of Interpretation

This has a direct implication for the WKE intention to move towards an End of Waste (EoW) classification of the pellets:

- EoW would result in them ceasing to be waste in a cement kiln/lime kiln user and would have to consider the production emissions
- Whereas continuing to classify as a waste would enable the zero rating to be used by the cement kiln/line kiln
- But EoW would enable them to be used in biomass type applications, at the production emissions previously set out of 0.68kgCO2e per kg used

Clearly here may be an option to classify them differently for different users, but this may undermine the argument to classify the as EoW if they were being sold as a waste derived material.

The table in the previous section is reproduced below to show the difference in interpretation for a cement kiln.

[10] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/291698/scho1207bnna-e-e.pdf

Table 5: Emissions Savings Replacing Pet Coke with SIRF Pellets in a Cement Kiln with Zero Production Emissions

Cement Kiln						
Total Load	100	GJ				
Scenario A						
	Fuel Classification	Fuel % Split	GJ	NCV (GJ/tonne)	Tonnes	Emissions kg CO2e
Petroleum coke	Fossil fuel	100%	100	34	2.94	11,144.79
Waste knot pellets	Waste	0%	0	22	0.00	0
Waste knot pellets	Waste	0%	0	20	0.00	0
Waste knot pellets	Waste	0%	0	18	0.00	0
					Potential Emission Savings =	0.00
Scenario B						
	Fuel Classification	Fuel % Split	GJ	NCV (GJ/tonne)	Tonnes	Emissions kg CO2e
Petroleum coke	Fossil fuel	75%	75	34	2.21	8,358.59
Waste knot pellets	Waste	25%	25	22	1.14	771.2
Waste knot pellets	Waste	25%	25	20	1.25	848.3
Waste knot pellets	Waste	25%	25	18	1.39	942.5
					Potential Emission Savings =	2,786.20
Scenario C						
	Fuel Classification	Fuel % Split	GJ	NCV (GJ/tonne)	Tonnes	Emissions kg CO2e
Petroleum coke	Fossil fuel	50%	50	34	1.47	5,572.40
Waste knot pellets	Waste	50%	50	22	2.27	1,542.32
Waste knot pellets	Waste	50%	50	20	2.50	1,696.55
Waste knot pellets	Waste	50%	50	18	2.78	1,885.06
					Potential Emission Savings =	5,572.40
Scenario D						
	Fuel Classification	Fuel % Split	GJ	NCV (GJ/tonne)	Tonnes	Emissions kg CO2e
Petroleum coke	Fossil fuel	25%	25	34	0.74	2,786.20
Waste knot pellets	Waste	75%	75	22	3.41	2,313.48
Waste knot pellets	Waste	75%	75	20	3.75	2,544.83
Waste knot pellets	Waste	75%	75	18	4.17	2,827.58
					Potential Emission Savings =	8,358.59

Taking the above example of the 20MJ/kg SIRF pellet but applying different NCV assumptions:

- At the zero-rated emissions approach above, the changing NCV and amount of pellets used makes no difference to the assumed calculations, delivering a 8.4 tonne CO2e saving for a 25% pet coke to 75% pellet ratio
- An 18MJ/kg SIRF Pellet would require more pellets and lead to a saving of 5.5 tonnes CO2e in the product emissions assumption (i.e. 2.9 tonnes CO2e lower than the CO2e above)
- A 22MJ/kg SIRF Pellet would require less pellets and lead to a saving of 6.1 tonnes CO2e in the zero-rated scenario (i.e. 2.3 tonnes CO2e more than CO2e above)

6. Appendix 1 – SOL and AEM Reports

Carbon Footprinting of Pellets
Waste Knot Energy Ltd.

Prepared for:
Wasteknot Energy Ltd.

Date:
February 2021

Project Issue Number:
RSOL2012WKE_01 Carbon Footprint of Pellets

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VERSION CONTROL RECORD			
Contract/Proposal Number:		RSOL2012WKE_01 Carbon Footprint of Pellets	
Authors Name:		Callum Barnes	
Signature:			
Issue	Description of Status	Date	Reviewer Initials
0	First Issue	9th February 2021	SMB
1	Revised	27th May 2021	SMB
2	Revised	28th May 2021	SMB

REPORT CONTENTS

1. INTRODUCTION

1.1 Background

Sol Environment Ltd ('Sol' hereafter) have been engaged by Waste Knot Energy Ltd. to undertake an assessment of Waste Knot's alternative fuel pellet product to determine the associated greenhouse gas (GHG) emissions.

The purpose of this report is to quantify the carbon emissions (CO_2e) associated with the production of Waste Knot's pellet by quantifying all significant GHG emissions during production.

1.2 Scope of the Study

At the time of writing, the proposed plant is not operational, as such as figures quoted are estimates based on proposed loads and outputs provided by the Waste Knot project team or benchmark figures in accordance with legislative requirements embedded within methodologies and software.

Therefore, all quoted figures are only indicative of potential performance. Particular reference is made to the follow areas of performance:

- SRF Composition – any changes to the SRF composition (such as moisture content) orientation may significantly affect energy performance and associated CO_2e emissions;
- Auxiliary load - this may be significantly reduced when specification of items such as automation equipment, sensors, etc. are finalised; and
- Plant Efficiency - performance may deteriorate over the operational lifetime, leading to changes in Regulated and Unregulated loads.

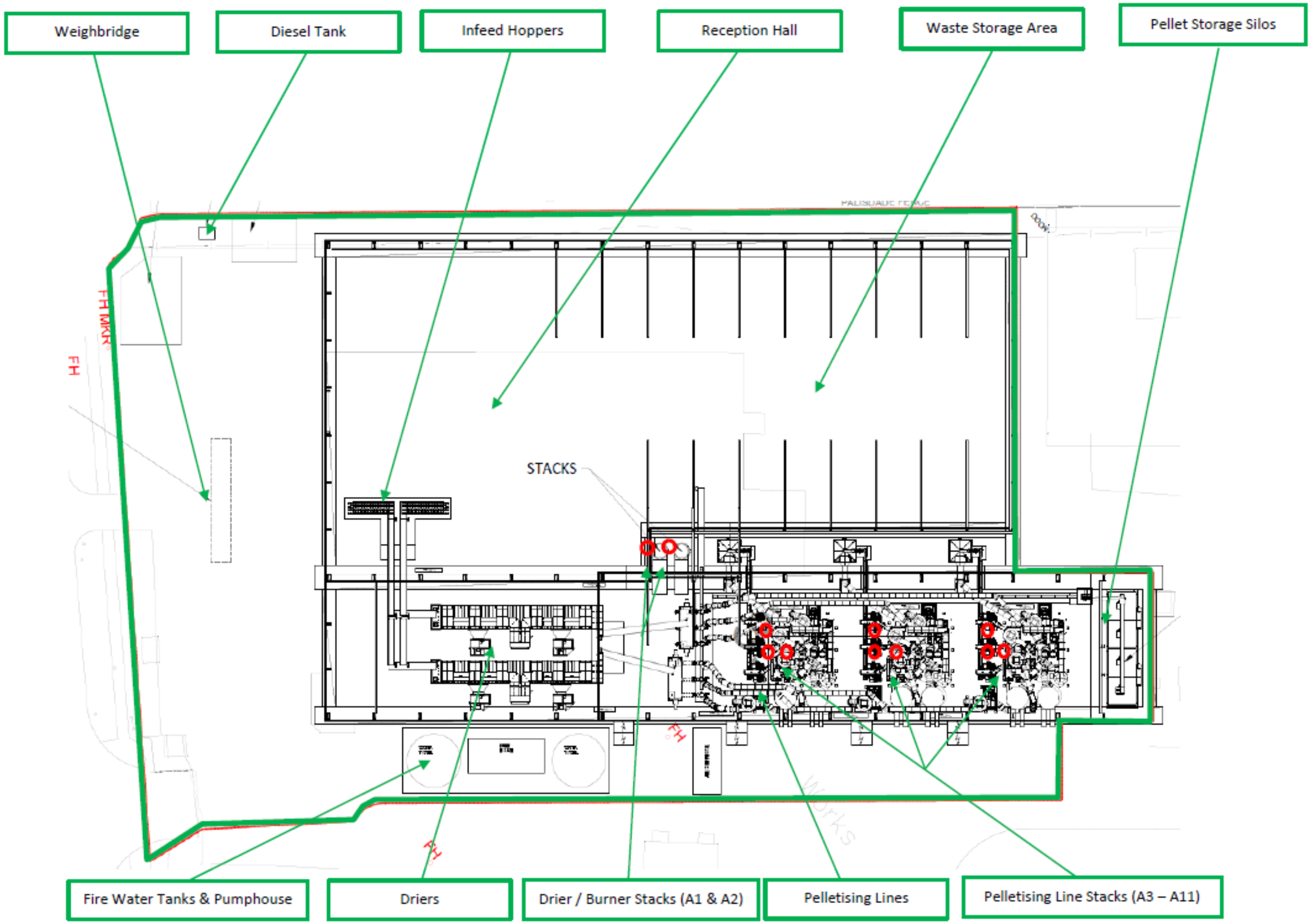


Figure 1: Proposed Site Layout

2. ASSOCIATED CARBON ASSESSMENT

2.1 System Boundary

The system boundary for the Carbon Footprint of the Product (CFP) has been established in accordance with the requirements of ISO 14067:2018 *'Greenhouse gases — Carbon footprint of products — Requirements and guidelines for quantification'*.

For the purposes of the system assessment the system boundary has been determined as follows:

- Boundary begins at the point at which Waste Knot's suppliers ship the SRF to the facility; and
- Boundary ends at the point at which the pellet becomes a final product (exit gate).

A visual representation of the assessed boundary can be found in figure 1 below.

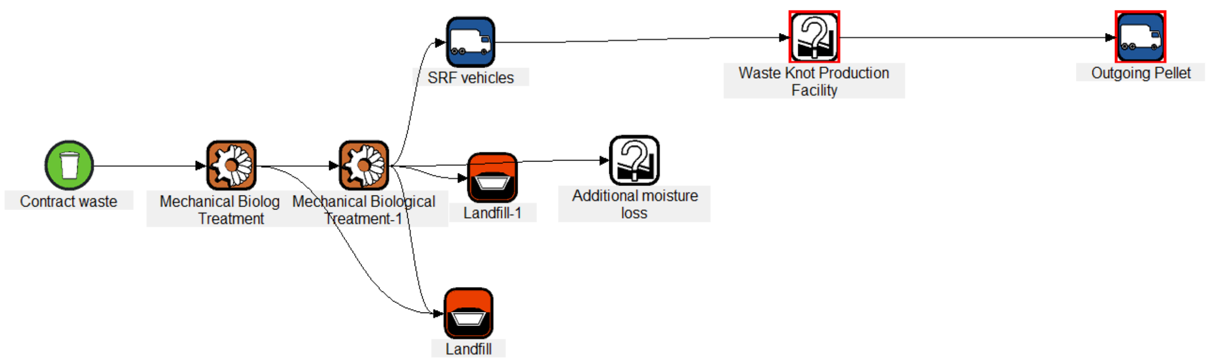


Figure 1: System Boundary

For further clarity, indicative associates carbon figures for transport to a number of proposed purchasers has also been including in section 2.5 of this report. These have not been included within the final summary comments and should be assessed on a case-by-case basis.

2.2 SRF Production Carbon Emissions

SRF Production emissions have been calculated using an electrical intensity figure of 70kWh per tonne of SRF as quoted in *'Mass, Energy and Material Balances of SRF production process. Part 3: Solid Recovered Fuel Produced from Municipal Solid Waste' (M. Nasrullah, 2015).*

The incoming produced tonnage has been estimated as 350,000 tonnes per annum to account for losses (such as moisture) during production. All additional figures have been derived from the Energy Mass Balance as found in Appendix A of the report.

The conversion factor applied has assumed a base factor of 0.23314 for grid supplied electricity plus a transmission loss factor of 0.02005 as per the *'UK Government GHG Conversion Factors for Company Reporting' (v1.0 – 2020).*

Table 2.2 – SRF Production Calculations	
A. Total SRF Produced (T/annum)	350,000
B. kWh per tonne	70
C. Total KWh (A x B)	24,500,000
D. Total Pellet Product (T)	243,541
E. kWh per tonne pellet (C/D)	100.59
F. Conversion Factor	0.25319
kgCO₂e Per Tonne Pellet (E*F)	***25.47***

Based on an incoming tonnage SRF tonnage of 302,400 tonnes per annum, the estimated SRF production emissions are ***25.46kgCO_2e*** per tonne of incoming material.

2.3 Incoming SRF Transport Carbon Emissions

Carbon emissions for emissions associated with transport of SRF to the pellet production plant have been calculated using an average pro-rata mileage of 77.84 miles per trip as detailed in Appendix B of this report.

Table 2.3 – SRF Transport Calculations	
A. Total SRF Transported (T/annum)	302,400
B. Tonnes per Artic Load	25
C. Total Loads (A/B)	12,096
D. Average Trip (miles)	77.84
E. Total Miles (C x D)	941,552.64
F. Conversion Factor	1.47366
G. Total Emissions (kgCO_2e)	1,387,528.46
H. Total Tonnes produced per annum (29 tonnes * 8400 hours)	243,600
kgCO_2e Per Tonne Pellet (G/H)	***5.69***

Based on an incoming SRF delivery distance of 77.84 miles, the estimated SRF transport emissions are ***5.69kgCO_2e*** per tonne of incoming material.

2.4 Pellet Production Load - Heating

The production heating load has been calculated based on a utilised capacity of 6.1MW_{th} within the production facility in accordance with the facilities Environmental Permit.

This figure covers all process heat derived from natural gas involved with the production of pellets such as drying SRF, etc. Conversion figures used as *'Natural Gas kWh (Gross CV)'* as listed within the *'UK Government GHG Conversion Factors for Company Reporting' (v1.0 – 2020).* Table 2.3 details the assumptions made during the calculation process and provides the overall estimated kgCO_2e for heating during the production process.

Table 2.4 – Production Heat Calculations (Natural Gas)	
A. Total KWh (provided by Waste Knot)	80,769,231
B. CO2 Conversion Factor (kgCO_2e gross CV)	0.18455
C. Total kgCO_2/Per Annum (A*B)	14,905,961
D. Total Tonnes produced per annum (29 tonnes * 8400 hours)	243,600
kgCO_2e Per Tonne Pellet (C/D)	***61.19***

2.5 Pellet Production Load - Electricity

Production load electricity estimates have been calculated using energy load data provided by Waste Knot assuming and an operational period of 8,400 hours per annum.

This figure covers all electricity used during the production of the pellets including ancillary activities such as offices and welfare facilities. The conversion factor applied has assumed a base factor of 0.23314 for grid suppled electricity plus a transmission loss factor of 0.02005 as per the *'UK Government GHG Conversion Factors for Company Reporting' (v1.0 – 2020).*

Table 2.5 – Production Energy Calculations	
A. Total kWh (provided by Waste Knot)	35,132,158
B. CO_2 Conversion Factor (kgCO_2e)	0.25319
C. Total kgCO_2/Per Annum (D*E)	8,895,111.08
D. Total Tonnes produced per annum (29 tonnes * 8400 hours)	243,600
kgCO2e per Tonne Pellets (C/D)	***36.52***

The total electrical load for pellet production (inclusive of ancillary activities) has been calculate as ***36.52kgCO_2e*** per tonne of pellet produced.

3. AVOIDED EMISSIONS

As part of the pellet production review process, a comparison of the avoided emissions of utilising waste for pellet production as opposed to landfill has been completed to establish the potential avoided emissions.

Unlike liquids, food wastes (biodegradable municipal waste [BMW]) and waste wood, there are no regulatory restrictions that limited the disposal of commercial and industrial solid waste, hence when considering the life cycle carbon impacts of the pellet we can consider the 'avoided emissions' resulting from diverting C&I waste from landfill.

Calculations have been completed in accordance with UNFCCC Resource Guide Module 3: National Greenhouse Gas Inventories using Tier 2 Emissions Factors. In this instance, factors mandated within the *'UK Government GHG Conversion Factors for Company Reporting' (v1.0 – 2020).*

The estimated avoided emissions for landfill waste can be found in Table 3.1 below.

Table 3.1 – Avoided Emissions	
A. Source C&I wastes into SRF plant (T)	350,000
B. Finished Pellets Produced (T)	243,541
C. A / B	1.437
D. Conversion Factor (Waste to Landfill)	458.16
kgCO2e per Tonne Pellets (C * D)	***658.38***

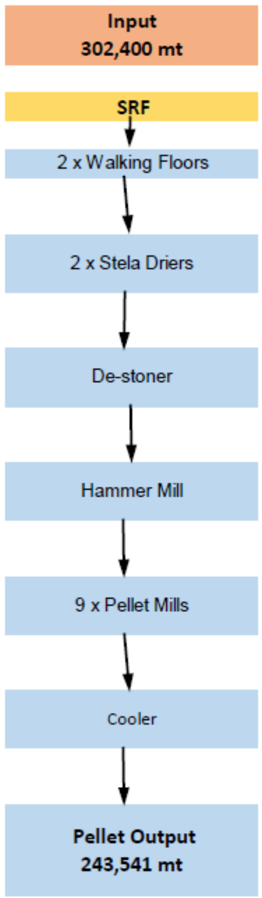
4. SUMMARY

Based on the calculation completed in section 2 of the report, the total embodied carbon for production of Waste Knot's alternative fuel pellet Is ***128.87kgCO_2e per tonne of pellet produced*** to the end of production, inclusive of process SRF and transportation to site.

Through production of the pellets, a net benefit of ***~530kgCO_2e per tonne of pellets produced*** by diverting SRF from landfill and utilising it in pellet product. As a result of, pellet production when looked at on a lifecycle basis has a net negative carbon balance.

APPENDIX A: ENERGY MASS BALANCE

FLOW CHART / MASS BALANCE - 243,541 tpa pellet production



SRF specification - see 'SRF SPECIFICATION' tab @ SG 0.1tonnes/m3 - assume 10 tonnes/walking floor. 302,400 tonnes = 36 tonnes/hr approx = 2 deliveries per hour

Each walking floor will handle 22 tonnes per hour
see MOISTURE CALC tab for moisture reduction

SRF Belt Drier rated @ 13.56 tonnes per hour
see MOISTURE CALC tab for reduction calculation

DS250 Air separator/de-stoner

MB315 Hammer Mill
grit and metal removal

GRB2 850.320.3R Pellet Mills

Pellet Specification - see 'PELLET SPECIFICATION' tab
Hours run = 24/day x 7days/wk x 50 wks/yr = 8,400 hrs
Output per hour = 243,541/8400 = 29 tonnes/hr

MASS BALANCE

INPUT tonnes	REDUCTION %	OUTPUT tonnes
302,400		302,400
302,400		302,400
302,400	9%	275,184
275,184	4%	264,177
264,177	4%	253,610
253,610	3%	246,001
246,001	1%	243,541
243,541		243,541

APPENDIX B: AVERAGE MILEAGE CALCULATION

SRF Provider	Distance from TS2 1UT (miles)	Tonnes per Annum
North West Recycling	99	100,000
AWM	74	100,000
Niramax	12	65,000
Hamilton Waste	156	20,000
Enva	127	20,000
*Pro-rata average mileage (distance * Tonnes) + (distance * Tonnes) / number of suppliers*		*77.84*

Review of Waste Knot Pellets Life Cycle Assessment

Sol Environment Ltd (SOL) were appointed by Waste Knot Energy Ltd (Waste Knot) to undertake an assessment of the greenhouse gas (GHG) emissions associated with the production of a 16 MJ pellet at their pelletising facility.

The assessment reviews the emissions associated with the following production phases:

1. Solid Recovered Fuel (SRF) – the emissions associated with the production of SRF were calculated using a proxy of 70kWh of electricity per tonne of production. This figure was then multiplied by an estimated incoming tonnage received at the Waste Knot Energy facility to calculate the total electrical load required to produce the SRF. The total electrical load was then multiplied by the CO2e emission metrics for UK grid supplied electricity and transmission and distribution UK Government GHG Conversion Factors for Company Reporting, 2020.

   The incoming tonnage has been estimated as 350,000 tonnes of C&I waste with 302,400 tonnes being transported onto the Waste Knot facility. It is understood that the difference, 47,600 tonnes, can be accounted for with losses through discarded material and moisture.

Comments: This approach maybe simplistic, and one may expect to see additional inputs involved in the SRF process apart from just electricity. Additionally, one may wish to include the scope 3 well-to-tank (WTT) emissions associated with the use of UK Electricity. These are available via the UK Government GHG Conversion Factors for Company Reporting.

2. Transportation of SRF to the Waste Knot facility – the emissions associated with the transportation of SRF from the processing facility to the Waste Knot site have been calculated using an average transport distance of 77.84 miles per trip. This figure has been calculated using a pro-rata calculation assessing the distance between several SRF producers and the tonnes of material they produce each year. Further details can be found in Appendix B in the SOL report.

   The calculation assumes 302,400 tonnes are transported in articulated lorries under average laden (25 tonnes).

Comments: This method appears suitable. However, it may be overly conservative as one would expect the lorries to transport a greater tonnage. Additionally the calculation does not include the scope 3 WTT emissions available for this type of transport. These will contribute a small amount to the final figure but should be included to gain a full understanding of the emissions associated with transportation.

3. Pellet Production Load: Heating – the emissions for the natural gas consumed during the drying phase at the Waste Knot facility have been calculation based on an annual load of 80,769,231 kWh of heat multiplied by the emission metric for 100% mineral blend natural gas.

Comments: The calculations method appears appropriate. However, the incorrect emission metric has been selected. The report uses the metric for natural gas 100% mineral blend (0.18455 kg CO2e per kWh). This metric is not appropriate for calculating the emissions associated with natural gas consumption from the National Grid. Instead one should use a metric of 0.18387 kg CO2e per kWh. It is noted that the difference is between the metrics is minor. No WTT emissions associated with the use of natural gas have been included.

4. Pellet Production Load – Electricity – the emissions for the electricity used during in the pelletisation process have been calculated based on an annual load of 35,132,158 kWh of electricity multiplied by the appropriate emission metric.

Comments: The calculations of the emissions associated with the use of natural gas appear appropriate. However, No WTT emissions associated with the use of natural gas have been included.

5. Waste Knot Facility Losses – during the pelletisation process there are losses associated with the evaporation of moisture and disposal of unsuitable materials. These are outlined in appendix A of the SOL report and summarised below:

Phase	Input (tonnes)	Losses %	Output (tonnes)
Walking floor	302,400	0%	302,400
SRF belt drier	304,400	9%	275,184
Air separator/ de-stoner	275,184	4%	264,177
Grit & metal removal	264,177	4%	253,610
Pellet mills	253,610	3%	246,001
Cooler	246,001	1%	243,541
		Pellets produced for market =	243,541
		Total losses =	58,859

Table 1: Material mass balance

6. Avoided Emissions – the SOL report completes a review of the emissions associated with utilising wastes for pellet production and compares this against the potential emissions avoided if this waste was sent to landfill to calculate an emission avoided figure. This figure is calculated as follows:

$$(350{,}000\ tonnes\ C\&I\ waste\ into\ SRF\ plant \times 458.16\ kg\ CO2e\ per\ tonne\ of\ waste) \div 243{,}541\ tonnes\ of\ finished\ pellets\ produced = 658.38\ kg\ CO2e\ per\ tonne\ of\ finished\ pellets\ produced$$

The figure for avoided emissions 658.38 kg CO2e per tonne of pellet has then been subtracted from the total emissions associated with the pellet production (SRF refining, transport, natural gas, and electricity) to calculate a carbon intensity of -530 kg CO2e per tonne of pellets produced.

Comments: This calculation assumes that if the C&I waste was not to be sent to the SRF plant to begin the pelletisation process it would be sent directly to landfill. The emissions avoid via alternative disposal methods such as incineration have been explored in the accompanying spreadsheet.

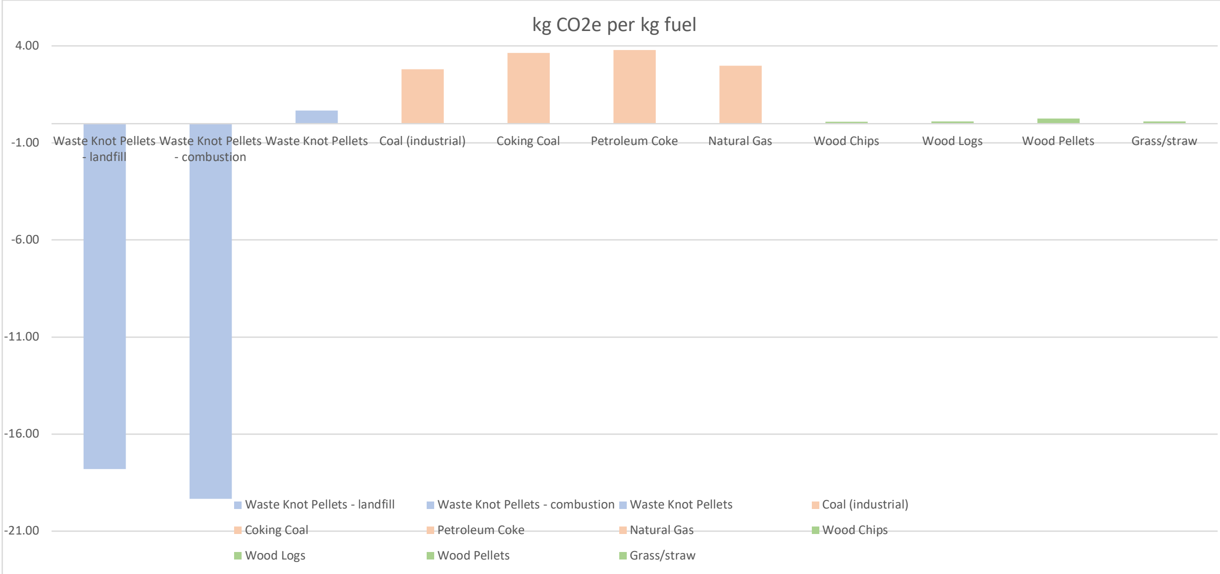
Fuel	Fuel Classification	Quantity of Fuel (kg)	Net Calorific Value (MJ/kg)	Energy Generated (kWh)
Waste Knot Pellets - landfill	Waste	1	21	5.89
Waste Knot Pellets - combustion	Waste	1	21	5.89
Waste Knot Pellets	Fuel	1	21	5.89
Coal (industrial)	Fossil Fuel	1	25	7.06
Coking Coal	Fossil Fuel	1	30	8.40
Petroleum Coke	Fossil Fuel	1	34	9.44
Natural Gas	Fossil Fuel	1	45	12.51
Wood Chips	Biofuel	1	14	3.78
Wood Logs	Biofuel	1	15	4.09
Wood Pellets	Biofuel	1	17	4.80
Grass/straw	Biofuel	1	13	3.74

Scope 1 (kg CO2e)	Scope 3 (kg CO2e)	kg CO2e per kg fuel
0.55	-18.35	-17.80
0.55	-19.89	-19.34
0.55	0.13	0.68
2.40	0.39	2.80
3.17	0.47	3.63
3.39	0.40	3.79
2.54	0.43	2.97
0.06	0.03	0.09
0.06	0.05	0.11
0.07	0.18	0.25
0.05	0.06	0.11

SOL Results		
SRF Production	25.47	kg CO2e per tonne of pellet
SRF Transport	5.69	kg CO2e per tonne of pellet
Pellet production load - heating	61.19	kg CO2e per tonne of pellet
Pellet production load - electricity	36.52	kg CO2e per tonne of pellet
Emissions	128.87	kg CO2e per tonne of pellet
Emissions	0.13	kg CO2e per kg of pellet

SOL Emissions Avoided		
C&I waste into SRF plant	350,000	tonnes
Pellets Produced	243,541	tonnes
Waste in / pellets produced	1.44	
Waste to landfill	658.46	kg CO2e per tonne of pellet

Alternative disposal - Combustion	702.76	kg CO2e per tonne of pellet



Items	Metric	Unit	Scope	Source
Conversion MJ > kWh	0.278			BEIS Conversion Factors 2021
Conversion kWh > MJ	3.600			BEIS Conversion Factors 2021
Coal (Industrial)	0.341	kg CO2e/ kWh (Net CV)	1	BEIS Conversion Factors 2021
Coal (Industrial) WTT	0.056	kg CO2e/ kWh (Net CV)	3	BEIS Conversion Factors 2021
Coal (Industrial)	2,403.84	kg CO2e/ tonne	1	BEIS Conversion Factors 2021
Coal (Industrial) WTT	393.14	kg CO2e/ tonne	3	BEIS Conversion Factors 2021
Petroleum Coke	0.359	kg CO2e/ kWh (Net CV)	1	BEIS Conversion Factors 2021
Petroleum Coke WTT	0.042	kg CO2e/ kWh (Net CV)	3	BEIS Conversion Factors 2021
Petroleum Coke	3,386.86	kg CO2e/ tonne	1	BEIS Conversion Factors 2021
Petroleum Coke WTT	399.25	kg CO2e/ tonne	3	BEIS Conversion Factors 2021
Natural Gas	0.203	kg CO2e/ kWh (Net CV)	1	BEIS Conversion Factors 2021
Natural Gas WTT	0.035	kg CO2e/ kWh (Net CV)	3	BEIS Conversion Factors 2021
Coking coal	0.377	kg CO2e/ kWh (Net CV)	1	BEIS Conversion Factors 2021
Coking coal WTT	0.056	kg CO2e/ kWh (Net CV)	3	BEIS Conversion Factors 2021
Wood chips	0.015	kg CO2e/ kWh (Net CV)	1	BEIS Conversion Factors 2021
Wood chips WTT	0.008	kg CO2e/ kWh (Net CV)	3	BEIS Conversion Factors 2021
Wood logs	0.015	kg CO2e/ kWh (Net CV)	1	BEIS Conversion Factors 2021
Wood logs WTT	0.013	kg CO2e/ kWh (Net CV)	3	BEIS Conversion Factors 2021
Wood pellets	0.015	kg CO2e/ kWh (Net CV)	1	BEIS Conversion Factors 2021
Wood pellets WTT	0.037	kg CO2e/ kWh (Net CV)	3	BEIS Conversion Factors 2021
Grass/straw	0.013	kg CO2e/ kWh (Net CV)	1	BEIS Conversion Factors 2021
Grass/straw WTT	0.016	kg CO2e/ kWh (Net CV)	3	BEIS Conversion Factors 2021
Household residual waste (combustion)	0.021	kg CO2e/ kg	1	BEIS Conversion Factors 2021
Commercial and industrial waste - landfill	458.18	kg CO2e / tonne	1 & 3	BEIS Conversion Factors 2020
Commercial and industrial waste - combustion	489.00	kg CO2e/ kWh (Net CV)	1	EcoInvent
Waste knot pellets - landfill	-3.118	kg CO2e per kWh		
Waste knot pellets - combustion	-3.378	kg CO2e per kWh		

Electricity
Electricity T&D
Electricity WTT
Natural Gas
Natural Gas WTT

Cement Kiln		
Total Load	100	GJ

Scenario A

	Fuel Classification	Fuel % Split	GJ	NCV (GJ/tonne)	Tonnes	Emissions kg CO2e
Petroleum coke	Fossil fuel	100%	100	34	2.94	11,144.79

Waste knot pellets	Waste	0%	0	22	0.00	0
Waste knot pellets	Waste	0%	0	20	0.00	0
Waste knot pellets	Waste	0%	0	18	0.00	0

Potential Emission Savings = 0.00

Scenario B

	Fuel Classification	Fuel % Split	GJ	NCV (GJ/tonne)	Tonnes	Emissions kg CO2e
Petroleum coke	Fossil fuel	75%	75	34	2.21	8,358.59

Waste knot pellets	Waste	25%	25	22	1.14	771.2
Waste knot pellets	Waste	25%	25	20	1.25	848.3
Waste knot pellets	Waste	25%	25	18	1.39	942.5

Potential Emission Savings = 2,786.20

Scenario C

	Fuel Classification	Fuel % Split	GJ	NCV (GJ/tonne)	Tonnes	Emissions kg CO2e
Petroleum coke	Fossil fuel	50%	50	34	1.47	5,572.40

Waste knot pellets	Waste	50%	50	22	2.27	1,542.32
Waste knot pellets	Waste	50%	50	20	2.50	1,696.55
Waste knot pellets	Waste	50%	50	18	2.78	1,885.06

Potential Emission Savings = 5,572.40

Scenario D

	Fuel Classification	Fuel % Split	GJ	NCV (GJ/tonne)	Tonnes	Emissions kg CO2e
Petroleum coke	Fossil fuel	25%	25	34	0.74	2,786.20

Waste knot pellets	Waste	75%	75	22	3.41	2,313.48
Waste knot pellets	Waste	75%	75	20	3.75	2,544.83
Waste knot pellets	Waste	75%	75	18	4.17	2,827.58

Potential Emission Savings = 8,358.59

Scenario A

	Fuel Classification	Fuel % Split	GJ	NCV (GJ/tonne)	Tonnes	Emissions kg CO2e
Petroleum coke	Fossil fuel	100%	100	34	2.94	11,144.79

Waste knot pellets	Fuel	0%	0	22	0.00	0
Waste knot pellets	Fuel	0%	0	20	0.00	0
Waste knot pellets	Fuel	0%	0	18	0.00	0

Potential Emission Savings
0
0
0

Scenario B

	Fuel Classification	Fuel % Split	GJ	NCV (GJ/tonne)	Tonnes	Emissions kg CO2e
Petroleum coke	Fossil fuel	75%	75	34	2.21	8,358.59

Waste knot pellets	Fuel	25%	25	22	1.14	771.2
Waste knot pellets	Fuel	25%	25	20	1.25	848.3
Waste knot pellets	Fuel	25%	25	18	1.39	942.5

Potential Emission Savings
2,015.04
1,937.92
1,843.67

Scenario C

	Fuel Classification	Fuel % Split	GJ	NCV (GJ/tonne)	Tonnes	Emissions kg CO2e
Petroleum coke	Fossil fuel	50%	50	34	1.47	5,572.40

Waste knot pellets	Fuel	50%	50	22	2.27	1,542.32
Waste knot pellets	Fuel	50%	50	20	2.50	1,696.55
Waste knot pellets	Fuel	50%	50	18	2.78	1,885.06

Potential Emission Savings
4,030.08
3,875.85
3,687.34

Scenario D

	Fuel Classification	Fuel % Split	GJ	NCV (GJ/tonne)	Tonnes	Emissions kg CO2e
Petroleum coke	Fossil fuel	25%	25	34	0.74	2,786.20

Waste knot pellets	Fuel	75%	75	22	3.41	2,313.48
Waste knot pellets	Fuel	75%	75	20	3.75	2,544.83
Waste knot pellets	Fuel	75%	75	18	4.17	2,827.58

Potential Emission Savings
6,045.12
5,813.77
5,531.01

	MD22-00317.001	MD21-01385.001	MD22-00293.001	MD21-01415.001	Average
Carbon content	51.30%	54.50%	55.50%	58.60%	55.0%
Net calorific value (MJ/kg)	21.92	20.40	22.15	20.30	21.19