NARA

NARA's Approach to Environmental Sustainability

Life Cycle Assessment

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Overview of the talk

- LCA 201: Bioenergy LCA
- LCA scenarios
- NARA Biojet LCA results
  - Including comparative LCA: NARA BioJet vs. PetroJet
- Completeness and Concluding remarks

LCA 201:
Bioenergy LCA

US Energy Independence and Security Act of 2007

Bio-Fuels necessary to move the United States toward greater energy independence and security LCA is required for public procurement

Suggested Greenhouse Gas Reduction Criterion

Subtitle A—Renewable Fuel Standard

(E) CELLULOSIC BIOFUEL –to be considered acceptable has to be "at least 60 percent less" than the baseline lifecycle greenhouse gas emissions.

LCA 201: Some definitions

- **Life Cycle Assessment (LCA)**

  LCA is a technique to assess the potential environmental impacts associated with a product, process, or service, by:

  - Compiling an inventory of relevant energy and material inputs and environmental releases
  - Evaluating the potential environmental impacts associated with identified inputs and releases
  - Interpreting the results to help you make a more informed decision
  - **Systems Thinking**

- The term **"life cycle"** refers to the major activities in the course of the product's life-span from its manufacture, use, and maintenance, to its final disposal, including the raw material acquisition required to manufacture the product.

LCA 201: Some more definitions

- **Life Cycle Inventory (LCI)**

A life cycle inventory is a process of quantifying energy and raw material requirements, atmospheric emissions, waterborne emissions, solid wastes for the entire life cycle of a product, process, or activity.

An inventory analysis produces a list containing the quantities of pollutants released to the environment and the amount of energy and material consumed.

- **Life Cycle Impact Assessment (LCIA)**
- LCIA is the evaluation of potential human health, resource depletion and environmental impacts of the environmental resources and releases identified during the LCI.
- LCIA will help us assess the impacts of carbon dioxide, methane or Nitrogen oxides released into the atmosphere?
  - For example: 44 tons of CO_2 vs 16 tons of CH_4 released in atmosphere. Which is worse?

LCA 201: System Boundary Considerations

Cradle-to-grave: from the earth to the earth.

Cradle-to-gate: from the earth to product

Gate-to-gate:
Int. product to product

CO_2

CO_2

CO_2, PM, No_x, So_x, H_20

Greenhouse & Land Prep.

Forest Stand

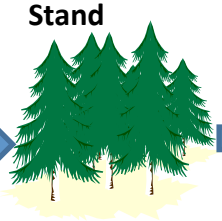
Harvest Operations

Prep. & Transport Biomass

Pre-treatment and Bio-jet conversion

Bio-Jet Fuel Transportation

Bio-Jet Fuel Combustion



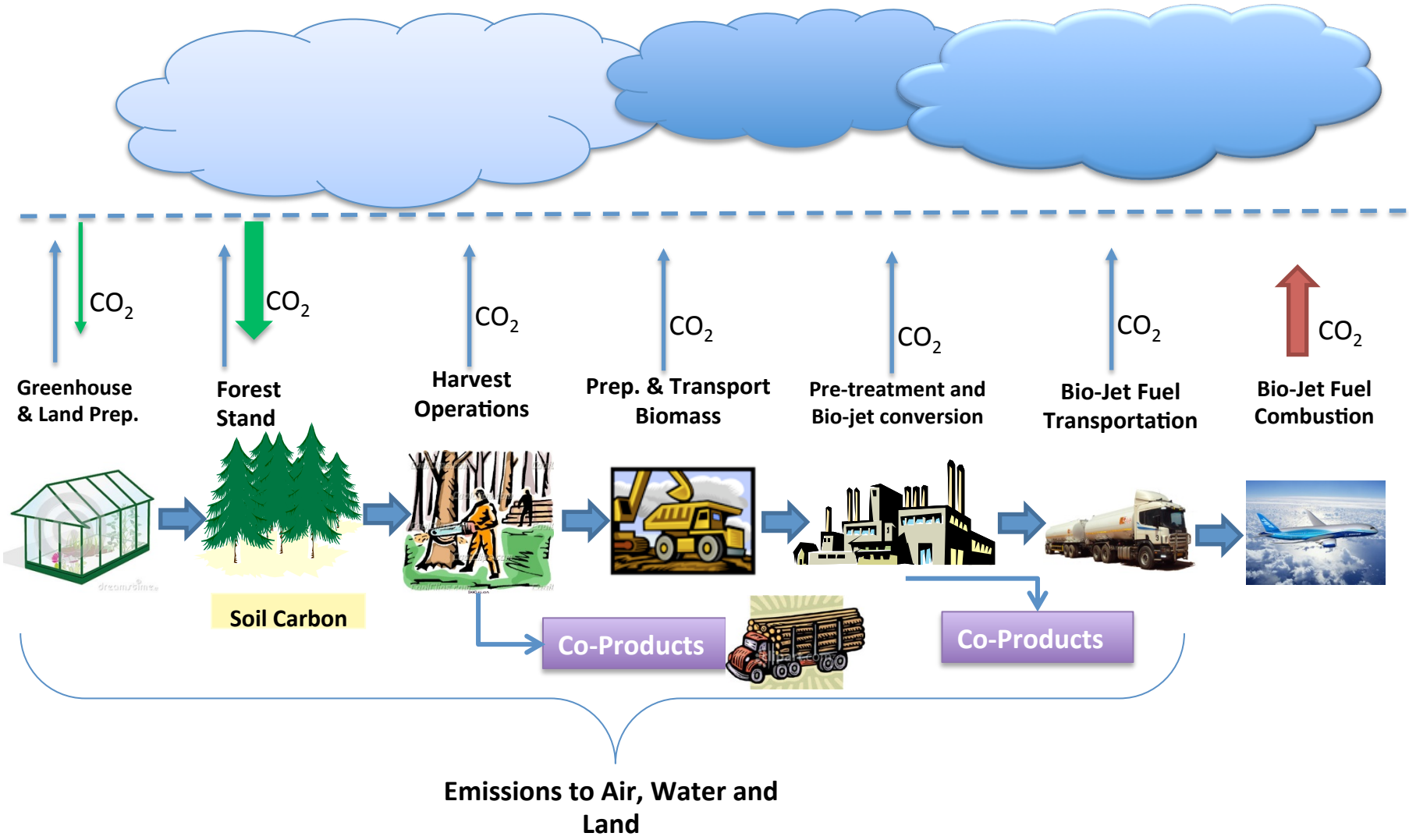
Soil Carbon

Co-Products

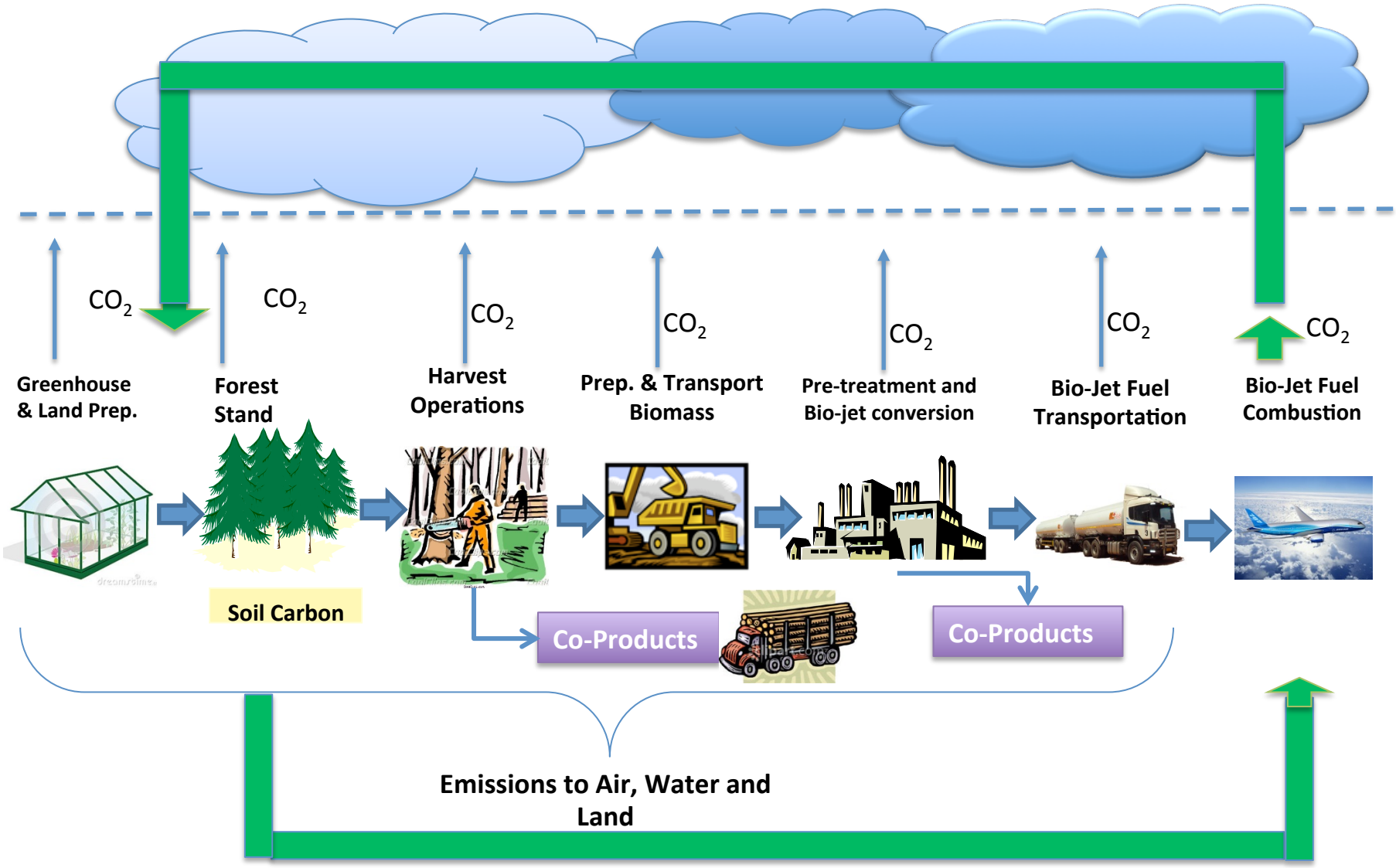
Co-Products

Emissions to Air, Water and Land

LCA 201: Biogenic Carbon (neutrality)



LCA 201: Biogenic Carbon (neutrality)



LCA 201: Allocation Methods

LCA definition for Co-products:

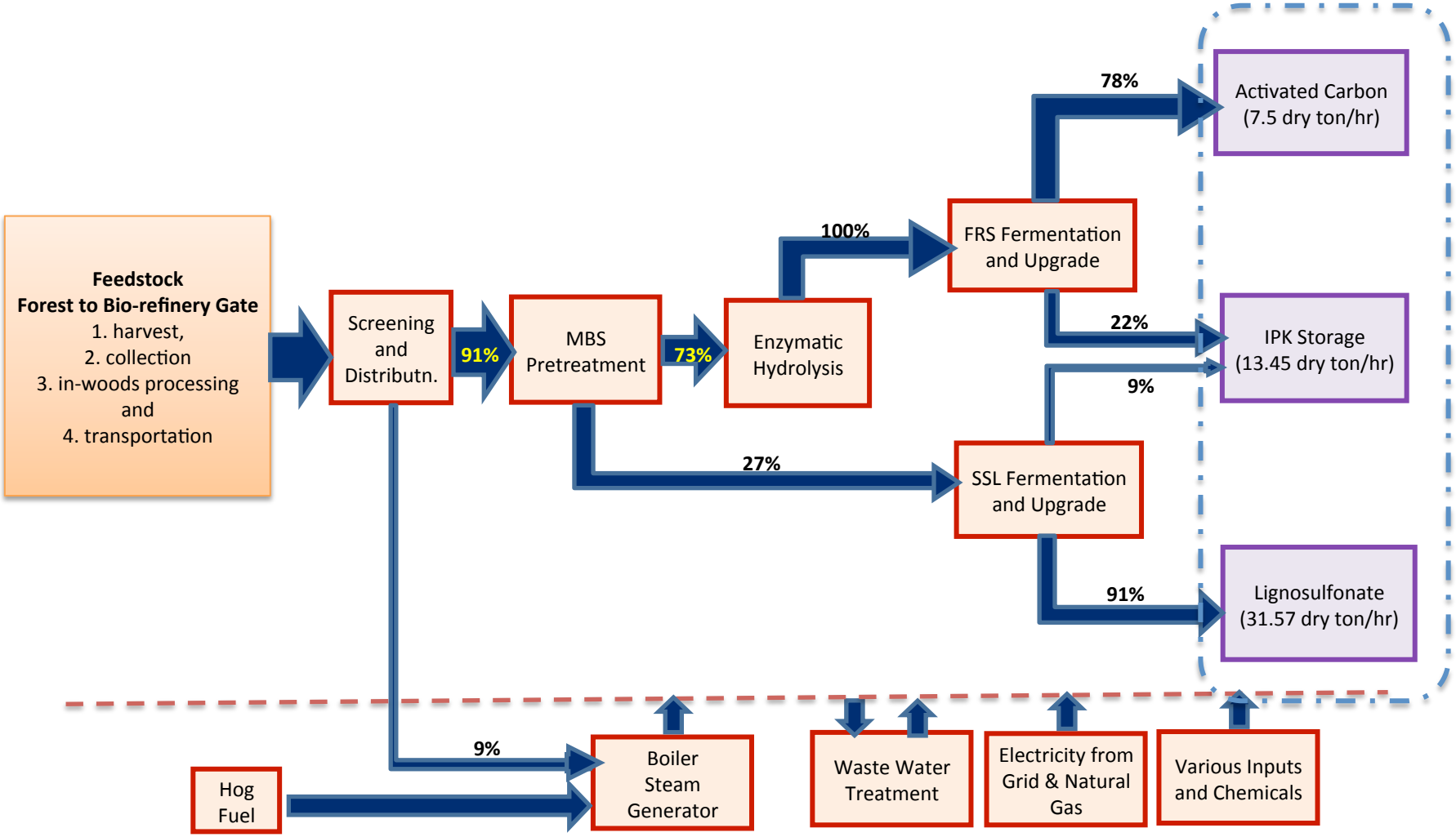
- Some processes generate multiple output streams in addition to waste streams. In attributional LCAs, only certain of these output streams are of interest with respect to the primary product being evaluated.
- The term co-product is used to define all output streams other than the primary product that are not waste streams and that are not used as raw materials elsewhere in the system.

LCA burden Allocation:

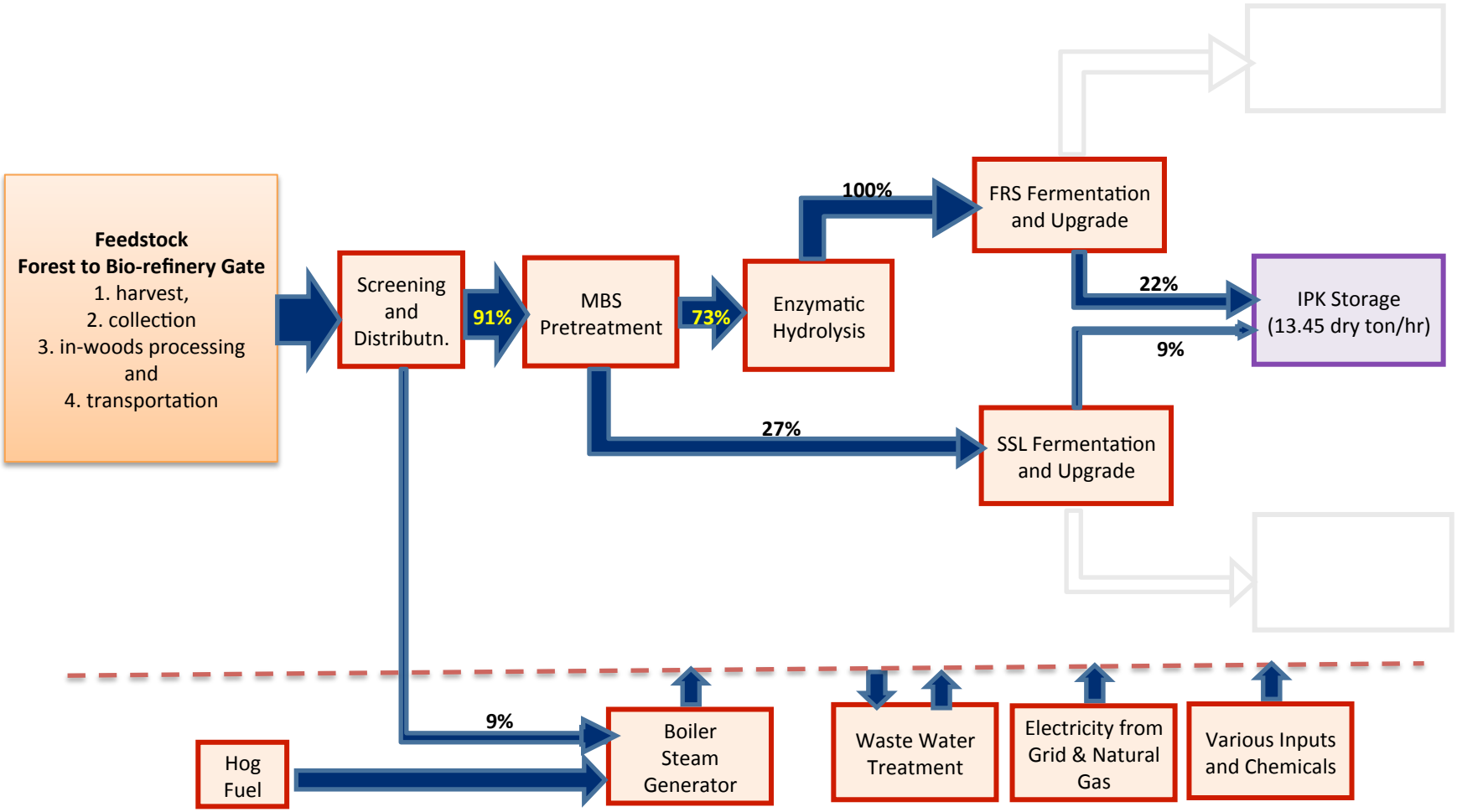
- partitioning the input and output flows of a process or a product system between the product system under study and one or more of the other product systems
- ISO methods suggest the following hierarchy (highly controversial and fluid)
  1. System Expansion and Avoided Credit
  2. Based of physical relationships (mass/volume/energy)
  3. Other non-physical relationships (economic)

LCA scenarios

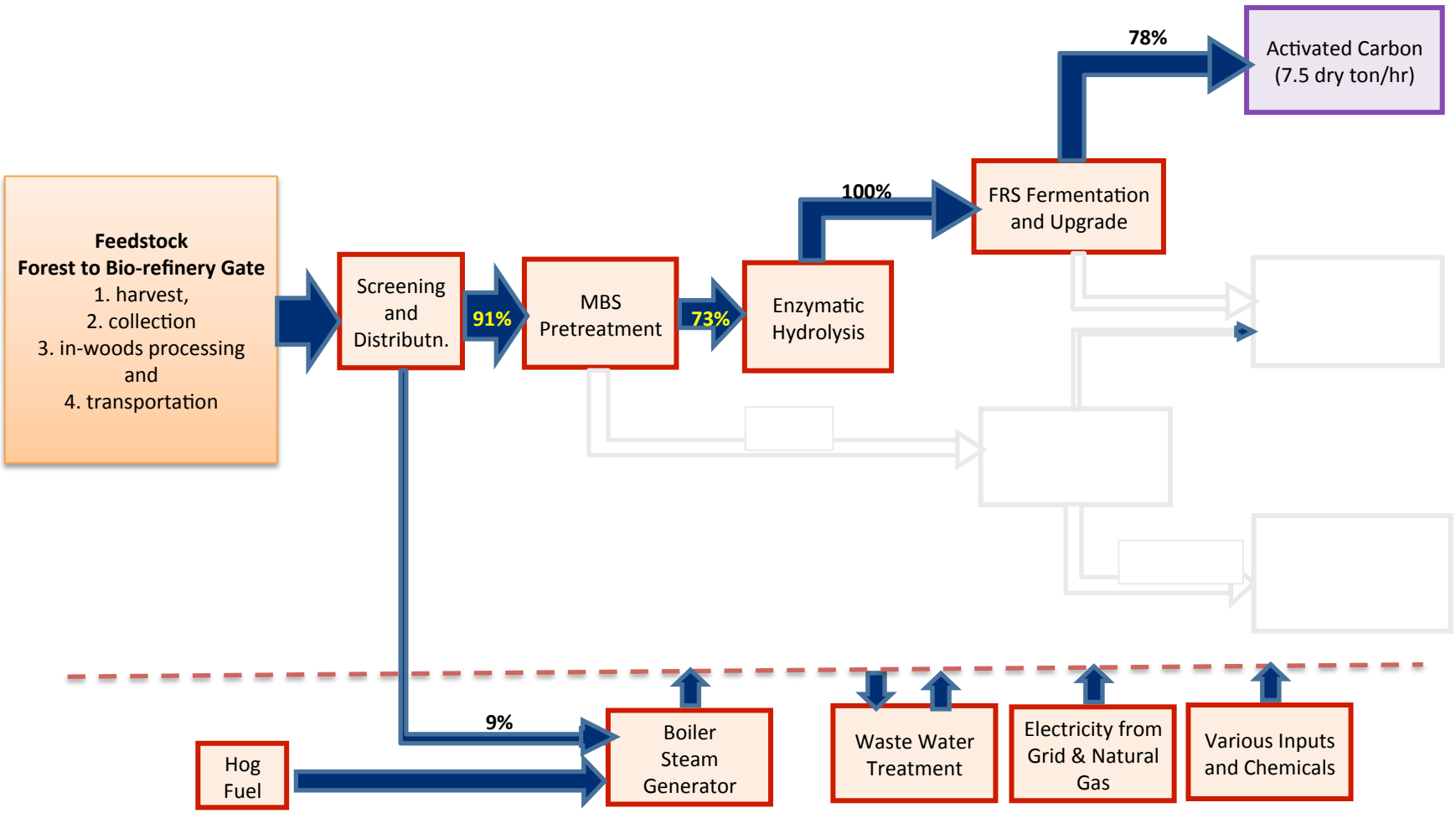
Three products LCI scenario (IPK plus two)



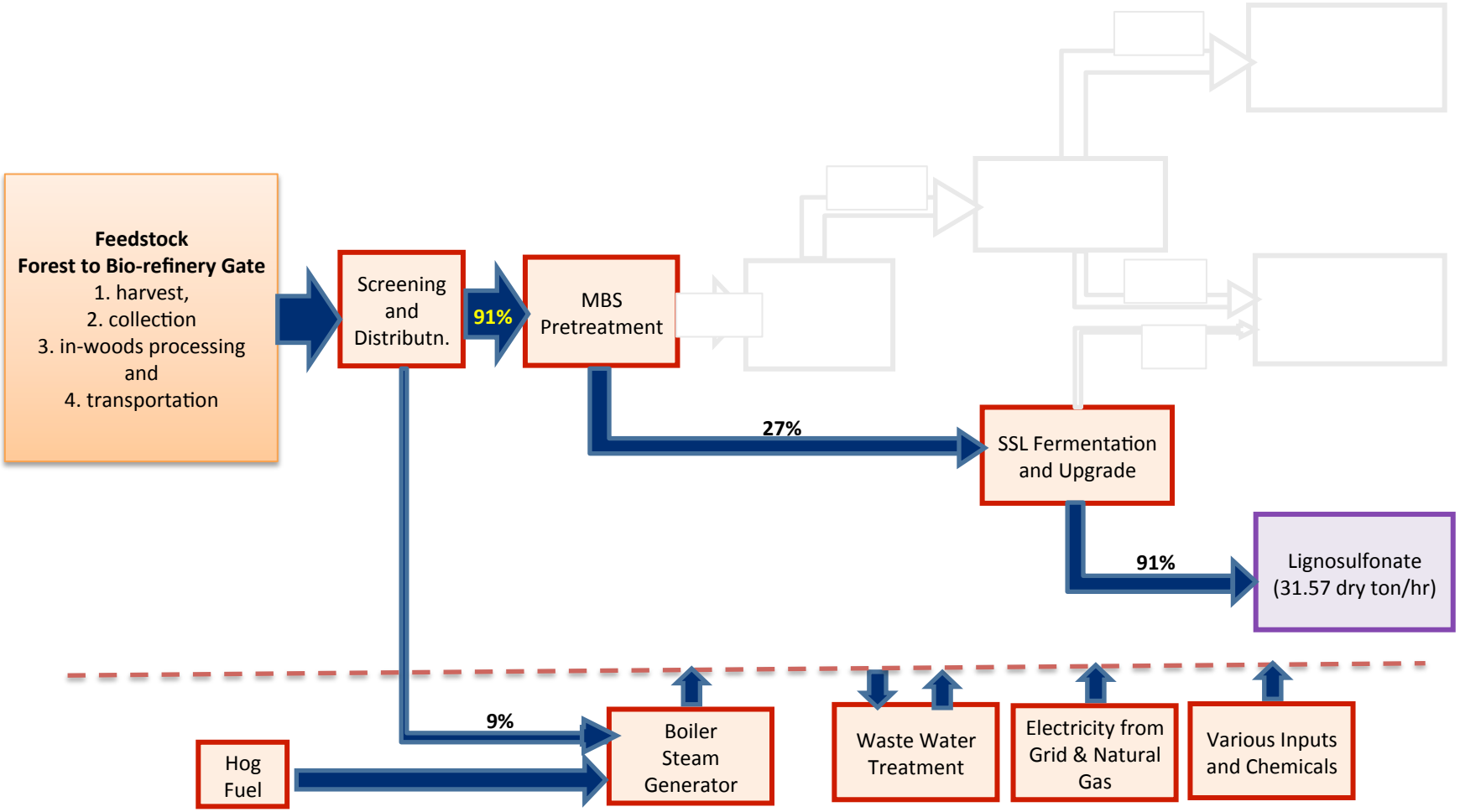
LCI of IPK


Feedstock
Forest to Bio-refinery Gate
1. harvest,
2. collection
3. in-woods processing
and
4. transportation
Screening and Distributn.
91%
MBS Pretreatment
73%
Enzymatic Hydrolysis
100%
FRS Fermentation and Upgrade
22%
IPK Storage (13.45 dry ton/hr)
9%
27%
SSL Fermentation and Upgrade
9%
Hog Fuel
Boiler Steam Generator
Waste Water Treatment
Electricity from Grid & Natural Gas
Various Inputs and Chemicals

LCI of Activated Carbon



LCI of Lignosulfonate



Incorporating Avoided Impact of Slash Pile Burning

Avoided Slash Pile Burn (conservative est)

Feedstock
Forest to Bio-refinery Gate
1. harvest,
2. collection
3. in-woods processing
and
4. transportation

Screening and Distributn.

91%

MBS Pretreatment

73%

Enzymatic Hydrolysis

100%

FRS Fermentation and Upgrade

78%

Activated Carbon (7.5 dry ton/hr)

22%

IPK Storage (13.45 dry ton/hr)

9%

27%

SSL Fermentation and Upgrade

91%

50% Lignosulfonate (31.57 dry ton/hr)

9%

Hog Fuel

Boiler Steam Generator

Waste Water Treatment

Electricity from Grid & Natural Gas

Various Inputs and Chemicals

LCI of IPK with Avoided Slash Burn Impact/Credit

Avoided Slash Pile Burn (50% slash burn)

Feedstock
Forest to Bio-refinery Gate
1. harvest,
2. collection
3. in-woods processing
and
4. transportation

Screening and Distributn.

91%

MBS Pretreatment

73%

Enzymatic Hydrolysis

100%

FRS Fermentation and Upgrade

22%

9%

IPK Storage (13.45 dry ton/hr)

27%

SSL Fermentation and Upgrade

9%

Hog Fuel

Boiler Steam Generator

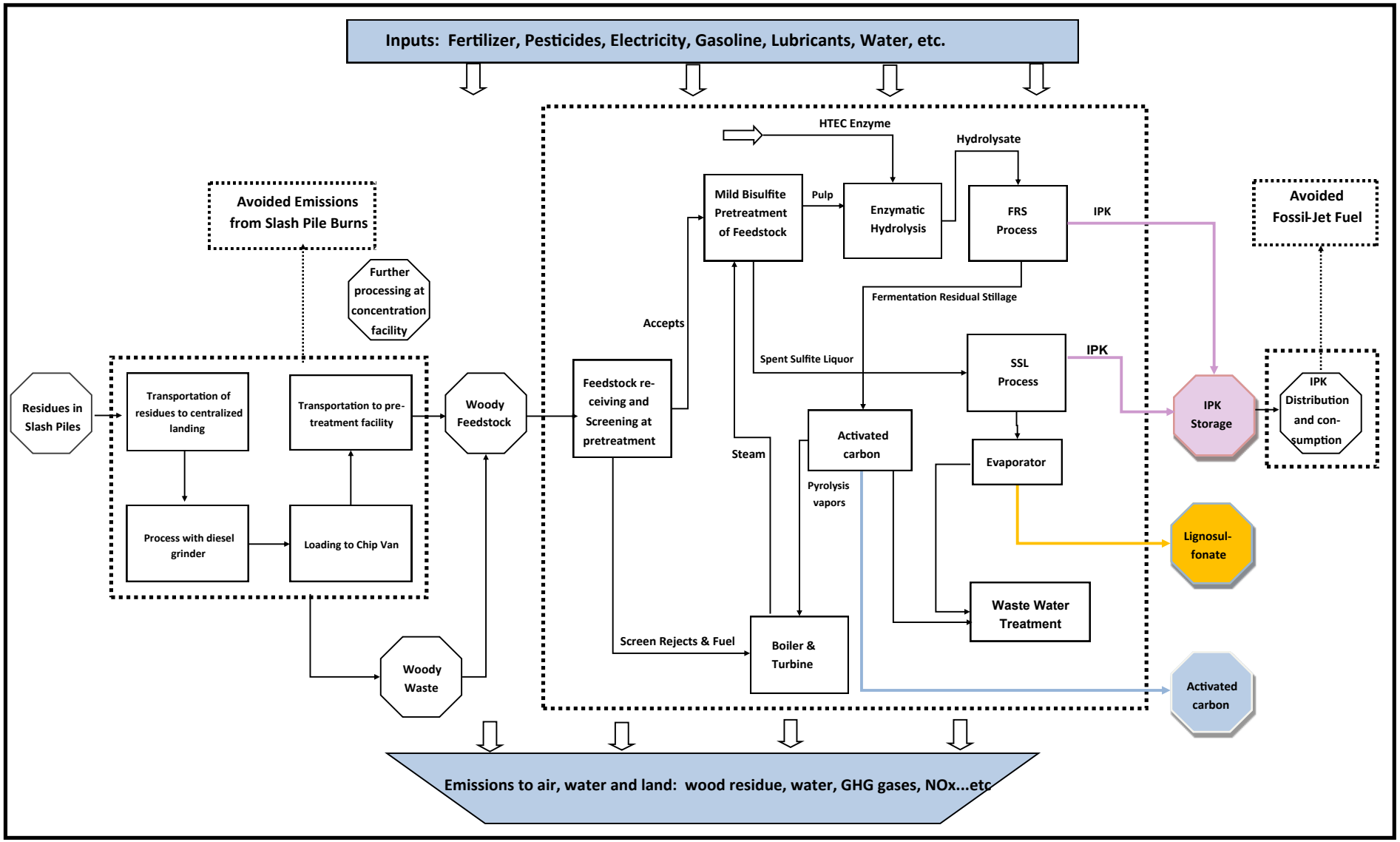
Waste Water Treatment

Electricity from Grid & Natural Gas

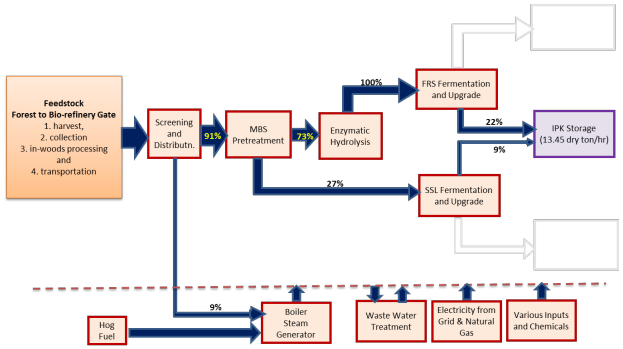
Various Inputs and Chemicals

NARA Biojet LCA results

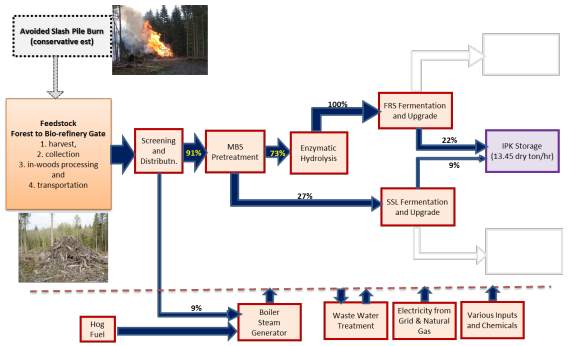
NARA LCA system boundary

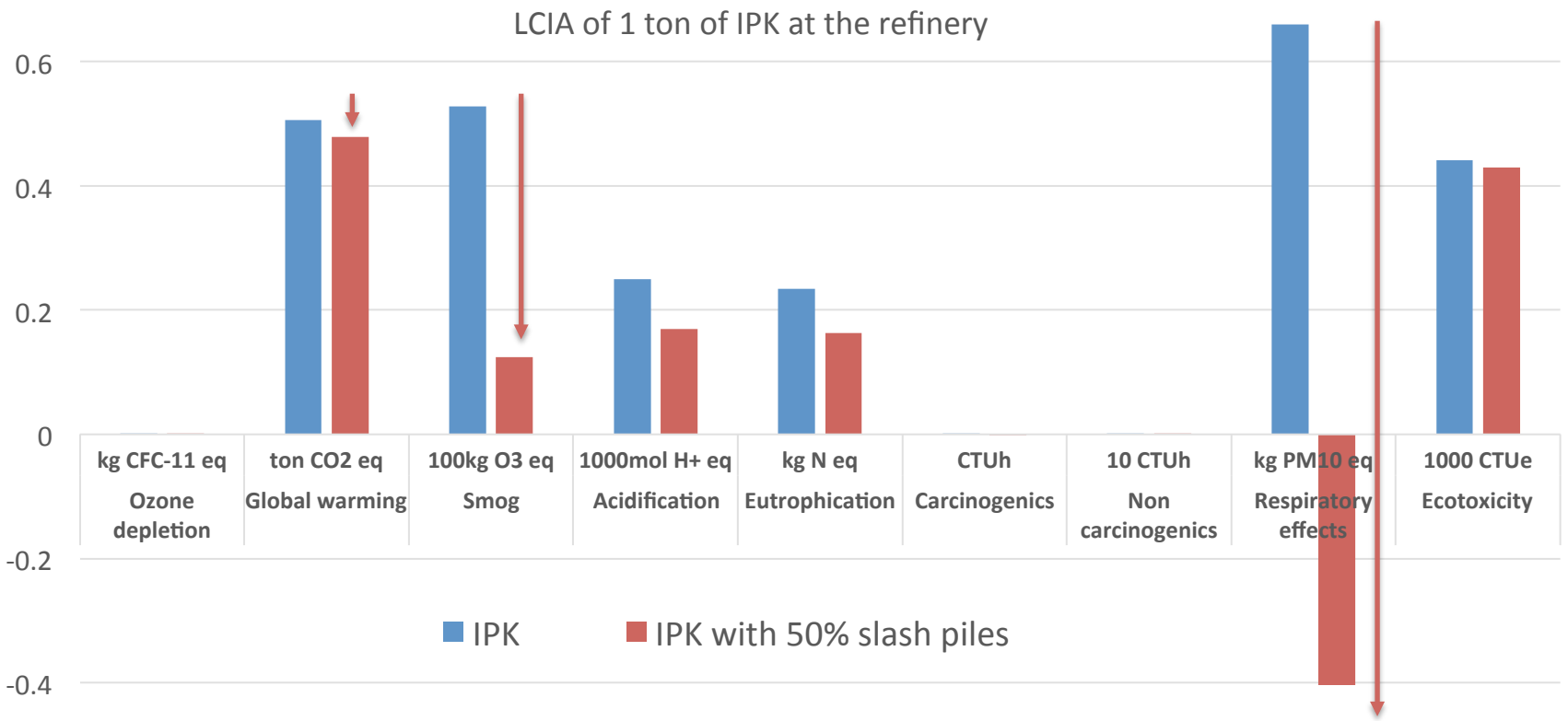


LCIA of 1 ton (metric) of IPK using mass allocation

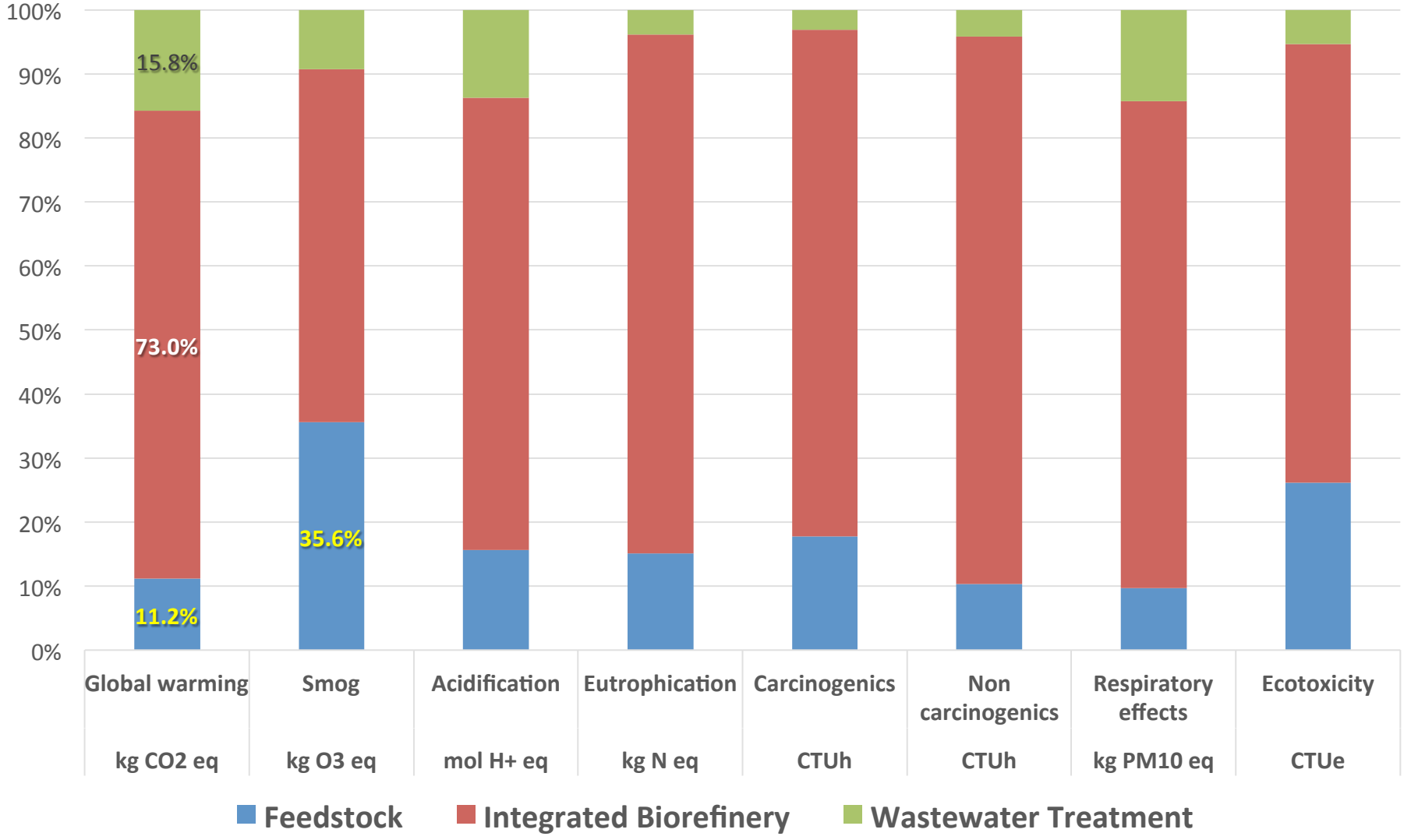


VS





Process Contribution Analysis of baseline IPK



Fossil Jet Fuel

Emissions to Air, Water and Land

Emissions: CO_2, PM, No_x, So_x, H_20

Crude Oil Extraction

Crude Oil Transportation

Refinery: Jet Fuel Production

Jet Fuel Transportation

Jet Fuel Combustion

Co-Products

VS

Bio Jet Fuel

CO_2

CO_2

CO_2, PM, No_x, So_x, H_20

Greenhouse & Land Prep.

Forest Stand

Soil Carbon

Harvest Operations

Co-Products

Prep. & Transport Biomass

Pre-treatment and Bio-jet conversion

Co-Products

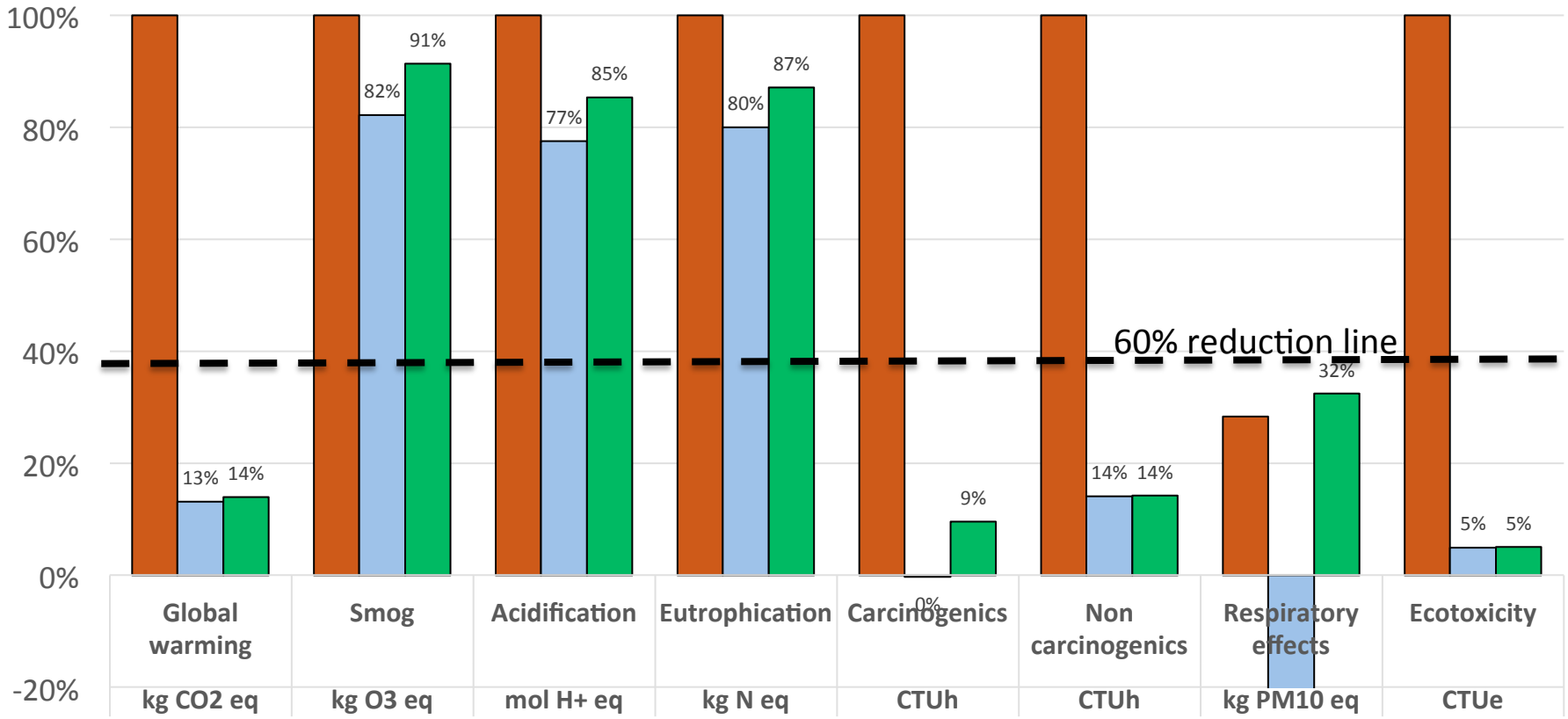
Bio-Jet Fuel Transportation

Bio-Jet Fuel Combustion

Emissions to Air, Water and Land

Well-to-Wake comparison:

NARA biojet vs Petroleum Jet (Baseline)



Kerosene Operation, aircraft, freight, intercontinental/RER U MJ

IPK (NARA) with avoided burn 50%, Operation, aircraft, freight, intercontinental/RER U MJ

IPK (NARA) Operation, aircraft, freight, intercontinental/RER U MJ

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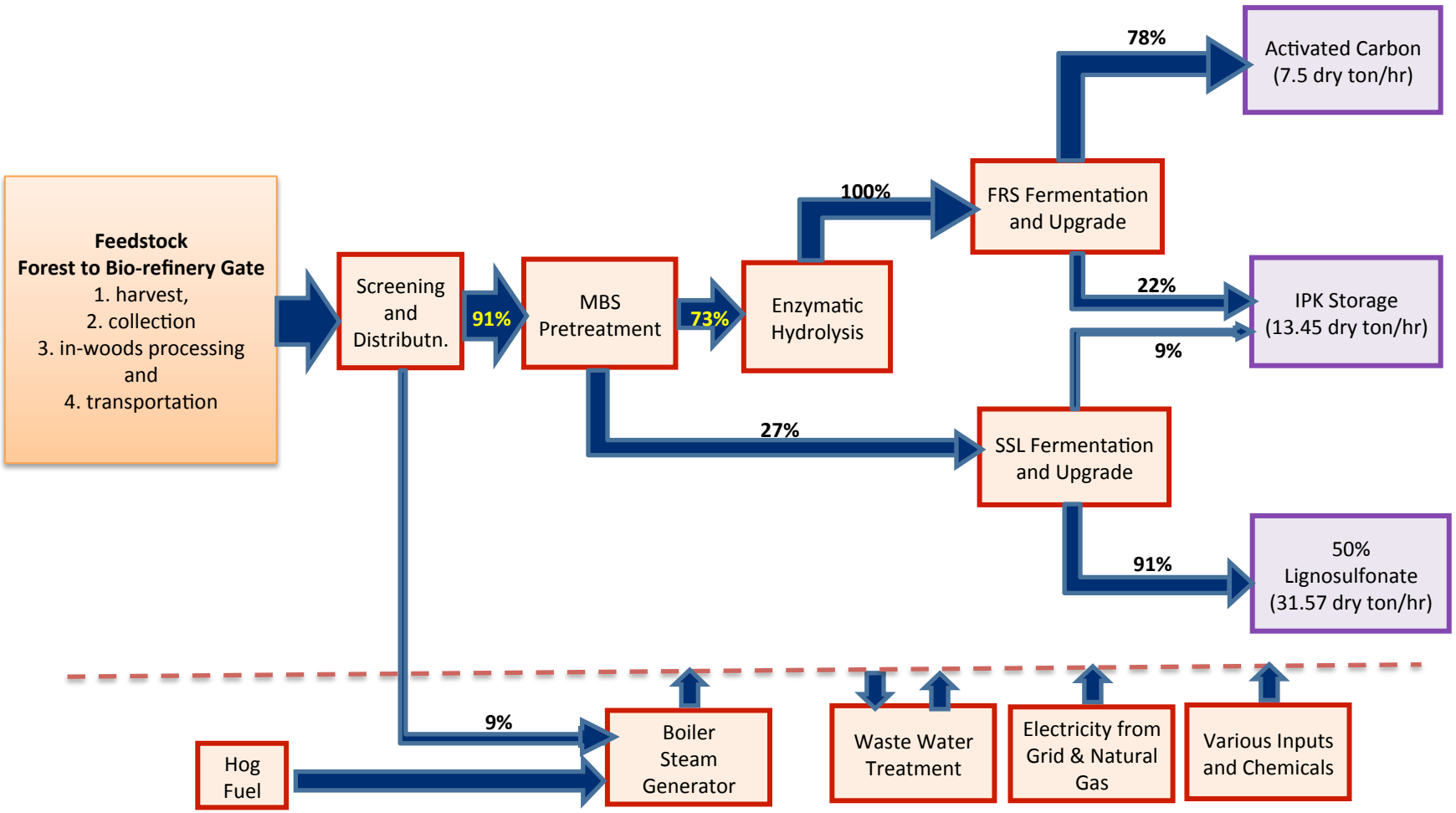
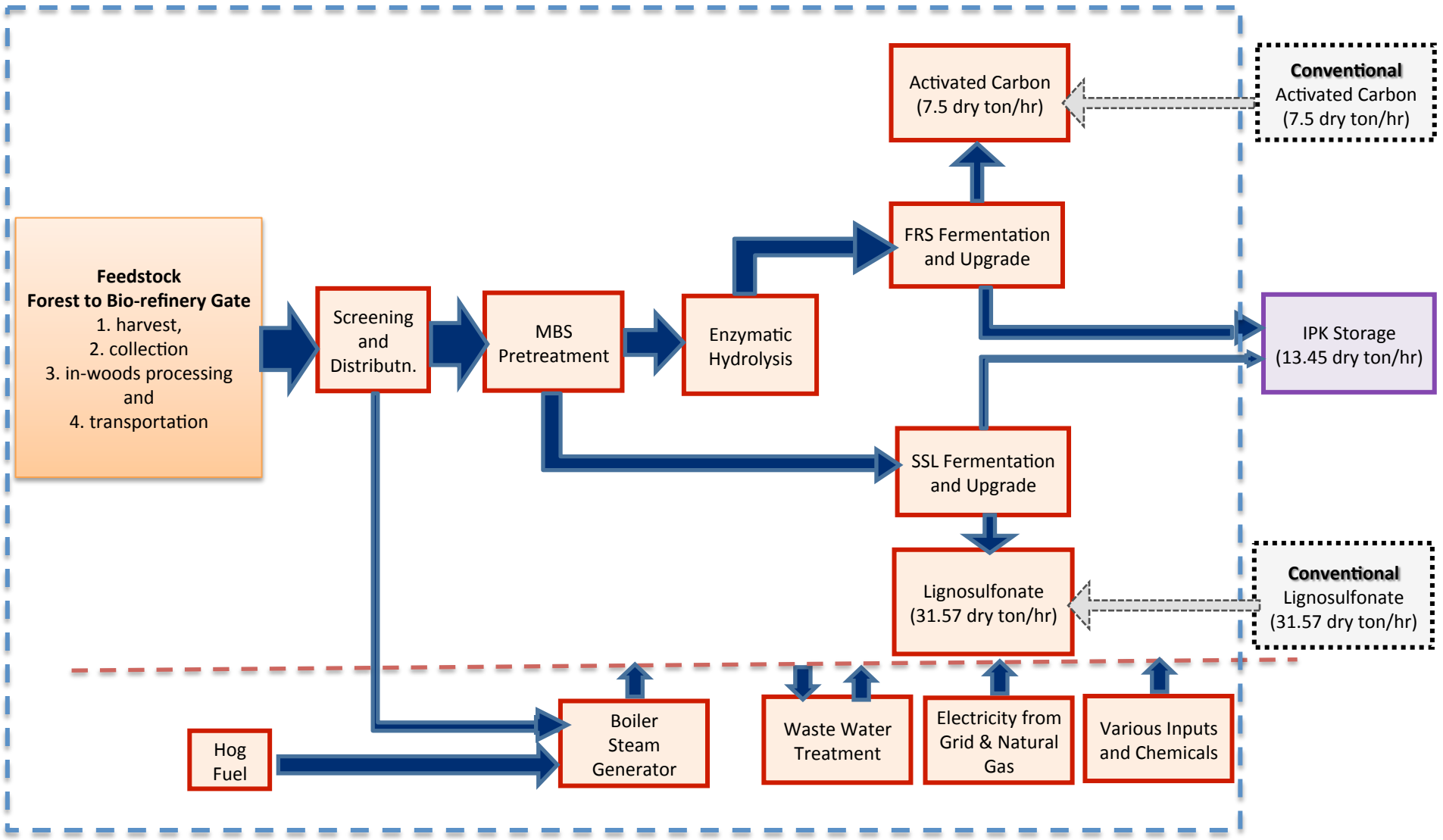
Completeness and Concluding remarks

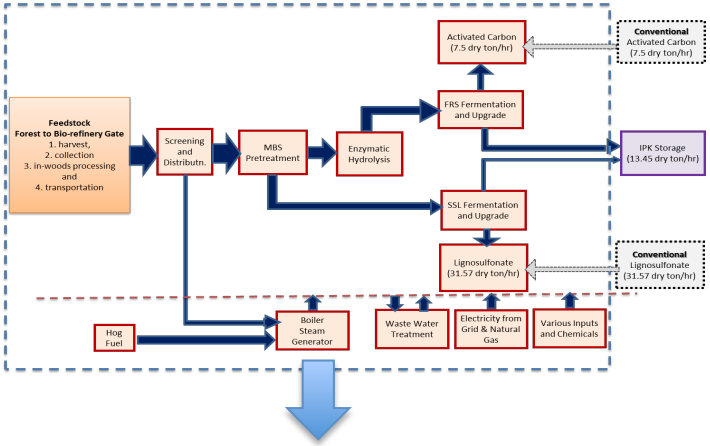
Completeness: Mass Allocation scenario

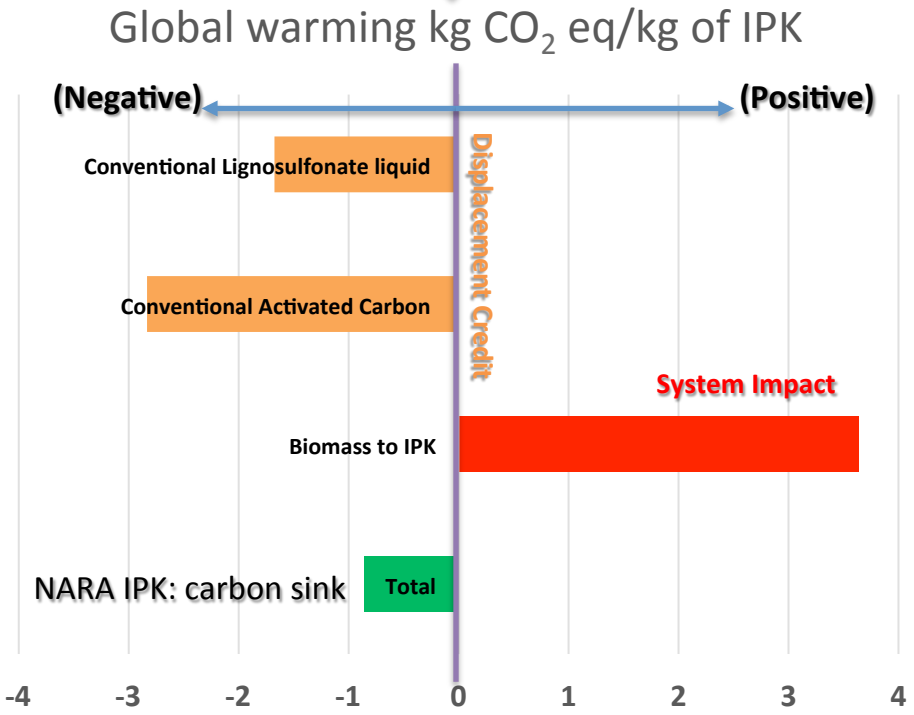


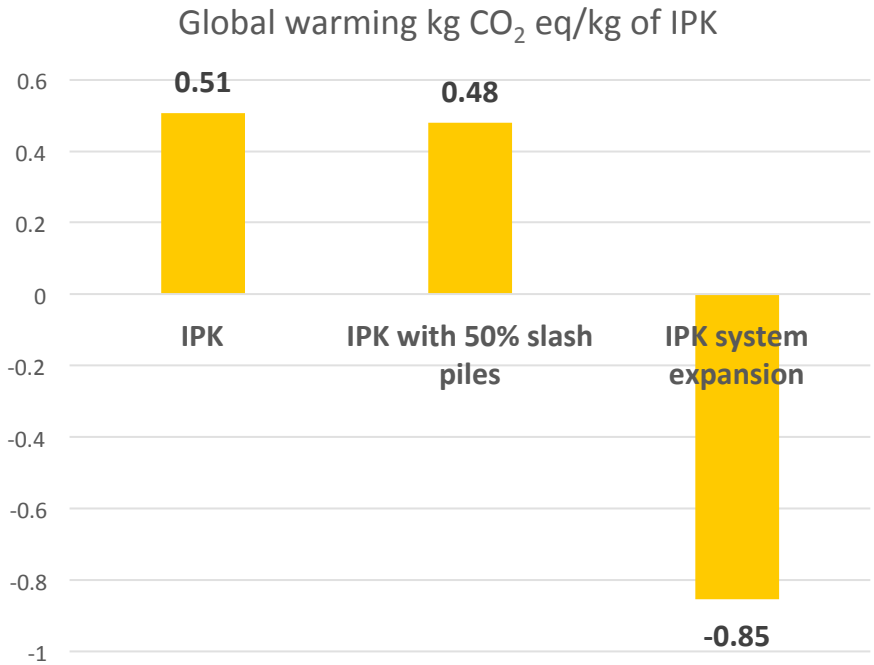
Completeness: IPK with system expansion scenario



Completeness: Sensitivity of the allocation options







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Concluding remarks

Significant improvement over previous results:

- With 86% reduction in GHG number, under the most conservative scenario, it is evident that NARA BioJet has much lower impact than the mandated 60% threshold.
- The cleaner NARA IPK is a result of:
  - Lower impact and efficient bio-refining process with high recovery rate
  - However, the most important is the production of co-products that
    - Share the mass allocated system impacts
    - And/or displaces higher impact or fossil based products

The pursuit of improvement and completeness is not over

- Along with the co-products LCA team and Gevo LCA consultant, we are working on developing tradeoffs between various forms of energy and the co-products.
- Our current LCA has adopted the TEA framework. We are exploring environmental sensitivities associated with the alternate routes.

Intermediary product LCAs and nuanced sectoral analysis

- The LCA team is also collaborating with multiple NARA teams and working on an array of substantive research.

Thank you

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