The Global Bioenergy Partnership Common Methodological Framework for GHG Lifecycle Analysis of Bioenergy

Version Zero

The following 10-step greenhouse gas (GHG) inventory framework is intended to guide policy makers and institutions when calculating GHG emissions from bioenergy and to enable life cycle assessments (LCA) of the GHG emissions of bioenergy to be compared on an equal basis. Not all 10 steps will apply to all biofuel or bioenergy systems, so in some applications it will be necessary to skip one or more steps of the Framework. At all stages, the user is invited to provide units of measurement and description of methodologies to add specificity to the report.

Step 1: GHGs Covered

The user is asked to provide Global Warming Potential values and/or a clear reference (e.g., "IPCC SAR values") for the GHGs included in the analysis. This is necessary to ensure consistency between reports and the repeatability of reported calculations.

CO_2 1

CH_4 25

N_2O 298

HFCs ____

PFCs ____

SF_6 ____

Other __________

Please report global warming potential used for each GHG covered.

Step 2: Source of biomass

The Framework distinguishes between waste and non-waste biofuels because LCA related to feedstock production is not relevant to "waste" biomass. The user is asked to specify the definition of "waste" biomass to ensure transparency at this critical point in the LCA.

Non-waste √

Identify Feedstock: Arundo donax

Residue or Other Waste __

Identify Feedstock: ________________________

* Please explain definition of waste:

Substance that the holder intended to discard ___

Substance that had zero or negative economic value ___

Substance for which the use was uncertain ___

Substance that was not deliberately produced and not ready for use without further processing ___

Substance that could have adversely affected the environment ___

Other: ____

Step 3: Land use change

Sub Group 1 was asked to develop a checklist for Parties to indicate what sources of GHG emissions related to land-use change (Step 3) and the production agricultural and forests based biofuel feedstocks (Step 4) they include in their approach to lifecycle analysis.

In developing the content of Steps 3 and 4, Sub-group 1 followed two guiding principles. The first was to avoid even the appearance of promoting or endorsing one methodology or approach over another. It was recognized that differences regarding the approach to LCA analysis or the choice of LCA methodologies could arise due to differences in national circumstances or legitimate differences of opinion regarding what should be included in lifecycle analysis. The second principle was to promote transparency. Suggestions that made it possible for Parties to be clearer about what is included in their LCA GHG emissions estimate for biofuels or allowed additional parties to use the framework were generally incorporated.

Accounting for land use change in a lifecycle framework for estimating emissions for bioenergy is a complicated matter. Many institutions around the world are developing their methodologies. Some account for land use change in a single, holistic assessment while others sub-divide bioenergy-associated land use change into direct and indirect changes. Some further distinguish between indirect land use changes that are domestic versus those that are international. The reporting framework presented below is intended to be flexible in order to clarify which of these multiple approaches is taken by the methodology being described.

√ Direct land use changes are taken into account **OR**

____ Indirect land use changes are taken into account **OR**

____ A combination of both is included

Explain the choice.

This study assumes the GREET1.8 default value for CO_2 emissions related to direct land use change, that is a net CO_2 uptake of 48,500 g/dry ton of biomass collected (English ton).

3a: Direct Land use Change

Sub Group 1 recognized that including land use changes as sources in frameworks to assess the full lifecycle GHG emissions associated with bioenergy products is very complicated. Any given approach must make choices regarding a number of technical considerations including (but not limited to) the type of baseline (e.g., point in time vs. business as usual), the set of boundaries (e.g., sector, activity, and geographic coverage), and the timeframe over which emissions are allocated. For each of these considerations (and others) there are technically defendable alternatives available that can significantly affect the magnitude of the estimated GHG emissions associated with land use change. Additionally, there are significant differences in the quantity and quality of information available to Parties to estimate GHG emissions associated with land use change. These include (but are not limited to) availability of relevant data to estimate land use changes and appropriate coefficients to estimate GHG emissions associated with specific land use changes. These differences can substantially limit the methods available to Parties to estimate GHG emissions related to land use change. Due to the above complications, Parties hold very strong views regarding the inclusion of land use change sources in frameworks to assess lifecycle GHG emissions associated with bioenergy products. Initially, Sub Group 1 tried to accommodate these concerns by developing a comprehensive list the sources, methods, and underlying assumptions as well as descriptive information relating to data and emissions coefficients. The Sub Group realized, however, that the length of list raised serious questions about who would use it. Ultimately, the Sub Group settled on an approach that explicitly identifies 5 key components that any method for estimating emissions related to land use change must address (see description of Step 3). It then asks Parties to provide related the information they feel are necessary to adequately clarify their approach and resulting estimates of emissions related to land use change.

Direct land use changes, when they occurred, are accounted for (Y or N).

Y

If yes:

1. Identify the reference period or scenario

2008 Historic (identify year or period)

___ Business-as-Usual (BAU) scenario (identify time frame: __________)

___ Other (explain)

2. Describe how the methodology attributes this type of land use change to biofuels

GREET1.8 methodology for the attribution of emissions related to direct land use change has been followed.

3. Explain key reference assumptions and characteristics relevant to estimating GHG emissions from direct land use change. Examples include (but are not limited to) identifying or describing:

- System boundaries (such as sector, activity, and geographic coverage)
- For BAU scenarios, assumed trends in key variables and land uses
- Omitted emissions sources
- Time period over which land use change emissions are allocated
- Definition of land cover classes and associated estimates of above and below ground carbon

4. Briefly describe the type of direct land-use changes accounted for (2–3 paragraphs). Examples include (but are not limited to) identifying or describing:

- Areas of land that change land use by type (such as forest, grassland, peat lands, pasture, to feedstock production)
- Carbon stocks, before shift to feedstock production, on lands that change land use by type

5. The following impacts of direct land use change are accounted for:

Accounted for net changes of carbon stocks in:[1]

[1] Depending on choice of methodology and temporal system boundary, the net changes in carbon stock in these carbon pools from land use conversion may be positive (increased carbon stock) or negative (decreased carbon stock). In responding to this question, please indicate the reason for including or disregarding changes in any of the carbon pools.

____ living biomass, ____ dead organic matter, ____ soils

____ Changes in carbon stocks in products (such as harvested wood products)

6. The methodology and data used are publicly available: Methodology (Y or N), Data (Y or N)

3b: Indirect Land use Change

Parties hold even stronger views regarding the inclusion of indirect land use change sources in frameworks to assess lifecycle GHG emissions associated with bioenergy products than they do views concerning direct land use change emissions. First, all of the complications described above for developing estimates of emissions for direct land use apply to developing estimates of emissions from indirect land use change sources. Additionally, the methods for estimating indirect land use changes associated with increases in acreage of biofuel feedstock commodities within a country or region are in the early stages of development. As such, the methods are still being developed, have had little peer review, and lack consensus among scientist overall quality of the estimates or the relative accuracy of alternative approaches.

Aside from technical issues, there are philosophical differences among Parties as to whether to include indirect land use change sources in lifecycle frameworks, and if so whether or not to distinguish them direct emissions sources.

After much discussion, Sub Group 1 addressed the philosophical issue by adding the chapeau at the top of Step 3. With respect to the technical issues, the Sub Group followed Guiding Principle 2, and included a section dealing with domestic indirect land use change sources and a section dealing with international indirect land use change sources. The information sought from Parties in these sections mirrored the information sought with respect to direct land use change.

____ Domestic indirect land use change is taken into account **OR**

____ International indirect land use change is taken into account **OR**

____ Both are taken into account separately **OR**

____ Both are taken into account without making the distinction

Explain the choice.

Domestic indirect land use changes are accounted for (Y or N). If yes:

1. Identify the reference period or scenario

   ___ Historic (identify year or period)

   ___ Business-as-Usual scenario (identify time frame: ___________)

   ___ Other (explain)

2. Describe how the methodology attributes this type of land use change to biofuels

3. Explain key reference assumptions and characteristics relevant to estimating GHG emissions from domestic indirect land use change. Examples include (but are not limited to) identifying or describing:

   - System boundaries
   - For BAU scenarios, assumed trend in key variables and land uses
   - Rules, methods, and assumptions used to assign indirect land use changes to biofuels (Such as, whether emissions allocated to products using a marginal, average, or other approach)
   - Time period over which land use change emissions are allocated
   - Land categories considered in the model, their definition, and associated estimates of above and below-ground carbon
   - Data set that provides baseline land cover or land use for the model; categories of land cover that are assumed to be available for human use

4. Briefly describe the type of domestic indirect land-use changes accounted for (2 – 3 paragraphs). Examples include (but are not limited to) identifying or describing:

   - Areas of land that change land use by type (such as forest, grassland, peat lands, pasture, to commodity production)

- Carbon stocks, before shift to feedstock production, on lands that change land use by type

5. The following impacts of indirect domestic land use change are accounted for:

   Accounted for net changes of carbon stocks in[2]:

   ___ living biomass, ___ dead organic matter, ___ soils

   ___ Changes in carbon stocks in products (such as harvested wood products)

6. The methodology and data used are publicly available: Methodology (Y or N), Data (Y or N)

International indirect land-use changes are accounted for (Y or N). If yes:

1. Identify the reference period or scenario

   ___ Historic (identify year or period)

   ___ Business-as-Usual scenario (identify time frame: ___________)

   ___ Other (explain)

2. Describe how the methodology attributes this type of land use change to biofuels

3. Explain key reference assumptions and characteristics relevant to estimating GHG emissions from international indirect land use change. Examples include (but are not limited to) identifying or describing:

   - System boundaries (such as sector, activity, and geographic coverage)
   - For BAU scenarios, assumed trend in key variables and land uses

[2] Depending on choice of methodology and temporal system boundary, the net changes in carbon stock in these carbon pools from land use conversion may be positive (increased carbon stock) or negative (decreased carbon stock). In responding to this question, please indicate the reason for including or disregarding changes in any of the carbon pools.

- Rules, methods, and assumptions used to assign indirect land use changes to biofuels (Such as, whether emissions allocated to products using a marginal, average, or other approach)
- Time period over which land use change emissions are allocated
- Land categories considered in the model, their definition, and associated estimates of above and below-ground carbon
- Data set that provides baseline land cover or land use for the model; categories of land cover that are assumed to be available for human use

4. Briefly describe the type of international indirect land-use changes accounted for (2–3 paragraphs). Examples include (but are not limited to) identifying or describing:

- Areas of land that change land use by type (such as forest, grassland, peat lands, pasture, to commodity production)
- Carbon stocks, before shift to feedstock production, on lands that change land use by type

5. The following impacts of international indirect land use change are accounted for:

Accounted for net changes of carbon stocks in[3]:

___ living biomass, ___ dead organic matter, ___ soils

___ Changes in carbon stocks in products (such as harvested wood products)

6. The methodology and data used are publicly available: Methodology (Y or N), Data (Y or N)

[3] Depending on choice of methodology and temporal system boundary, the net changes in carbon stock in these carbon pools from land use conversion may be positive (increased carbon stock) or negative (decreased carbon stock). In responding to this question, please indicate the reason for including or disregarding changes in any of the carbon pools.

Step 4: Biomass feedstock production

Step 4 consists of two parts – a checklist reflecting direct sources of emissions related to feedstock production, and, a checklist of embodied sources of emissions (i.e., emissions that occur in the production of inputs used in feedstock production. There was quick agreement among the group that the sources of direct emissions should be included in Step 4 and discussion centered around which sources to list explicitly and which to bundle into the "Other" group.

There was considerable debate on whether or not to include embodied emissions in Step 4. There were two main concerns that argued against including embodied emissions. First, if the GBEP framework is adopted for use in a broader (say national) LCA framework, including embodied emissions increases the likelihood of double counting. Second, there are no logical or generally agreed on guidelines for Parties to follow in establishing boundaries for embodied emissions. Hence, what sources a Party chooses to include in this group of emissions are arbitrary.

There was general agreement that the two concerns raised with respect to embodied emissions were valid. However, based on the second guiding principle, it was ultimately decided to include them in Step 4. To address the "double counting" concern, direct and embodied emissions are reported separately. To address the boundaries concern, Parties are asked to make clear the assumptions they use in developing the emissions estimate for each source (direct and embodied). Finally, to increase transparency Parties are asked to indicate whether or not the methods and the data used to develop the emissions associated with sources indicated in Step 4 are publicly available.

GHG Sources and Sinks due to land use and management:

1. Sources of direct GHG emissions and removals are accounted for:

   √ Emissions from operating farm/forestry machinery

   √ Emissions from energy used in irrigation

   √ Emissions from energy used to prepare feedstocks (drying grains, densification of biomass, etc.)

   √ Emissions from energy used in transport of feedstocks

√ CO_2 emissions from lime/dolomite applications

√ N_2O emissions resulting from the application of nitrogen fertilizers:

√ direct; √ volatilization; √ runoff/leaching

___ CH_4 emissions from lands (especially wetlands)

___ Net changes in soil organic carbon (due to management practices, not land use conversion (step 3a.5 and 3b.5, for both domestic and international)[4]

___ Other (please specify)

2. For all checked, clarify assumptions and emissions reference values used
   - The study assumes that 85,516 Btu/dry ton of biomass are consumed to cultivate, harvest and collect the feedstock. In particular, 48,744 Btu/dry ton is the diesel consumption (used on farm machinery for cultivation, harvesting and collection) and 36,772 Btu/dry ton is the consumption of electricity for biomass irrigation (no direct GHG emissions are related to the use of electricity).

     GREET1.8 default coefficients for CH4, N2O and CO2 emissions from diesel combustion have been assumed.
   - Feedstock is chopped during the harvesting and directly transported to the ethanol plant by truck. The average transportation distance has been assumed to be 35km. Each truck can deliver 15.4 dry ton of arundo donax (30.8 ton of wet biomass). GREET1.8 default values have been assumed for trucks diesel consumption.
   - No lime/dolomite is applied during arundo donax cultivation.
   - N2O emission rate from nitrogen fertilizers: 1.325%.

3. The methodology and data used are publicly available: Methodology (Y or N), Data (Y or N)

Methodology: Yes - Data: Yes

[4] Depending on choice of methodology and temporal system boundary, the net changes in carbon pool due to management practices may be positive (increased carbon stock) or negative (decreased carbon stock). In responding to this question, please indicate the reason for including or disregarding changes in this carbon pool.

Embodied Emissions:

1. Sources of GHG emissions embodied in inputs accounted for:

   √ Emissions embodied in the manufacture of farm/forestry machinery

   ___ Emissions embodied in buildings

   √ Emissions embodied in the manufacture of fertilizer inputs.

   √ Emissions embodied in the manufacture of pesticide inputs

   √ Emissions embodied in purchased energy:

   √ electricity; √ transport fuels; ___ other (e.g., fuel for heat)

   ___ Emissions embodied in the production of seeds

   √ Other (please specify) Emissions embodied in herbicides production

2. For all checked, clarify assumptions
   - Emissions related to manufacturing, assembly and maintenance of farm machinery for biomass production, harvesting and collecting have been considered. GREET1.8 default values have been assumed for GHG emissions embodied in steel and rubber used for farm machinery manufacturing.
   - GREET1.8 default values have been assumed for GHG emissions related to fertilizers, herbicides, pesticides, electricity (US mix for stationary use) and transport fuel production.

3. The methodology and data used are publicly available: Methodology (Y or N), Data (Y or N)

   Methodology: Yes - Data: Yes

Step 5: Transport of biomass

Production chains of bioenergy commonly include a number of transport processes. Following parameters have a decisive effect on the level of transport contribution to the GHG balance of a biofuel: The distance between the location of production and of use, the number of single stages, the type of vehicle and the question whether there are empty returns. The user is asked to give information about these parameters. There are several transport data models available which facilitates data provision, transparency and standardization. The user shall explain if such a data model is applied. From a general point of view long transport distances are perceived to be a crucial aspect in terms of environmental respectively GHG performance. However existing state of the art GHG balances for biomass transport processes mostly provide comparably minor contribution to the total GHG performance. Nevertheless transport is a non- negligible component of the life-cycle.

Biomass is transported from farm/plantation/forest to processing plant (Y or N) **Yes**

If yes:

1. ___ The biomass transported in a different commodity type.

    1a. ___ A description of intermediate processing steps is available.

    1b. ___ Emissions associated with intermediate processing are accounted for (including, e.g., electricity used for processing).

2. ___ There is a multi-stage transport chain (e.g. truck to ship to truck or train).

    2a. List all stages in the transport chain.

    2b. Specify the stages for which emissions are accounted.

3. Transport from production site to use/processing plant is dedicated to this purpose (Y or N) Yes

If Yes:

3a. √ All transport emissions are included

If No:

3b. ___ A portion of transport emissions are allocated, and the allocation methodology is described.

4. √ Return run of transport equipment is accounted for.

4a. During the return run, transport equipment is:

√ empty ___ otherwise utilized

5. For relevant sections, clarify assumptions

Average transportation distance: 35km
Truck load: 15.4 dry ton/truck

Step 6: Processing into fuel

The user is asked where biomass is processed into fuel which associated GHG emissions related to this process are taken into account. For those types of emissions where different methods of taking them into account could be envisaged, further specification is asked in order to allow for a complete comparison of LCAs.

The biomass requires processing to produce fuel (Y or N) Yes

1. ___ GHG emissions associated with material inputs used in the conversion process (e.g. chemicals, water) are accounted for.

2. √ GHG emissions associated with the energy used in the conversion process are accounted for.

2a. Specify the method used to account for grid-related emissions (e.g. average/marginal, national/regional, actual/future): US mix has been considered for electricity generation.

3. ___ GHG emissions from wastes and leakages (including waste disposal) are accounted for.

4. ___ Other GHG emissions from the process are accounted for.

4a. List which ones: ___

5. ___ GHG emissions associated with the plant construction are accounted for.

5a. Estimates of emissions associated with plant construction have been pro-rated to account for:

___ Other uses of the plant

___ Design life of the plant

___Other parameters; specify which ones: ___________________________

6. For relevant sections, clarify assumptions

The process is independent from external electricity and thermal energy supply, due to the use of the lignin component of the biomass as feedstock for the co-generation of heat and electricity.

Step 7: By-products and co-products

The user is asked how co- and/or by-products are considered in the LCA. This is an area where different approaches in LCAs can potentially produce quite different results and therefore clarity of the approach is important for useful comparison of LCAs. The framework identifies three general points related to whether feedstocks for the co- and/or by-products originate from biomass or non-biomass, what would actual fall under the definition of co- and/or by-products and the methodology to take them into account. On some of those points, further methods are asked to allow for a full comparison.

By-products or co-products are produced (Y or N) Yes

1. √ By/Co-products from the biomass are accounted for.

2. ___ By/Co-products from non-biomass feedstocks are accounted for.

3. Explain definition of by/co-products: Co-product is meant as a product of the process that is not the principal purpose of the process itself.

4. An allocation method is used (Y or N): No

   ___ Allocation by mass

   ___ Allocation by energy content

      Method to determine energy content: ______________________________

   ___ Allocation by economic value

      Method to determine economic value: ________________________________

   ___ Other allocation method

      Specify method: ___________

      Method to determine parameters needed: __________

5. A substitution method is used (Y or N) Yes

   Identify method used to determine the exact type of use/application of a co-product: displacement method has been used for the calculation of credits from electricity co-produced; a part of this electricity will meet the ethanol plant needs while the remaining part will be exported to the grid.

   Identify method used to determine what product the co-product would substitute for and what the associated GHG emissions are for that product: US mix electricity will be substituted.

6. Another method or combination of methods is used (Y or N)

   Specify method: ___________________________________

   Method to determine parameters needed: ___________________________

7. For relevant sections, clarify assumptions

Thermal energy co-produced is used to satisfy the whole thermal energy need of the plant. A fraction of the electricity co-produced is internally used by the plant while the remaining part is exported to the external electric grid and is accounted for the calculation of co-product credits by means of the displacement method (substitution method).

Step 8: Transport of fuel

Fuel is transported from processing plant to use site (Y or N) Yes

If yes:

(please consider all emissions, including, for example, methane emissions from biogas equipment)

1. ___ The fuel transported in a different commodity type.

    1a. ___ A description of intermediate processing steps is available.

    1b. ___ Emissions associated with intermediate processing are accounted for (including, e.g., electricity used for processing).

2. ___ There is a multi-stage transport chain (e.g. truck to ship to truck or train).

    2a. List all stages in the transport chain.

    Ethanol is transported from the plant to the bulk terminals by truck (40% of the ethanol, average distance 130km) or by rail (60% of the ethanol, average distance 1300km). Ethanol is then distributed to the refuelling stations (truck transportation, average distance 50km).

    2b. Specify the stages for which emissions are accounted.

    Emissions are accounted for both the stages described above.

3. Transport from the processing plant to the use site is dedicated to this purpose. (Y or N) Yes

    If Yes:

    3a. √ All transport emissions are accounted for.

    If No:

    3b. ___ Transport emissions are pro-rated, and the methodology for pro-rating is described.

4. √ Return run of transport equipment is accounted for.

    4a. During the return run, transport equipment is:

√ empty ____ otherwise utilized

5. For relevant sections, clarify assumptions

Step 9: Fuel use

The use of biomass is the core process converting the carbon feedstock into the non-fossil CO_2 replacing fossil fuel and therefore fossil CO_2 emissions. At the beginning the basic type of use has to be explained: biofuel for transportation or biofuel for stationary use (electricity). In both cases the user shall explain whether efficiency of use is taken into account, and if yes, the approach shall be explained.

For solid biomass and liquid and gaseous fuels used in stationary applications:

1. Analysis addresses electricity and/or heat (thermal energy)? (Y or N) Yes

    1a. Facility is a CHP plant? (Y or N) Yes

    1b. Electric efficiency of the use process 15%

    1c. Thermal efficiency of the use process 70%

    1d. Electricity sent to a general grid (Y or N) Yes

    1e. In case of CHP, indicate method used to account for electricity and heat (i.e., allocation, substitution, etc.), as in LCA Step 7. Substitution (displacement method).

2. Specific emissions are addressed by the usage (Y or N) Yes

    2a. Identify conversion/combustion technology IGCC turbine

3. The technique specifically causes significant non-CO_2 emissions of:

    √ N_2O (e.g. CFB-type boilers)

    ____ CH_4 (e.g. low level technique or small-scale)

    ____ Other

    3a. Describe evidence to exclude the occurrence of such specific GHG emissions.

4. Biomass is tainted with fossil material (e.g. in case of waste sources) (Y or N) No

4a. If yes, provide analysis on degree of fossil content, if available

5. The analysis addresses a technology upgrade (e.g. pile burning to modern energy technology)

5a. If yes, provide emissions data on the replaced way of biomass burning, if available.

	VOC	CO	NOx	PM10	PM2.5	SOx	CH4	N2O	CO2
Emissions [g/mmBtu biomass burnt]	1.254	10.481	9.168	5.557	2.778	4.100	3.834	11.000	62,143.000

6. For relevant sections, clarify assumptions

For transport fuels:

1. Miles (km) per energy unit are addressed (Y or N) Yes

1a. Miles (km) per energy unit: 395.5 km/mm Btu

1b. Describe how energy efficiency is factored into fuel use analysis.

The same energy efficiency has been considered for vehicles fuelled with gasoline, E85, E10 and E5.

2. Tailpipe gas is addressed (Y or N). No

If yes, describe methodology:

e.g.: CO_2 emissions associated with combustion source and feedstock sink are netted out; CH_4 and N_2O emissions from combustion are included.

Step 10: Comparison with replaced fuel

The production processes of fossil fuel and biofuels are intrinsically different. Therefore, some of their stages are not directly comparable. It is important to list every single stage of the production processes and evaluate which of them should be included in the LCA, being comparable to one another or not. One of the main difficulties in setting up a comparison between the fossil fuel LCA and the biofuel LCA is exactly the depth of this analysis, that is, the production stages included and evaluated in both LCAs should present an equivalent level of complexity.

Rational: The user is asked to perform a LCA for the replaced fossil fuel as similar as possible to LCA performed for the bio-fuel.

The user is asked to answer all questions listed in step 10 keeping in mind what was considered in previous steps.

1. Identify Methodology for LCA of replaced fuel(s) / energy production system(s)

   LCA on gasoline used on light duty vehicles has been carried out by means of the GREET1.8 model with the same methodology used for the LCA on bioethanol from Arundo donax.

2. This methodology is publicly available (Y or N) Yes

   - If yes, provide references

     Centre for Transportation Research, Argonne National Laboratory, Chicago, IL

3. Gases covered:

   CO_2 √

   CH_4 √

   N_2O √

   HFCs ____

   PFCs ____

   SF_6 ____

   Other __________

   Please report global warming potential used for each GHG covered.

CO_2: 1 - CH_4: 25 - N_2O: 298

4. An LCA is performed on the replaced fuel(s) / energy production system(s). (Y or N) Yes

   4a. Please list any sources of inconsistency between LCA of biofuel and LCA of replaced fuels/systems.

   4b. Describe the system boundaries.

   LCA on replaced fuels considers all steps from petroleum recovery to gasoline use on light duty vehicles.

   4c. Indicate how direct and indirect land use change is addressed in the LCA of the replaced fuels/systems

   Land use change is not considered in the LCA on replaced fuel.

5. Specify which sources of emissions embodied in infrastructure are accounted for and clarify assumptions.

   ___ Emissions embodied in buildings and facilities

   ___ Emissions embodied in transportation fleet and infrastructure

   ___ Emissions embodied in the manufacture of machinery

   ___ Other sources of emissions embodied in infrastructure (please specify)

I. Biofuel is used to replace transport fossil fuel (for stationary use, skip to section II)

6. Relevant characteristics of crude:

   6a. Type of crude:

   √ Conventional crude 91%

   √ Canadian oil sands 9% (4.5% surface mining – 4.5% in situ production)

   ___ Canadian/Venezuelan heavy oil

   ___ Other

   ___ Not specified

6b. Origin of fuel (region, refinery, etc), if specified

6c. Other important fuel characteristics, if specified

6d. Applicability conditions of the replaced fuel characteristics

√ The reference fuel is a world average Standard refinery procedure. Additive with respect to European and USA directives depending on simulated scenario.

____ The reference fuel applicable only to one region (specify region)

____ Other applicability conditions apply (please specify)

7. Emissions prior to extraction/production are accounted for (Y or N) No

   7a. If yes, specify pre-production sources included (e.g., geophysics, prospecting) and geographic/temporal coverage of analysis.

   7b. Explain method for applying pre-production emissions to per barrel calculations.

8. Emissions from extraction/production are accounted for (Y or N) Yes

   8a. Direct and embodied emissions in extraction/production accounted for:

   √ Fuel combustion from drilling

   ____ Fugitive methane emissions from equipment

   √ Fuel combustion from turbines and compressors

   ____ Transportation emissions from helicopters and supply vessels

   √ Use of electricity (e.g., gasoil or fuel oil generators)

   ____ Use of chemical inputs

   √ Other CH_4 emissions during crude processing in oil fields

   8b. Natural gas emissions accounted for: GREET1.8 default assumptions

   ____ Emissions from flaring natural gas

   ____ Emissions from combustion equipment (specify gases included)

   ____ Emissions from reinjection of natural gas

   ____ Emissions from direct use of natural gas

____ Emissions from other processing of natural gas

____ Emissions from gas processing point to remove liquids

____ Emissions from extracted liquids

____ Emissions from electricity production

8c. Describe method for allocating emissions between crude oil and natural gas production

GREET1.8 default data have been assumed.

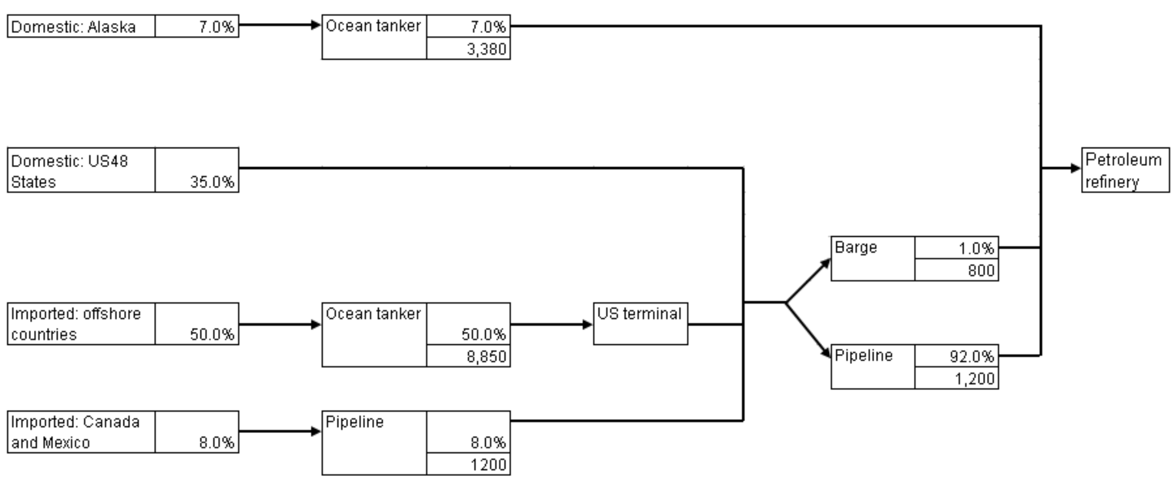
8d. Emissions for other extraction/production by/co-products are accounted for (Y or N) GREET default

- If yes, describe methodologies for calculating emissions and for allocating emissions between crude and by/co-products.

9. Crude is transported to the refinery (Y or N) Yes

9a. Specify transport distance and mode(s) of transport (pipeline, tanker, etc.).

Conventional crude (distances are in [km]):



Canadian oil sands: pipeline – average distance 3,060km

9b. For internationally transported crude, specify whether domestic, international, or total transport emissions are accounted for.

Total transport emissions are considered.

- Describe use of country-specific parameters in calculating transport emissions.

  GREET1.8 default values have been assumed.

9c. Fugitive emissions during transport are accounted for (Y or N) Yes

9d. Return journeys of transport fleet are accounted for (Y or N) Yes

9e. The production/transport system involves liquified natural gas (Y or N) Yes

9f. Emissions from the regasification plant are accounted for (Y or N)

10. Refinery emissions are accounted for (Y or N) Yes

10a. Describe assumptions on refinery characteristics (e.g., existing, typical, local average) GREET1.8 default refinery emissions have been assumed

10b. Describe method for calculating direct refinery emissions

10c. Emissions embodied in chemicals (catalysts, solvents, etc.) are accounted for (Y or N)

- If yes, describe method.

10d. Fugitive emissions accounted for (Y or N)

- If yes, describe method.

10e. Emissions for hydrogen production are accounted for (Y or N) Yes, GREET1.8 values have been assumed.

- If yes, specify the production process.

10f. Emissions for purchased and generated electricity are accounted for (Y or N) Yes

- If yes, specify electricity mix of the purchased electricity

US mix

Residual oil	2.7%
Natural gas	18.9%
Coal	50.7%
Nuclear power	18.7%
Biomass	1.3%
Others	7.7%

10g. Emissions from wastes and leakages are accounted for (Y or N)

- If yes, describe method

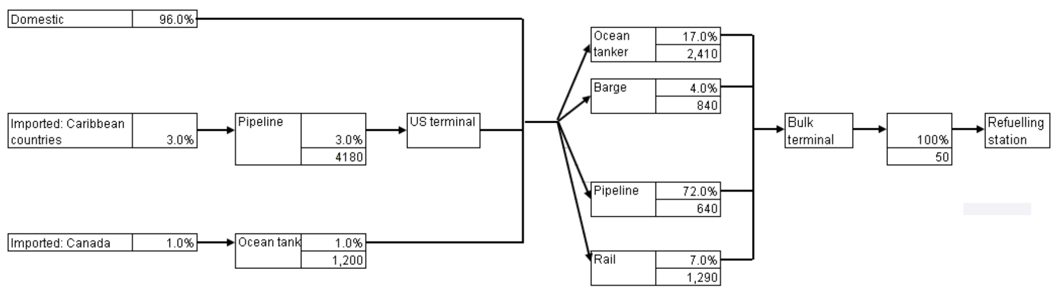
10h. Emissions for refinery by-products and co-products are accounted for (Y or N)

- If yes, describe methodologies for calculating emissions and for allocating emissions between fuel and by/co-products.

11. Fuel is transported or distributed prior to use (Y or N) Yes

    11a. Specify transport distance and mode(s) of transport (truck, tanker, etc.).

    Distances are in [km].



    11b. For internationally transported fuels, specify whether domestic, international, or total transport emissions are accounted for.

    Total transport emissions are considered.

- Describe use of country-specific parameters in calculating transport emissions.

    11c. Fugitive emissions during transport are accounted for (Y or N)

    11d. Return journeys of transport fleet are accounted for (Y or N) Yes

12. Fuel use emissions are accounted for (Y or N) Yes

    (please consider consistency with Step 9)

    If no:

    12a: Please explain how equivalency with the biofuel system is defined (e.g. lower heating value)

    If yes:

    12b: Please explain how equivalency with the biofuel system is defined.

    Do you refer to energy content of the fuel Yes

    Do you refer to miles (km) per energy unit Yes

    12c: Describe how energy efficiency is factored into fuel use analysis.

The study assumes that light duty vehicles show the same energy efficiency in terms of km/gallon gasoline equivalent when fuelled with gasoline, E85, E10 or E5.

12d: Tailpipe gas is addressed (Y or N). If yes, describe methodology.

Yes.

Fuel		VOC exhaust	VOC evap.	CO	NOx	PM10 exhaust	PM10 TBW	PM2.5 exhaust	PM2.5 TBW	CH4	N2O	CO2
Gasoline, E10, E5	[g/km]	0.0425	0.0255	1.0000	0.0600	0.0009	0.0024	0.0009	0.0008	0.0055	0.0062	193.9
E85	[g/km]	0.0425	0.0217	1.0000	0.0600	0.0009	0.0024	0.0009	0.0008	0.0055	0.0062	190.8

13. Please identify any elements of the fossil fuel LCA not included in the above questions and describe methodology used to calculate emissions.

II. Stationary use of biofuel for electricity/heat

7. Describe technologies, methodologies and data for calculating the extraction/production/transport of replaced energy source, using Transport Fuel questions 6-11, above, as guidance where appropriate.

8. Fuel use emissions are accounted (Y/N)

   (please consider consistency with Step 9)

   If no:

   8a: Please explain how equivalency with the biofuel system is defined (e.g. lower heating value of utilized fuel)

   8b: What type of fossil fuel is assumed to be replaced by the biofuel system?

   Explain the assumption.

   If yes:

   8c: Please explain how equivalency with the biofuel system is defined.

Do you refer to energy content of the fuel (Y/N)

Do you refer to useful energy taking end use efficiency into account (Y/N)

If yes:

8d: Which method is used to define the production of replaced electricity/heat?

___ national average mix

___ marginal production

___ other _______

please explain your choice and assumptions.

8e: Report energy efficiency for electricity generation, and/or heat generation and describe how it is used in emissions analysis.

8f: Describe methodology for calculating evaporative emissions.

8g: Describe conversion/combustion technologies and method for calculating associated emissions, including trace gases.

9. Please identify any elements of the fossil fuel LCA not included in the above questions and describe methodology used to calculate emissions.