Biomass Waste for Energy Project Reporting Protocol

GHG Emission Reduction Accounting

Version 6.3

January 2013

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1.0 Introduction

This protocol provides accounting, reporting, and monitoring procedures to determine greenhouse gas (GHG) reductions associated with biomass waste for energy projects.

The protocol is for projects which process and transport biomass waste for the generation of energy (e.g. electricity and process heat). The protocol is limited to projects where, under baseline, business as usual conditions, at the start of the project, the biomass waste would have otherwise been legally disposed of through: (1) open burning; (2) decay and decomposition in the field; or (3) landfill. The protocol is also limited to biomass waste that is the result of sustainable harvesting operations; and includes urban woody post-consumer yard wastes.

Biomass waste for energy projects reduce GHG emissions through: (1) avoiding methane (CH_4) and nitrous oxide (N_2O) emissions that occur during disposal through open burning, decay and decomposition, and/or landfilling; and (2) producing renewable energy that displaces GHG emissions from fossil fuel combustion needed for an equivalent energy supply.

2.0 Project

Biomass waste is generated from forestry, agriculture, urban landscape, and related industries. Biomass is defined as non-fossilized and biodegradable organic material originating from plant material. Biomass waste disposal methods include open burning, decay and decomposition in the field, or landfill. Biomass waste includes:

- Forest slash (non-merchantable) remains from forest management activities including timber harvesting or forest thinning and fuel hazard reduction. These include small trees, brush, tree tops, and branches.
- Defensible space clearing residues (brush, tree branches and trunks, clippings).
- Orchard and vineyard removals and prunings.
- Field straws and stalks.
- Urban prunings/cuttings residues.

Biomass waste has energy content that can be utilized in energy recovery facilities, which include:

- Direct biomass combustion, producing heat and/or electricity.

- Biomass gasification, producing syngas used for heat or electricity production, or conversion into alternative transportation fuels (e.g. biofuels).

Sources of GHG emissions from a biomass waste for energy project are shown in Table 1.

2.1 Project Definition

For this protocol, the GHG reduction project involves the use of biomass wastes for energy recovery, where otherwise under baseline, business as usual conditions, the biomass waste would have been disposed of through open burning, left to decay and decompose in the field, or landfilled.

The project developer must provide information defining the project operations, including:

- Location where the biomass waste is generated.
- Operation for which the biomass waste is a byproduct, i.e. how is the biomass waste generated.
- Generation (rate and timing) of the biomass waste.
- Composition of the biomass waste.
- Historical, current, and anticipated future, disposal practice for the biomass waste in the absence of the proposed biomass waste to energy project.
- Biomass waste processing operations prior to transport, such as conveyors, grinders, and loaders.
- Biomass waste transportation method.
- Location of energy recovery facility.

- Type of energy produced (e.g. electricity, heat, fuels).
- Estimated cost of processing and transporting biomass waste to the energy recovery facility.
- Generation rate of energy from biomass waste.
- User(s) / purchaser(s) of energy generated from biomass waste.
- Permitting status of the energy recovery facility.
- Documentation of environmental assessments required as part of the biomass waste generating activities. These might include the National Environmental Policy Act (NEPA), California Environmental Quality Act (CEQA), California Forest Practices Rules and Regulations, Timber Harvest Plans, and Best Management Practices assessments.

This information must be provided in Form A, included as an attachment to the protocol. Form A must be completed, submitted, and approved prior to project commencement.

2.2 Project Developer

Project developers can include biomass generators, biomass waste energy recovery operators, and/or third party aggregators. Ownership of the GHG reductions must be established by clear and explicit title, where ownership is determined through agreement between project developers. This is important to avoid double counting of reductions by the energy recovery operator, biomass processor, biomass owner (landowner), or third party investor.

2.3 Methane and Nitrous Oxide Global Warming Potential Characterization Factors

Methane (CH_4) has a global warming potential characterization factor of 21 tons of CO_{2e} per ton of methane.

Nitrous oxide (N_2O) has a global warming potential characterization factor of 310 tons CO_{2e} per ton N_2O.

3.0 Eligibility

Projects must meet the following requirements to be eligible for GHG offset credits under this protocol.

3.1 Biomass from Qualified Operations

The biomass waste material used for energy recovery must be characterized as:

- "Biomass" – The material must be non-fossilized and biodegradable organic material.

- "Excess waste" – The material must be an excess waste byproduct that, in the absence of the project, would be disposed of through open burning, or deposited in the field or landfilled.

- "Sustainable" – The material must be a byproduct of operations which:

  -- Protect or enhance long-term productivity of the site by maintaining or improving soil productivity, water quality, wildlife habitat, and biodiversity.

  -- Meet all local, state, and federal environmental regulations, including National Environmental Policy Act (NEPA), California Environmental Quality Act (CEQA), California Forest Practices Rules and Regulations, Timber Harvest Plans, and Best Management Practices.

3.2 Additionality

Project GHG emission reductions must be "additional" to what would have otherwise occurred.

It must be demonstrated that the existing, baseline business as usual disposal practice of the biomass wastes at the beginning date of the project is through either:

- Open burning in the vicinity of the production site. It must be demonstrated that this disposal practice is a legally allowable method under the local Air District and the State and that an open pile burn permit has been or could be obtained.

- Decay and decomposition in the vicinity of the production site, with no commercial value derived from the end-product.

- Landfilled.

The project developer must demonstrate there are no alternative uses for the biomass waste. It must not be currently economical within the local market to utilize or sell the biomass waste as a product or process feedstock. This requires providing documentation of previous historical disposal practices, current disposal practices in the absence of the proposed project, and future planned/anticipated disposal practices.

3.3 Energy Recovery

The biomass waste must be used in an energy recovery facility. The energy recovery facility must:

- Meet all Federal, State, and local environmental regulations, including (but not limited to) air quality, water discharge, and solid waste.
- Produce energy (e.g. electricity, heat, fuel) that is under control of a project participant, or an entity that has a contractual agreement or is an affiliate with the project developer.
- Produce energy that is valuable and utilized, and would not have otherwise been generated.

3.4 Energy Sales

Energy produced from the biomass wastes must be documented to not be claimed for use by other projects for GHG mitigation purposes.

3.5 Location

This protocol is applicable to biomass generation and energy recovery project operations that are located in California.

3.6 Project Start Date

Projects are eligible which begin after the date of approval of the protocol (January 2013), or after January 1, 2007 for qualifying early action projects, and after the necessary project initiation forms have been completed and approved (including Form A).

4.0 Assessment Boundary

The biomass waste for energy project boundary is defined to include all GHG emissions from operations that are the result of the biomass waste for energy project. The physical boundary of the biomass waste for energy project is shown in Figure 1. GHG emissions must be accounted for operations, as detailed in Table 1, including:

Baseline, Business as Usual

- Open biomass burning. Includes quantification of CO_2, CH_4, and N_2O.
- Decay and decomposition of biomass disposal in field. Includes quantification of CH_4 and N_2O.
- Landfill. Includes quantification of CH_4.

Biomass Waste for Energy Project

- Fossil fuel fired engines, at the site where the biomass waste is generated, that would not have been used had the biomass waste been disposed of through open burning or left to decay. This includes engines that power biomass waste processing equipment used at the site of biomass waste generation – including chippers, grinders, shredders, loaders, excavators, conveyors, etc. Includes quantification of CO_2.
- Fossil fuel fired engines used to facilitate transport of biomass waste from the site of generation to the energy recovery facility. Includes quantification of CO_2.
- Biomass waste usage at the energy recovery facility. For biomass combustion boilers, quantification of CO_2 is required. The quantification of CH_4 and N_2O is not required as it is considered negligible for a combustor that meets state and local air quality regulations. Other types of energy recovery units may require quantification of CH_4 and N_2O.
- Fossil fuel fired engines used for transportation of equipment and personal to the biomass waste processing site. Includes quantification of CO_2 emissions.
- Fossil fuel fired engines used at energy recovery facility for operation of auxiliary equipment, such as conveyors and loaders, that would not have been used otherwise in the absence of the project. Includes quantification of CO_2 emissions.

5.0 Calculation Methods

5.1 Biomass Waste for Energy Project

5.1.1 Biomass Processing Rate

Determine the quantity of biomass (total wet weight), BM_W , meeting the above eligibility criteria, which is delivered to the energy recovery facility:

$BM_{T,W}$ Quantity of wet (green) biomass utilized at energy recovery facility (wet tons). Determined from the summation of direct weight measurement of every separate biomass delivery received at the energy recovery facility.

Determine the quantity of biomass (total bone dry weight), $BM_{T,D}$, as.

$$BM_{T,D} = BM_{T,W} * (1 - M) \qquad \text{(Eq. 1)}$$

where:

M Moisture content of biomass (%). Determined through sampling and analysis of the biomass delivered to the energy recovery facility. (Sampling and measurement will be based on ASTM E870-82, ASTM D 3173, or equivalent. Sampling will occur at biomass energy recovery facility.)

5.1.2 Energy Produced from Biomass

Determine the energy content of biomass waste delivered to the biomass energy recovery facility, Q_{BM}, (MMBtu) as:

$$Q_{BM} = BM_{T,D} * HHV_{BM} \qquad \text{(Eq. 2)}$$

where:

HHV_{BM} Higher Heating Value of biomass waste (MMBtu/dry ton). Determined by periodic or most current sampling and analysis of biomass. (Measurement of HHV will be based on ASTM E870-82, ASTM D 5865, or equivalent.). HHV is utilized within this protocol instead of LHV because it is more prominently used in the biomass energy recovery industry. If LHV is utilized, appropriate conversion factors must be used to calculate an equivalent HHV.

Next, determine the energy produced from the biomass at the energy recovery facility, E_{BM}, as:

$$E_{BM} = Q_{BM} * f \quad \text{(Eq. 3)}$$

where:

f — Energy production generation efficiency. Determined as the ratio of net useful energy produced by the facility (gross energy produced minus parasitic plant energy requirements) to the total fuel heat input rate. This parameter must be determined on a basis of HHV.

For the production of electricity, this is referred to as the facility heat rate (determined as the kWh_e new electricity / MMBtu fuel input).

The efficiency will be based on measurements of facility operations using the biomass waste based on an annual facility average efficiency.

5.1.3 GHG Displaced by Energy Produced from Biomass

Determine the GHG emissions from fossil fuel combustion that are displaced by the energy produced from the biomass, GHG_E, as:

$$GHG_E = E_{BM} * EF_E \quad \text{(Eq. 4)}$$

where:

EF_E — Emission factor for CO_{2e} from energy generation that is displaced by the biomass for energy project (tons CO_{2e} / unit of energy supplied by the excess biomass for energy facility).

For displaced electricity, it might be appropriate to the use of a factor of 800 lb CO_{2e} / MWh – based on marginal electricity generation supplied by a combined cycle natural gas system.

Alternatively, it may be appropriate to utilize the local serving utility CO_2 emission factor, determined as the average of all baseload and marginal production sources. Particularly, in cases where the utility overall average is lower than that of combined cycle natural gas generation system.

5.1.4 GHG Emissions from Ancillary Biomass Handling, Processing, and Transportation Operations

Determine the amount of GHG resulting from ancillary biomass handling, processing, and transport operations, GHG_{AUX} , as:

$$GHG_{AUX} = GHG_{TRANS} + GHG_{PROC} \quad \text{(Eq. 5)}$$

where:

$GHG_{TRANS} = VM * MPG * EF_{FF}$ (Eq. 6)

GHG_{TRANS} CO_{2e} emissions from vehicles used to transport biomass to the energy recovery facility; and vehicles used to transport workers to the biomass processing site.

VM Vehicle miles driven for biomass transport (round trip); and miles driven to transport workers to the biomass processing site. In reporting period.

MPG Vehicle mileage achieved by transport vehicles (miles/gallon).

EF_{FF} Emission factor for CO_2 for fossil fuel combustion (lb CO_2 / gal fuel) -- for diesel, 22.23 lb CO_2/gallon; for gasoline, 19.37 lb CO_2/gal.

and

$GHG_{PROC} = (T_{FF} * R_{FF}) * EF_{FF}$ (Eq. 7)

where:

T_{FF} Time equipment used to operate biomass processing equipment, including grinders, chippers, shredders, conveyors, and loaders, bulldozers, and excavators. (Reported in hours).

R_{FF} Average volumetric fuel use rate (gallons per hour) for equipment used to operate biomass processing equipment, including grinders, chippers, shredders, conveyors, and loaders, bulldozers, and excavators. (Reported in hours).

5.1.5 *GHG Emissions From Biomass Combustion*

Determine CO_2 from biomass combustion, as:

$GHG_{BCOM} = BM_{T, D} * EF_{CO2\ BM}$

where:

$EF_{CO2\ BM}$ Emission factor for CO_2 from biomass combustion, recommended as 1.8 tons CO_2 / ton dry biomass.

5.1.6 *GHG Emissions From Biomass for Energy Project*

Determine the biomass for energy project GHG emissions, GHG_{PROJ}, as:

$GHG_{PROJ} = GHG_{AUX} – GHG_{E} + GHG_{BCOM}$ (Eq. 8)

5.2 Baseline

5.2.1 Baseline Biomass Disposal Practice

Determine the quantity (dry tons) of biomass that would have been uncontrolled open burned, $BM_{OB, D}$, the quantity of biomass that would have been left to decay in the field, $BM_{DD, D}$, and the quantity of biomass that would have been landfilled, $BM_{LF, D}$:

$BM_{OB, D} = BM_{T, D} * X_{OB}$ (Eq. 9)

$BM_{DD, D} = BM_{T, D} * X_{DD}$ (Eq. 10)

$BM_{LF, D} = BM_{T, D} * X_{LF}$ (Eq. 11)

where:

X_{OB} Fraction (dry weight %) of biomass that would have been uncontrolled open burned. Based on historical, current, and future projected practices.

X_{DD} Fraction (dry weight %) of biomass that would have been left to decay in the field. Based on historical, current, and future projected practices.

X_{LF} Fraction (dry weight %) of biomass that would have been landfilled.

5.2.2 GHG Emissions from Baseline Disposal

Determine GHG emissions that would have resulted from the baseline disposal practices, GHG_{BASE}, as the sum of emissions from uncontrolled open burning, GHG_{OB}, field decay and decomposition, GHG_{DD}, and landfilled, GHG_{LF}, as:

$GHG_{BASE} = GHG_{OB} + GHG_{DD} + GHG_{OB}$ (Eq. 12)

where:

GHG_{BASE} Total baseline greenhouse gas emissions, as CO_2 equivalent (tons CO_{2e})

GHG_{OB} Greenhouse gas emissions from uncontrolled open burning, as CO_2 equivalent (tons CO_{2e})

GHG_{DD} Greenhouse gas emissions from field decay and decomposition, as CO_2 equivalent (tons CO_{2e})

GHG_{LF} Greenhouse gas emissions from landfilling, as CO_2 equivalent (tons CO_{2e})

and,

$$GHG_{OB} = (EF_{OB, CO2} * BM_{OB, D} * BF) + (EF_{OB, CH4} * BM_{OB, D} * BF * 21) + (EF_{OB, N2O} * BM_{OB, D} * 310) \quad \text{(Eq. 13)}$$

$$GHG_{DD} = EF_{DD, CH4} * BM_{DD} * 21 + EF_{DD, N2O} * BM_{DD} * 310 \quad \text{(Eq. 14)}$$

$$GHG_{LF} = EF_{LF, CH4} * BM_{DD} * 21 \quad \text{(Eq. 15)}$$

where:

EF_{OB} Emission factor for CO_2, CH_4 and N_2O from uncontrolled open pile burning of biomass. Recommend the use of:

- CO_2 : 1.73 tons CO_2 / ton dry biomass
- CH_4 : 0.005 ton CH_4 / ton dry biomass
- N_2O : 0.00015 ton N_2O / tons dry biomass

BF Biomass consumption burn out efficiency of the open pile burn. Recommend the use of 95%.

EF_{DD} Emission factor for CH_4 and N_2O from in-field decay and decomposition of biomass. Recommend the use of 0.05 ton CH_4 / ton dry biomass. Recommend the use of 0 tons N_2O / ton dry biomass.

EF_{LF} Emission factor for CH_4 from landfilling of biomass. Recommend the emission factor be determined using the procedure contained in the Climate Action Reserve Landfill Protocol for GHG Offset Projects.

5.3 Net GHG Project Reduction

Determine GHG reductions from biomass waste to energy recovery project, GHG_{NET}, as:

$$GHG_{NET} = GHG_{BASE} – GHG_{PROJ} \quad \text{(Eq. 14)}$$

6.0 <u>Monitoring</u>

Project data monitoring requirements are shown Form B.

7.0 Reporting and Recordkeeping

7.1 Project Commencement

Form A must be completed, submitted, and approved prior to project commencement, as discussed in Section 2.1 and Section 3.6.

7.2 Recordkeeping

Form B can be used to collect, maintain, and document the required information. Information is to be kept for a period of 10 years after it is generated, or 7 years after the last verification.

7.3 Reporting

Form C can be used to report on project emission reductions. Reporting must be made on a monthly basis.

Project developers must report GHG emission reductions on an annual (12-month) calendar basis.

8.0 Verification

Project activities and GHG emission reductions must be verified and certified by a qualified third party prior to GHG emission reduction issuance. The verifier must review and assess the reported data to confirm that is adheres with the all the requirements of this protocol; and determine that the emissions reductions are accurate, consistent, and credible. The third party verifier must be approved by the responsible entity that issues the emission reductions.

9.0 Glossary of Terms

Additionality: Biomass residue management practices that are above and beyond business as usual operation, exceed the baseline characterization, and are not mandated by regulation.

Biomass energy recovery operator: Entity that owns and/or operates a facility that processes and utilizes biomass waste as a feedstock to generate useful energy (electricity, heat, fuels).

Biomass generator: Landowner or independent contractor that conducts operations that result in the generation of biomass waste residuals.

Biomass waste residue: Non-fossilized and biodegradable organic material originating from plant material, which due to economic considerations are disposed of through open burning or deposited at the site of generation and left to decay and decompose or are transported to a landfill.

Carbon dioxide (CO_2): Greenhouse gas consisting of a single carbon atom and two oxygen atoms.

CO_2 equivalent (CO_{2e}): The quantity of a given GHG multiplied by its total global warming potential.

Emission factor (EF): A value for determining an amount of a greenhouse gas emitted for a given quantity of activity data (e.g. short tons of methane emitted per dry ton of biomass combusted).

Fossil fuel: A fuel, such as coal, oil, and natural gas, produced by the decomposition of ancient (fossilized) plants and animals.

Greenhouse gas (GHG): Includes carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulfur hexafluoride (SF_6), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs).

Global Warming Potential (GWP): The ratio of radiative forcing (degree to warming to the atmosphere) that would result from the emission of one unit of a given GHG compared to one unit of CO2).

kWh_e: Kilowatt-hour of electricity.

Methane (CH_4): Greenhouse gas with a GWP of 21, consisting of a single carbon atom and four hydrogen atoms.

MMBtu: Million British Thermal Units.

MWh_e: Megawatt-hour of electricity.

Nitrous oxide (N_2O): Greenhouse gas with a GWP of 310, consisting of two nitrogen atoms and a single oxygen atom.

Open burning: The intentional combustion of biomass material in piles for disposal without processing or energy recovery operations.

Project developer(s): An entity (or multiple entities) that undertakes a project activity, as defined in the Biomass for Energy Protocol. Project developers include, but are not limited to biomass waste generators, biomass waste energy recovery operators, and/or third party aggregators.

Syngas: Synthetic gas produced through industrial processing of biomass material into gaseous (i.e. methane) or further refined into liquid fuels (biofuels).

Third Party Aggregator: An entity that facilitates the project as is not the landowner, biomass waste generator, or biomass waste energy recovery operator for the purpose of generating GHG emission offset credits.

10.0 References

California Air Resources Board (CARB), Greenhouse Gas Inventory, 1990-2004, Nov. 17, 2007.

Delmas, R., J.P. Lacaux, and D. Brocard, “Determination of biomass burning emission factors: methods and results,” Journal of Environmental Monitoring and Assessment, Vol. 38, pp. 181-204, 1995.

Intergovernmental Panel on Climate Change (IPCC), Fourth Assessment Report, Changes in Atmospheric Constituents and in Radiative Forcing, Chapter 2, pp. 211-216, 2007.

Jenkins, B., et al., Atmospheric Pollutant Emission Factors from Open Burning of Agricultural and Forest Biomass by Wind Tunnel Simulations, CARB Report No. A932-196, April 1996.

Kopmann, R., K. Von Czapiewski, and J.S. Reid, “A review of biomass burning emissions, part I; gaseous emission of carbon monoxide, methane, volatile organic compounds, and nitrogen containing compounds,” Amos. Chem. Phys. Discuss., Vol. 5, pp. 10455-10516, 2005.

Mann, M. and P. Spath, “Life Cycle Assessment Comparisons of Electricity from Biomass, Coal, and Natural Gas,” 2002 Annual Meeting of the American Institute of Chemical Engineers, National Renewable Energy Laboratory, Golden, Colorado, 2002.

U.S. EPA, Compilation of Air Pollutant Emission Factors, AP-42, Section 2.5, Open Burning, October 1992.

U.S. EPA, Compilation of Air Pollutant Emission Factors, AP-42, Section 13.1, Prescribed Burning, October 1996.

U.S. EPA, “Emission Facts – Average Carbon Dioxide Emissions Resulting from Gasoline and Diesel Fuel,” EPA420-F-05-001, February 2005.

11.0 Emission Factors

Methane Emission Factors for Open Burning of Biomass

Reference / Burn Type	CH4 as reported by author	CH4 lb/dry ton fuel consumed

U.S. EPA, Compilation of Air Pollutant Emission Factors, AP-42, Section 13.1, Prescribed Burning, October 1996, Table 13.1-3.

Broadcast Logging Slash		
Hardwood (fire)	6.1 g/kg fuel consumed	12.2
Conifer short needle (fire)	5.6 g/kg fuel consumed	11.2
Conifer long needle (fire)	5.7 g/kg fuel consumed	11.4
Logging slash debris dozer piled conifer (fire)	1.8 g/kg fuel consumed	3.6

D.E. Ward, C.C. Hardy, D.V. Sandberg, and T.E. Reinhardt, Mitigation of prescribed fire atmospheric pollution through increased utilization or hardwoods, pile residues, and long-needled conifers, Part III, Report IAG DE-AI179-85BP18509 (PNW-85-423), USDA Forest Service, Pacific Northwest Station, 1989.

Broadcast Burned Slash		
Douglas fir	11.0 lb/ton fuel consumed	11.0
Ponderosa pine	8.2 lb/ton fuel consumed	8.2
Mixed conifer	12.8 lb/ton fuel consumed	12.8
Pile and Burn Slash		
Tractor piled	11.4 lb/ton fuel consumed	11.4
Crane piled	21.7 lb/ton fuel consumed	21.7

U.S. EPA, Compilation of Air Pollutant Emission Factors, AP-42, Section 2.5, Open Burning, October 1992, Table 2.5-5.

Unspecified	5.7 lb/ton material burned	10.4
Hemlock, Douglas fir, cedar	1.2 lb/ton material burned	2.4
Ponderosa pine	3.3 lb/ton material burned	6.6

W. Battye and R. Battye, Development of Emissions Inventory Methods for Wildland Fire, prepared under Contract EPA No. 68-D-98-046, Work Assignment No. 5-03, February 2002. (Based on data from D.E. Ward and C.C. Hardy, Smoke emissions from wildland fires, Environment International, Vol. 17, pp. 117-134, 1991.)

90% combustion efficiency	3.8 g/kg fuel consumed	7.6

B. Jenkins, S. Turn, R. Williams, M. Goronea, et al., Atmospheric Pollutant Emission Factors from Open Burning of Agricultural and Forest Biomass by Wind Tunnel Simulations, CARB Report No. A932-196, April 1996.

Ponderosa pine pile burn	1.3 g/kg dry fuel	1.7
Almond pruning pile burn	1.2 g/kg dry fuel	2.6
Douglas fire pile burn	1.9 g/kg dry fuel	3.0
Walnut pruning pile burn	2.0 g/kg dry fuel	4.0

R. Kopmann, K. von Czapiewski, and J.S. Reid, A review of biomass burning emissions, part I; gaseous emission of carbon monoxide, methane, volatile organic compounds, and nitrogen containing compounds, Amos. Chem. Phys. Discuss., Vol. 5, pp. 10455-10516, 2005.

Literature search on biomass open burning	1 - 20 g/kg dry fuel	10.0

Nitrous Oxide Emission Factors for Open Burning of Biomass

Delmas, R., Lacaux, J.P., Brocard, D. "Determination of biomass burning emission factors: methods and results," Journal of Environmental Monitoring and Assessment, Vol. 38, 181-204, 1995.	0.00015 ton / ton dry

Methane Emission Factors for Decay and Decomposition of Biomass

Mann, M. K., and P. L. Spath, "Life Cycle Assessment Comparisons of Electricity from Biomass, Coal, and Natural Gas," 2002 Annual Meeting of the American Institute of Chemical Engineers. Golden, Colorado, National Renewable Energy Laboratory, 2002.	0.05 ton / ton dry

Assumes 9% carbon in biomass is converted to carbon in methane. Biomass has a molecular formula of $C_6H_{10}O_6$.

Nitrous Oxide Emission Factors for Decay and Decomposition of Biomass

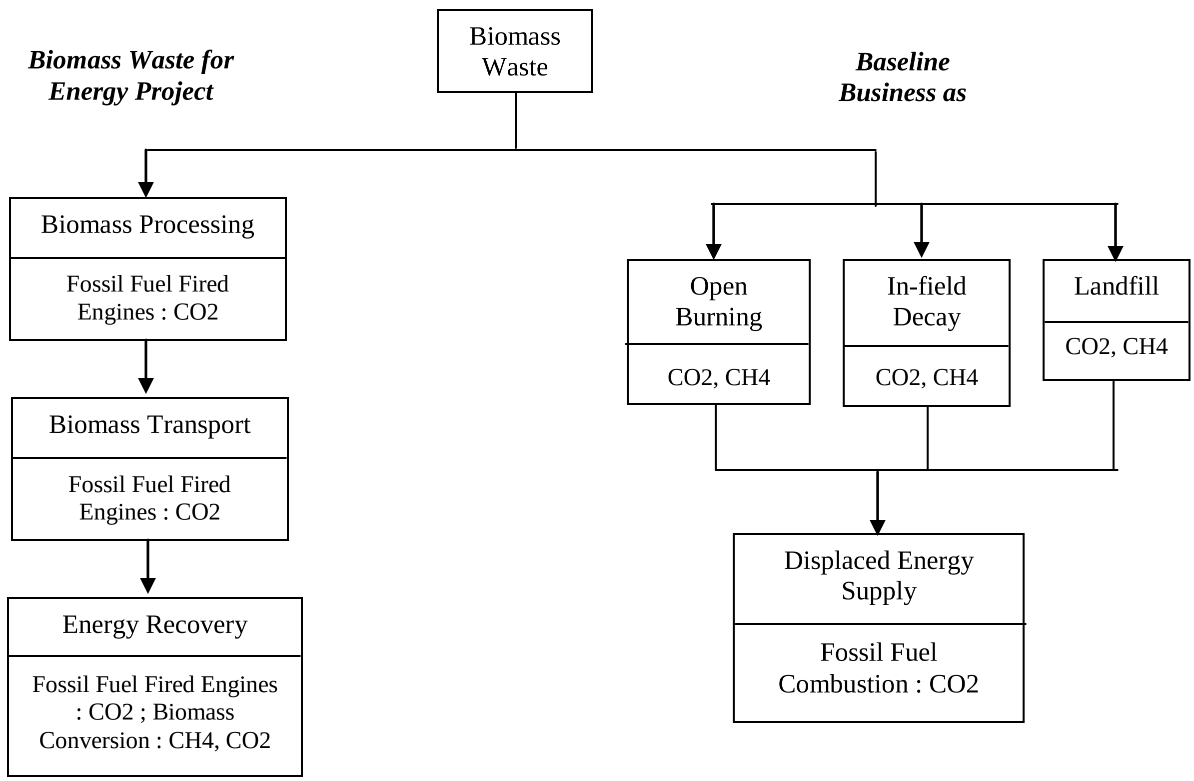
Engineering judgment. At temperatures of in-field decay and decomposition, N_2O is expected to be negligible. Nitrogen in fuel will go to NH_3.	0 ton /ton dry

12.0 Attachments

Table 1. Biomass for Energy Project -- Source Categories, GHG Sources, and GHG Emissions

Source	Associated GHGs	Included in GHG assessment boundary
Baseline		
Open Uncontrolled Pile Burning	CO_2	Included
	CH_4	Included
	N_2O	Included
In-field Decay and Decomposition	CO_2	Included
	CH_4	Included
	N_2O	Included
Landfill	CO_2	Included
	CH_4	Included
Biomass for Energy Project		
Transportation -- engine combustion of fossil fuels	CO_2	Included
	CH_4	Not included; negligible
	N_2O	Not included; negligible
Processing and Handling at Generation Site -- engine combustion of fossil fuels	CO_2	Included
	CH_4	Not included; negligible
	N_2O	Not included; negligible
Energy Recovery Facility	CH_4	Not included for combustors; may need to be included for other energy processing types
	CO_2	Included
	N_2O	Not included; negligible
Processing and Handling at Energy Recovery Facility – engine combustion of fossil fuels	CO_2	Included
	CH_4	Not included; negligible
	N_2O	Not included; negligible
GHGs from conventional energy production displaced by energy from biomass waste	Dependent on conventional energy source	Included

Figure 1. System Boundary Definition



Form A. Project Definition

Date:				
Project Title:				
Project Developer:				
Project Address:				
Anticipated Project Dates:	Start Date:		End Date:	
Permitting Status:				
Biomass Generation & Disposal Information				
Composition of Biomass (including moisture content)				
Historic, Current, and Anticipated Disposal Practice				
Biomass Generation Rate (green tons/day)				
Cost of Biomass Processing and Transport ($/green ton)				
Biomass Energy Recovery Information				
Type of Energy Produced	Electricity	Heat	Fuels	Other
Name & Location of Energy Recovery Facility				
Generation Rate of Recovered Energy (MMBtu/day)				
Users/Purchasers of Recovered Energy				

Form B. Monitoring and Recordkeeping

Date:			
Project Title:			
Project Developer:			
Start Date of Monitoring Period:		End Date of Monitoring Period:	

Monitoring and Parameter Measurements

Parameter	Description	Data Unit	How Measured	Measurement Frequency	Reported Measurement
$BM_{T, W}$	Biomass delivered to energy recovery facility	wet tons / delivery	Transport vehicle weight scale	Every separate delivered load	
M	Moisture content of biomass	moisture, wt. %	Sampling and analysis of biomass wastes	Every separate delivered load	
HHV_{BM}	Higher heating value of biomass waste	Btu/lb, dry	Sampling and analysis of biomass wastes	Periodic – at least once per month	
f	Energy production efficiency of energy recovery facility	net useful energy / biomass heat input	Measurement of boiler output and waste fuel input. Alternatively, based on manufacturer design specifications	Start of program; and updated as needed	
VM	Vehicle miles traveled for biomass transport	miles	Vehicle odometer	Periodically (at least weekly)	
MPG	Transport vehicle gas mileage	miles / gallon	Measurement of vehicle miles traveled and gas usage	Start of program, and updated as needed	

Parameter	**Description**	**Data Unit**	**How Measured**	**Measurement Frequency**	**Reported Measurement**
V_{FF}	Volume of fossil fuels used to power biomass processing equipment, e.g. shredders, chipper, grinders, conveyors, loaders, excavators, bulldozers	gallons	Measurement of diesel fuel usage and/or equipment operating hours	Periodically (at least weekly)	
X_{OB}	Fraction of biomass that would have been open burned	%, wet biomass	Determined based on current economics and operating practices	Start of program, and updated as needed	
X_{DD}	Fraction of biomass that would have been left in field to decay and decompose	%, wet biomass waste	Determined based on current economics and operating practices	Start of program, and updated as needed	
X_{LF}	Fraction of biomass that would have been landfilled	%, wet biomass waste	Determined based on current economics and operating practices	Start of program, and updated as needed	

Form C. Reporting

Date:	
Project Title:	
Project Developer:	
Reporting Period:	

Parameter	Description	Data Unit	Reported Value
$BM_{DD, D}$	Biomass left in field to decay	bone dry tons	
$BM_{OB, D}$	Biomass open burned	bone dry tons	
$BM_{LF, D}$	Biomass landfilled	Bone dry tons	
$BM_{T, D}$	Biomass delivered to energy recovery facility, adjusted for moisture	bone dry tons / delivery	
$BM_{T, W}$	Biomass delivered to energy recovery facility	wet tons / delivery	
E_{BM}	Energy produced from energy recovery facility	kWh	
$EF_{DD, CH4}$	Emission factor for in-field decay and decomposition	tons CH_4/ton dry biomass	
$EF_{DD, N2O}$	Emission factor for nitrous oxide from in-field decay and decomposition	tons N_2O/ton dry biomass	
EF_E	Emission factor for CO_2e for existing electricity generation	tons CO_2e/unit energy	
EF_{FF}	Emission factor for fossil fuel combustion	lb CO_2/gallon fuel	
$EF_{OB, CH4}$	Emission factor for methane from open pile burning	tons CH_4/ton dry biomass	
$EF_{OB, N2O}$	Emission factor for nitrous oxide from open pile burning	tons N_2O/ton dry biomass	
$EF_{LF, CH4}$	Emission factor for methane from landfill	tons CH_4/ton dry biomass	
f	Energy production efficiency of energy recovery facility	net useful energy / biomass waste heat input	

Parameter	Description	Data Unit	Reported Value
GHG_{AUX}	GHG resulting from ancillary biomass handling, processing, and transport	tons CO_2e	
GHG_{BASE}	GHG resulting from baseline disposal practices	tons CO_2e	
GHG_{DD}	GHG resulting from decay and decomposition	tons CO_2e	
GHG_{E}	GHG displaced from energy production from biomass	tons CO_2e	
GHG_{NET}	Net GHG reductions from	tons CO_2e	
GHG_{OB}	GHG resulting from open burning activities	tons CO_2e	
GHG_{LF}	GHG resulting from landfilling activities	tons CO_2e	
GHG_{PROC}	GHG resulting from ancillary biomass handling and processing	tons CO_2e	
GHG_{PROJ}	GHG resulting from the biomass waste to energy project	tons CO_2e	
GHG_{TRANS}	GHG resulting from transport operations	tons CO_2e	
HHV_{BM}	Higher heating value of biomass	Btu/lb, dry	
M	Moisture content of biomass	moisture, wt. %	
MPG	Transport vehicle gas mileage	miles / gallon	
Q_{BM}	Heat content per delivery of biomass at facility	MMBtu	
R_{FF}	Average volumetric fuel use rate for processing equipment	gallons/hour	
T_{FF}	Time equipment used for processing operations	hours	

Parameter	Description	Data Unit	Reported Value
V_{FF}	Volume of fossil fuels used to power biomass processing equipment, e.g. shredders, chipper, grinders, conveyors, loaders, excavators, bulldozers	gallons	
VM	Vehicle miles traveled for biomass waste transport	miles	
X_{DD}	Fraction of biomass that would have been left in field to decay and decompose	%, wet biomass	
X_{OB}	Fraction of biomass that would have been open burned	%, wet biomass	
X_{LF}	Fraction of biomass that would have been landfilled	%, wet biomass	