Research to support the review of the Renewable Obligation Scotland and impact of the Renewable Heat Incentive

Part 2: Biomass thresholds for electricity, CHP and heat generation

Appendices

Designing practical solutions for a sustainable future

NORTH ENERGY

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Part 2: Biomass threshold for electricity; CHP and heat generation

Appendices

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October 2011

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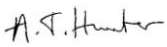
Checked by	Jane Hunter		8 December 2011
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APPENDIX A: Parameters for Biomass Energy Technologies

Type of Biomass Feedstock	Specification of Biomass Feedstock: Moisture Content (%)	Use of Conversion Technology	Scale of Plant: Input Rate (t/h)		Scale of Plant: Output Rate (MW)		Specification of Plant: Net Thermal Efficiency (%)		Specification of Plant: Heat to Power Ratio (CHP only)
			Lower Range	Higher Range	Lower Range	Higher Range	Lower Range	Higher Range	
Wood Logs	20	Individual Domestic Heating	0.00368	0.0245	0.015 thermal	0.1 thermal	80	91	
Round Wood	53	Power only	64	64	44 electricity	44 electricity	32	32	
Wood Briquettes	8	Individual Domestic Heating	0.00306	0.0653	0.015 thermal	0.32 thermal	80	93	
Clean Wood Chips	35	Group Domestic Heating, Commercial and Industrial Heating	0.0157	6.26	0.05 thermal	20 thermal	90	90.4	
	35	Commercial and Industrial Combined Heat and Power Generation	0.689	54.79	0.4 electricity 1.8 thermal	50 electicity 125 thermal	16 electrical 86.5 overall (elec + heat)	24.7 electrical 29.4 heat 54 overall (electricity + heat)	1.2 - 4.4
	35	Power generation with flue gas heat recovery	17.84	135	50 electricity 7 thermal	100 electricity 13.7 thermal	33 net electrical 3.58 thermal	33 net electrical 3.58 thermal	0.137
	35	Power generation Only	15.65	109.58	50 electricity	350 electricity	33 net electrical	33 net electrical	

Type of Biomass Feedstock	Specification of Biomass Feedstock: Moisture Content (%)	Use of Conversion Technology	Scale of Plant: Input Rate (t/h)		Scale of Plant: Output Rate (MW)		Specification of Plant: Net Thermal Efficiency (%)		Specification of Plant: Heat to Power Ratio (CHP only)
			Lower Range	Higher Range	Lower Range	Higher Range	Lower Range	Higher Range	
Unclean Wood Chips	5-55	Commercial and Industrial Heating	0.069	6.26	0.1 thermal	20 thermal	88.9 net	90.4 net	
	5-55	Commercial and Industrial Combined Heat and Power Generation	0.689	54.79	0.4 electricity 1.8 thermal	50 electricity 125 thermal	16 electrical 86.5 overall (elec + heat)	24.7 electrical 29.4 heat 54 overall (electricity + heat)	1.2 - 4.4
	5-55	Power Only Generation	15.65	109.58	50 electricity	350 electricity	33 net electrical		
Wood Pellets	10	Individual Domestic Heating	0.00426	0.011	0.02 thermal	0.05 thermal	90	94	
	10	Domestic, Commercial and Industrial Heating	0.00426	0.04	0.02 thermal	0.180 thermal	93	94	

APPENDIX B: Summary of Typical Results

Biomass Chain	Scale: net output rating (MW)	End Use Thermal Efficiency (%)	Transport in Forest	Transport to Processing	Transport to End User	Results		
						Primary Energy: fossil fuels (MWh/MWh)	Primary Energy: biomass (odt/MWh)	Total Greenhouse Gas Emissions (kg eq. CO_2/MWh)
Individual Domestic Heating by Combustion of Roundwood Logs (DRWL)	0.015 – 0.100	91.0	Typical road round trip distance: 16 km	Typical road round trip distance: 66 km	Typical local road round trip distance: 80 km	0.119	0.228	39.3
Individual Domestic Heating by Combustion of Roundwood Logs (DRWL)	0.015 – 0.100	80.0	Typical road round trip distance: 16 km	Typical road round trip distance: 66 km	Typical local road round trip distance: 80 km	0.134	0.259	43.1
Individual Domestic Heating by Combustion of Wood Briquettes from Roundwood (DRWB)	0.015 – 0.320	93.0	Typical road round trip distance: 16 km	Typical road round trip distance: 66 km	Typical local road round trip distance: 80 km	0.193	0.237	53.6
Individual Domestic Heating by Combustion of Wood Briquettes from Roundwood (DRWB)	0.015 – 0.320	80.0	Typical road round trip distance: 16 km	Typical road round trip distance: 66 km	Typical local road round trip distance: 80 km	0.224	0.276	60.4

Biomass Chain	Scale: net output rating (MW)	End Use Thermal Efficiency (%)	Transport in Forest	Transport to Processing	Transport to End User	Results		
						Primary Energy: fossil fuels (MWh/MWh)	Primary Energy: biomass (odt/MWh)	Total Greenhouse Gas Emissions (kg eq. CO_2/MWh)
Individual Domestic Heating by Combustion of Wood Pellets from Roundwood (DRWP)	0.020 – 0.050	94.0	Typical road round trip distance: 16 km	Typical road round trip distance: 66 km	Typical local road round trip distance: 80 km	0.177	0.242	39.5
Individual Domestic Heating by Combustion of Wood Pellets from Roundwood (DRWP)	0.020 – 0.050	90.0	Typical road round trip distance: 16 km	Typical road round trip distance: 66 km	Typical local road round trip distance: 80 km	0.183	0.253	40.8
Individual Domestic Heating by Combustion of Wood Pellets from Roundwood (DRWP)	0.020 – 0.050	94.0	Typical road round trip distance: 16 km	Typical road round trip distance: 66 km	Maximum national road round trip distance: 600 km	0.198	0.242	45.2
Individual Domestic Heating by Combustion of Wood Pellets from Roundwood (DRWP)	0.020 – 0.050	90.0	Typical road round trip distance: 16 km	Typical road round trip distance: 66 km	Maximum national road round trip distance: 600 km	0.205	0.253	46.8

Biomass Chain	Scale: net output rating (MW)	End Use Thermal Efficiency (%)	Transport in Forest	Transport to Processing	Transport to End User	Results		
						Primary Energy: fossil fuels (MWh/MWh)	Primary Energy: biomass (odt/MWh)	Total Greenhouse Gas Emissions (kg eq. CO_2/MWh)
Individual Domestic Heating by Combustion of Wood Pellets from Forest Residues (DFRP)	0.020 – 0.050	94.0	Typical road round trip distance: 16 km	Typical road round trip distance: 66 km	Typical local road round trip distance: 80 km	0.102	0.242	22.1
Individual Domestic Heating by Combustion of Wood Pellets from Forest Residues (DFRP)	0.020 – 0.050	90.0	Typical road round trip distance: 16 km	Typical road round trip distance: 66 km	Typical local road round trip distance: 80 km	0.105	0.253	22.6
Individual Domestic Heating by Combustion of Wood Pellets from Forest Residues (DFRP)	0.020 – 0.050	94.0	Typical road round trip distance: 16 km	Typical road round trip distance: 66 km	Maximum national road round trip distance: 600 km	0.124	0.242	27.8
Individual Domestic Heating by Combustion of Wood Pellets from Forest Residues (DFRP)	0.020 – 0.050	90.0	Typical road round trip distance: 16 km	Typical road round trip distance: 66 km	Maximum national road round trip distance: 600 km	0.127	0.253	28.6

Biomass Chain	Scale: net output rating (MW)	End Use Thermal Efficiency (%)	Transport in Forest	Transport to Processing	Transport to End User	Results		
						Primary Energy: fossil fuels (MWh/MWh)	Primary Energy: biomass (odt/MWh)	Total Greenhouse Gas Emissions (kg eq. CO_2/MWh)
Individual Domestic Heating by Combustion of Wood Briquettes from Clean Waste Wood (DCWB)	0.015 – 0.320	93.0	Not applicable	Processed on site of waste generation	Typical local road round trip distance: 80 km	0.098	n.a.	19.5
Individual Domestic Heating by Combustion of Wood Briquettes from Clean Waste Wood (DCWB)	0.015 – 0.320	80.0	Not applicable	Processed on site of waste generation	Typical local road round trip distance: 80 km	0.102	n.a.	20.2

Biomass Chain	Scale: net output rating (MW)	End Use Thermal Efficiency (%)	Transport in Forest	Transport to Processing	Transport to End User	Results		
						Primary Energy: fossil fuels (MWh/MWh)	Primary Energy: biomass (odt/MWh)	Total Greenhouse Gas Emissions (kg eq. CO_2/MWh)
Commercial or Industrial Heating by Combustion of Wood Chips from Roundwood (IRWC)	0.050 – 20.000	90.0	Typical road round trip distance: 16 km	Typical road round trip distance: 66 km	Typical local road round trip distance: 80 km	0.177	0.338	42.8
Commercial or Industrial Heating by Combustion of Wood Chips from Roundwood (IRWC)	0.050 – 20.000	90.0	Typical road round trip distance: 16 km	Typical road round trip distance: 66 km	Maximum national road round trip distance: 600 km	0.239	0.338	59.6

Biomass Chain	Scale: net output rating (MW)	End Use Thermal Efficiency (%)	Transport in Forest	Transport to Processing	Transport to End User	Results		
						Primary Energy: fossil fuels (MWh/MWh)	Primary Energy: biomass (odt/MWh)	Total Greenhouse Gas Emissions (kg eq. CO_2/MWh)
Commercial or Industrial Heating by Combustion of Wood Chips from Forest Residues (IFRC)	0.050 – 20.000	90.0	Typical road round trip distance: 16 km	Typical road round trip distance: 66 km	Typical local road round trip distance: 80 km	0.074	0.338	18.9
Commercial or Industrial Heating by Combustion of Wood Chips from Forest Residues (IFRC)	0.050 – 20.000	90.0	Typical road round trip distance: 16 km	Typical road round trip distance: 66 km	Maximum national road round trip distance: 600 km	0.137	0.338	35.8
Commercial or Industrial Heating by Combustion of Wood Chips from Clean Waste Wood (ICWC)	0.050 – 20.000	90.0	Not applicable	Processed on site of waste generation	Typical local road round trip distance: 80 km	0.042	n.a.	10.8
Commercial or Industrial Heating by Combustion of Wood Chips from Clean Waste Wood (ICWC)	0.050 – 20.000	90.0	Not applicable	Processed on site of waste generation	Maximum national road round trip distance: 600 km	0.077	n.a.	20.2

Biomass Chain	Scale: net output rating (MW)	End Use Thermal Efficiency (%)	Transport in Forest	Transport to Processing	Transport to End User	Results		
						Primary Energy: fossil fuels (MWh/MWh)	Primary Energy: biomass (odt/MWh)	Total Greenhouse Gas Emissions (kg eq. CO_2/MWh)
Commercial or Industrial Heating by Combustion of Wood Chips from Unclean Waste Wood (IUWC)	0.100 – 20.000	90.0	Not applicable	Processed on site of waste generation	Typical local road round trip distance: 80 km	0.141	n.a.	29.4
Commercial or Industrial Heating by Combustion of Wood Chips from Unclean Waste Wood (IUWC)	0.100 – 20.000	89.0	Not applicable	Processed on site of waste generation	Typical local road round trip distance: 80 km	0.142	n.a.	29.7
Commercial or Industrial Heating by Combustion of Wood Chips from Unclean Waste Wood (IUWC)	0.100 – 20.000	90.0	Not applicable	Processed on site of waste generation	Maximum national road round trip distance: 600 km	0.176	n.a.	38.9
Commercial or Industrial Heating by Combustion of Wood Chips from Unclean Waste Wood (IUWC)	0.100 – 20.000	89.0	Not applicable	Processed on site of waste generation	Maximum national road round trip distance: 600 km	0.177	n.a.	39.2

Biomass Chain	Scale: net output rating (MW)	End Use Thermal Efficiency (%)	Heat to Power Ratio	Transport in Forest	Transport to Processing	Transport to End User	Results[(a)]		
							Primary Energy: fossil fuels (MWh/MWh)	Primary Energy: biomass (odt/MWh)	Total Greenhouse Gas Emissions (kg eq. CO_2/MWh)
Commercial or Industrial Heating from Combined Heat and Power Generation by Combustion of Wood Chips from Roundwood (CRWC)	1.800 – 125.000 heat	86.5	4.4	Typical road round trip distance: 16 km	Typical road round trip distance: 66 km	Typical local road round trip distance: 80 km	0.126	0.297	30.0
Commercial or Industrial Heating from Combined Heat and Power Generation by Combustion of Wood Chips from Roundwood (CRWC)	1.800 – 125.000 heat	54.0	1.2	Typical road round trip distance: 16 km	Typical road round trip distance: 66 km	Typical local road round trip distance: 600 km	0.236	0.387	58.5

Notes

(a) Assuming a ratio of value of electricity to value of heat of 2.00 from the UK Emissions Trading Scheme.

Biomass Chain	Scale: net output rating (MW)	End Use Thermal Efficiency (%)	Heat to Power Ratio	Transport in Forest	Transport to Processing	Transport to End User	Results[(a)]		
							Primary Energy: fossil fuels (MWh/MWh)	Primary Energy: biomass (odt/MWh)	Total Greenhouse Gas Emissions (kg eq. CO_2/MWh)
Commercial or Industrial Heating from Combined Heat and Power Generation by Combustion of Wood Chips from Forest Residue (CFRC)	1.800 – 125.000 heat	86.5	4.4	Typical road round trip distance: 16 km	Typical road round trip distance: 66 km	Typical local road round trip distance: 80 km	0.036	0.297	9.1
Commercial or Industrial Heating from Combined Heat and Power Generation by Combustion of Wood Chips from Forest Residue (CFRC)	1.800 – 125.000 heat	54.0	1.2	Typical road round trip distance: 16 km	Typical road round trip distance: 66 km	Typical local road round trip distance: 600 km	0.118	0.387	31.2

Notes

(a) Assuming a ratio of value of electricity to value of heat of 2.00 from the UK Emissions Trading Scheme.

Biomass Chain	Scale: net output rating (MW)	End Use Thermal Efficiency (%)	Heat to Power Ratio	Transport in Forest	Transport to Processing	Transport to End User	Results[(a)]		
							Primary Energy: fossil fuels (MWh/MWh)	Primary Energy: biomass (odt/MWh)	Total Greenhouse Gas Emissions (kg eq. CO_2/MWh)
Commercial or Industrial Heating from Combined Heat and Power Generation by Combustion of Wood Chips from Clean Waste Wood (CCWC)	1.800 – 125.000 heat	86.5	4.4	Not applicable	Processed on site of waste generation	Typical local road round trip distance: 80 km	0.008	n.a.	2.0
Commercial or Industrial Heating from Combined Heat and Power Generation by Combustion of Wood Chips from Clean Waste Wood (CCWC)	1.800 – 125.000 heat	54.0	1.2	Not applicable	Processed on site of waste generation	Typical local road round trip distance: 600 km	0.050	n.a.	13.4

Notes
(a) Assuming a ratio of value of electricity to value of heat of 2.00 from the UK Emissions Trading Scheme.

Biomass Chain	Scale: net output rating (MW)	End Use Thermal Efficiency (%)	Heat to Power Ratio	Transport in Forest	Transport to Processing	Transport to End User	Results[(a)]		
							Primary Energy: fossil fuels (MWh/MWh)	Primary Energy: biomass (odt/MWh)	Total Greenhouse Gas Emissions (kg eq. CO_2/MWh)
Commercial or Industrial Heating from Combined Heat and Power Generation by Combustion of Wood Chips from Unclean Waste Wood (CUWC)	1.800 – 125.000 heat	86.5	1.2	Not applicable	Processed on site of waste generation	Typical local road round trip distance: 80 km	0.094	n.a.	18.4
Commercial or Industrial Heating from Combined Heat and Power Generation by Combustion of Wood Chips from Unclean Waste Wood (CUWC)	1.800 – 125.000 heat	54.0	1.2	Not applicable	Processed on site of waste generation	Typical local road round trip distance: 600 km	0.163	n.a.	34.8

Notes
(a) Assuming a ratio of value of electricity to value of heat of 2.00 from the UK Emissions Trading Scheme.

Biomass Chain	Scale: net output rating (MW)	End Use Thermal Efficiency (%)	Heat to Power Ratio	Transport in Forest	Transport to Processing	Transport to End User	Results[(a)]		
							Primary Energy: fossil fuels (MWh/MWh)	Primary Energy: biomass (odt/MWh)	Total Greenhouse Gas Emissions (kg eq. CO_2/MWh)
Commercial or Industrial Electricity from Combined Heat and Power Generation by Combustion of Wood Chips from Roundwood (CRWC)	0.400 – 50.000 electricity	86.5	4.4	Typical road round trip distance: 16 km	Typical road round trip distance: 66 km	Typical local road round trip distance: 80 km	0.251	0.366	60.0
Commercial or Industrial Electricity from Combined Heat and Power Generation by Combustion of Wood Chips from Roundwood (CRWC)	0.400 – 50.000 electricity	54.0	1.2	Not applicable	Processed on site of waste generation	Typical local road round trip distance: 600 km	0.471	0.478	117.0

Notes
(a) Assuming a ratio of value of electricity to value of heat of 2.00 from the UK Emissions Trading Scheme.

Biomass Chain	Scale: net output rating (MW)	End Use Thermal Efficiency (%)	Heat to Power Ratio	Transport in Forest	Transport to Processing	Transport to End User	Results[(a)]		
							Primary Energy: fossil fuels (MWh/MWh)	Primary Energy: biomass (odt/MWh)	Total Greenhouse Gas Emissions (kg eq. CO_2/MWh)
Commercial or Industrial Electricity from Combined Heat and Power Generation by Combustion of Wood Chips from Forest Residue (CFRC)	0.400 – 50.000 electricity	86.5	4.4	Typical road round trip distance: 16 km	Typical road round trip distance: 66 km	Typical local road round trip distance: 80 km	0.071	0.593	18.2
Commercial or Industrial Electricity from Combined Heat and Power Generation by Combustion of Wood Chips from Forest Residue (CFRC)	0.400 – 50.000 electricity	54.0	1.2	Not applicable	Processed on site of waste generation	Typical local road round trip distance: 600 km	0.236	0.774	62.3

Notes
(a) Assuming a ratio of value of electricity to value of heat of 2.00 from the UK Emissions Trading Scheme.

Biomass Chain	Scale: net output rating (MW)	End Use Thermal Efficiency (%)	Heat to Power Ratio	Transport in Forest	Transport to Processing	Transport to End User	Results[(a)]		
							Primary Energy: fossil fuels (MWh/MWh)	Primary Energy: biomass (odt/MWh)	Total Greenhouse Gas Emissions (kg eq. CO_2/MWh)
Commercial or Industrial Electricity from Combined Heat and Power Generation by Combustion of Wood Chips from Clean Waste Wood (CCWC)	0.400 – 50.000 electricity	86.5	4.4	Not applicable	Processed on site of waste generation	Typical local road round trip distance: 80 km	0.015	n.a.	4.0
Commercial or Industrial Electricity from Combined Heat and Power Generation by Combustion of Wood Chips from Clean Waste Wood (CCWC)	0.400 – 50.000 electricity	54.0	1.2	Not applicable	Processed on site of waste generation	Typical local road round trip distance: 600 km	0.099	n.a.	26.7

Notes

(a) Assuming a ratio of value of electricity to value of heat of 2.00 from the UK Emissions Trading Scheme.

Biomass Chain	Scale: net output rating (MW)	End Use Thermal Efficiency (%)	Heat to Power Ratio	Transport in Forest	Transport to Processing	Transport to End User	Results[(a)]		
							Primary Energy: fossil fuels (MWh/MWh)	Primary Energy: biomass (odt/MWh)	Total Greenhouse Gas Emissions (kg eq. CO_2/MWh)
Commercial or Industrial Electricity from Combined Heat and Power Generation by Combustion of Wood Chips from Unclean Waste Wood (CUWC)	0.400 - 50.000 electricity	86.5	4.4	Not applicable	Processed on site of waste generation	Typical local road round trip distance: 80 km	0.188	n.a.	36.8
Commercial or Industrial Electricity from Combined Heat and Power Generation by Combustion of Wood Chips from Unclean Waste Wood (CUWC)	0.400 - 50.000 electricity	54.0	1.2	Not applicable	Processed on site of waste generation	Typical local road round trip distance: 600 km	0.325	n.a.	69.5

Notes
(a) Assuming a ratio of value of electricity to value of heat of 2.00 from the UK Emissions Trading Scheme.

Biomass Chain	Scale: net output rating (MW)	End Use Thermal Efficiency (%)	Transport in Forest	Transport to Processing	Transport to End User	Results		
						Primary Energy: fossil fuels (MWh/MWh)	Primary Energy: biomass (odt/MWh)	Total Greenhouse Gas Emissions (kg eq. CO_2/MWh)
Power Only Generation by Combustion of Roundwood (PRWC)	5 – 350 electricity	30.0[(b)]	Typical road round trip distance: 16 km	Not applicable	Typical local road round trip distance: 80 km	0.283	0.706	84.1
Power Only Generation by Combustion of Roundwood (PRWC)	5 – 350 electricity	30.0[(b)]	Typical road round trip distance: 200 km	Not applicable	Typical international ship round trip distance: 4000 km	0.441	0.706	126.7
Power Only Generation by Combustion of Wood Chips from Forest Residues (PFRC)	5 – 350 electricity	30.0[(b)]	Typical road round trip distance: 16 km	Not applicable	Typical local road round trip distance: 80 km	0.067	0.706	33.9
Power Only Generation by Combustion of Wood Chips from Forest Residues (PFRC)	5 – 350 electricity	30.0[(b)]	Typical road round trip distance: 200 km	Not applicable	Typical international ship round trip distance: 4000 km	0.225	0.706	77.6

Note

(b) Assuming an initial average net thermal efficiency of 33% reduced to 32% for chipping/milling at the power plants and adjusted for 5.7% transmission and distribution losses to 30%.

Biomass Chain	Scale: net output rating (MW)	End Use Thermal Efficiency (%)	Transport in Forest	Transport to Processing	Transport to End User	Results		
						Primary Energy: fossil fuels (MWh/MWh)	Primary Energy: biomass (odt/MWh)	Total Greenhouse Gas Emissions (kg eq. CO_2/MWh)
Power Only Generation by Combustion of Wood Pellets from Forest Residues (PFRP)	5 – 350 electricity	31.0[(c)]	Typical road round trip distance: 16 km	Typical local road round trip distance: 80 km	Typical local road round trip distance: 80 km	0.160	0.706	53.3
Power Only Generation by Combustion of Wood Pellets from Forest Residues (PFRP)	5 – 350 electricity	31.0[(c)]	Typical road round trip distance: 200 km	Typical local road round trip distance: 80 km	Typical international ship round trip distance: 4000 km	0.248	0.706	76.5

Note
(c) Assuming an initial average net thermal efficiency of 33% adjusted for 5.7% transmission and distribution losses to 31%.

Biomass Chain	Scale: net output rating (MW)	End Use Thermal Efficiency (%)	Transport in Forest	Transport to Processing	Transport to End User	Results		
						Primary Energy: fossil fuels (MWh/MWh)	Primary Energy: biomass (odt/MWh)	Total Greenhouse Gas Emissions (kg eq. CO_2/MWh)
Power Only Generation by Combustion of Wood Chips from Clean Waste Wood (PCWC)	5 – 350 electricity	31.0[(c)]	Not applicable	Processed on site of waste generation	Typical local road round trip distance: 80 km	0.025	n.a.	23.7
Power Only Generation by Combustion of Wood Chips from Clean Waste Wood (PCWC)	5 – 350 electricity	31.0[(c)]	Not applicable	Processed on site of waste generation	Typical international ship round trip distance: 4000 km	0.115	n.a.	48.5
Power Only Generation by Combustion of Wood Pellets from Clean Waste Wood (PCWP)	5 – 350 electricity	31.0[(c)]	Not applicable	Processed on site of waste generation	Typical local road round trip distance: 80 km	0.108	n.a.	38.7
Power Only Generation by Combustion of Wood Pellets from Clean Waste Wood (PCWP)	5 – 350 electricity	31.0[(c)]	Not applicable	Processed on site of waste generation	Typical international ship round trip distance: 4000 km	0.154	n.a.	51.4

Note
(c) Assuming an initial average net thermal efficiency of 33% adjusted for 5.7% transmission and distribution losses to 31%.

Biomass Chain	Scale: net output rating (MW)	End Use Thermal Efficiency (%)	Transport in Forest	Transport to Processing	Transport to End User	Results		
						Primary Energy: fossil fuels (MWh/MWh)	Primary Energy: biomass (odt/MWh)	Total Greenhouse Gas Emissions (kg eq. CO_2/MWh)
Power Only Generation by Combustion of Wood Chips from Unclean Waste Wood (PUWC)	5 – 350 electricity	31.0[(c)]	Not applicable	Processed on site of waste generation	Typical local road round trip distance: 80 km	0.310	n.a.	60.4
Power Only Generation by Combustion of Wood Chips from Unclean Waste Wood (PUWC)	5 – 350 electricity	31.0[(c)]	Not applicable	Processed on site of waste generation	Typical international ship round trip distance: 4000 km	0.399	n.a.	85.3
Power Only Generation by Combustion of Wood Pellets from Unclean Waste Wood (PUWP)	5 – 350 electricity	31.0[(c)]	Not applicable	Processed on site of waste generation	Typical local road round trip distance: 80 km	0.393	n.a.	75.5
Power Only Generation by Combustion of Wood Pellets from Unclean Waste Wood (PUWP)	5 – 350 electricity	31.0[(c)]	Not applicable	Processed on site of waste generation	Typical international ship round trip distance: 4000 km	0.439	n.a.	88.2

Note
(c) Assuming an initial average net thermal efficiency of 33% adjusted for 5.7% transmission and distribution losses to 31%.

APPENDIX C: Comparison of Total Primary Energy (fossil fuel) Inputs for Providing Heat and/or Electricity from Wood and Fossil Fuels

Option	Total Primary Energy (fossil fuel) Input (MWh/MWh)
Domestic Heating:	
- coal-fired	1.457 - 2.040
- oil-fired	1.311 - 1.748
- natural gas-fired	1.188 - 1.527
- wood-fired (roundwood logs)	0.119 - 0.134
- wood-fired (roundwood briquettes)	0.193 - 0.224
- wood-fired (roundwood pellets)	0.177 - 0.205
- wood-fired (forest residue pellets)	0.102 - 0.127
- wood-fired (clean waste wood briquettes)	0.098 - 0.102
Commercial or Industrial Heating from Heat Only Plant:	
- coal-fired	1.275 - 1.457
- oil-fired	1.166 - 1.499
- natural gas-fired	1.188 - 1.311
- wood-fired (roundwood chips)	0.081 - 0.143
- wood-fired (forest residue chips)	0.074 - 0.137
- wood-fired (clean waste wood chips)	0.042 - 0.077
- wood-fired (unclean waste wood chips)	0.141 - 0.177
Commercial or Industrial Heat from CHP Plant:	
- coal-fired	0.445 - 1.299
- oil-fired	0.457 - 1.336
- natural gas-fired	0.466 - 1.361
- wood-fired (roundwood chips)	0.126 - 0.236
- wood-fired (forest residue chips)	0.036 - 0.118
- wood-fired (clean waste wood chips)	0.008 - 0.050
- wood-fired (unclean waste wood chips)	0.094 - 0.163
Commercial or Industrial Electricity from CHP Plant:	
- coal-fired	0.590 - 0.743
- oil-fired	0.607 - 0.762
- natural gas-fired	0.619 - 0.777
- wood-fired (roundwood chips)	0.251 - 0.471
- wood-fired (forest residue chips)	0.071 - 0.236
- wood-fired (clean waste wood chips)	0.015 - 0.099
- wood-fired (unclean waste wood chips)	0.188 - 0.235
Electricity from Power Only Plant:	
- coal-fired	2.914 - 4.080
- oil-fired	2.997 - 4.020
- natural gas-fired	2.376 - 3.563
- wood-fired (roundwood)	0.283 - 0.441
- wood-fired (forest residue chips)	0.067 - 0.225
- wood-fired (forest residue pellets)	0.160 - 0.248
- wood fired (clean waste wood chips)	0.025 - 0.115
- wood-fired (clean waste wood pellets)	0.108 - 0.154
- wood-fired (unclean waste wood chips)	0.310 - 0.399
- wood-fired (unclean waste wood chips)	0.393 - 0.439

APPENDIX D: Typical Primary Energy [fossil fuel] Inputs for Energy Generation from Wood

Figure D1 Range of Typical Results for Total Primary Energy [fossil fuel] Inputs for the Use of Roundwood

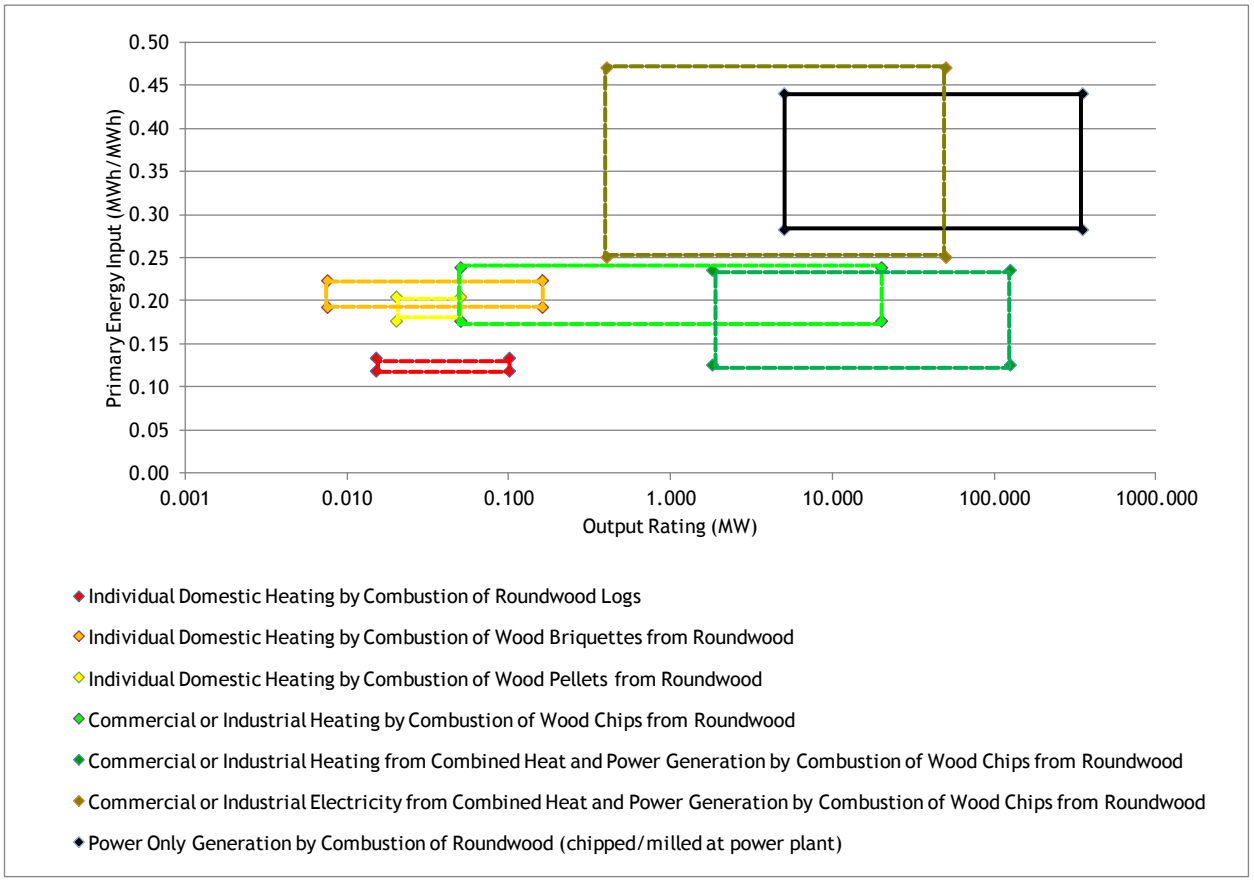


Figure D2 Range of Typical Results for Total Primary Energy [fossil fuel] Inputs for the Use of Forest Residues

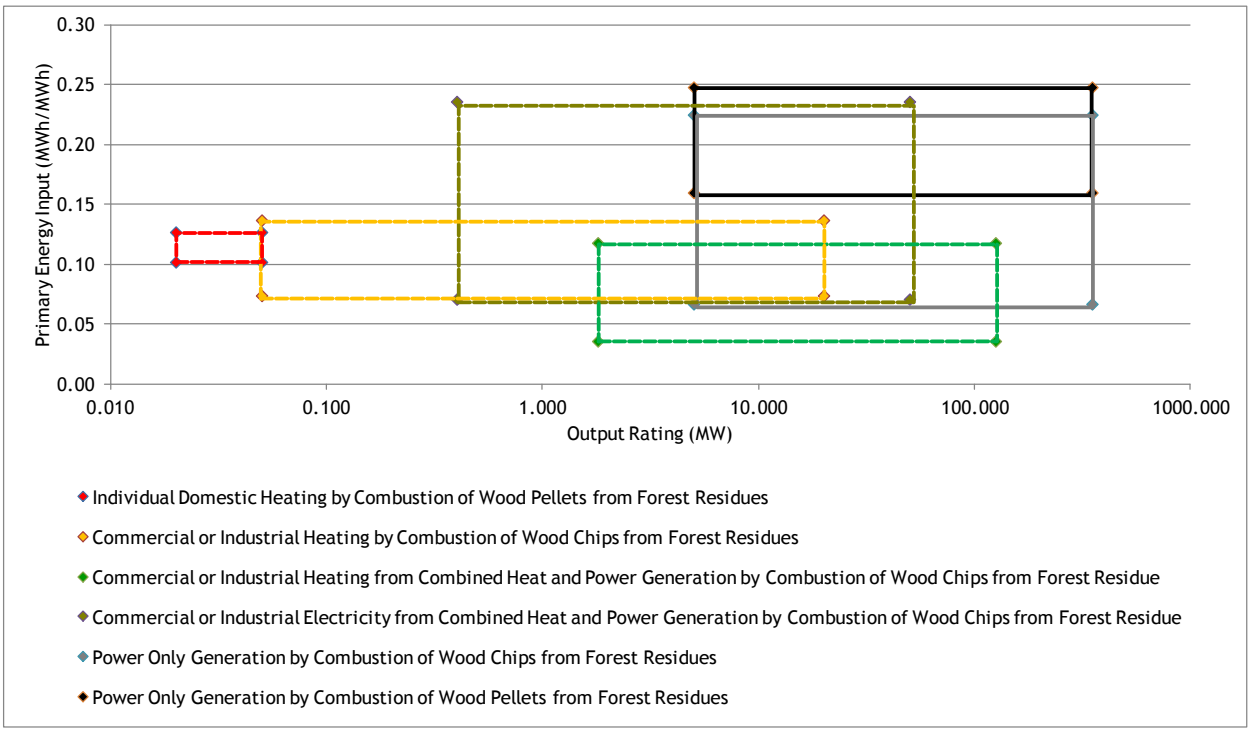


Figure D3 Range of Typical Results for Total Primary Energy [fossil fuel] Inputs for the Use of Clean Waste Wood

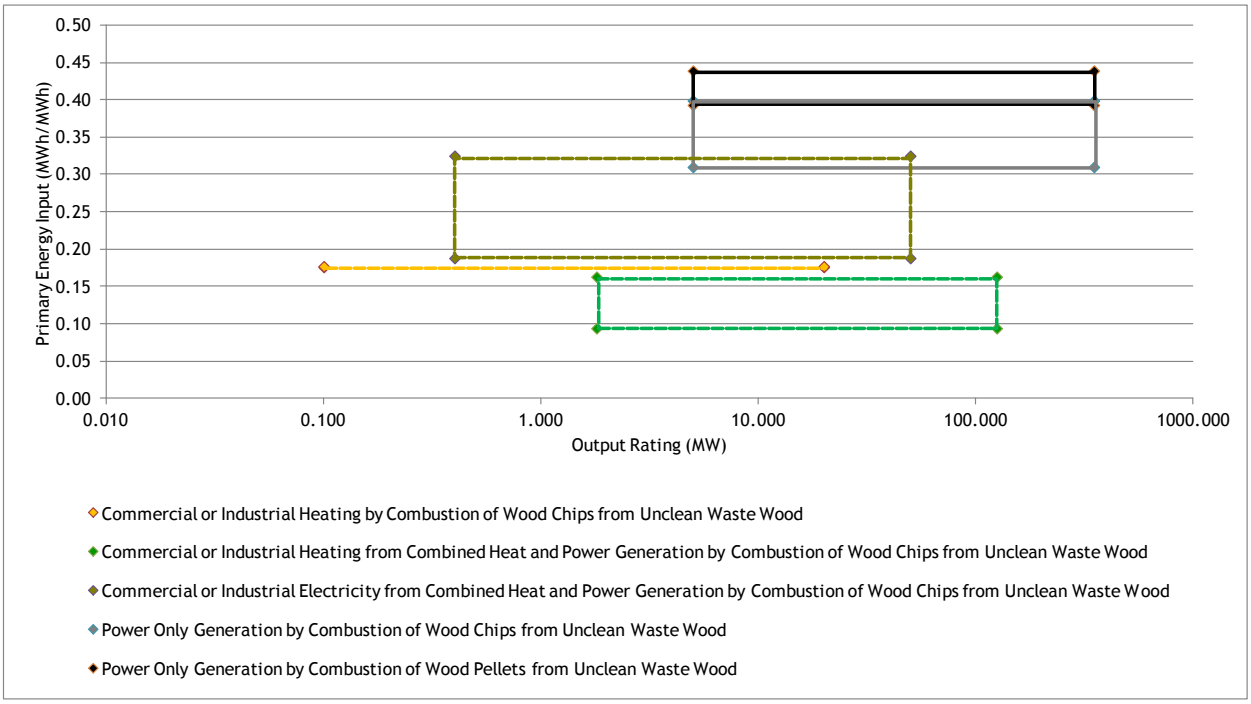
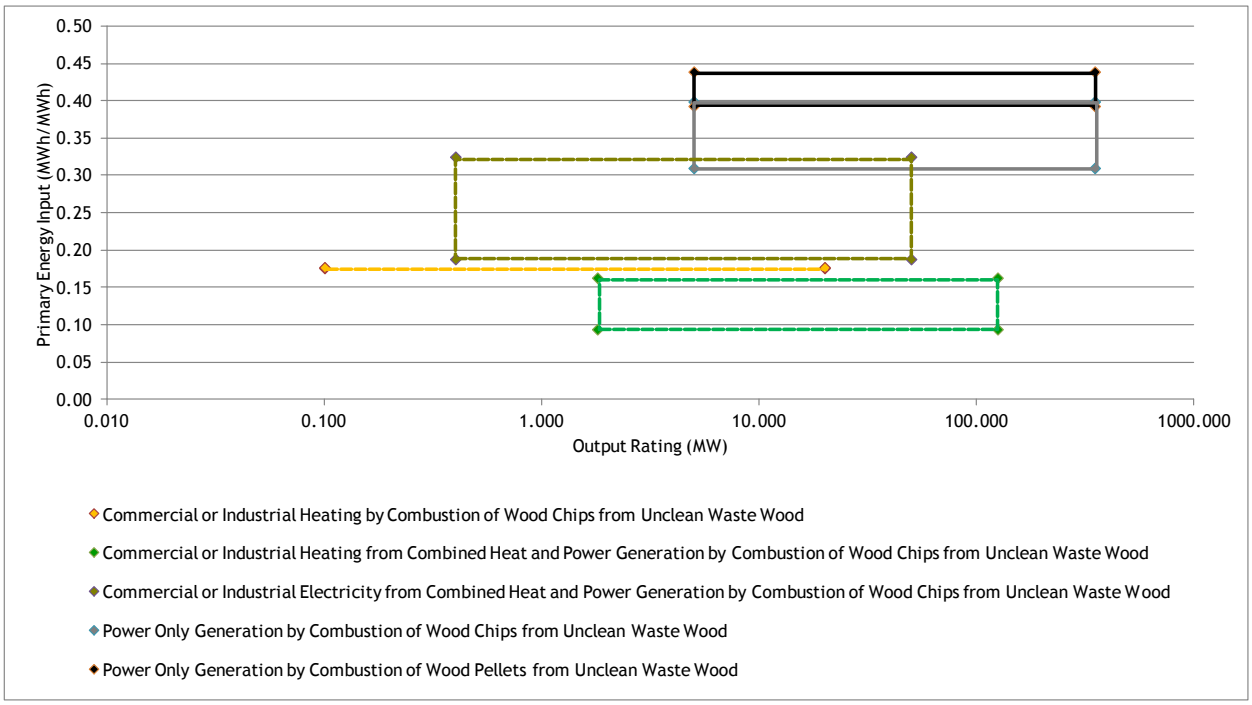


Figure D4 Range of Typical Results for Total Primary Energy [fossil fuel] Inputs for the Use of Unclean Waste Wood



APPENDIX E: Typical Primary Energy [biomass] Requirements for Energy Generation from Wood

Figure E1 Range of Typical Results for Total Primary Energy [biomass] Requirements for the Use of Roundwood

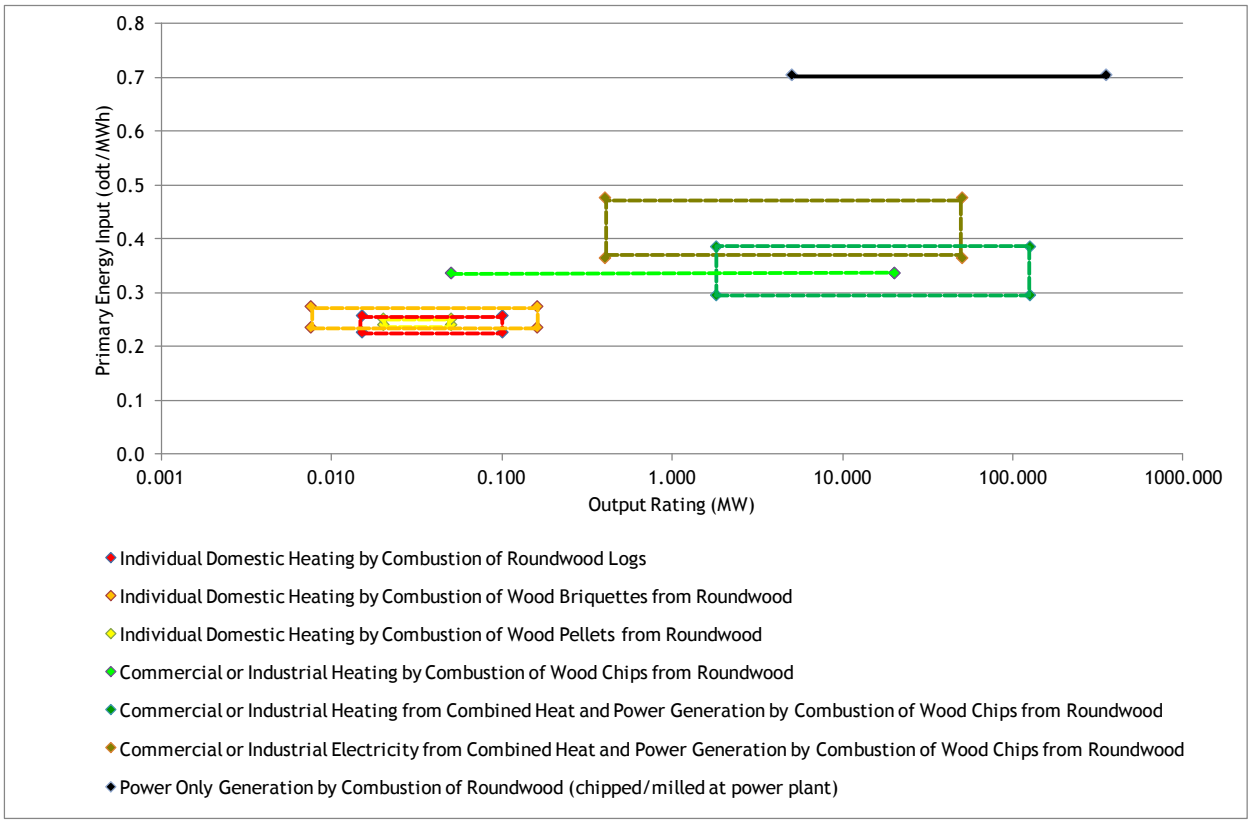
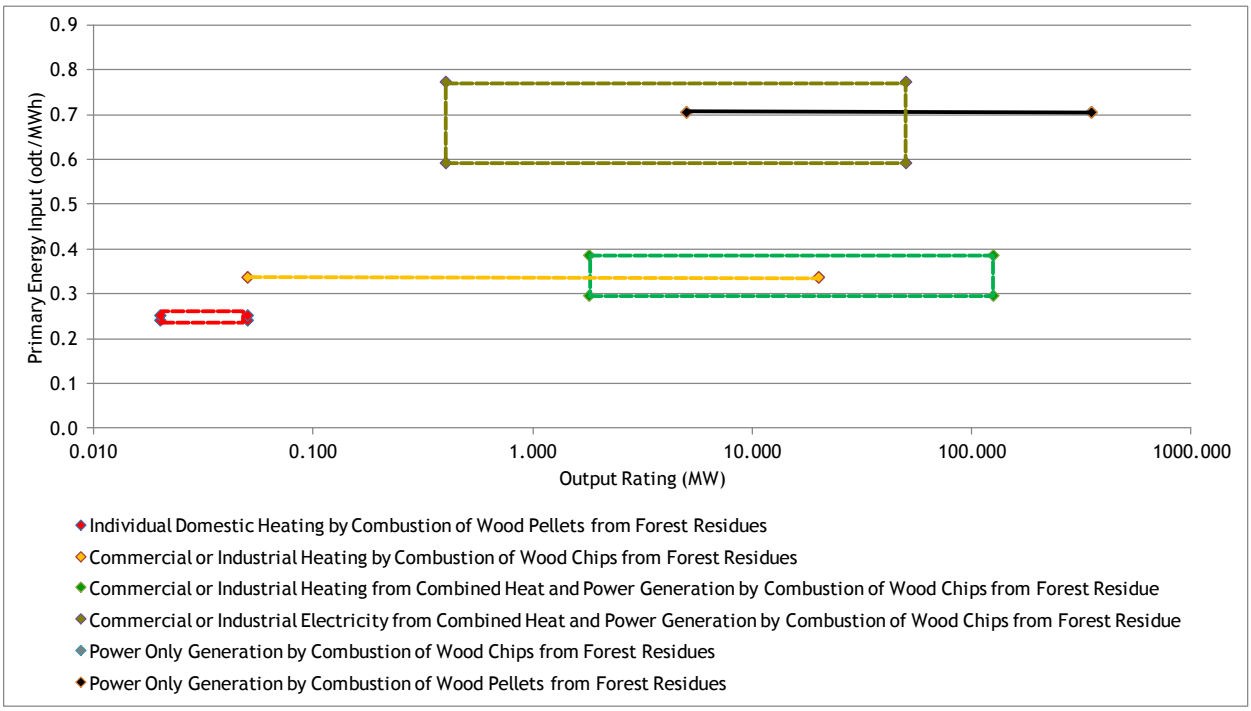


Figure E2 Range of Typical Results for Total Primary Energy [biomass] Requirements for the Use of Forest Residues



APPENDIX F: Results of Idealised Modelling: Total Greenhouse Gas Emissions

Figure F1 Variation of Total Greenhouse Gas Emission with Scale from an Idealised Model; Roundwood Logs for Domestic Heating Plants and Roundwood for a Power Only Plant

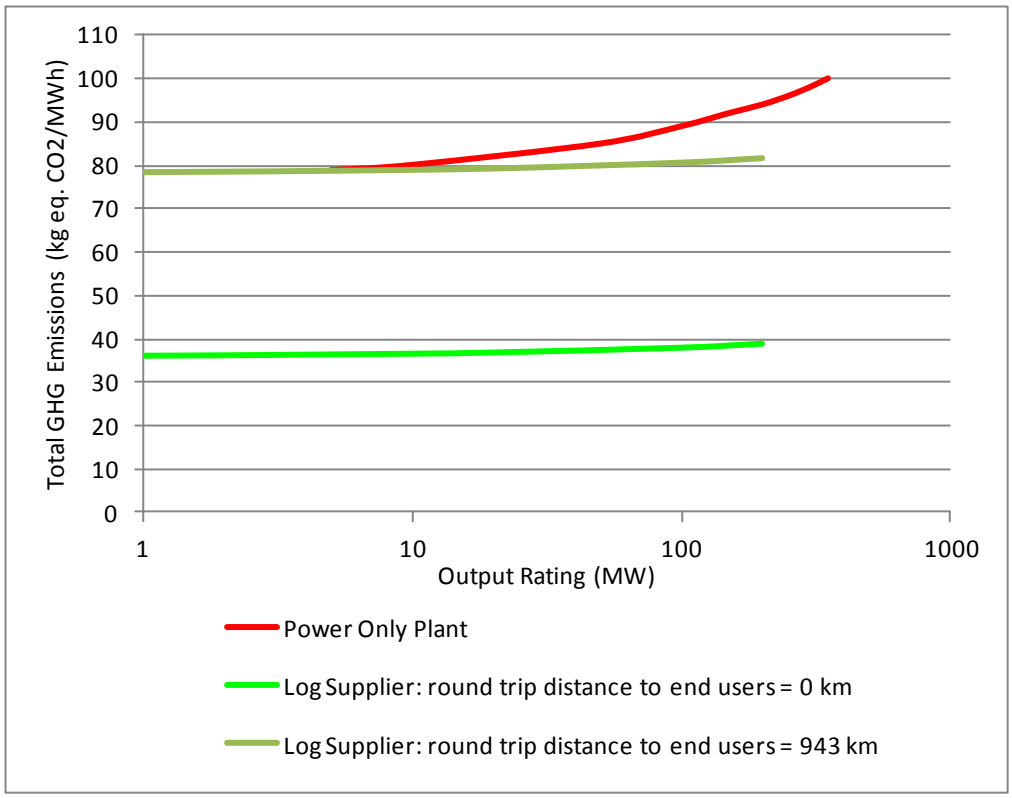


Figure F2 Variation of Total Greenhouse Gas Emission with Scale from an Idealised Model; Roundwood Briquettes for Domestic Heating Plants and Roundwood for a Power Only Plant

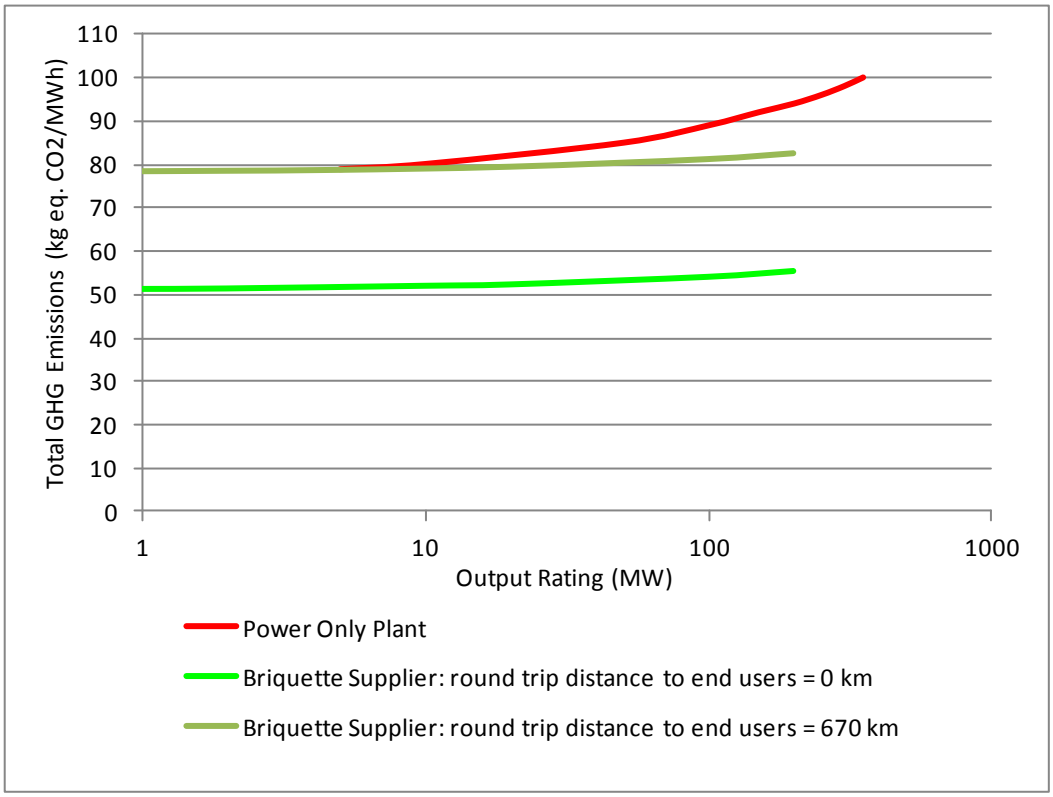


Figure F3 Variation of Total Greenhouse Gas Emission with Scale from an Idealised Model; Roundwood Pellets for Domestic Heating Plants and Roundwood for a Power Only Plant

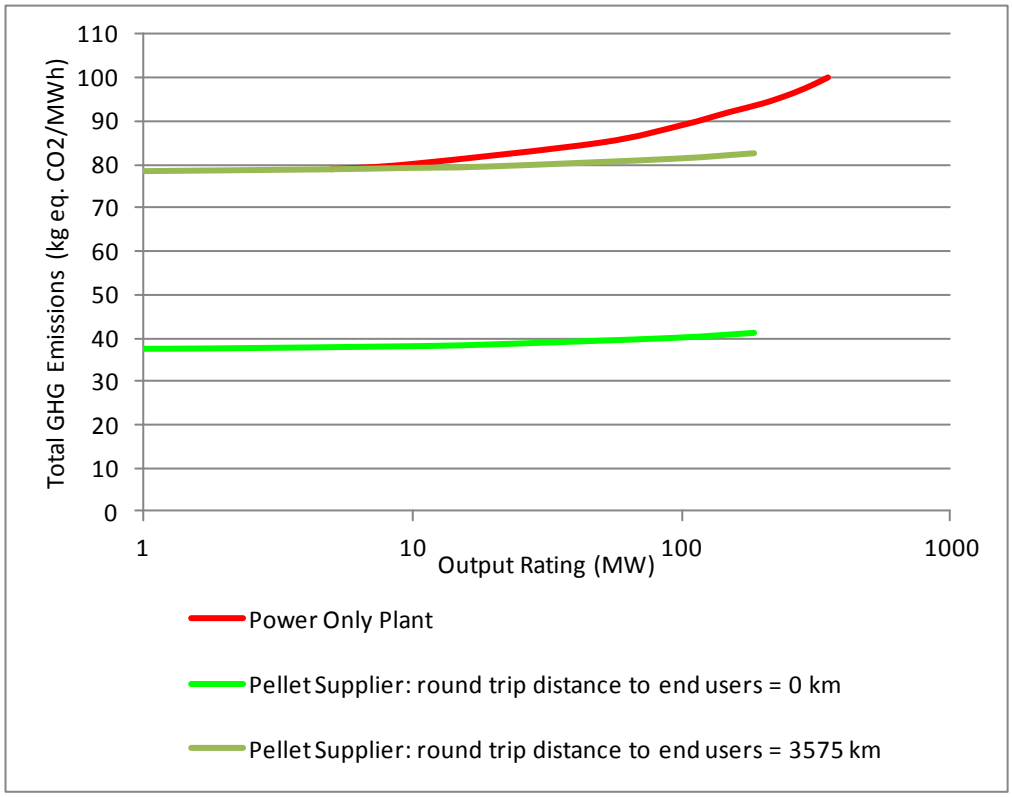


Figure F4 Variation of Total Greenhouse Gas Emission with Scale from an Idealised Model; Roundwood Chips for a Commercial and Industrial Heat Only Plant and Roundwood for a Power Only Plant

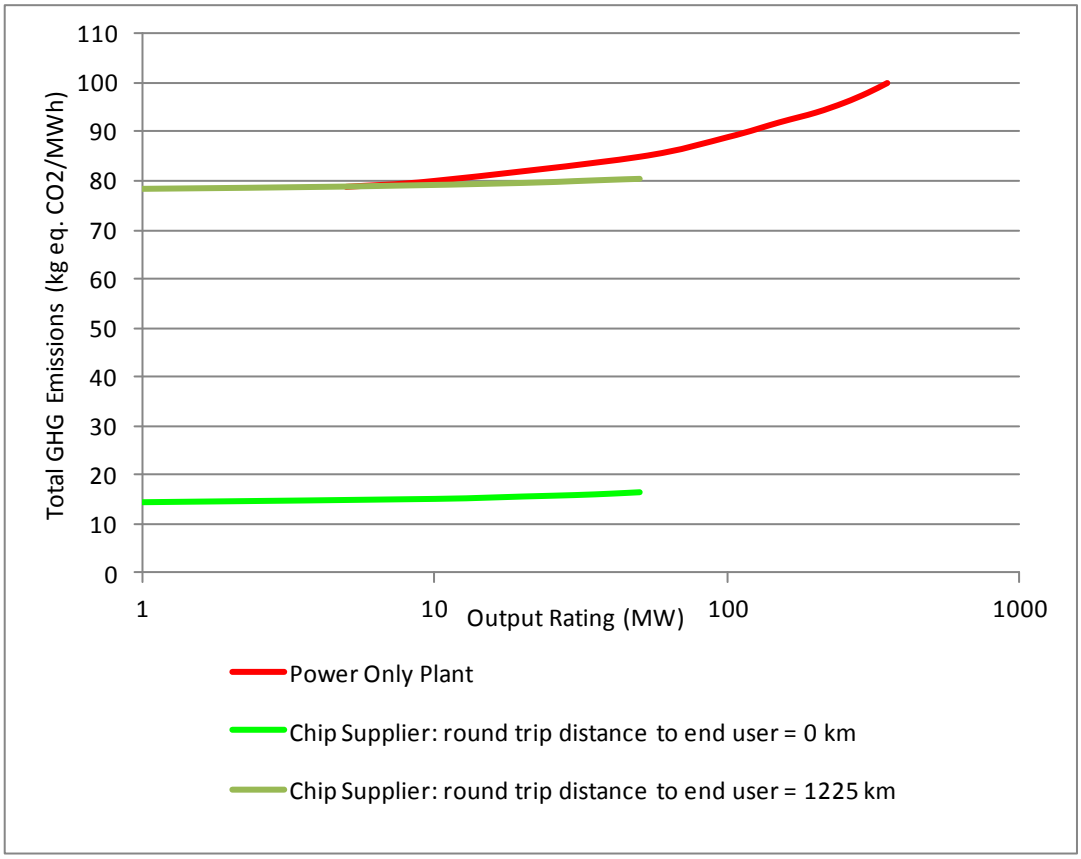


Figure F5 Variation of Total Greenhouse Gas Emission with Scale from an Idealised Model; Roundwood Chips for Commercial and Industrial Heating with a Combined Heat and Power Plant and Roundwood for a Power Only Plant

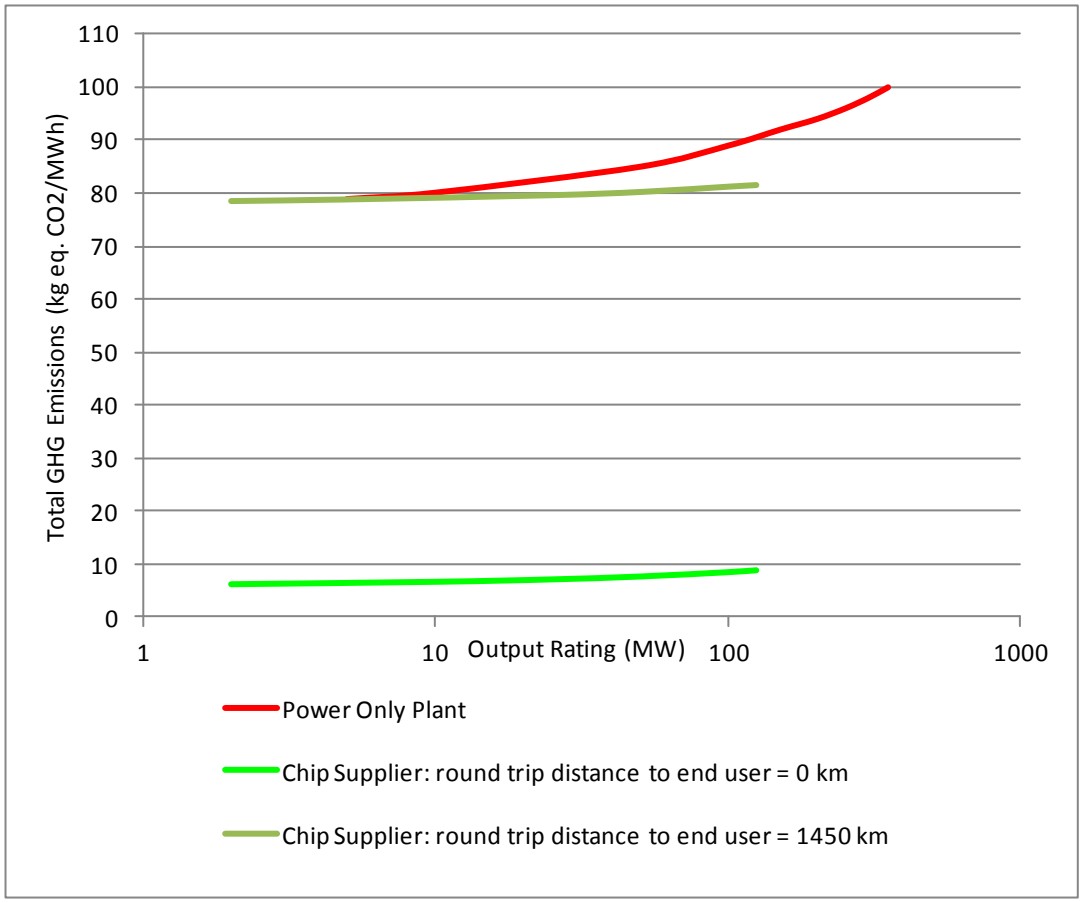


Figure F6 Variation of Total Greenhouse Gas Emission with Scale from an Idealised Model; Forest Residue Pellets for Domestic Heating Plants and Forest Residues for a Power Only Plant

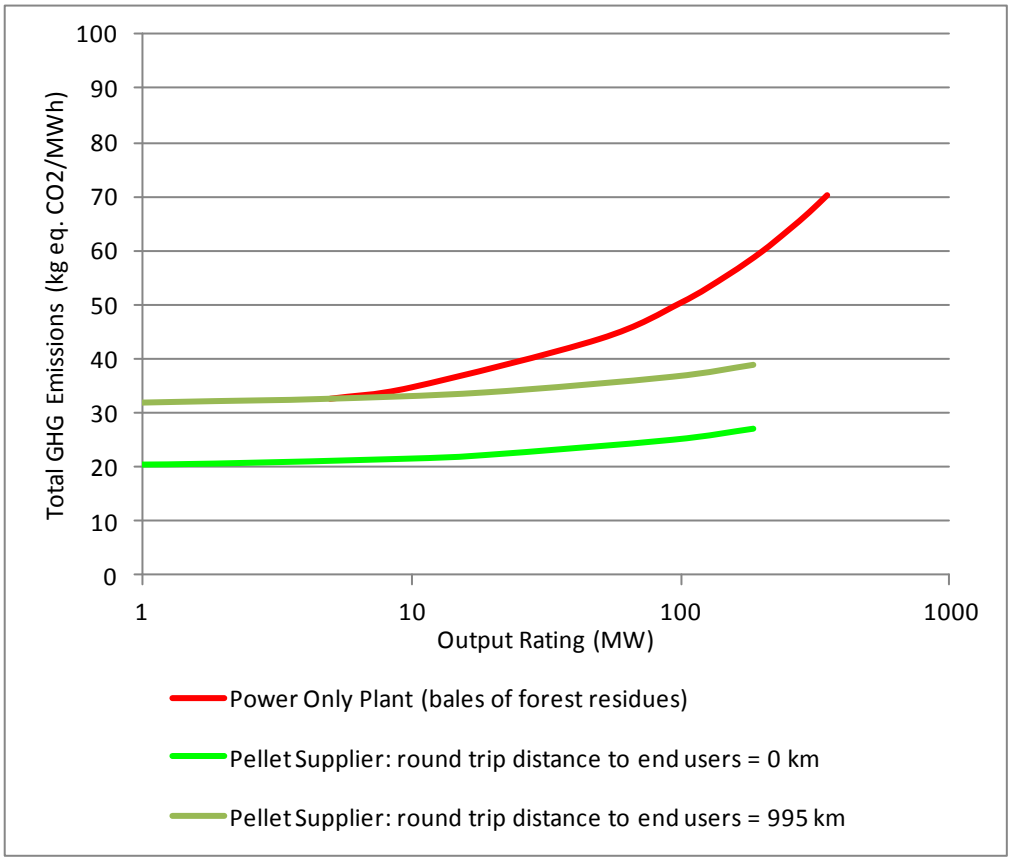


Figure F7 Variation of Total Greenhouse Gas Emission with Scale from an Idealised Model; Forest Residue Chips for a Commercial or Industrial Heat Only Plant and Forest Residues for a Power Only Plant

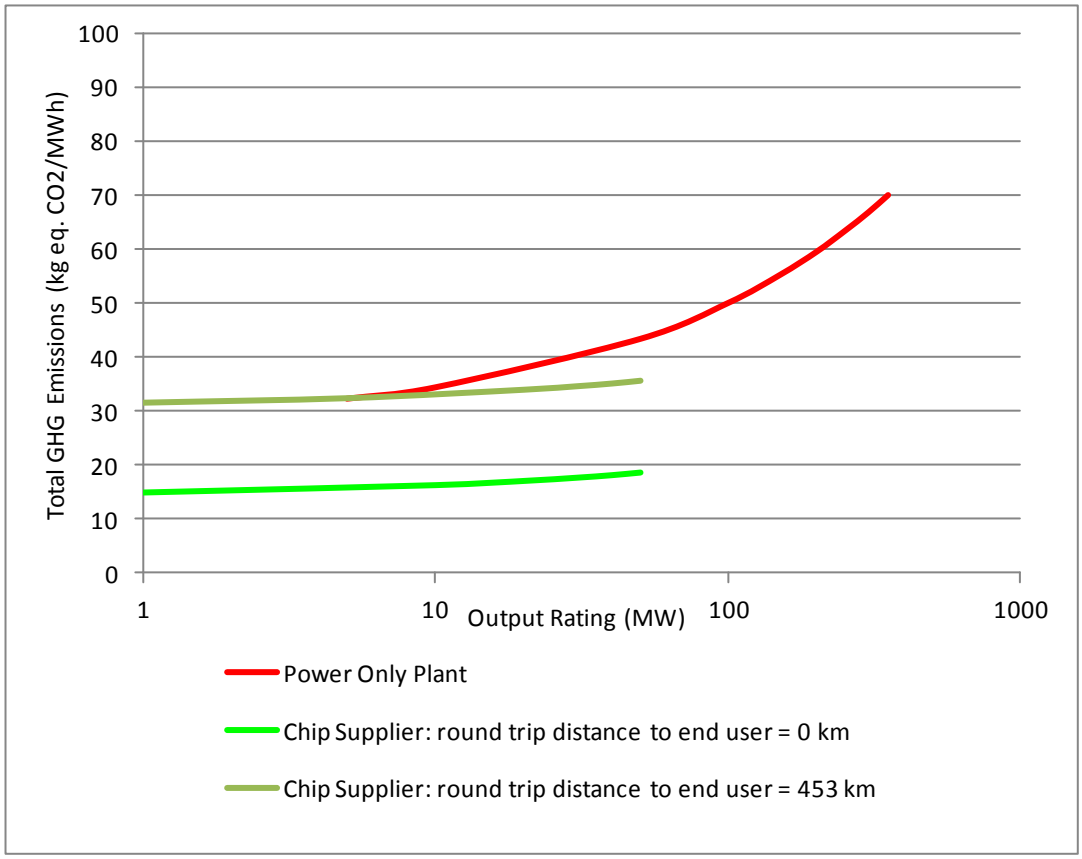
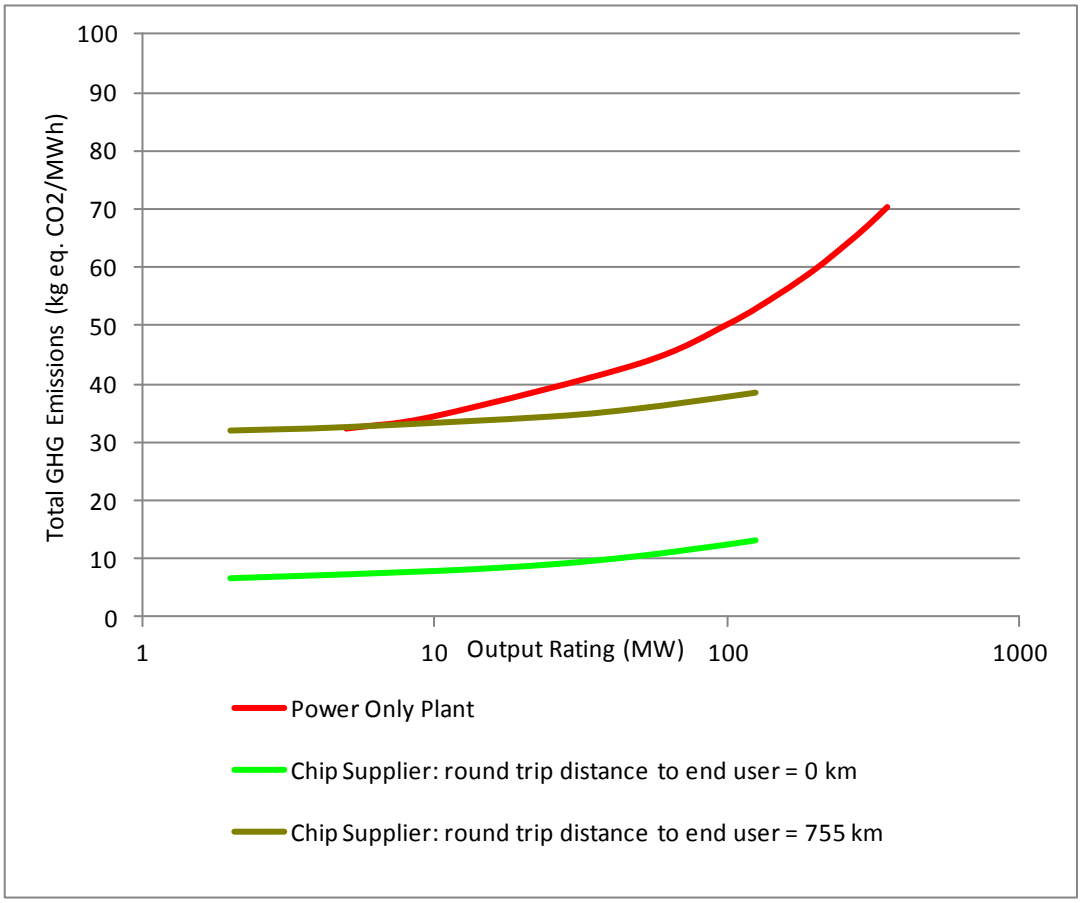


Figure F8 Variation of Total Greenhouse Gas Emission with Scale from an Idealised Model; Forest Residue Chips for Commercial or Industrial Heating with a Combined Heat and Power Plant and Forest Residues for a Power Only Plant



APPENDIX G: Effect of Weighting on Total Greenhouse Gas Emissions for Electricity and Heat from Wood-fired Combined Heat and Power Plants

Figure G1 Effect of Weighting of Value of Electricity to Value of Heat on Total Greenhouse Gas Emissions for Electricity and Heat from a Typical Combined Heat and Power Plant Using Roundwood Chips

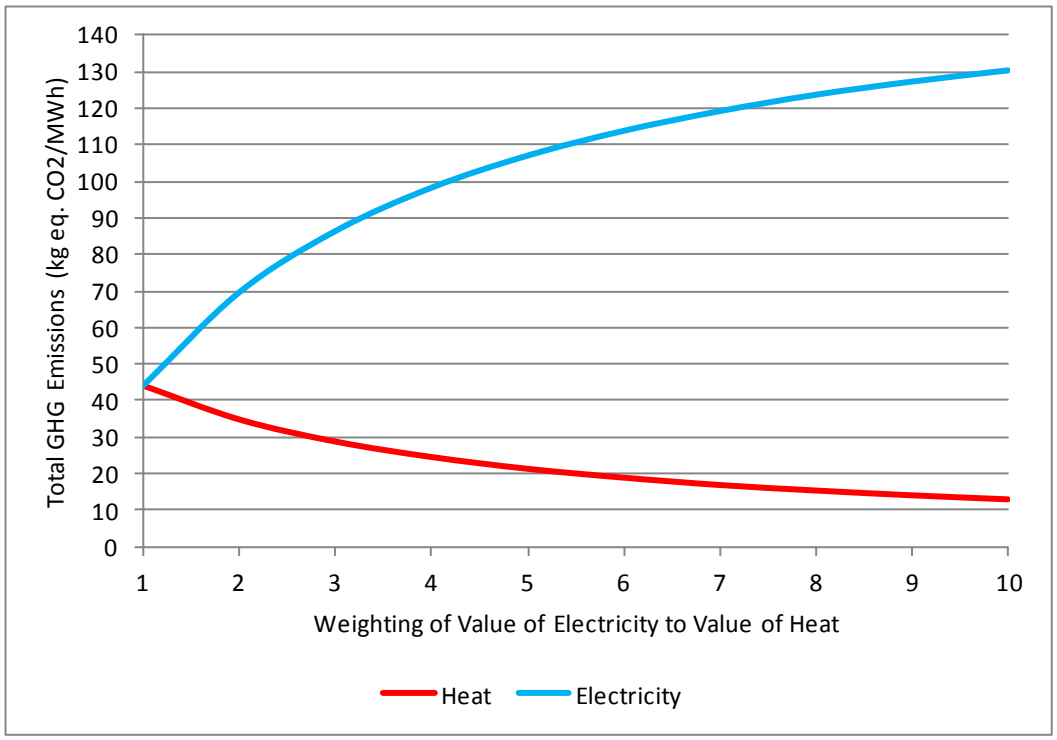


Figure G2 Effect of Weighting of Value of Electricity to Value of Heat on Total Greenhouse Gas Emissions for Electricity and Heat from a Typical Combined Heat and Power Plant Using Forest Residue Chips

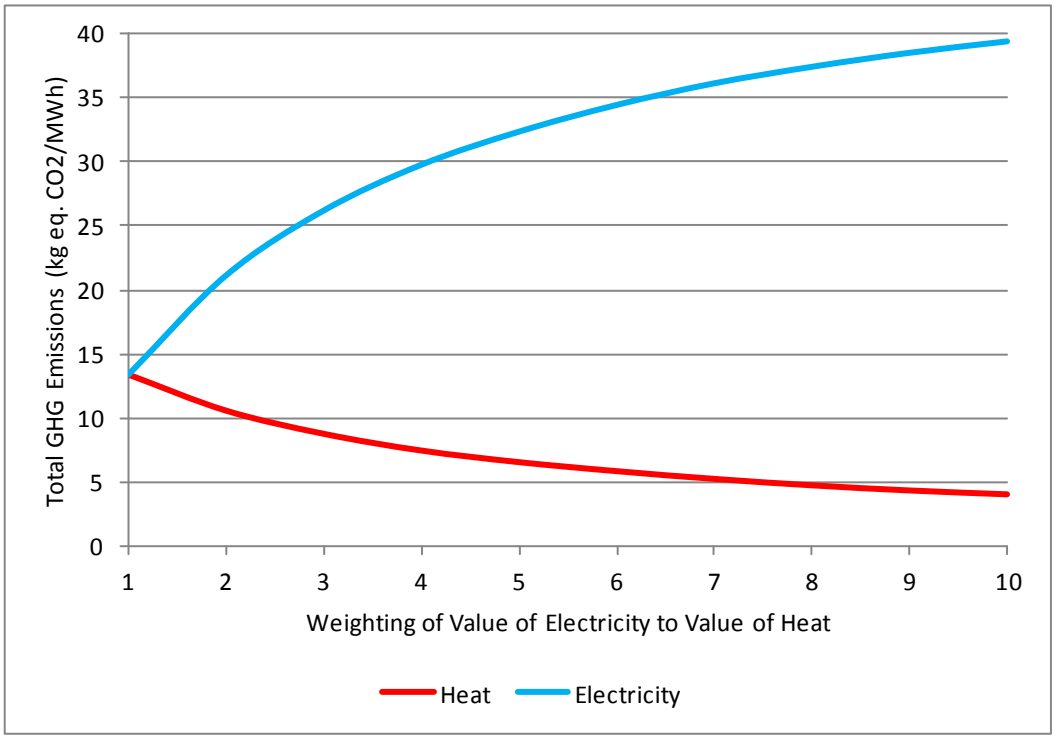


Figure G3 Effect of Weighting of Value of Electricity to Value of Heat on Total Greenhouse Gas Emissions for Electricity and Heat from a Typical Combined Heat and Power Plant Using Clean Waste Wood Chips

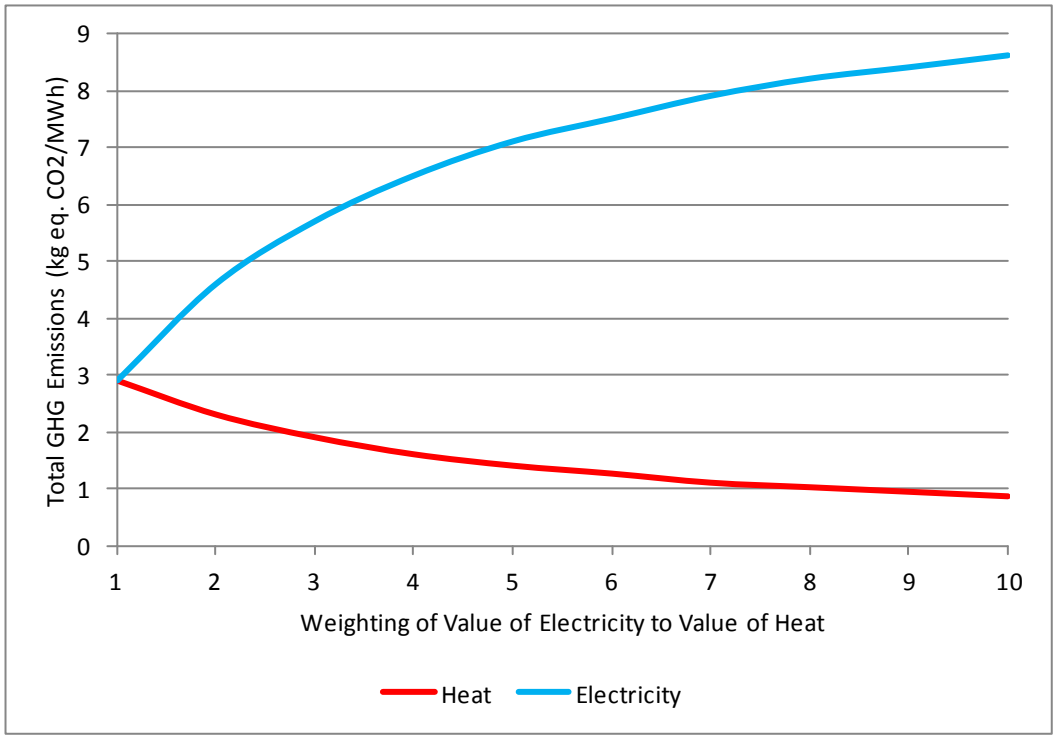
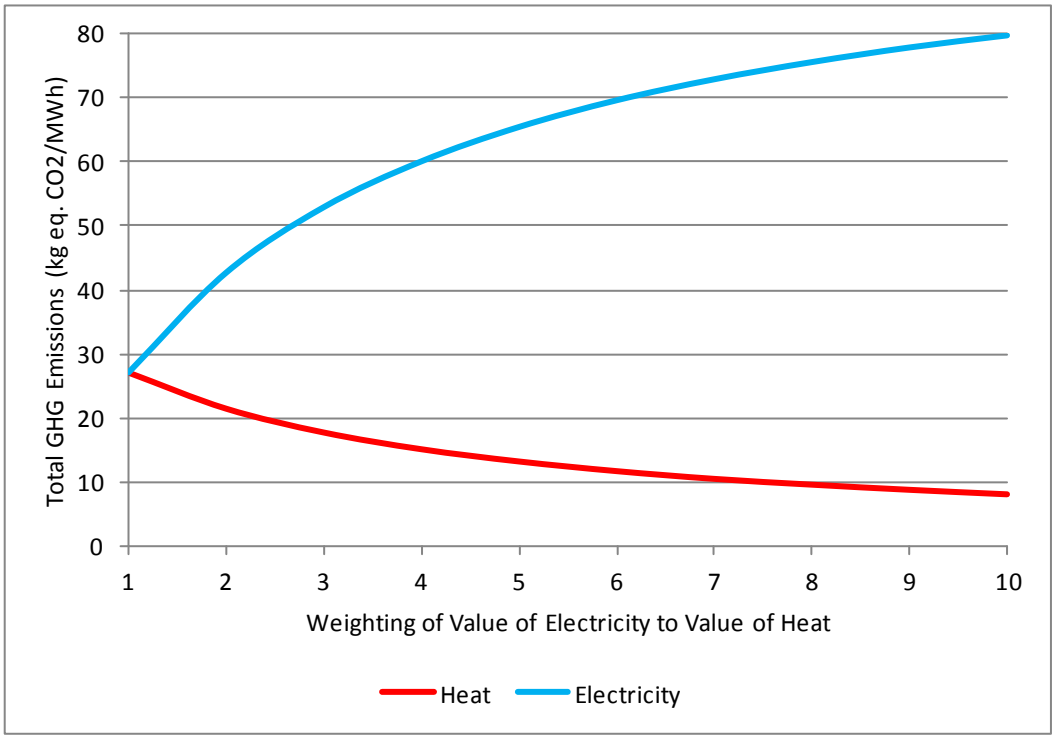


Figure G4 Effect of Weighting of Value of Electricity to Value of Heat on Total Greenhouse Gas Emissions for Electricity and Heat from a Typical Combined Heat and Power Plant Using Unclean Waste Wood Chips



APPENDIX H: Variations in Proportional Price Differentials

Figure H1 Variation of Proportional Price Differential with Round Trip Transport Distance to End Users: Roundwood Logs for Domestic Heating

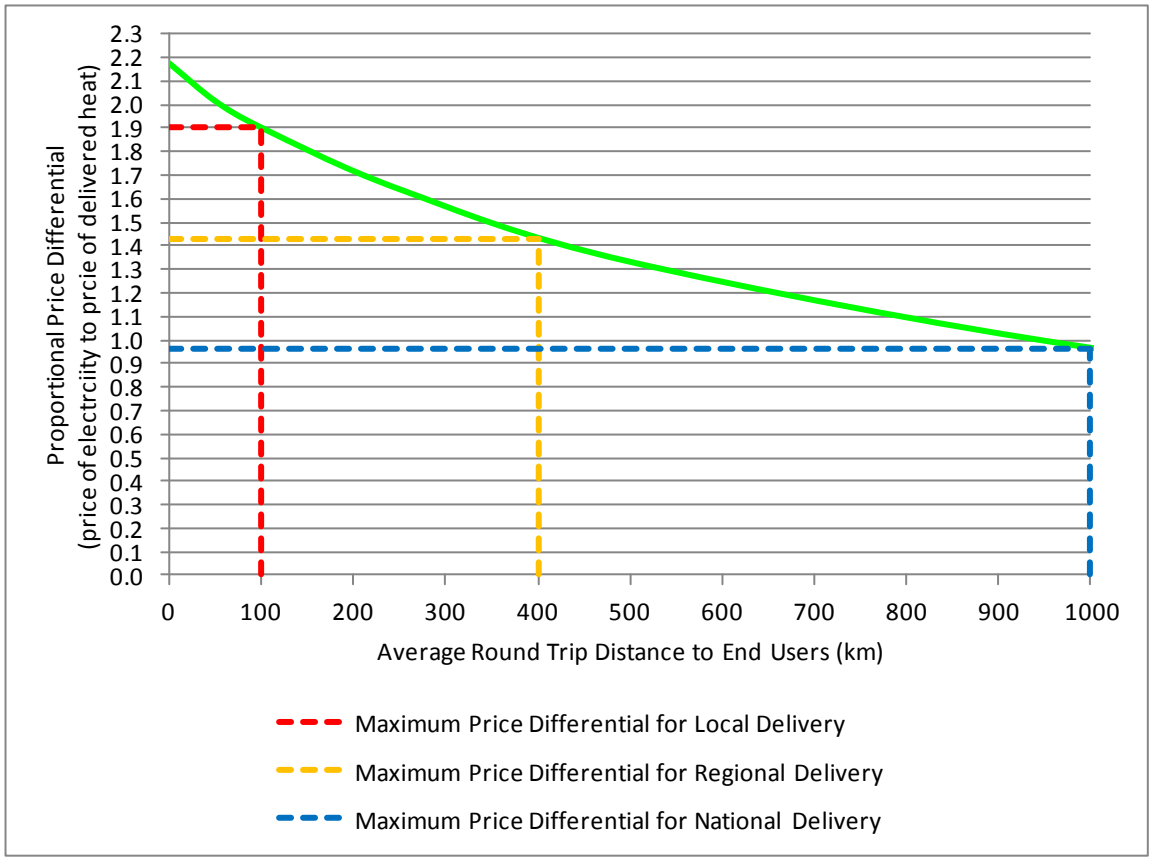


Figure H2 Variation of Proportional Price Differential with Round Trip Transport Distance to End Users: Roundwood Briquettes for Domestic Heating

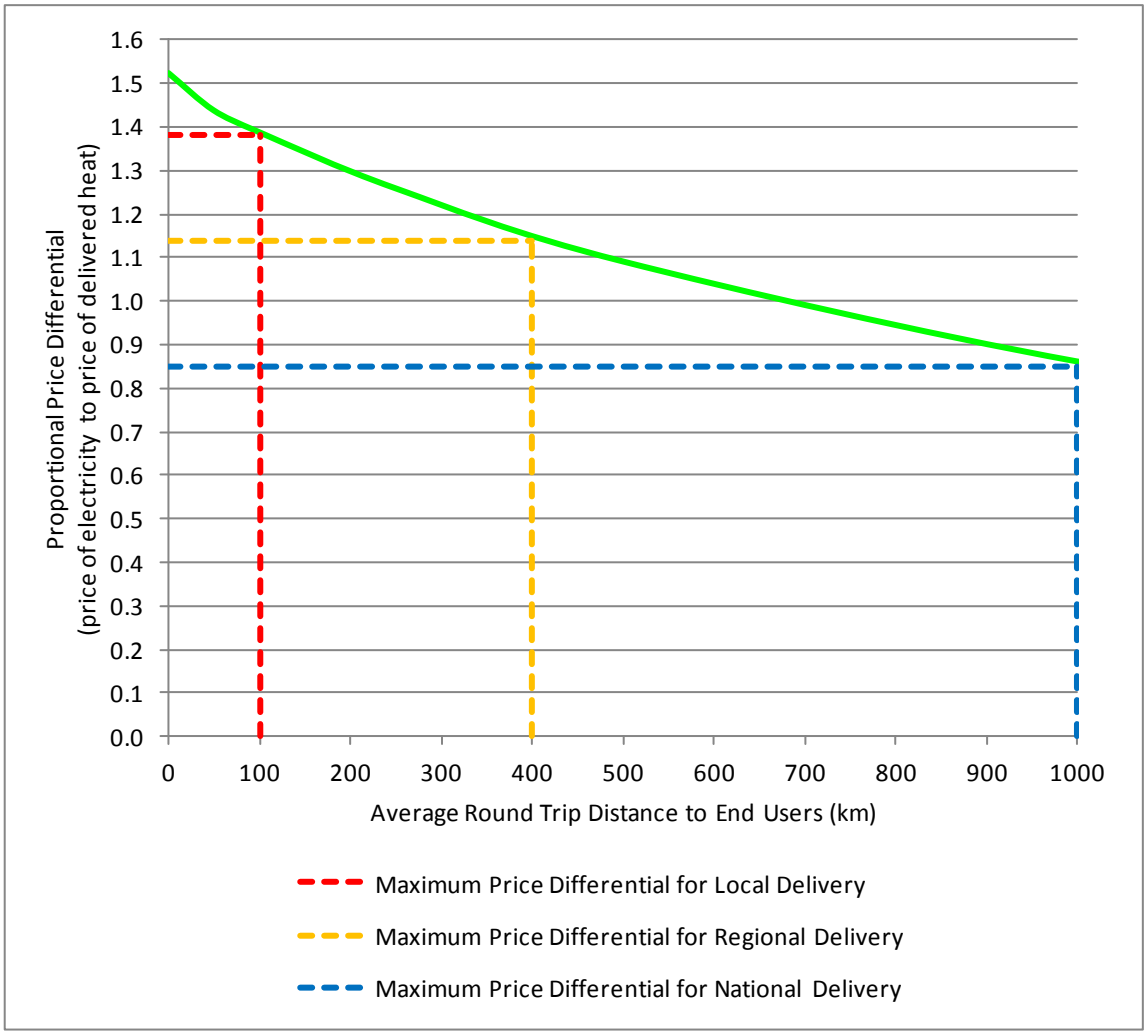


Figure H3 Variation of Proportional Price Differential with Round Trip Transport Distance to End Users: Roundwood Pellets for Domestic Heating

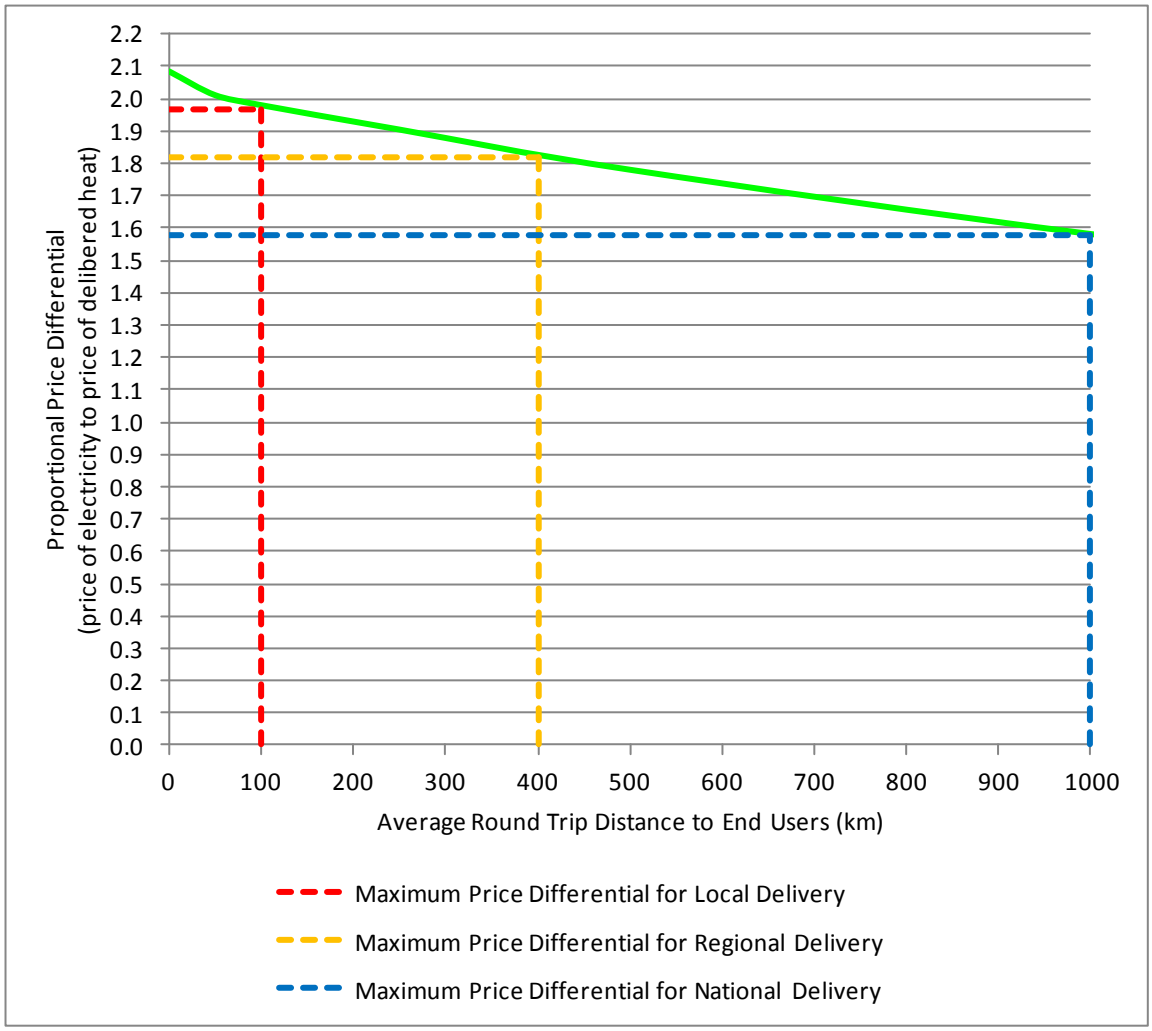


Figure H4 Variation of Proportional Price Differential with Round Trip Transport Distance to End Users: Roundwood Chips for Commercial and Industrial Heating

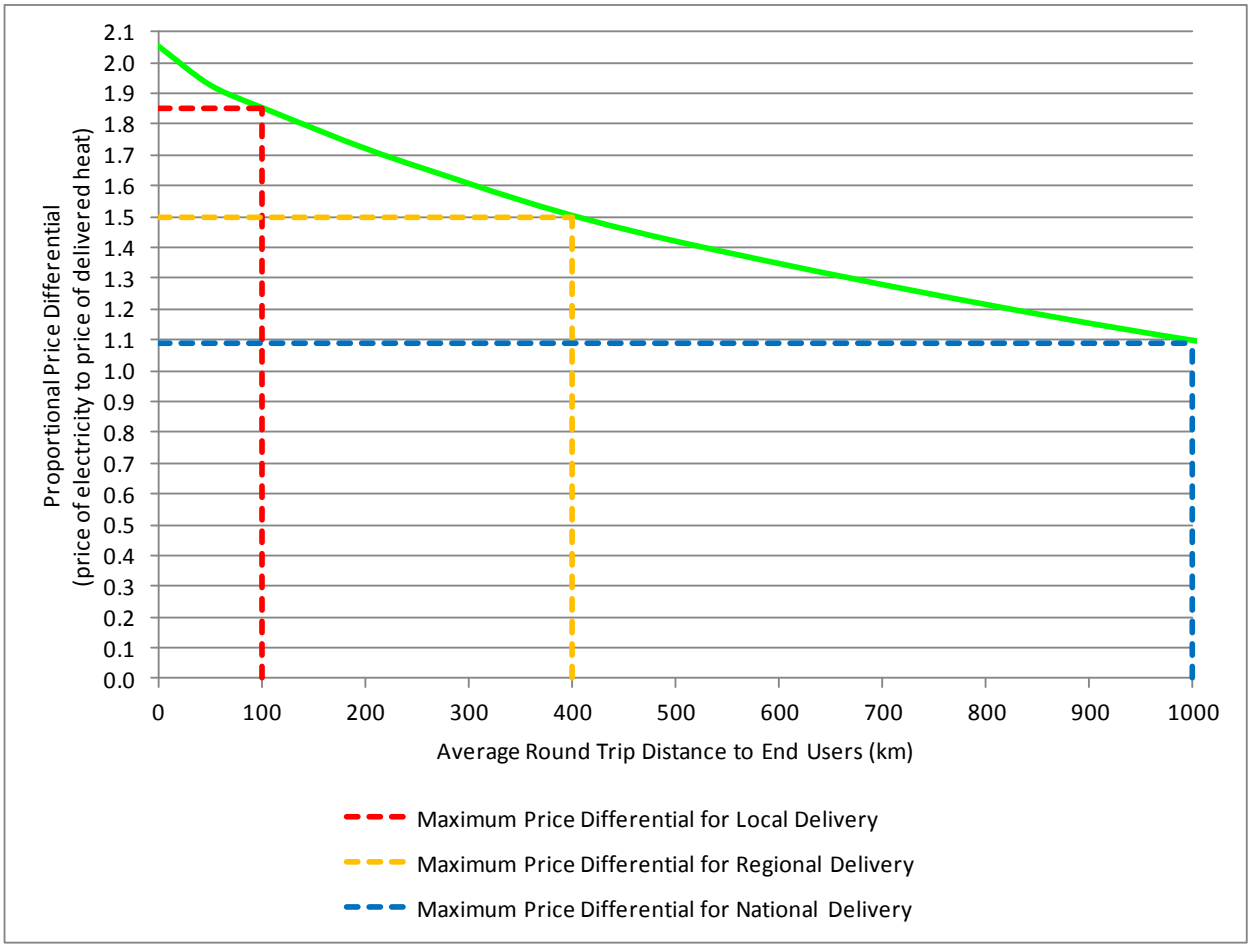


Figure H5 Variation of Proportional Price Differential with Round Trip Transport Distance to End Users: Roundwood Chips for Commercial and Industrial Combined Heat and Power Generation

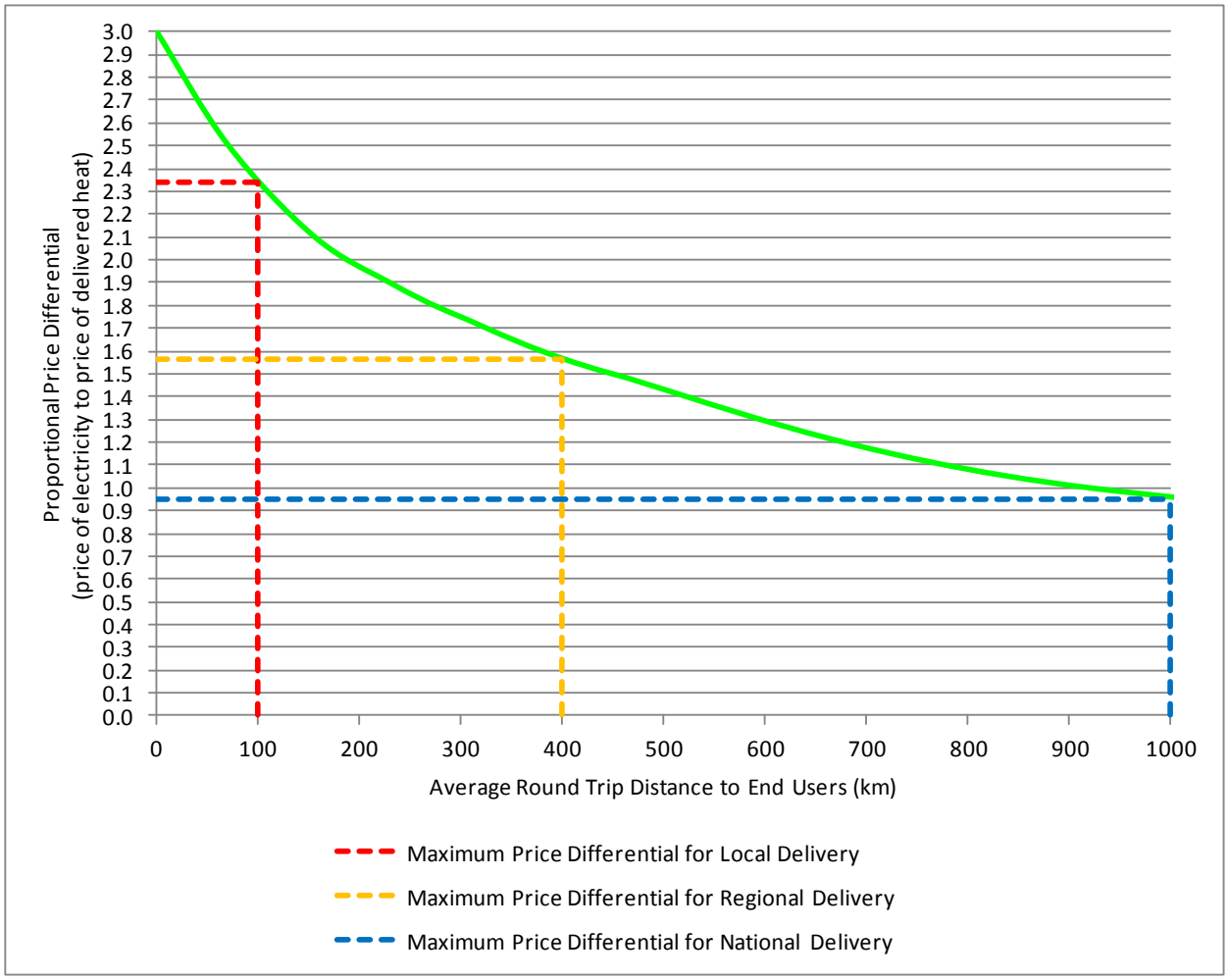


Figure H6 Variation of Proportional Price Differential with Round Trip Transport Distance to End Users: Forest Residue Pellets for Domestic Heating

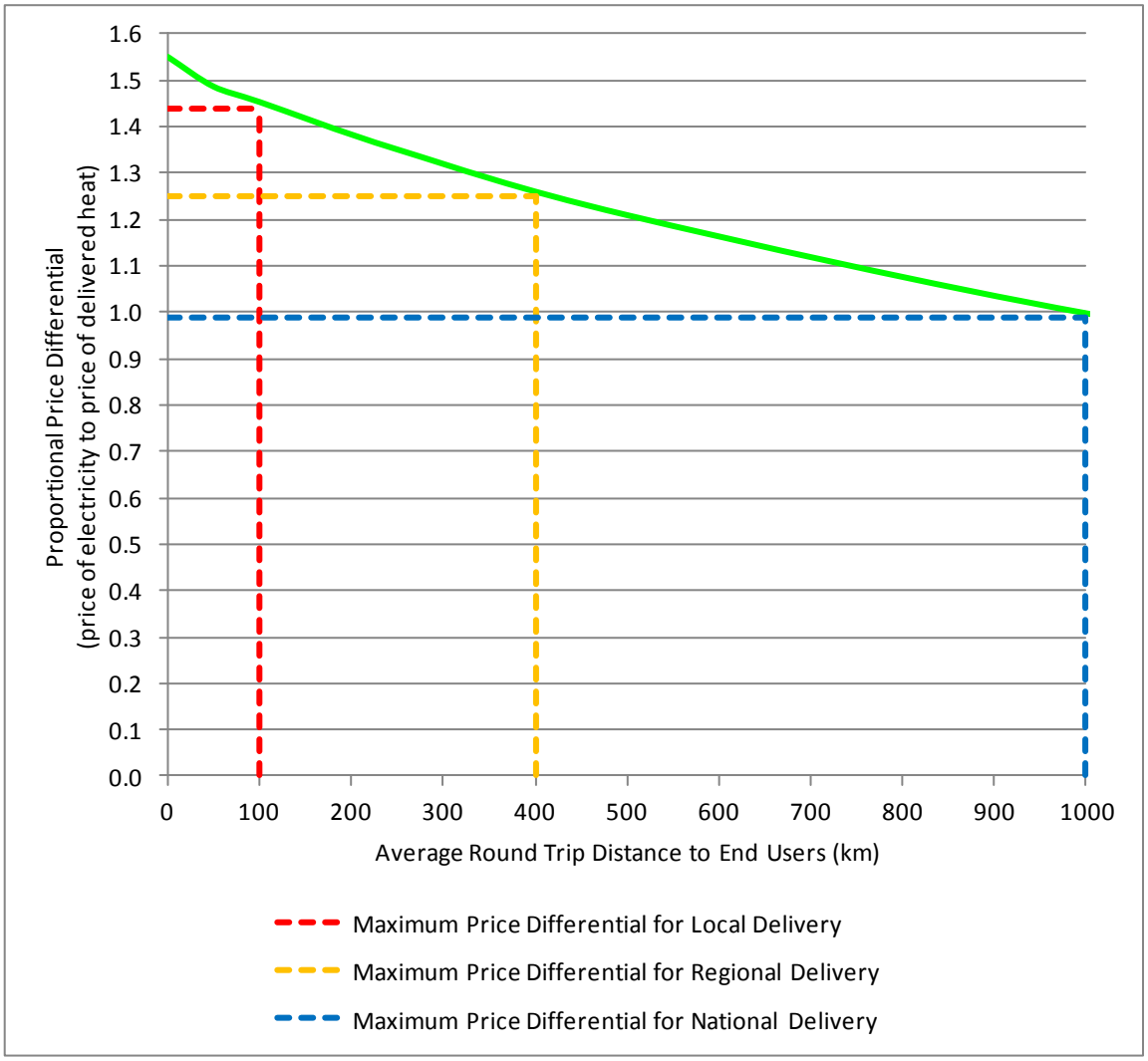


Figure H7 Variation of Proportional Price Differential with Round Trip Transport Distance to End Users: Forest Residue Chips for Commercial and Industrial Heating

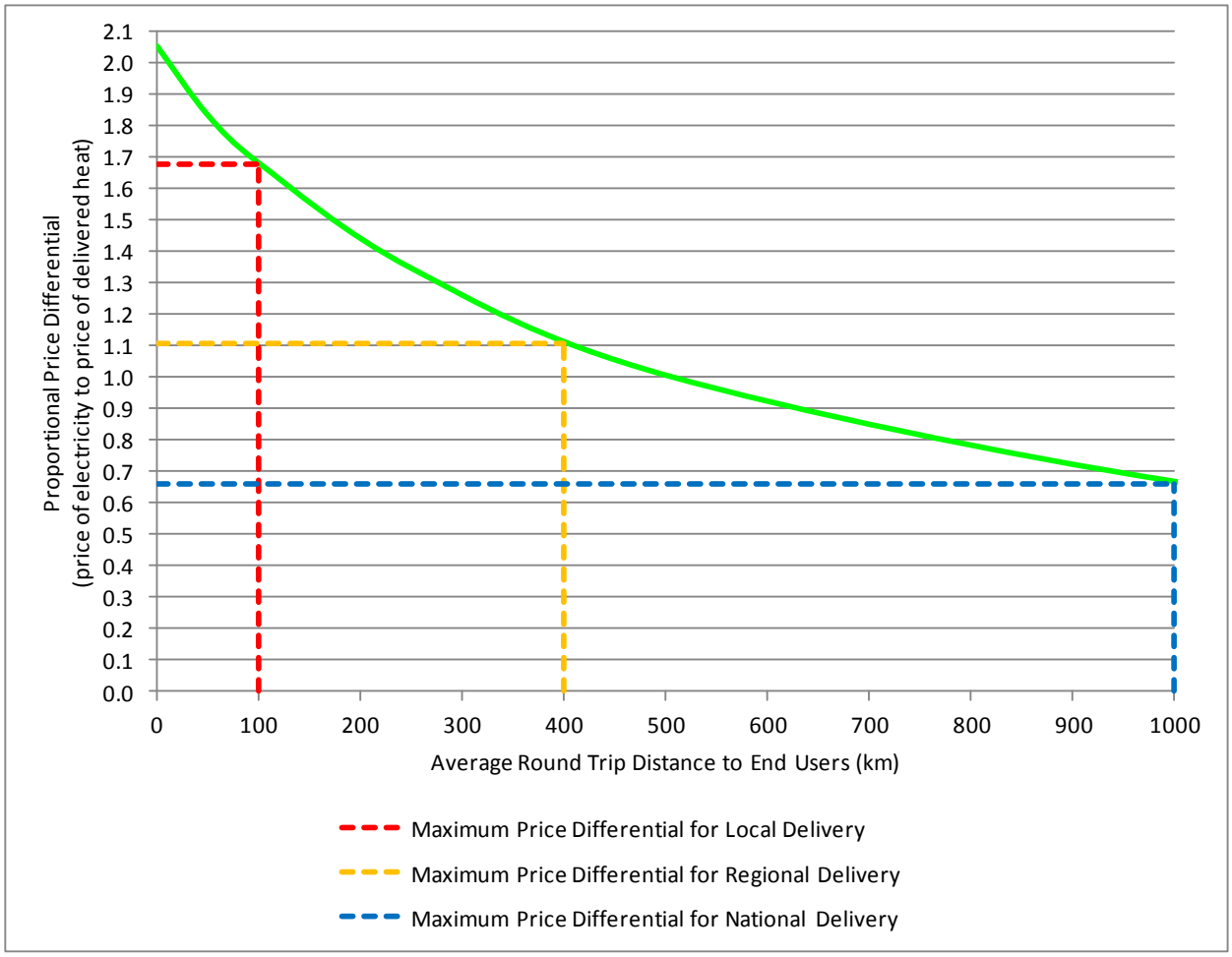


Figure H8 Variation of Proportional Price Differential with Round Trip Transport Distance to End Users: Forest Residue Chips for Commercial and Industrial Combined Heat and Power Generation

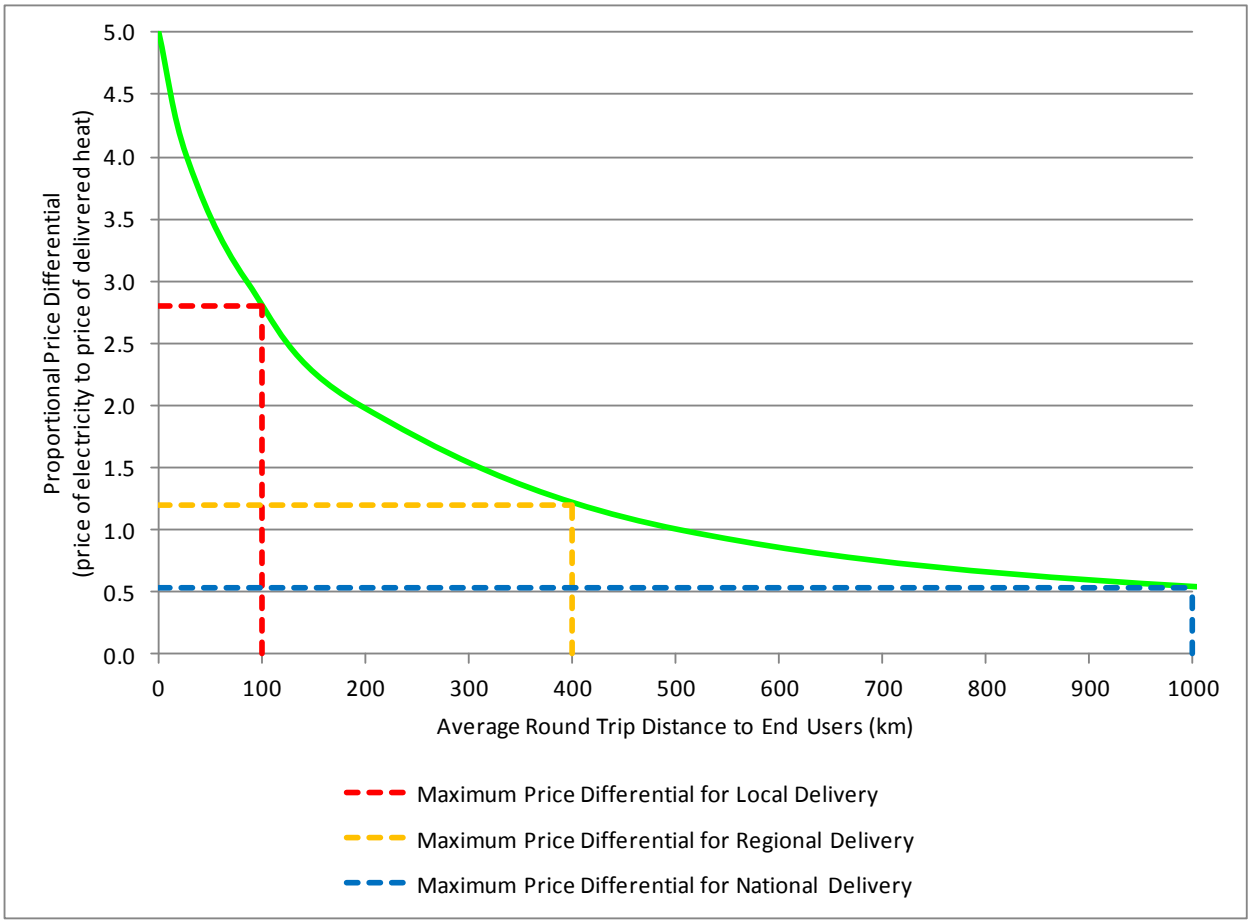


Figure H9 Variation of Proportional Price Differential with Round Trip Transport Distance to End Users: Clean Waste Wood Briquettes for Domestic Heating

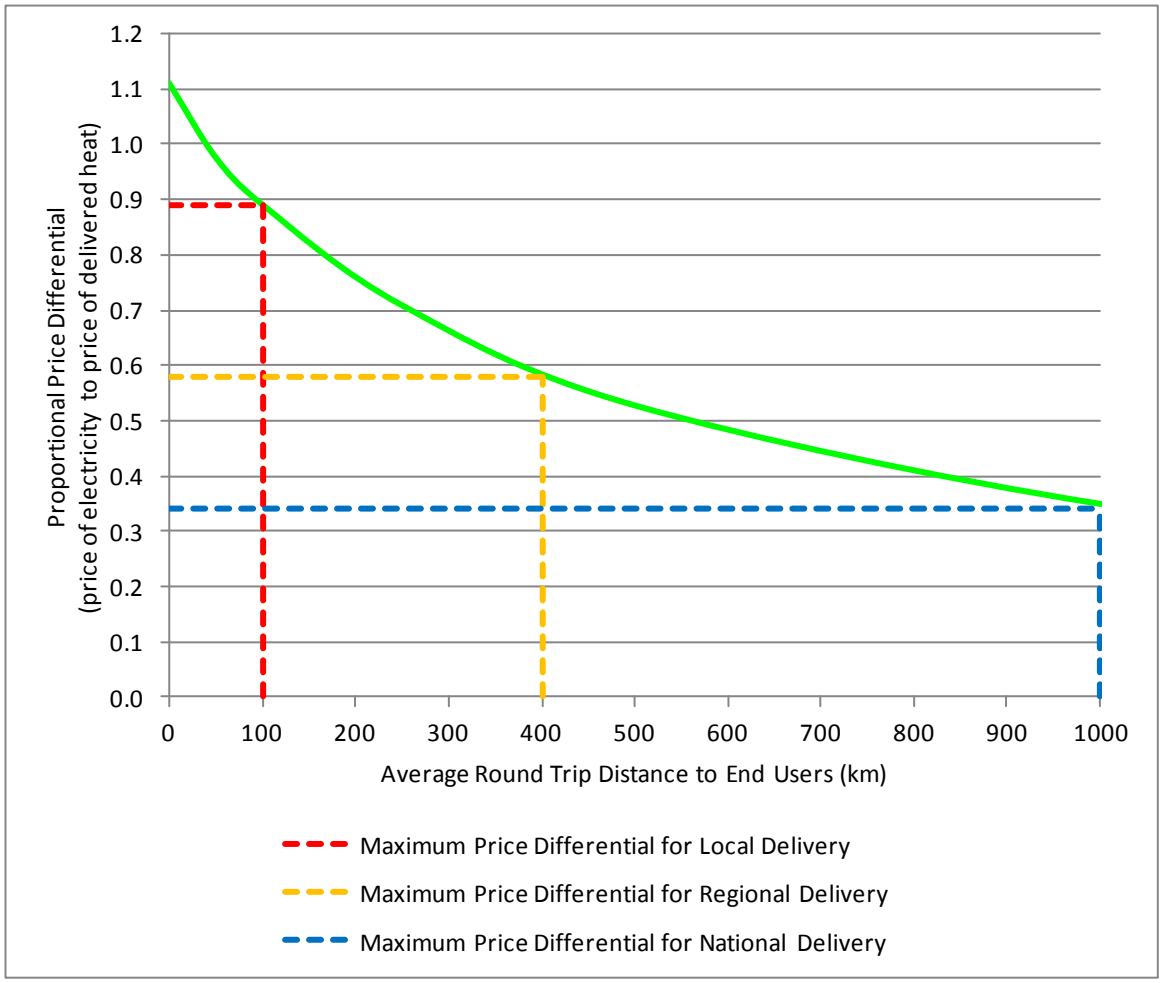


Figure H10 Variation of Proportional Price Differential with Round Trip Transport Distance to End Users: Clean Waste Wood Pellets for Domestic Heating

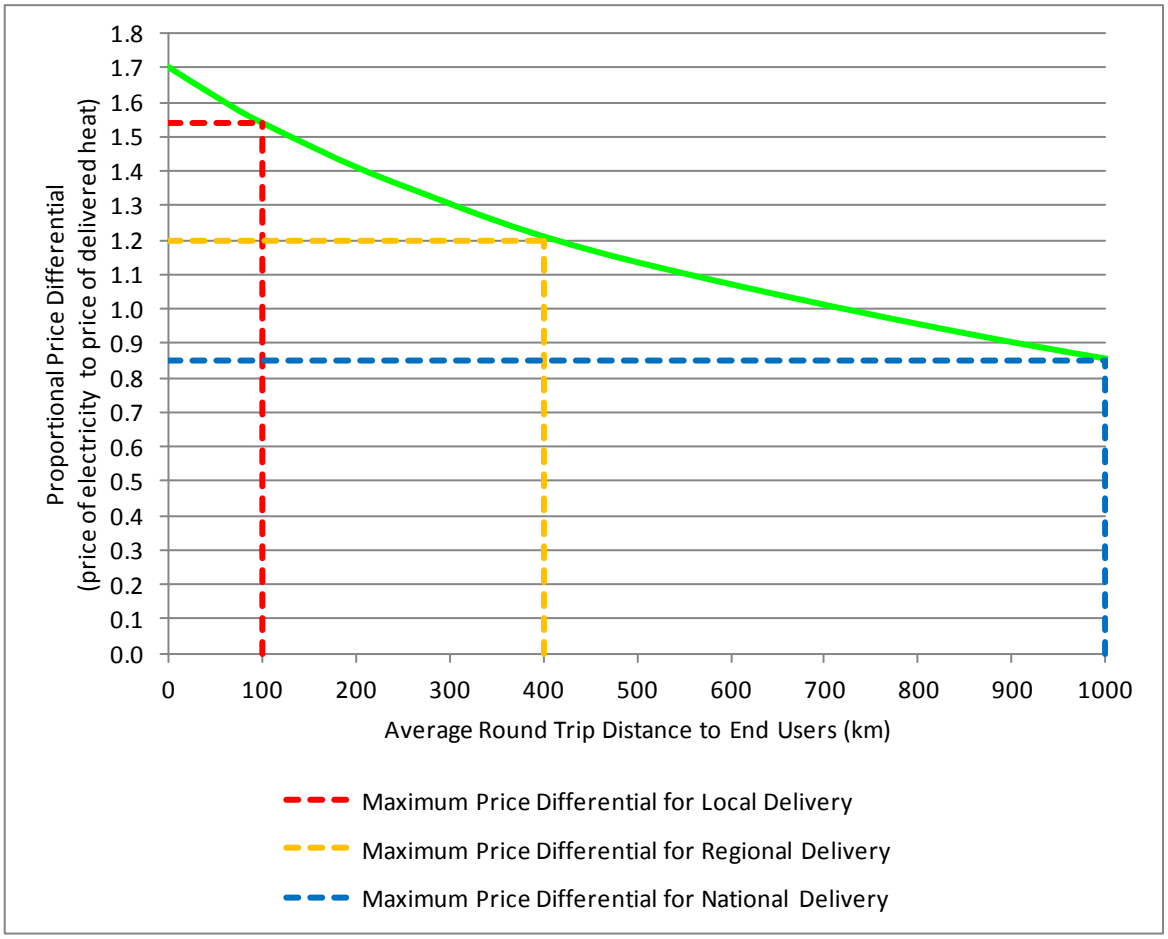


Figure H11 Variation of Proportional Price Differential with Round Trip Transport Distance to End Users: Clean Waste Wood Chips for Commercial and Industrial Heating

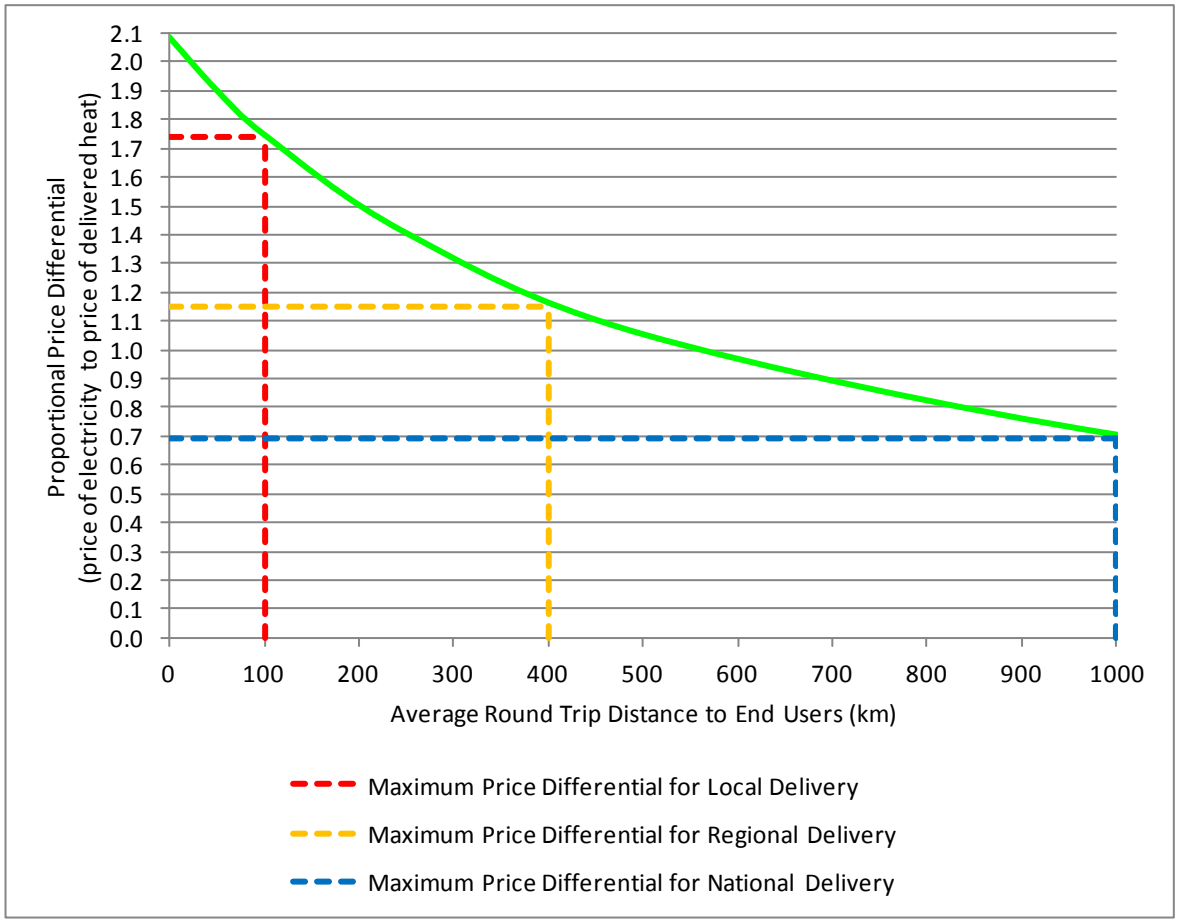


Figure H12 Variation of Proportional Price Differential with Round Trip Transport Distance to End Users: Clean Waste Wood Chips for Commercial and Industrial Combined Heat and Power Generation

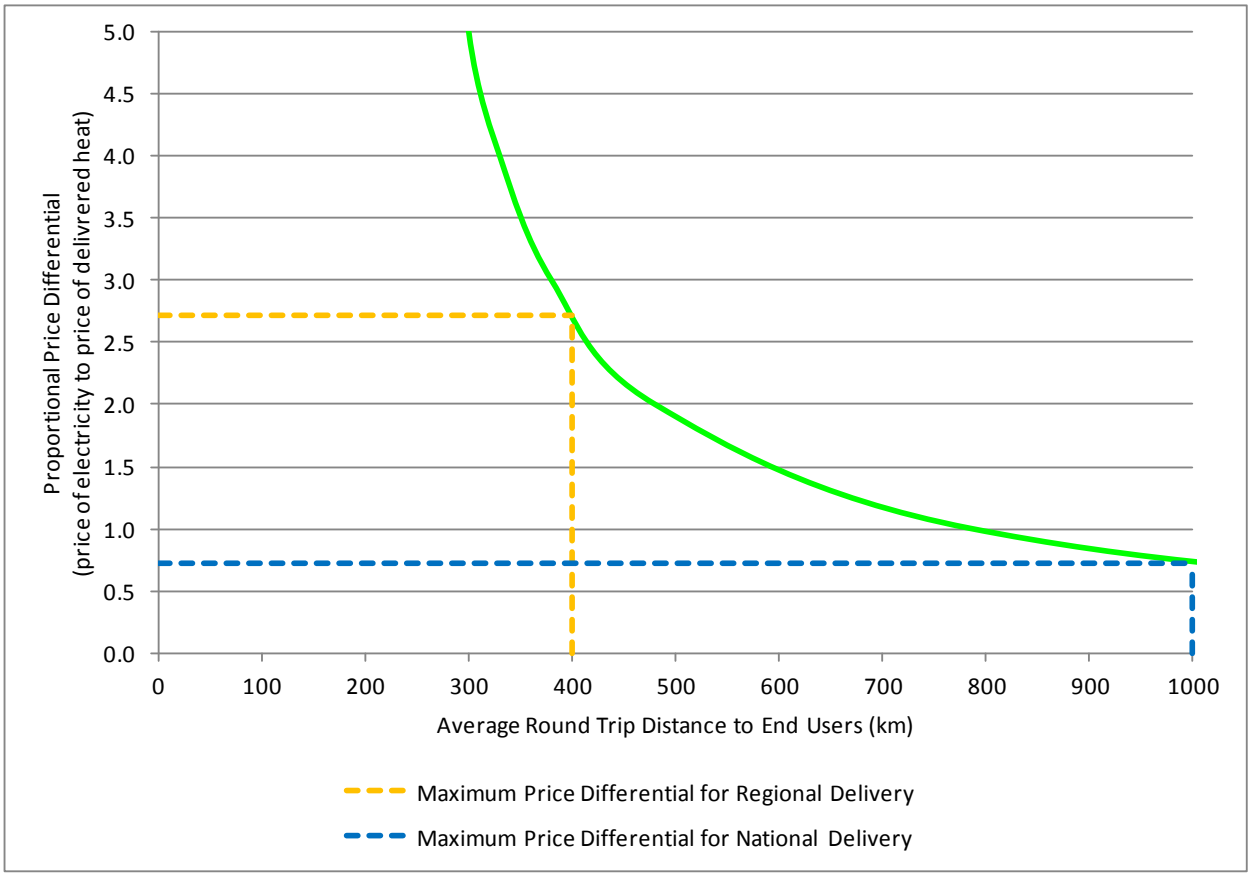


Figure H13 Variation of Proportional Price Differential with Round Trip Transport Distance to End Users: Unclean Waste Wood Chips for Commercial and Industrial Heating

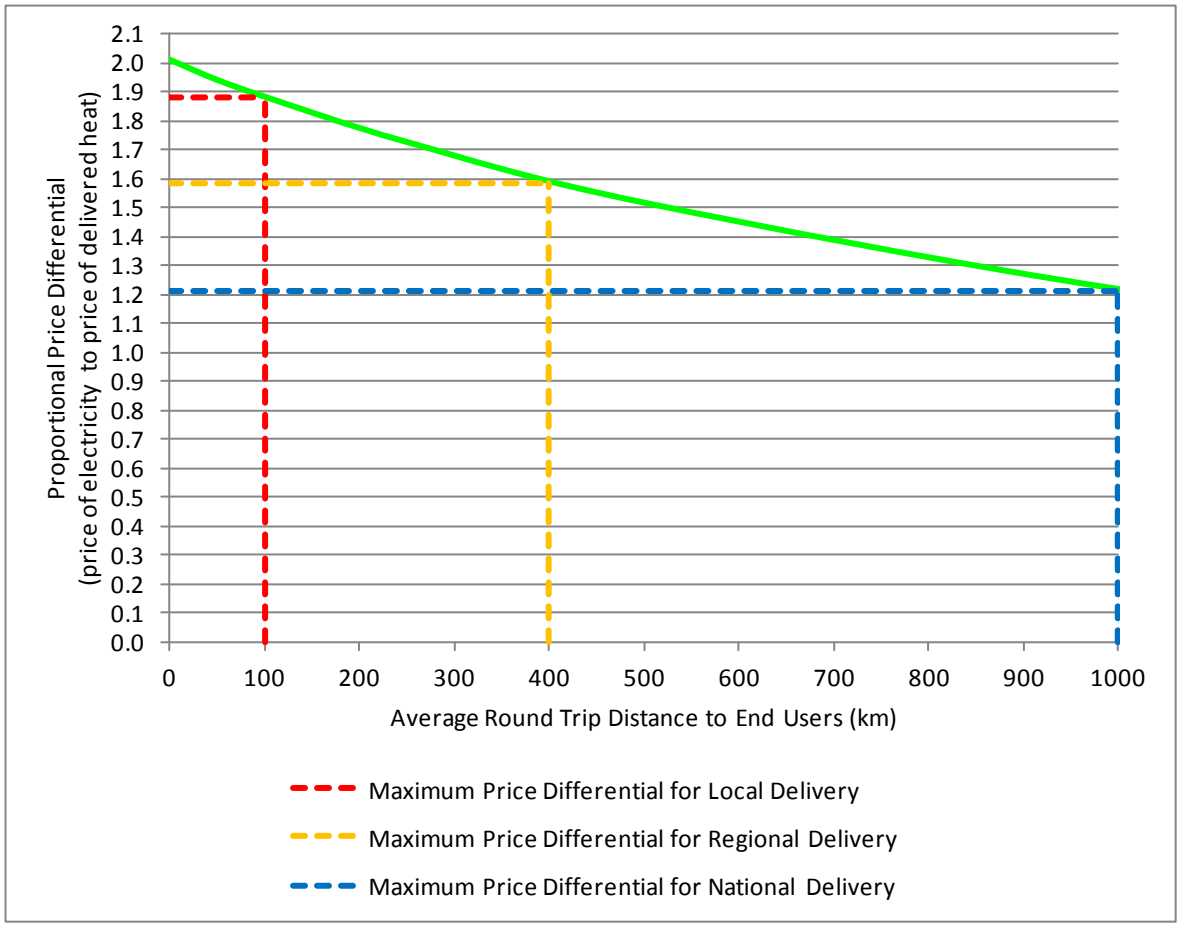


Figure H14 Variation of Proportional Price Differential with Round Trip Transport Distance to End Users: Unclean Waste Wood Chips for Commercial and Industrial Combined Heat and Power Generation