School of Environmental and Forest Sciences
UNIVERSITY of WASHINGTON
College of the Environment

NARA

CINTRAFOR
Center for International Trade in Forest Products

Environmental assessments of woody biomass feedstock for bio-jet fuel production

Presented by:

Indroneil Ganguly

Assistant Professor (Res.)

Co-Authors/Contributors:

Indroneil Ganguly[1], Ivan Eastin[1], Francesca Pierobon[2,]
Tait Bowers[1], Ikechukwu Nwaneshiudu[1], Cindy Chen[1] and Cody Sifford[1]

[1] School of Environmental and Forest Sciences, University of Washington, Seattle, WA 98195
[2] Department of Land, Environment, Agriculture and Forestry (LEAF), University of Padua, 35020 Legnaro (PD), Italy

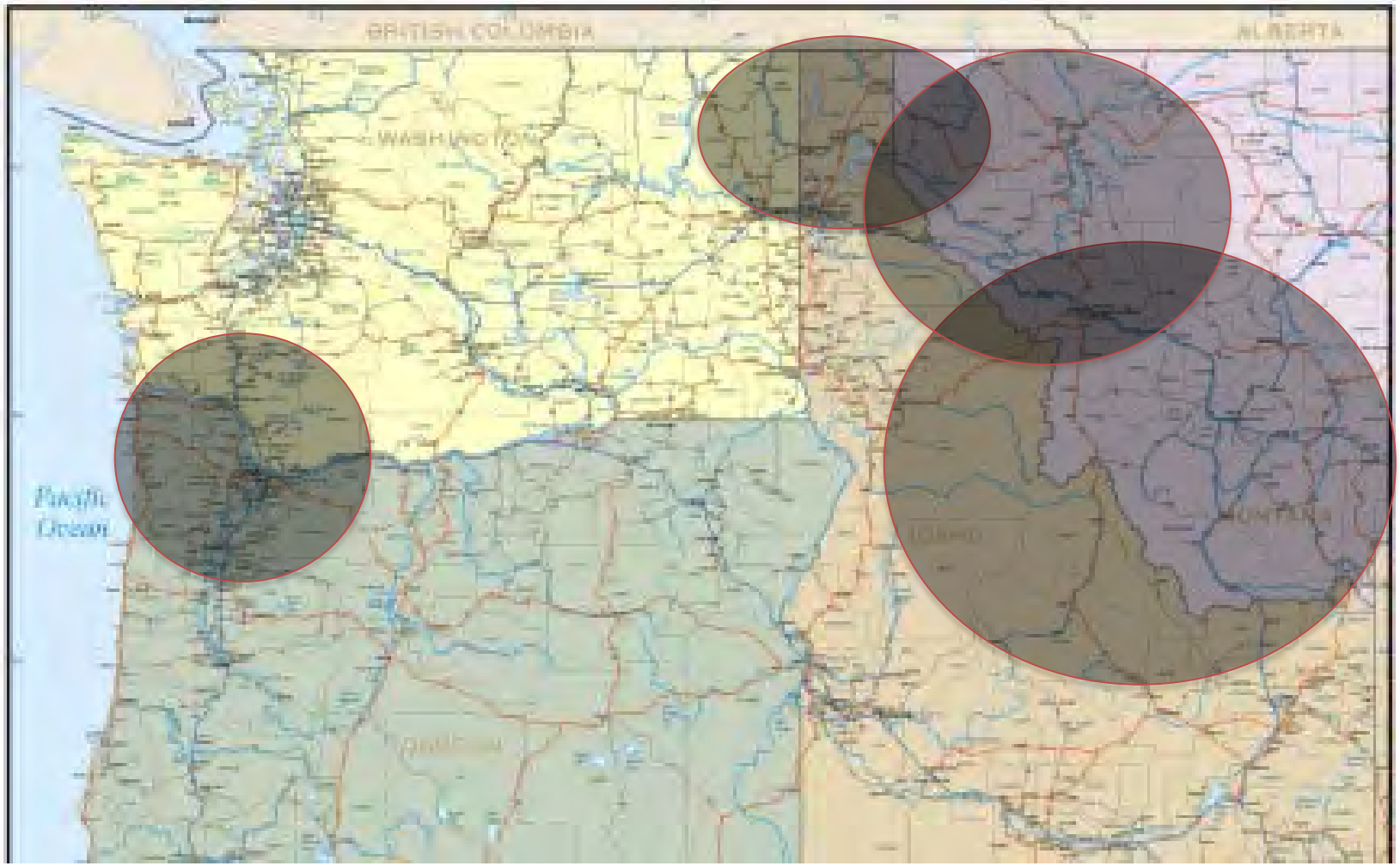
Northwest Wood-Based Biofuels and Co-Products Conference
April 28-30, 2014

Things to be covered

- Overall Framework LCA for NARA bio jet fuel
  - Using surrogate NREL pretreatment
  - East and west of the Cascades
- Advertise some of the LCA related posters
  - LCA of two NARA pretreatments
    - Wet Oxidation and Mild Bisulfite
  - Carbon neutrality analysis for West of Cascades feedstock zone
  - Bundling vs Loose residue hauling

NARA

Regional Scope: PNW Pilot areas West and East of the Cascades



NARA

Life Cycle Assessment

Definition:

"Compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle"

This establishes an environmental profile of the system!

ISO = International Organization for Standardization
Ensures that an LCA is completed in a certain way.

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".

NARA

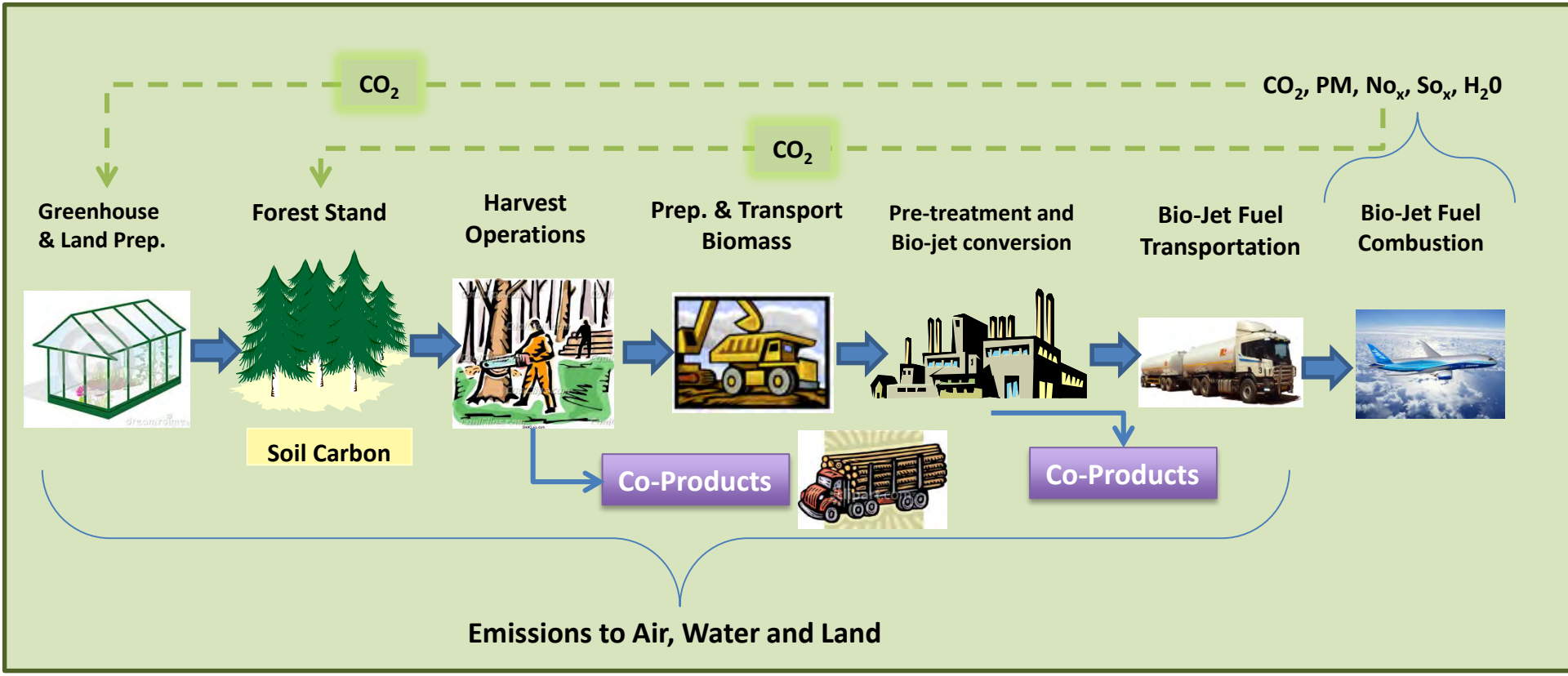
Impact Category and Classification

LOCAL and/or GLOBAL

Impact category	Media
Ozone depletion	Air
Global climate	Air
Acidification Air	Air
Eutrophication	Air, water
Smog formation Air	Air
Human health criteria Air	Air
Human health cancer	Urban air, nonurban air, freshwater, seawater, natural soil, agricultural soil
Human health noncancer	
Ecotoxicity Urban	

NARA

NARA Bio-Jet Fuel Process



NARA

FOREST MANAGEMENT

Net Primary Production
(CO_2 uptake)

CO_2, CO, NMVOC

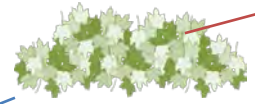
NO_2, NO_x

CH_4

61% Stem; Sawlogs: Considered as Co-Product (i.e., Burden Shared)

39% tops and branches: Harvest Residues:

Decay: CO_2



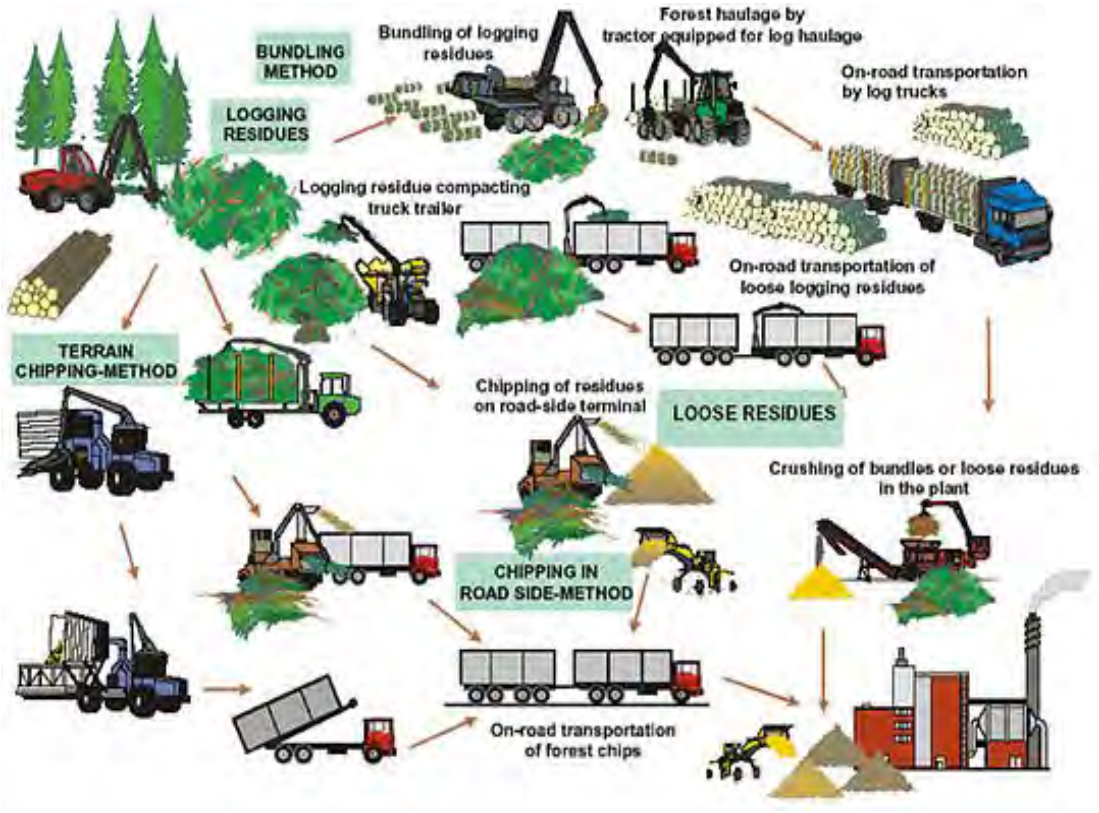
Harvest litter on forest floor; 35% of Tops and Branches

Stumps and Roots not included in our present analysis (will be incorporated)

Soil carbon

NARA

Biomass recovery and production systems



Source: Cindy Chen et al., 2014

Slash recovery operation Options

- Dump truck slash shuttle & centralized grinding
- Roll-off/Hook-lift truck slash shuttle & centralized grinding
- Bundling slash & Centralized grinding
- Pile-to-pile on site grinding

Transportation of processed biomass from centralized landing to processing facility

- Transport ground/chipped biomass to processing faculty using 120 CY chip van.

NARA

Baseline scenarios developed for recovery of landing residue

East Side Forest: Natural regeneration – 75 years selective harvest cycle
West Side Forest: Plantation forest – 45 years clear cut to clear cut cycle

Harvest Operation Scenario	Harvest System	Loose Residue Shuttle (to secondary landing)	Chipper at Central Landing	Chip transportation to pre-treatment gate
Benchmark for both east and west side	Gentle Slope; Mechanized; (Feller Buncher, Track Skidder)	Modified dump truck (30 CY capacity)	Large Chipper; Direct Loader	Chip van (120 CY capacity)

Transportation		Spur Road	1 ½ lane	Gravel	Highway	Interstate	Total
Benchmark (for East of the Cascades)	Avg. miles/hr	6	20	29	55	62	
	One way haul miles	2.5	5	10	20	37.5	75
Benchmark (for West of the Cascades)	Avg. miles/hr	5 - 10	10-15		60-70		
	One way haul miles	1.5	13.5		35		50

NARA

Incorporating the avoided emissions

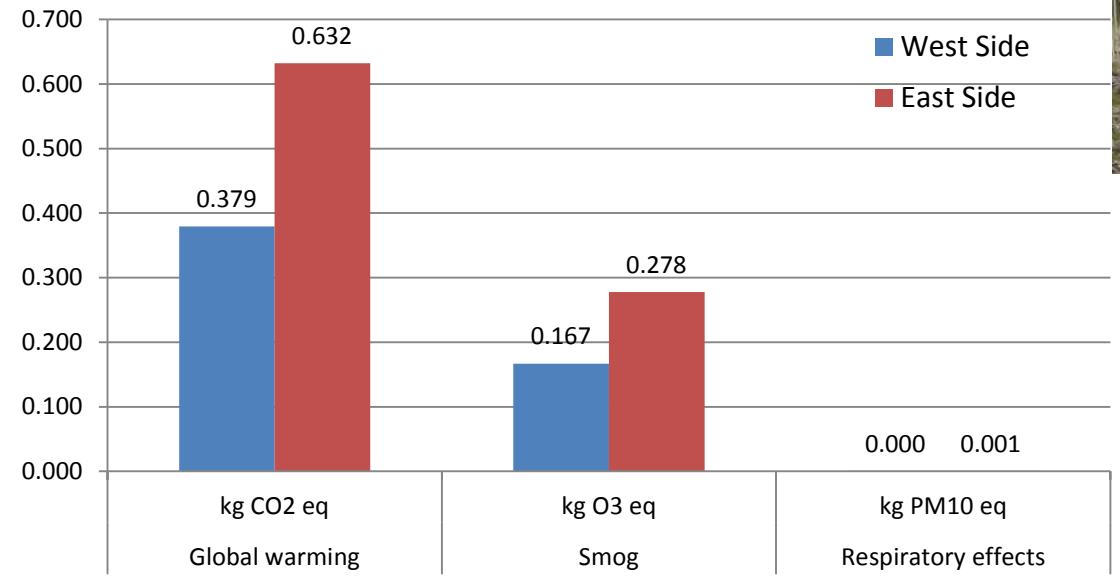


Figure 1: System Impact associated with harvest, in woods processing and transportation of feedstock for NARA biofuels

All Emissions Scaled to **6.857 kg of feedstock**, which is required to produce **1kg of IPK**

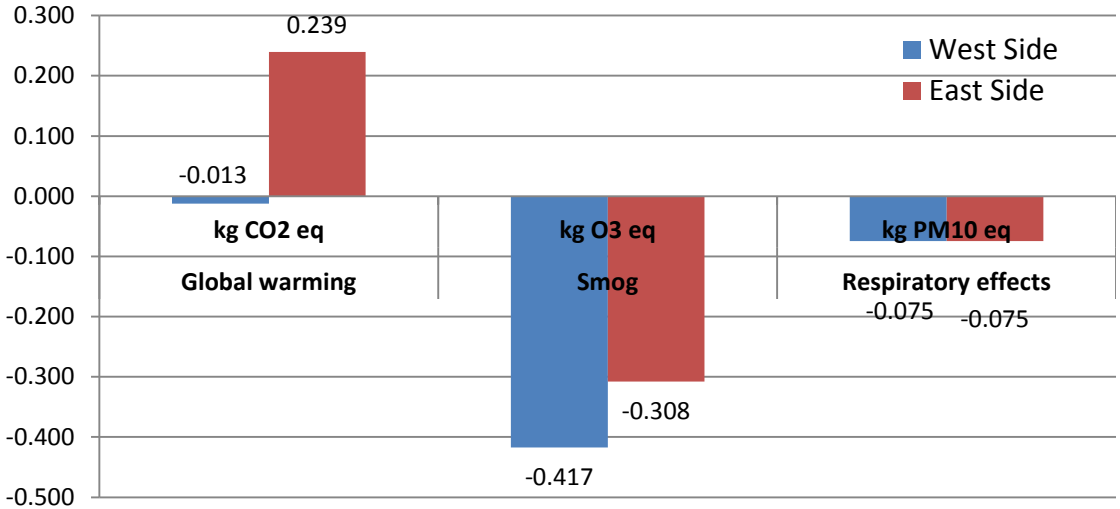


Figure 2: System Impact after accounting for the avoided emissions

NARA

Complete Biomass collection to fuel storage IPK Process:

Environmental Performance of 1 kg of IPK (with avoided slash pile burning)

Impact category	Unit	IPK with feedstock sourced from West Side	IPK with feedstock sourced from East Side
Ozone depletion	kg CFC-11 eq	0.000	0.000
Global warming	kg CO2 eq	1.257	1.509
Smog	kg O3 eq	-0.281	-0.171
Acidification	mol H+ eq	0.004	0.199
Eutrophication	kg N eq	0.005	0.005
Carcinogenics	CTUh	0.000	0.000
Non carcinogenics	CTUh	0.000	0.000
Respiratory effects	kg PM10 eq	-0.073	-0.073
Ecotoxicity	CTUe	1.486	2.178

NARA

Fossil Jet Fuel

Emissions to Air, Water and Land

Emissions: CO_2, PM, No_x, So_x, H_20

Crude Oil Extraction

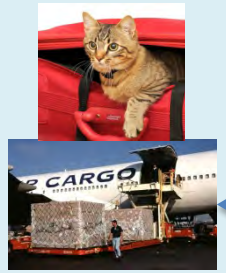
Crude Oil Transportation

Refinery: Jet Fuel Production

Jet Fuel Transportation

Jet Fuel Combustion

Aviation Productivity



Co-Products

Bio Jet Fuel

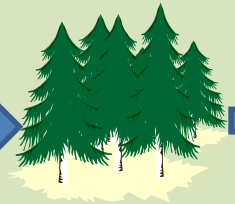
CO_2

CO_2, PM, No_x, So_x, H_20

CO_2

Greenhouse & Land Prep.

Forest Stand



Soil Carbon

Harvest Operations

Prep. & Transport Biomass

Pre-treatment and Bio-jet conversion

Bio-Jet Fuel Transportation

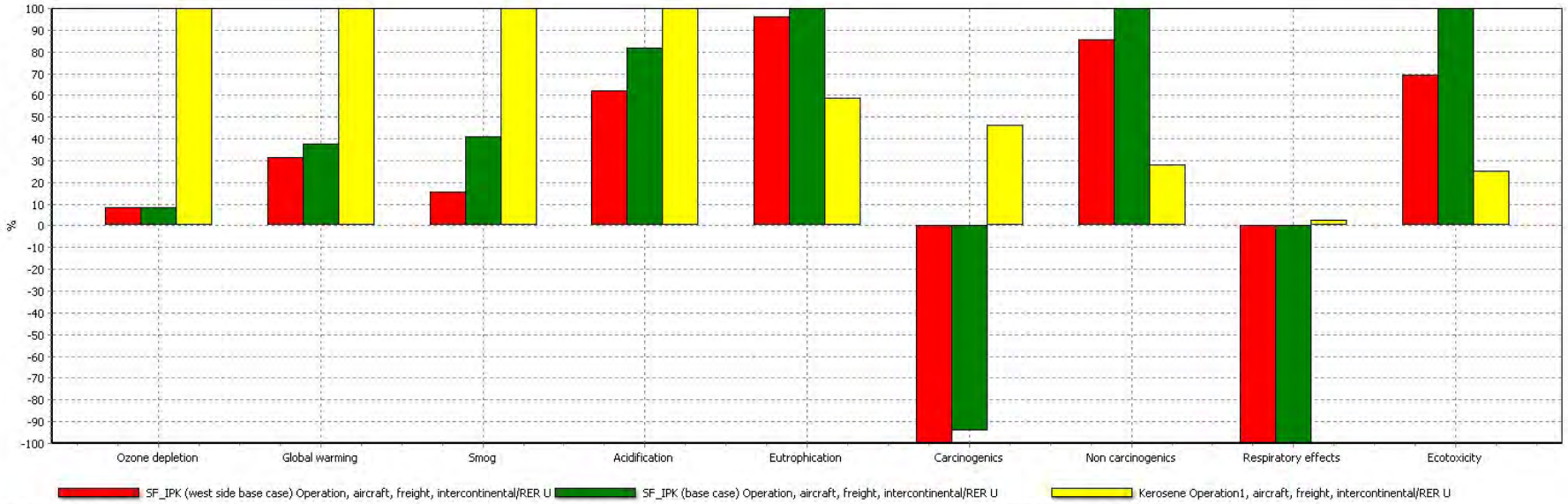
Bio-Jet Fuel Combustion

Co-Products

Co-Products

Emissions to Air, Water and Land

Comparative Analysis of fossil based biojet vs NARA biojet fuel



Comparing 1 tkm 'SF_IPK (west side base case) Operation, aircraft, freight, intercontinental/RER U', 1 tkm 'SF_IPK (base case) Operation, aircraft, freight, intercontinental/RER U' and 1 tkm 'Kerosene Operation1, aircraft, freight, intercontinental/RER U';
Method: TRACI 2 V4.00 / Characterization

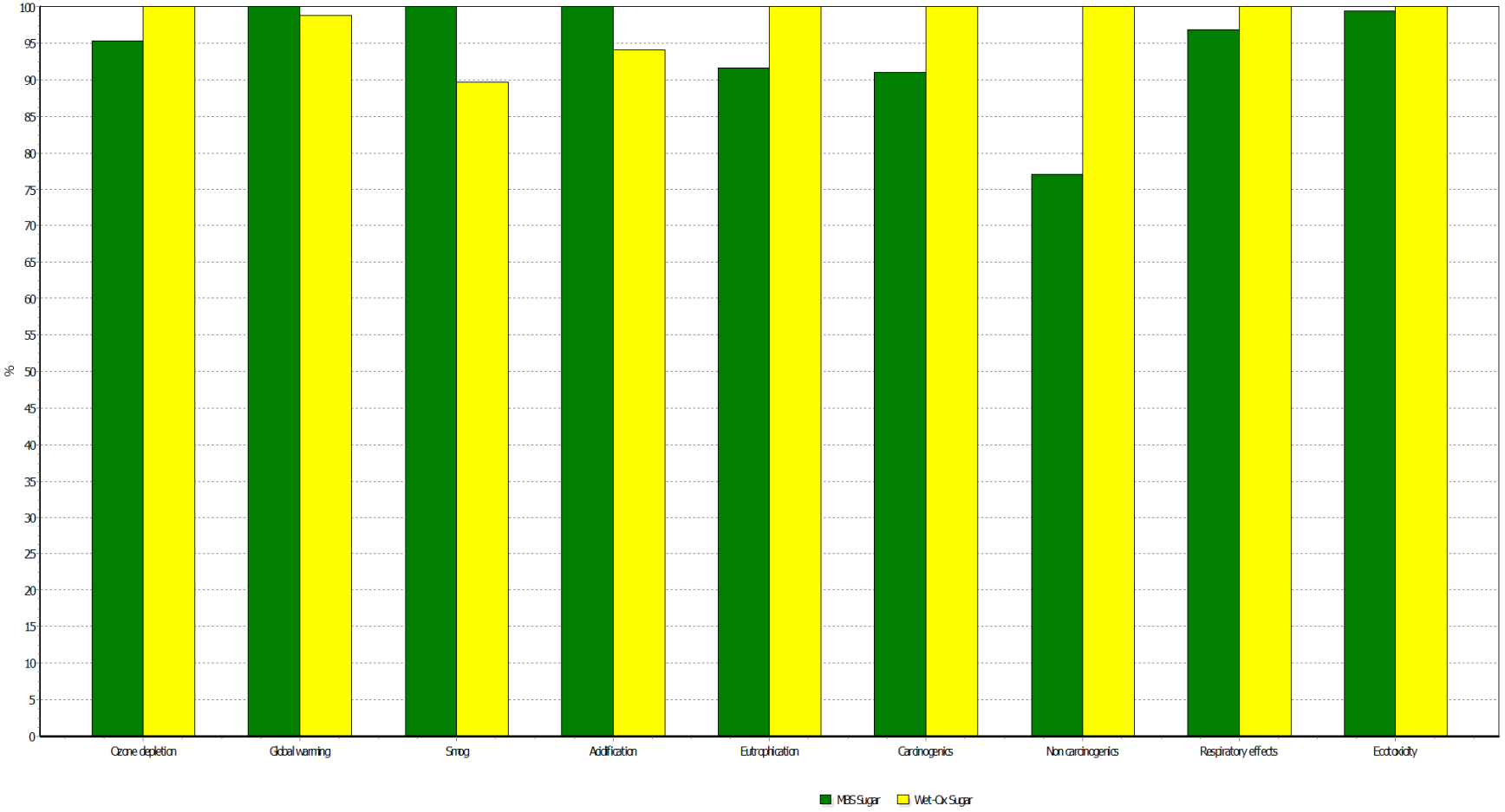
NARA

Conclusions

- Both east and west of cascades feedstock based NARA IPK makes the 60% reduction in GWP indicator criterion
- For ease of feedstock transportation and in-woods processing in the plantation logging zones, and higher density of biomass availability, west of cascades scenario produces favorable results.
- Both the NARA pre-treatments compare favorably to the NREL process, so selection of one over the other is not likely to impact the overall IPK results adversely.
- The overall IPK emissions results are not completely NARA biofuel results: A number of intermediary components are yet to be modeled within ASPEN (NREL surrogates are used in a number of places) so these results should be used carefully.

NARA

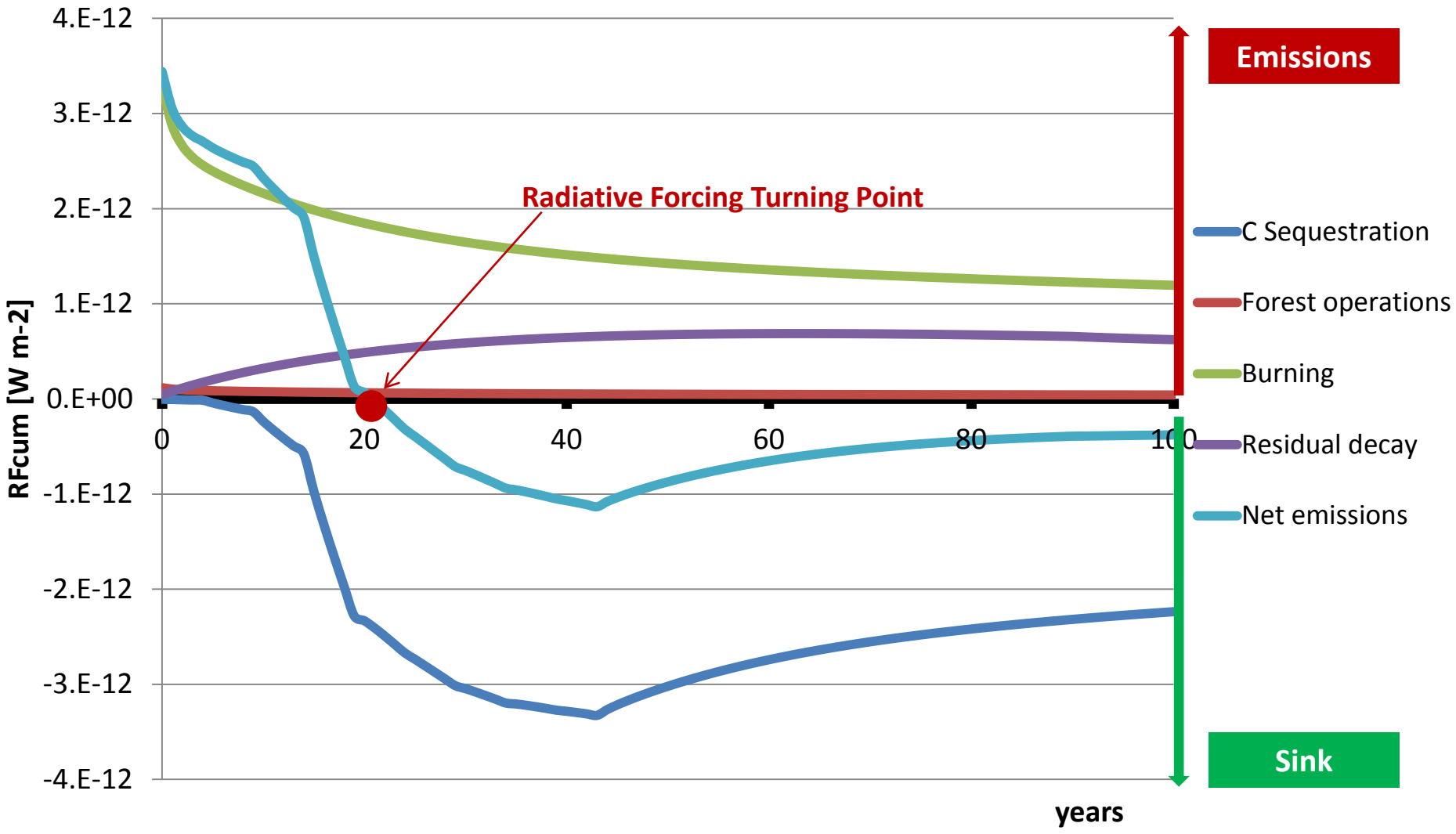
Comparative LCA of **MBS** and **Wet-Ox** Pre-treatments



Comparing 1 kg 'MBS Sugar' with 1 kg 'Wet-Ox Sugar';
Method: TRACI 2 V4.00 / Characterization

NARA

Carbon stocks, carbon sinks from FVS model normalized to the functional unit and cumulative radiative forcing of emissions and absorption sources in the LCA study.



NARA

THANK YOU

NARA