Laboratory for Aviation and the Environment
Massachusetts Institute of Technology

Argonne NATIONAL LABORATORY

A comparison of LC GHG accounting for alternative fuels in the US and EU

Robert Malina, Mark Staples (MIT)
Michael Wang, Amgad Elgowainy, Jeongwoo Han (ANL)

Website: LAE.MIT.EDU
Twitter: @MIT_LAE

Motivation

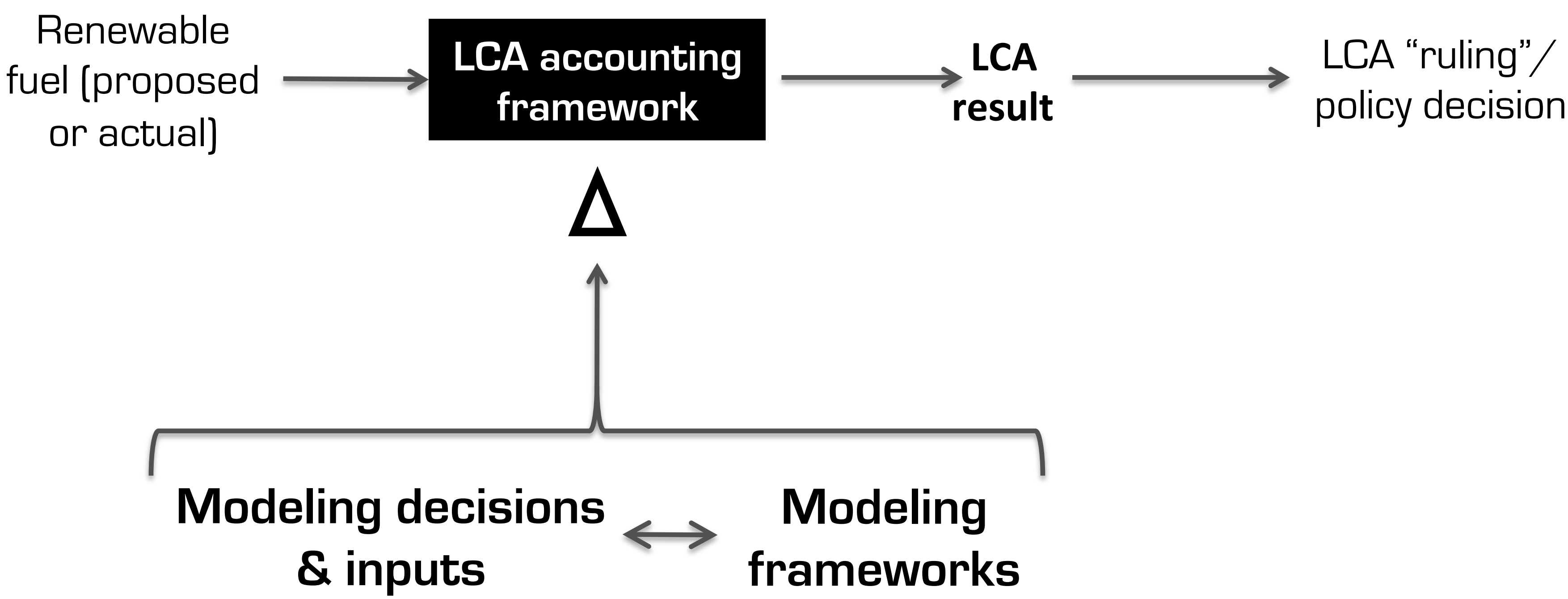
- There are differences between EU and US policy decisions regarding biofuels for aviation

- We are aiming to understand the differences in regulatory regimes and their execution, and to quantify how these differences lead to differences in the evaluation of different biofuels under these regimes

Context

- Previous work on policy/regulatory scheme comparisons:
  - Argonne National Lab
  - (S&T)[2] Consultants
  - Life cycle associates
  - ...
- This analysis is the first to quantitatively disentangle differences in GHG emission results between US and EU for pathways particularly relevant to alternative jet fuel
- The purpose is to engender discussion on the prospects for harmonizing regulatory attitudes towards alternative jet between the US and EU

Potential sources of discrepancy



Technical Issues with LCA

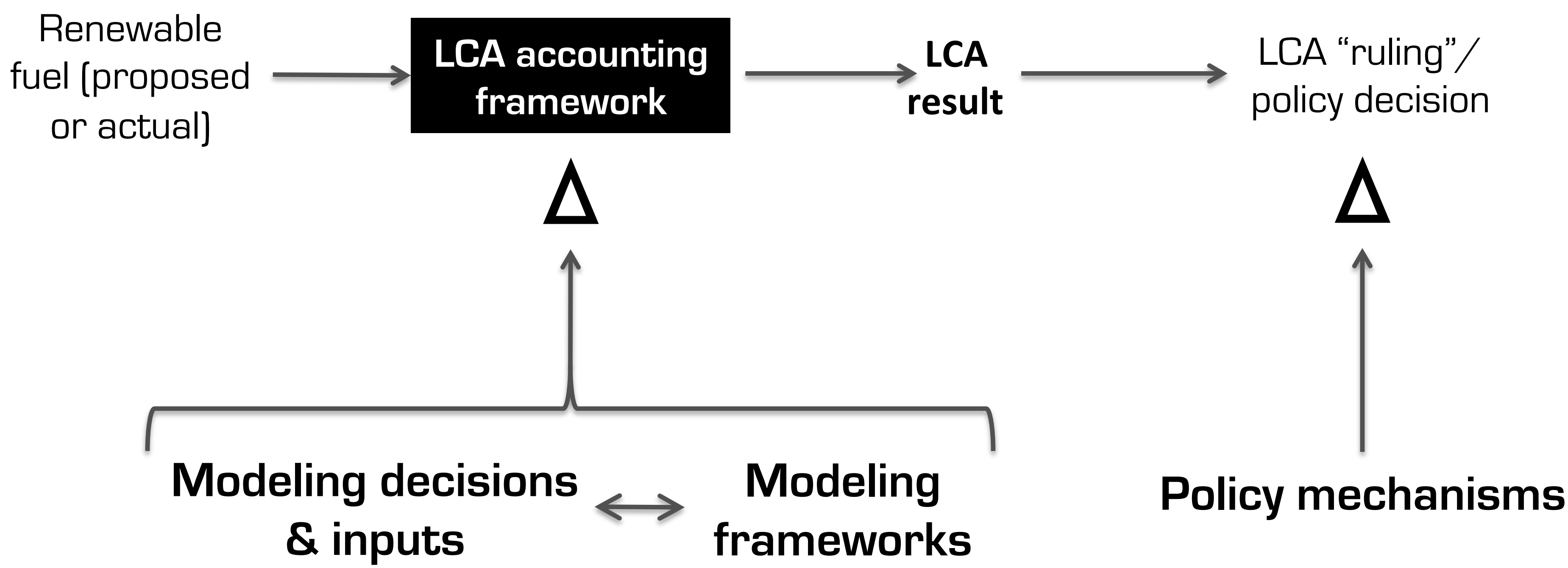
Modeling decisions & inputs:

- Allocation methodology
- System boundary definition
- Data inputs
  - Regional/geo-spatial assumptions
  - References & databases used
  - Technology development over time

Modeling framework:

- Consequential vs. attributional
- US EPA: DAYCENT, GREET, FASOM & FAPRI-CARD
- EU: JRC WTW, BioGrace, & feedstock sustainability certification

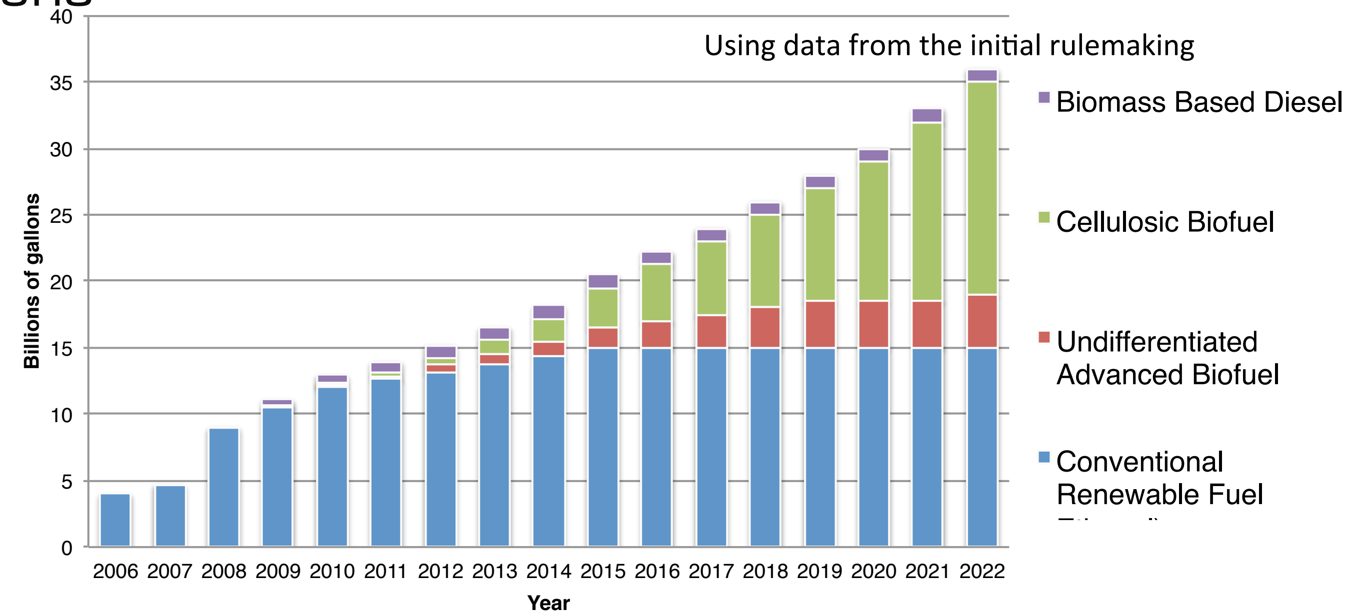
Potential sources of discrepancy



US Federal Framework on biofuels: RFS 2

Renewable Fuels Standard under the Energy Security and Independence Act of 2007 (RFS 2)

- Contains mandates for several renewable fuel categories with minimum GHG reductions relative to 2005 conventional gasoline and diesel emissions



Threshold GHG savings: conventional renewable fuel: -20% (Only new installations), undifferentiated advanced, and biomass based diesel: -50%, cellulosic biofuel: -60%.

RFS 2

- Company-specific renewable fuel volume obligations & trading mechanism
- Compliance of fuel with RFS 2 determined by EPA based on lifecycle greenhouse gas emissions
- LUC emissions included
- Initial 2010 ruling: Full suite of models for certain pathways. Subsequent rulings: Based on comparative analyses of additional pathways to the original pathways

EU regulatory framework for biofuels

- Main legislation:
  - **Renewable Energy Directive "RED" (2009/28/EC)**
  - **Fuel Quality Directive "FQD" (2009/30/EC)**
- Target: 20% share of renewable energy in the EU by 2020; 10% of transportation energy demand to come from renewable sources by 2020 (fuels from non-food biomass and waste oils count double), national targets in place as well.
- Achievement of the target is responsibility of the member states who are obliged to introduce support schemes and other measures to promote energy from renewable sources.

EU regulatory framework for biofuels

- Biofuel produced needs to be meet sustainability criteria, otherwise it does count towards the EU target and is not eligible for public support (biofuel mandates, tax breaks, subsidies) through the member states

- Sustainability has been defined in the EU legislation in terms of
  - Lifecycle GHG emission reductions: 35%, will be increased to 50% and 60%: Default values available, companies can show in certification that their pathway is better, emission accounting must include direct land-use change
  - Land usage for biomass cultivation: Restrictions for, inter alia, use of wetland, forested areas, peatland, protected areas Feedstock needs to be certified

Select GHG estimates employed under EU regulation

Biofuel production pathway	Typical greenhouse gas emission saving	Default greenhouse gas emission saving
Rape seed biodiesel	45 %	38 %
Sunflower biodiesel	58 %	51 %
Soybean biodiesel	40 %	31 %
Palm oil biodiesel (process not specified)	36 %	19 %
Palm oil biodiesel (process with methane capture at oil mill)	62 %	56 %
Waste vegetable or animal (*) oil biodiesel	88 %	83 %
Hydrotreated vegetable oil from rape seed	51 %	47 %
Hydrotreated vegetable oil from sunflower	65 %	62 %
Hydrotreated vegetable oil from palm oil (process not specified)	40 %	26 %
Hydrotreated vegetable oil from palm oil (process with methane capture at oil mill)	68 %	65 %
Pure vegetable oil from rape seed	58 %	57 %

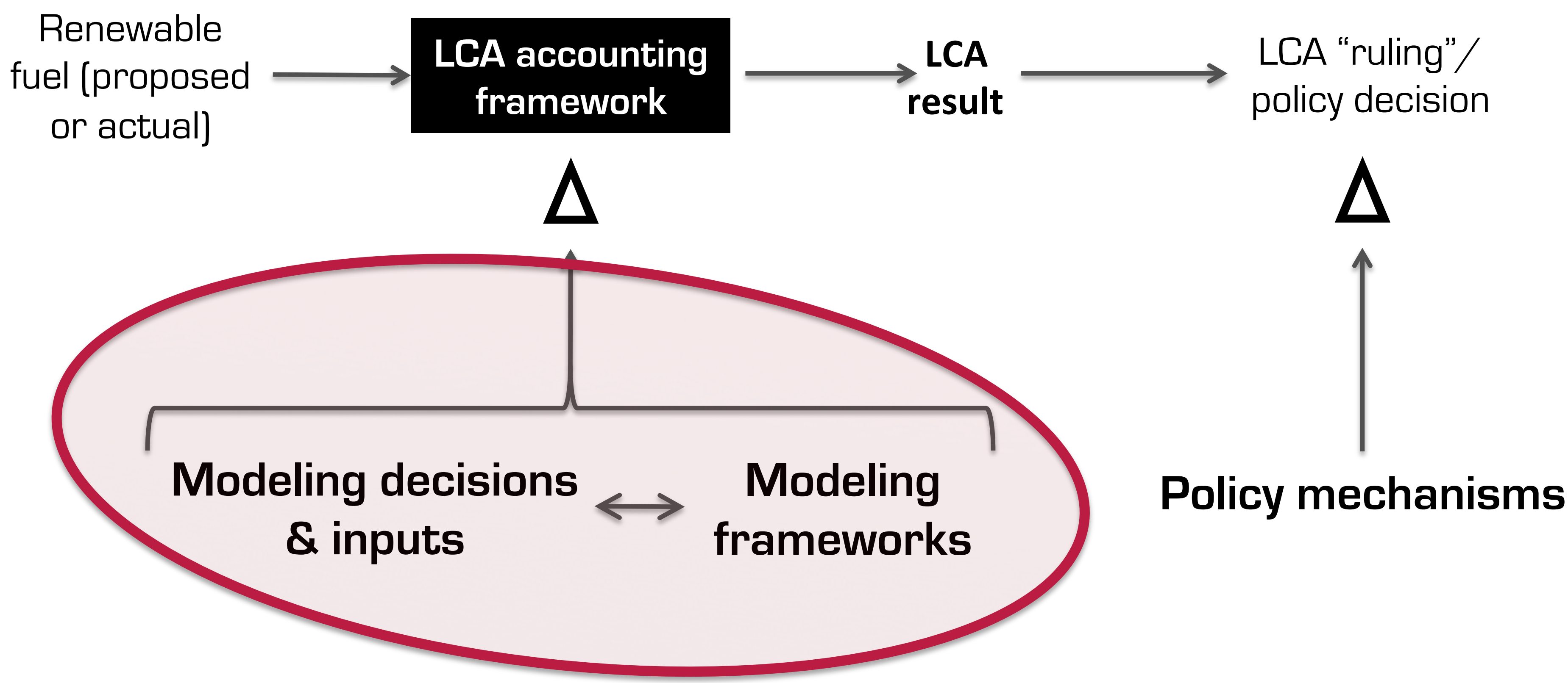
Table taken from RED and FQD

Note: Values are without emissions from land-use change

Proposed regulatory EU framework for biofuels

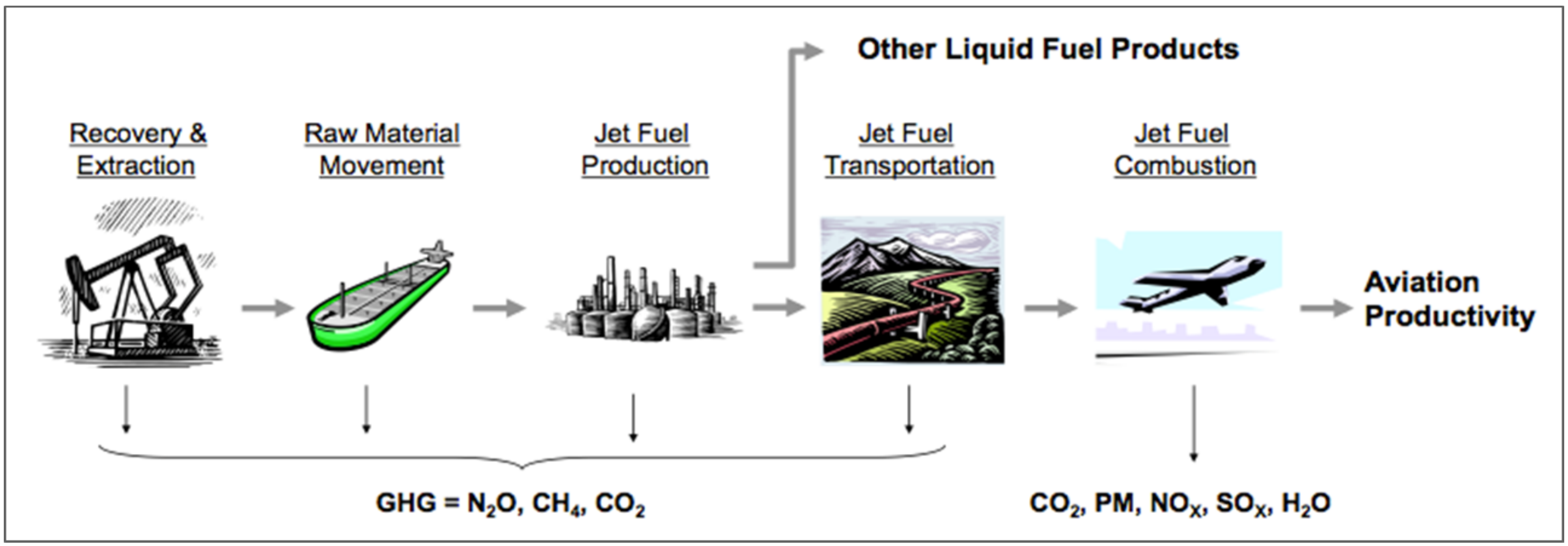
- EU Commission proposal for RED/FQD revision:
  - Limitation of contribution of biofuels from food crops to 5% of transportation energy demand
  - Default values for ILUC GHG emissions:
    - 12 gCO_2e/MJ for starchy crops
    - 13 gCO_2e/MJ for sugars
    - 55 gCO_2e/MJ for oily crops
  - "Quadruple" counting (in addition to double-counting) for biofuels from low-ILUC feedstocks such as algae, straw, bagasse
- EU Commission "Policy framework for climate and energy" (January 22nd, 2014): Aims at implementing target for renewable energy usage of 27% by 2030, <u>no dedicated target</u> for biofuels

Quantitative analysis



GREET modeling framework

- DOE EERE has been sponsoring GREET development and applications since 1995
- GREET is available at Argonne's GREET website: greet.es.anl.gov
- A new GREET version (GREET1_2013) was released on Oct. 2013



GREET aviation module includes the following jet fuel pathways

Fuels and Feedstocks

- ❑ **Petroleum Jet Fuel**
  - Conventional Crude
  - Oil Sand
- ❑ **Pyrolysis Oil Jet Fuel**
  - Crop Residues
  - Forest Residues
  - Dedicated Energy Crops
- ❑ **Hydrotreated Renewable Jet Fuel**
  - Soybeans
  - Palm Oil
  - Rapeseeds
  - Jatropha
  - Camelina
  - Algae
- ❑ **Fischer-Tropsch Jet Fuel**
  - North American Natural Gas
  - Non-North American Natural Gas
  - Renewable Natural Gas
  - Shale Gas
  - Biomass via Gasification
  - Coal via Gasification
  - Coal/Biomass via Gasification

Aircraft Types

- ❑ **Passenger Aircraft**
  - Single Aisle
  - Small Twin Aisle
  - Large Twin Aisle
  - Large Quad
  - Regional Jet
  - Business Jet
- ❑ **Freight Aircraft**
  - Single Aisle
  - Small Twin Aisle
  - Large Twin Aisle
  - Large Quad
- ❑ **LCA Functional Units**
  - Per MJ of fuel
  - Per kg-km
  - Per passenger-km

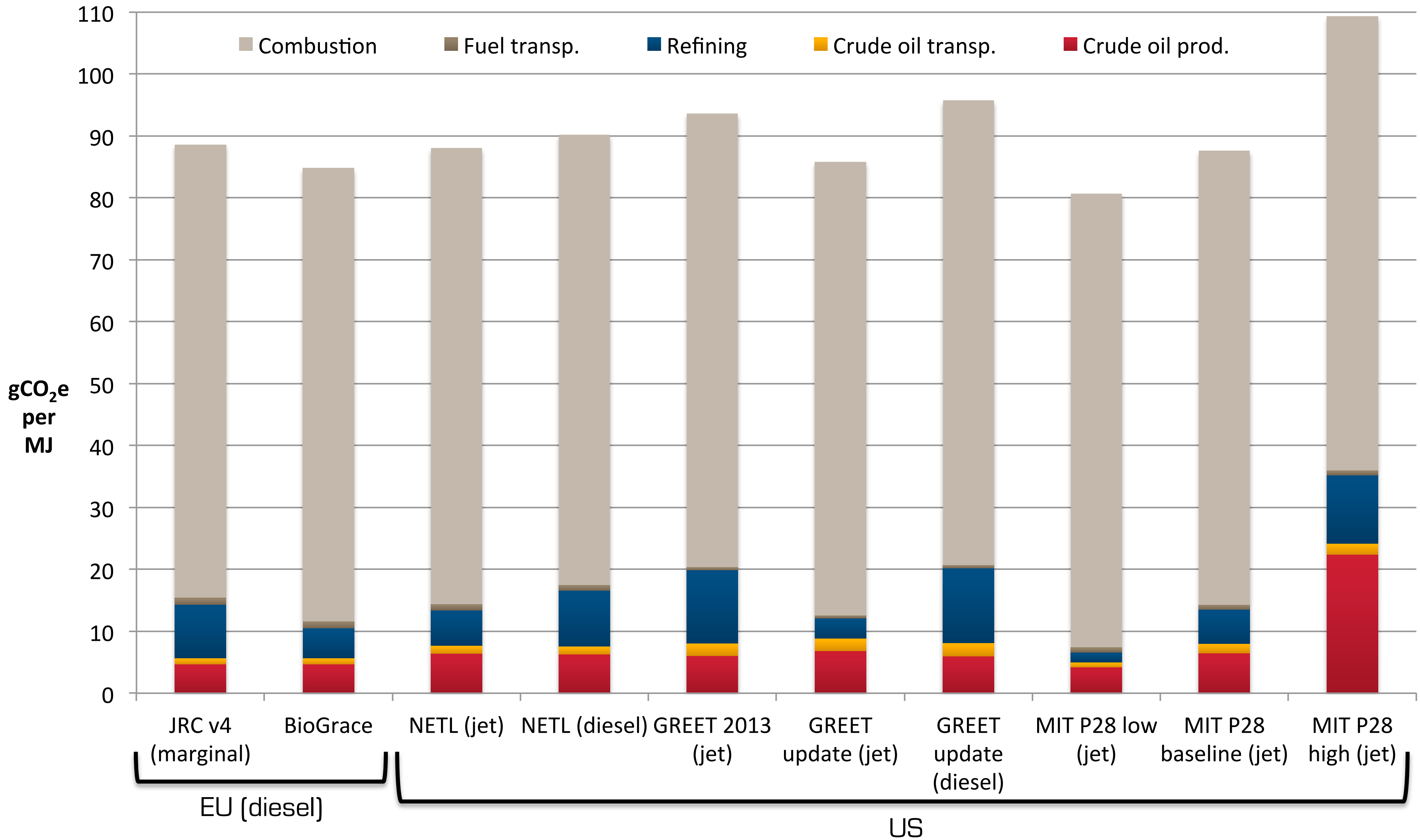
BioGrace modeling framework

- **BIO**fuel **GR**eenhouse gas emissions: **A**lignment of **C**alculations in **E**urope
- Goal: Harmonization and standardization of GHG accounting for transportation fuels in the EU, avoidance of "cherry picking" by operators
- Freely available, Excel-based GHG calculation tool
- Covers 22 feedstock to fuel pathways, <u>does not contain jet fuel specific calculations</u>
- Can serve as part of fuel certification, needs to be supplemented by feedstock sustainability analysis

Scope of quantitative analysis

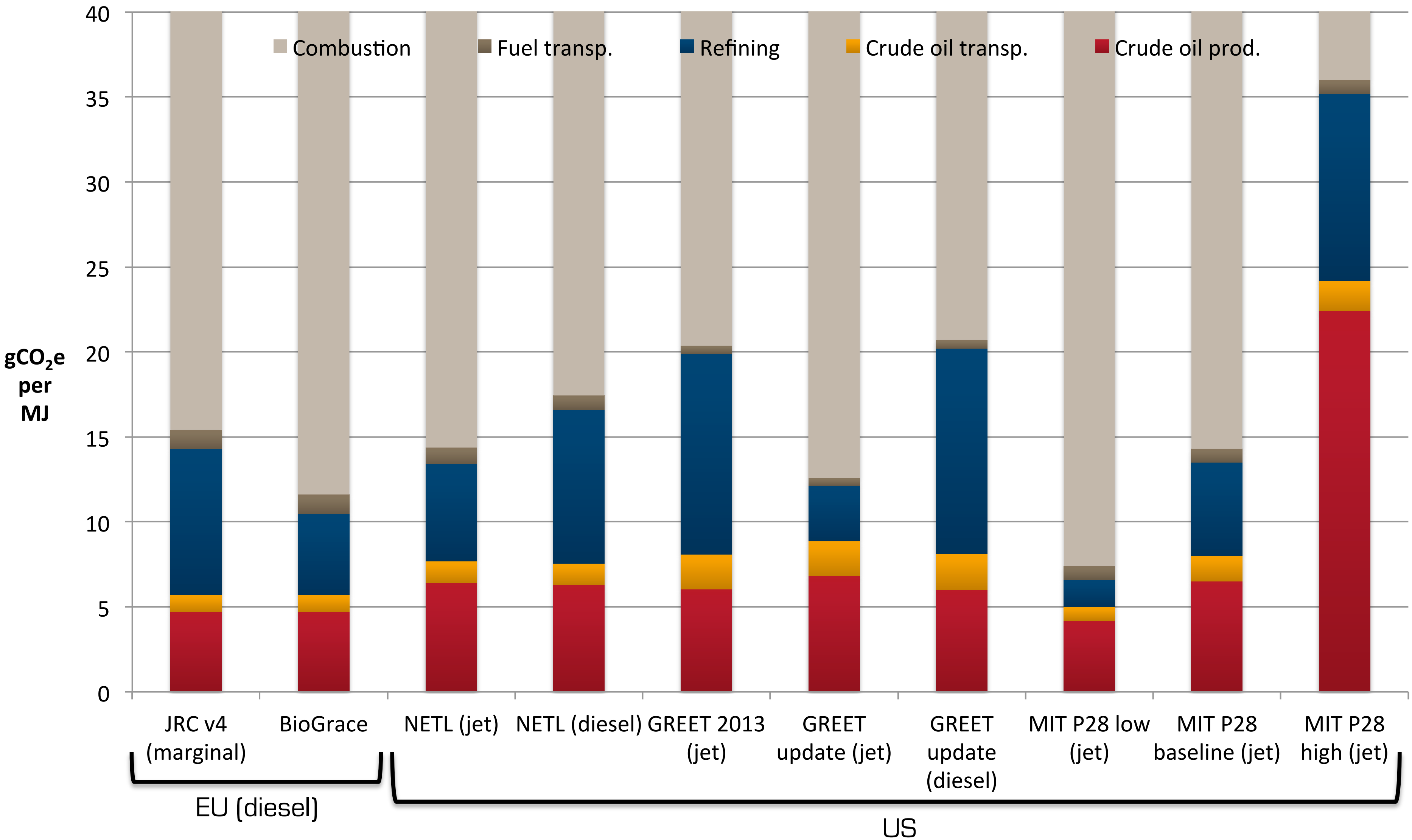
• Conventional fuel	**Direct comparison US – EU possible**
• Rapeseed HEFA	**Direct comparison US – EU possible**
• Soybean HEFA	**"Direct" comparison US – EU possible**
• Camelina HEFA	**Relevant in terms of treatment of ILUC**
• Tallow HEFA	**Showcases the importance of system boundary definitions**
• BTL from farmed wood & waste wood	**"Direct" comparison US – EU possible**

Conventional fuels (jet & diesel)



Note: For comparison purposes in this presentation, conventional jet fuel will be assumed to have lifecycle GHG emissions of ~87.5 gCO_2e/MJ from MIT P28 report

Conventional fuels (jet & diesel) – zoom in



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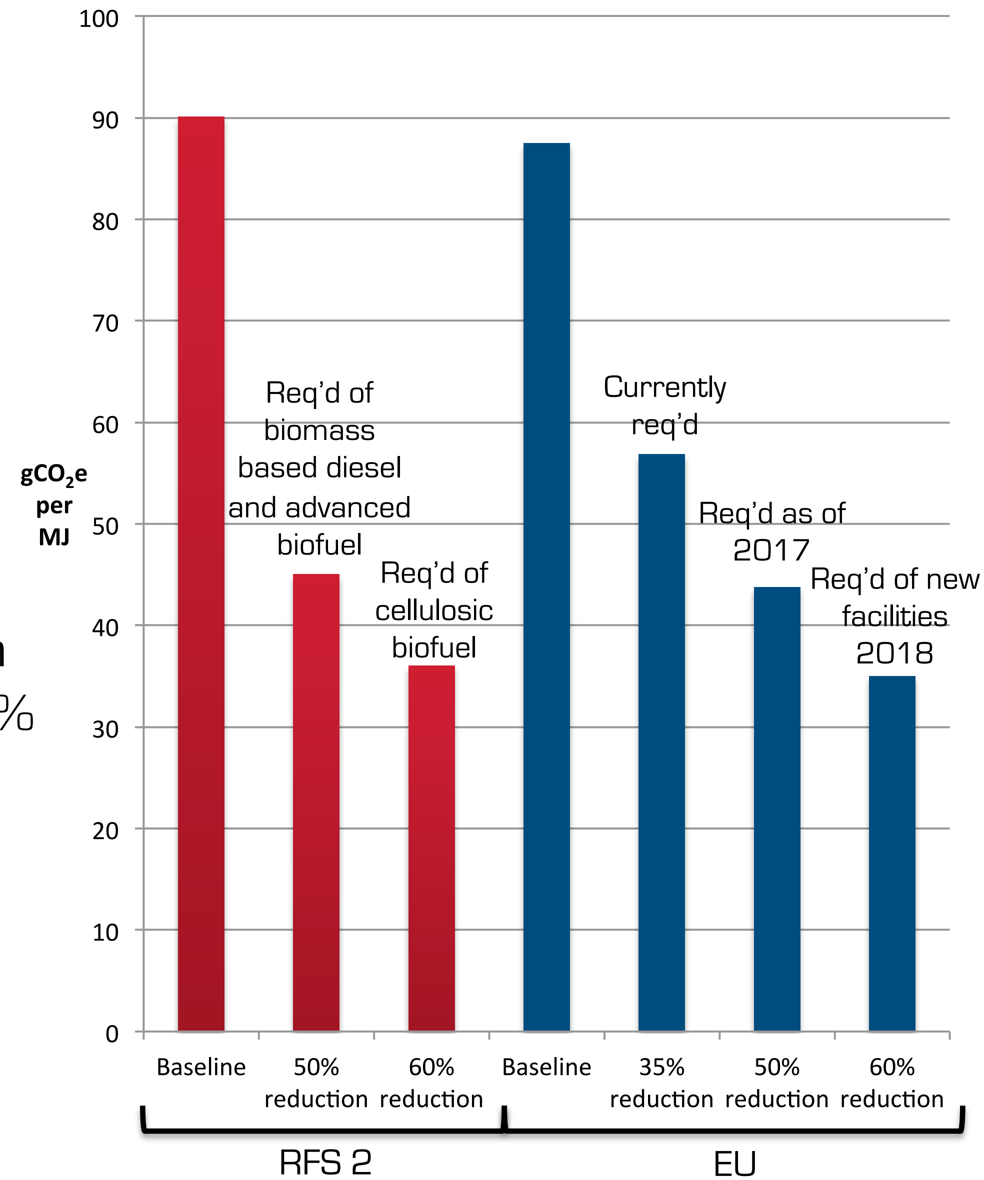
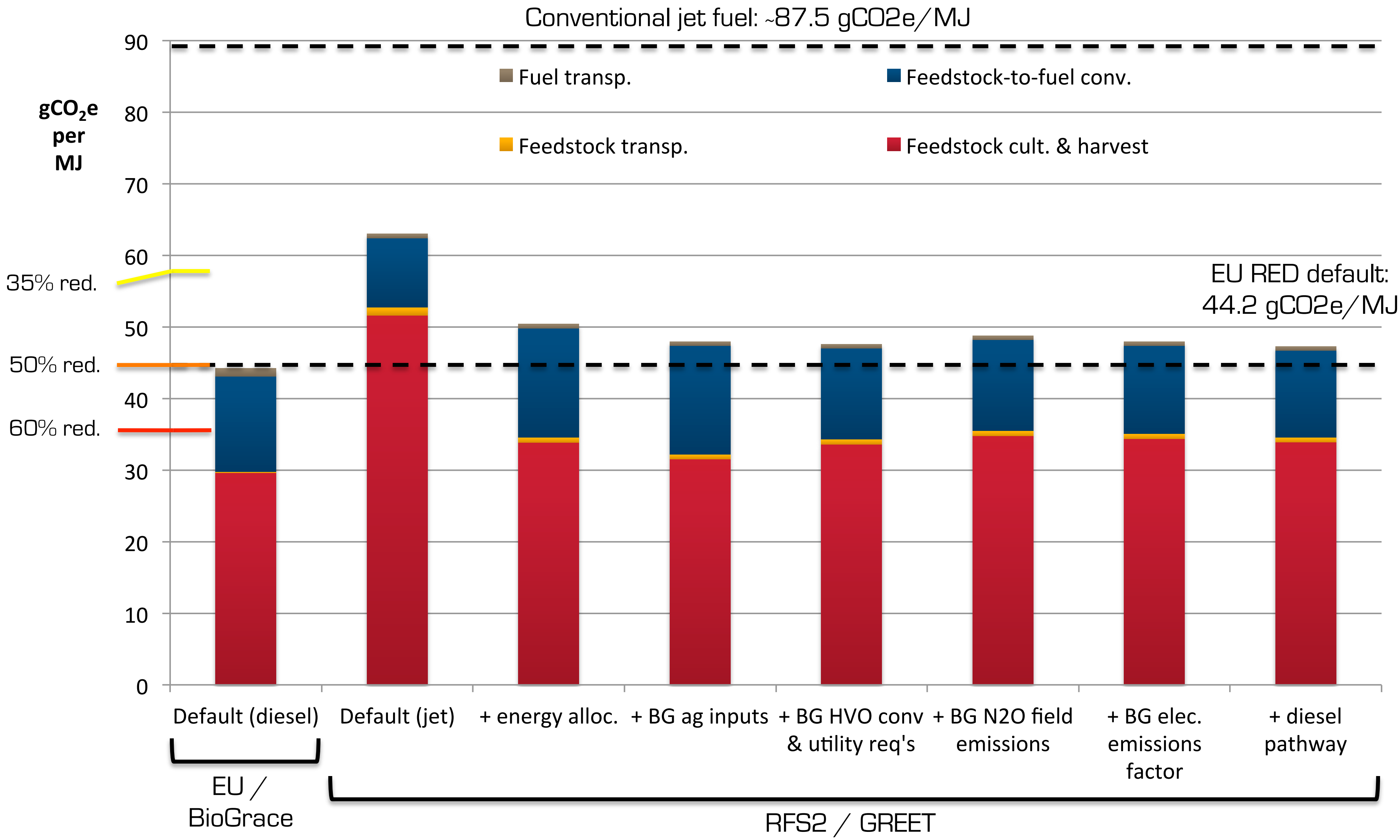
Differences in emission thresholds for biofuels

- **RFS2:** must be 50% or 60% below conventional fuel
- **EU RED/FQD:**
  - For facilities operating from 01/23/2008, 35% reduction threshold → 50% as of 01/01/2017
  - For facilities beginning production on or after 01/01/2017 → 60% as of 01/01/2018

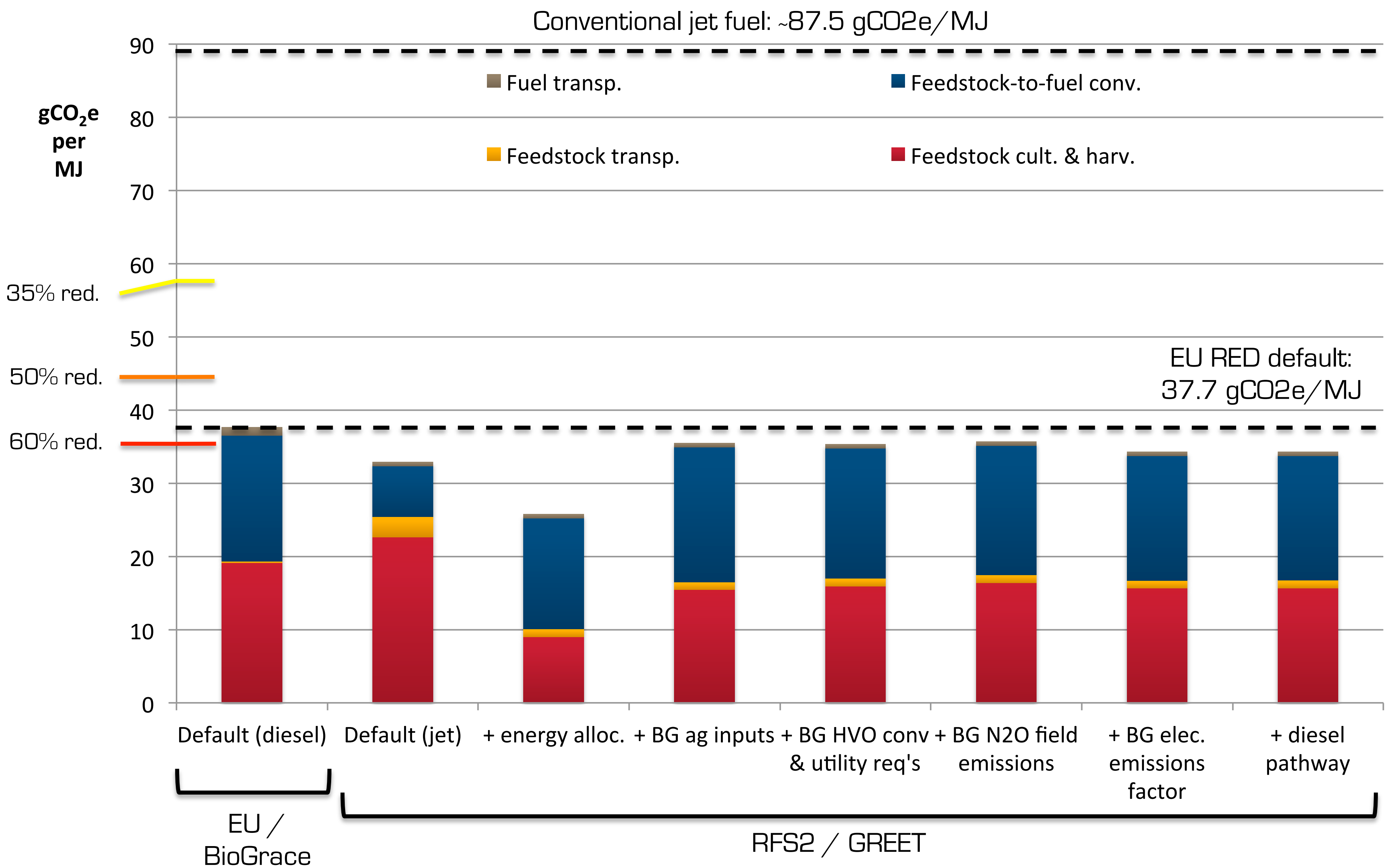


Rapeseed HEFA/HVO



PRELIMINARY RESULTS – PLEASE DO NOT CITE OR QUOTE

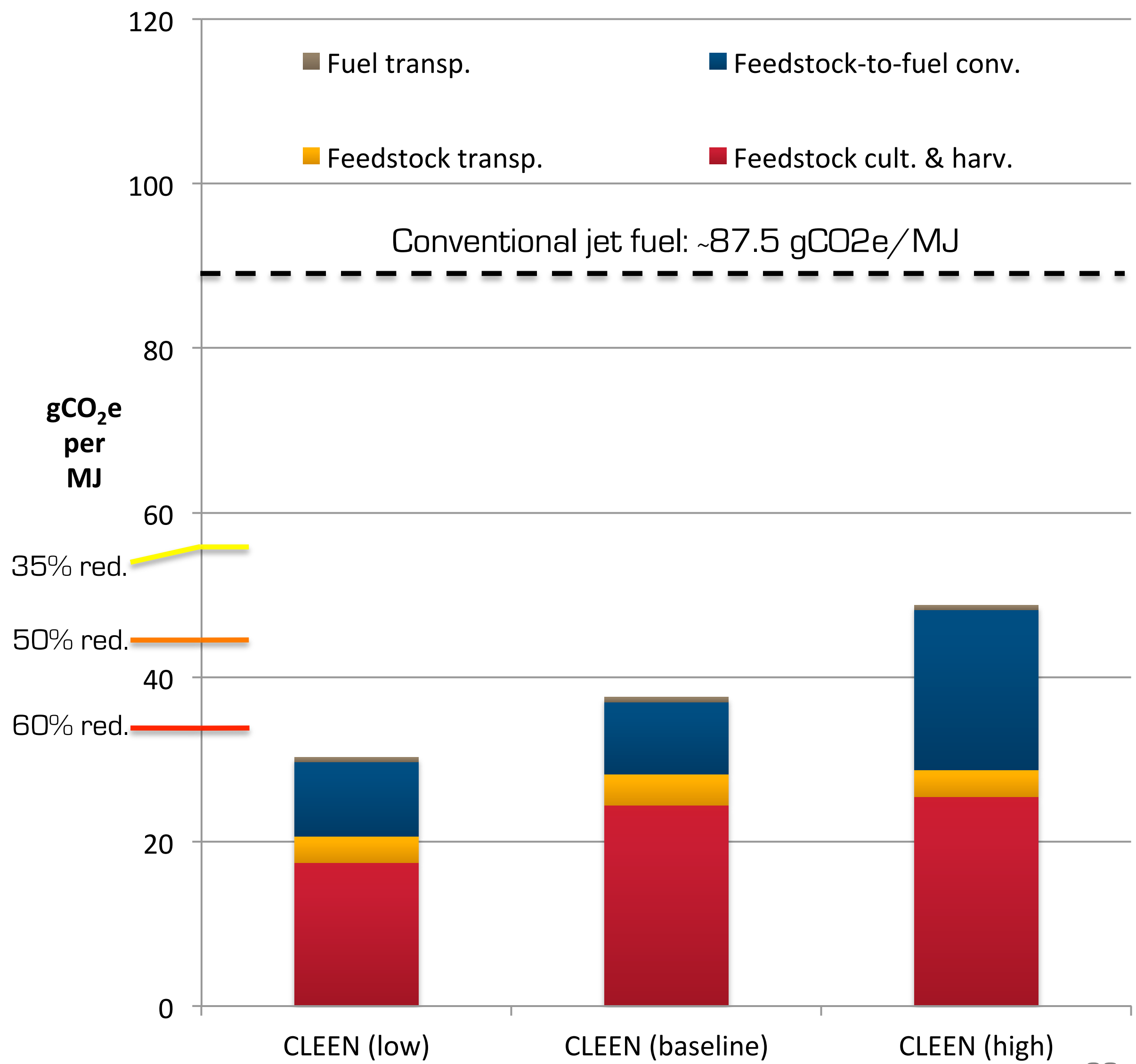
Soybean HEFA/HVO



PRELIMINARY RESULTS – PLEASE DO NOT CITE OR QUOTE

Camelina HEFA jet

- Camelina HEFA jet qualifies under RFS2:
  - This was determined by comparison to the qualified soybean bio-diesel pathway (no full analysis)
- EPA does not consider LUC because camelina is assumed to be grown on fallow land
- According to MIT modeling for the CLEEN program, camelina HEFA is likely to be able to meet a 50 or 60% reduction threshold
- Proposed change of system boundary in EU: ILUC factor of 55 gCO_2e/MJ for oilseed feedstocks is proposed



PRELIMINARY RESULTS – PLEASE DO NOT CITE OR QUOTE

Camelina HEFA jet + LUC factor

- Camelina HEFA jet qualifies under RFS2:
  - This was determined by comparison to the qualified soybean bio-diesel pathway (no full analysis)
- EPA does not consider LUC because camelina is assumed to be grown on fallow land
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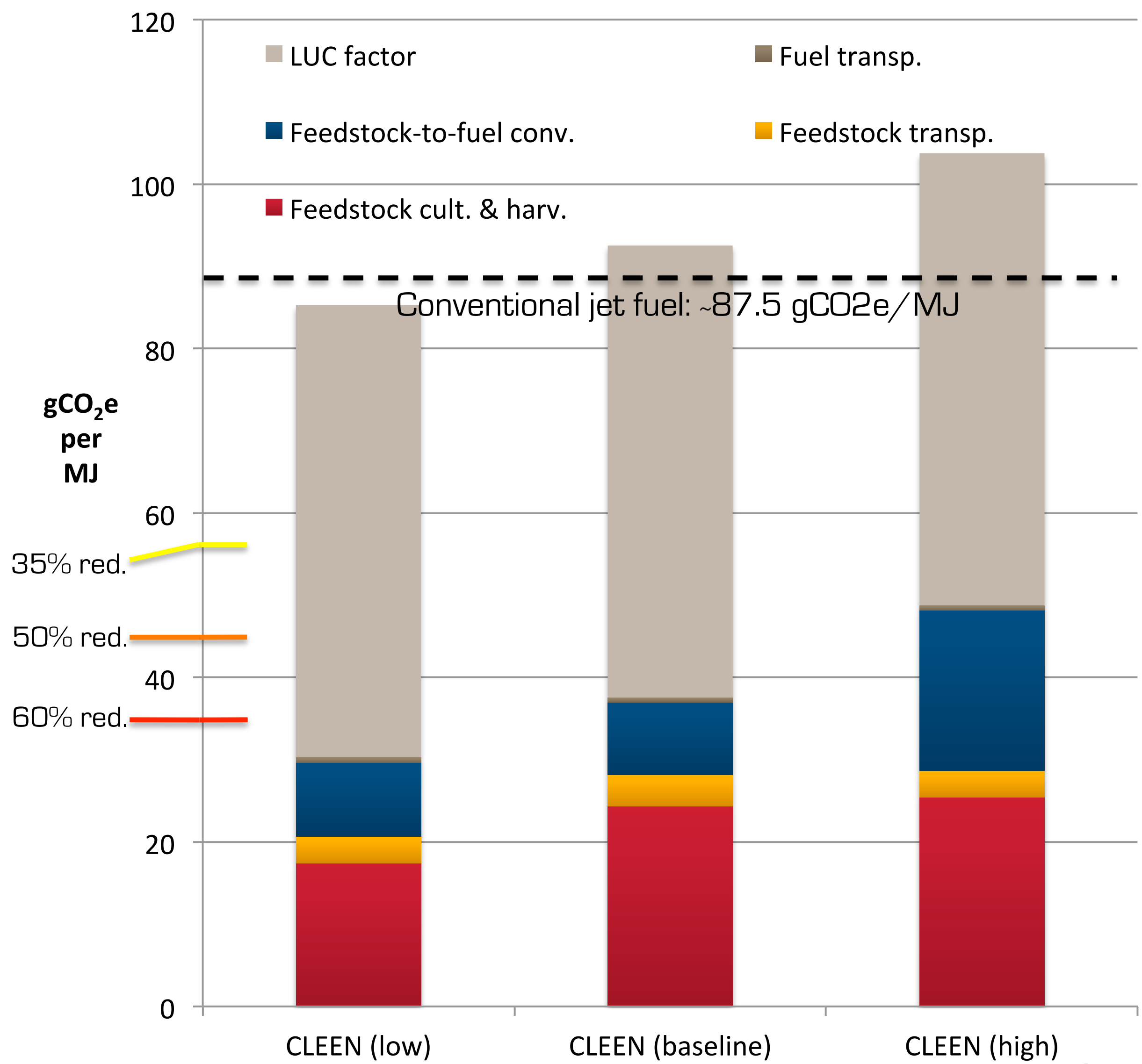
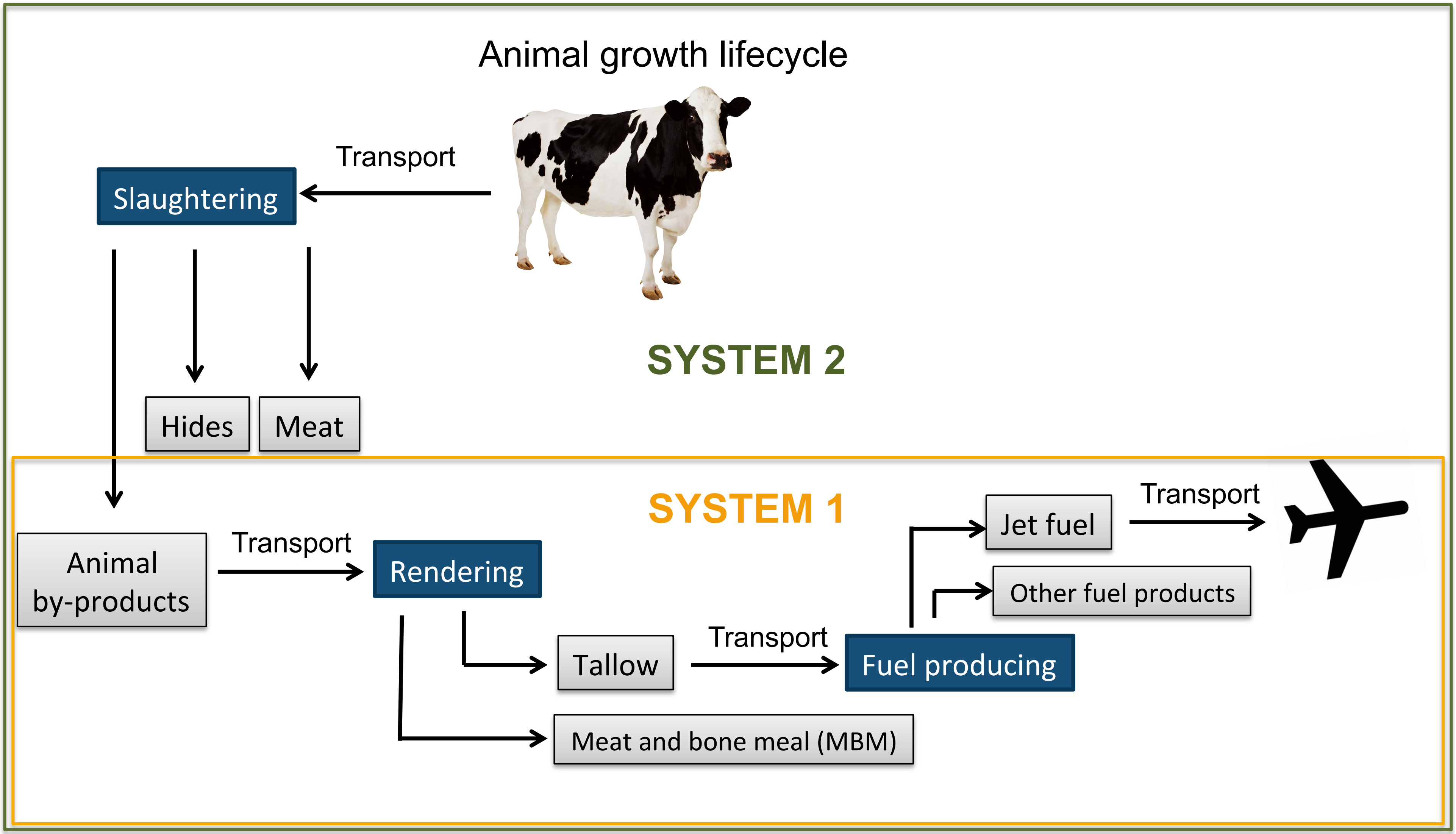
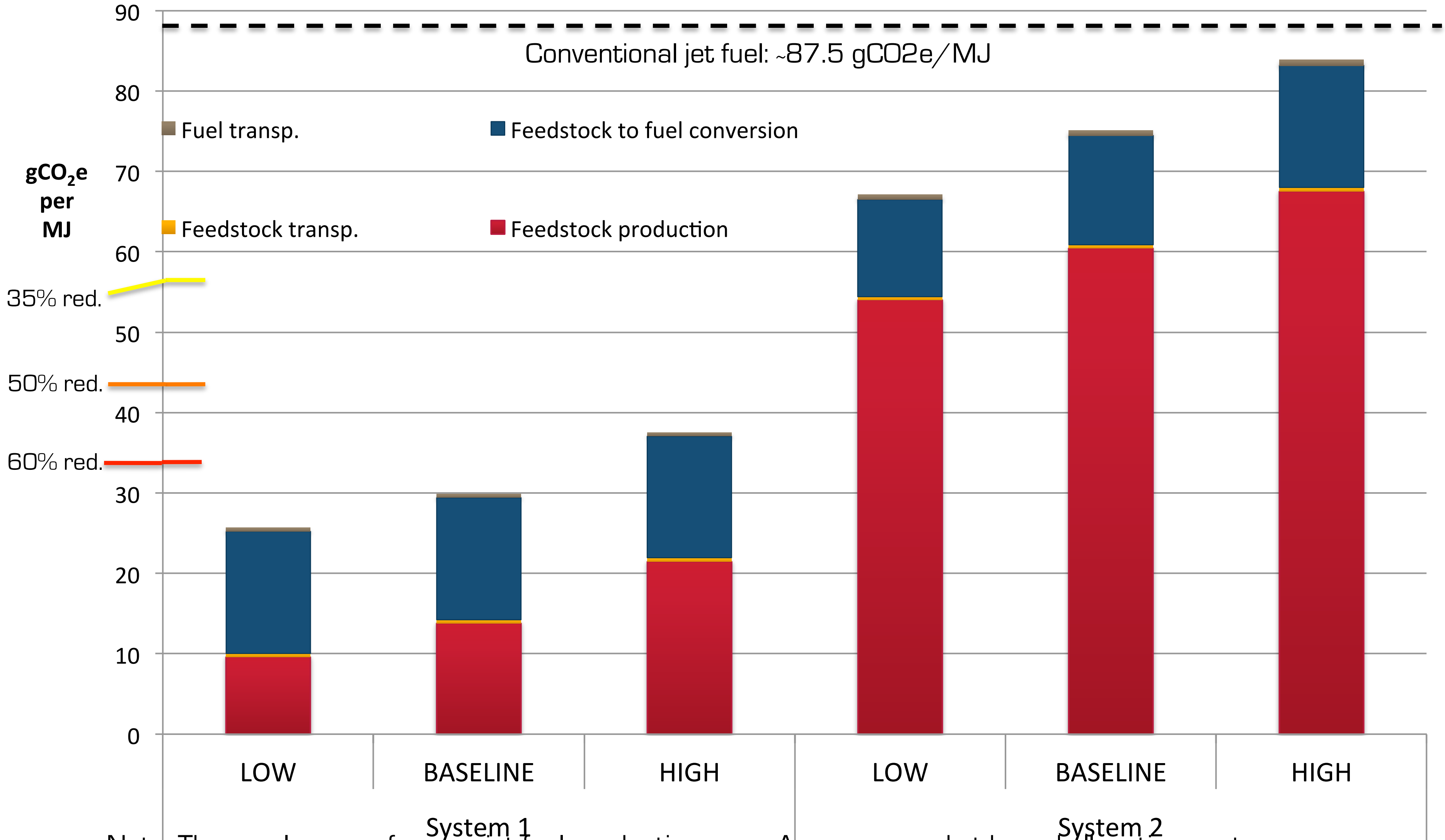


PRELIMINARY RESULTS – PLEASE DO NOT CITE OR QUOTE

System boundaries: Tallow example



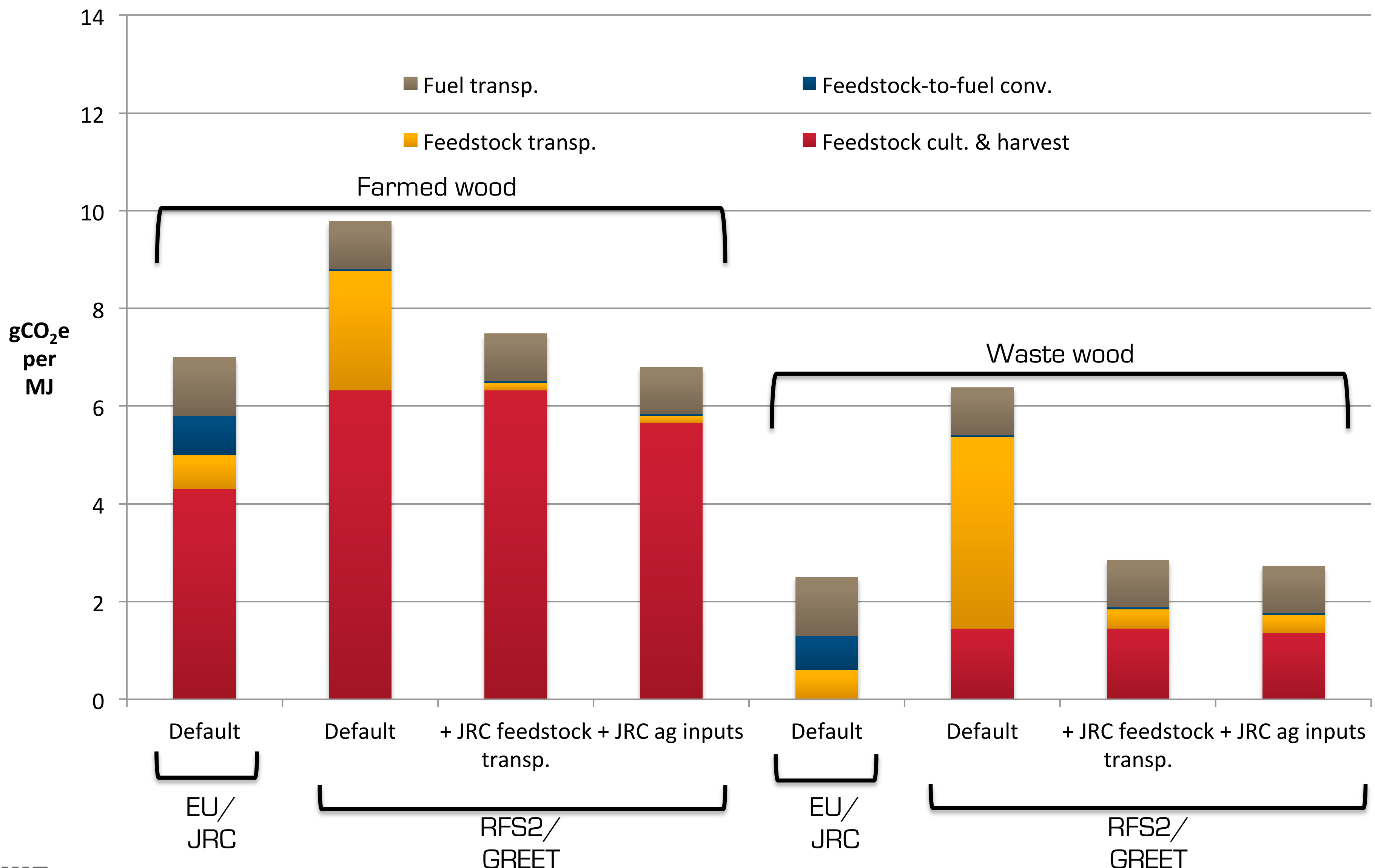
Tallow lifecycle GHG emission results



Note: These values are for max jet fuel production case. Assumes market based allocation upstream & energy allocation among fuel products

PRELIMINARY RESULTS – PLEASE DO NOT CITE OR QUOTE

FT pathways (all diesel)



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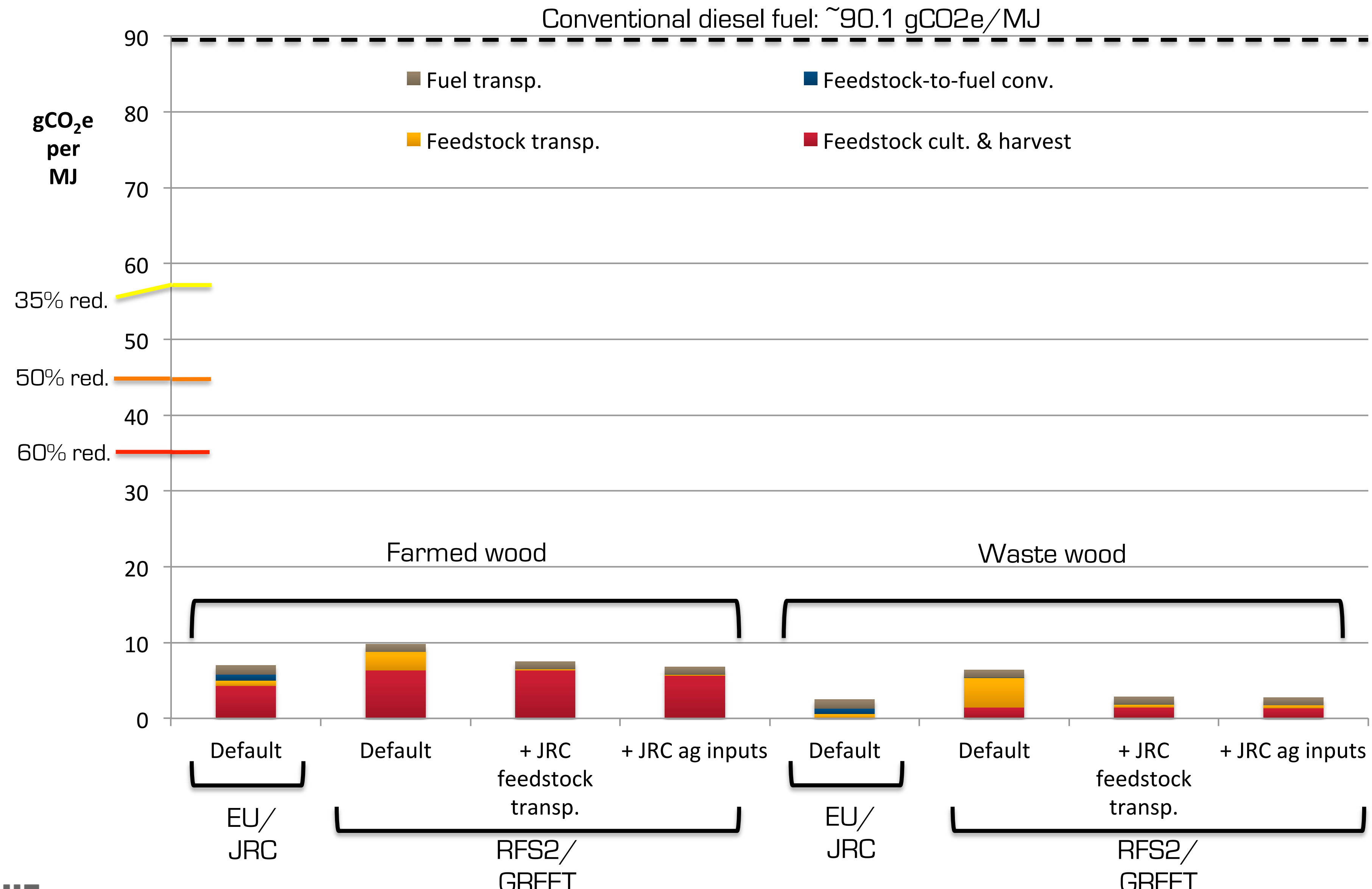
FT pathways (all diesel)



PRELIMINARY RESULTS – PLEASE DO NOT CITE OR QUOTE

Conclusions (1 of 2)

Decisions made within framework	US	EU
Main focus	GHG emissions	GHG emissions+ feedstock sustainability
Jet-fuel relevant emission reduction thresholds	50%, 60%	35% currently, will change to 50%, 60%
Eligibility scope	Feedstock to fuel pathway approval	Company & feedstock-specific fuel certification
Allocation rules	Energy (for RIN generating products), Displacement	Energy (with exceptions)
System boundary for land use change	LUC in general	Only DLUC (subject to revision)
Consequences of eligibility	Access to RIN markets	Access to support schemes by member states

Conclusions (2 of 2)

- Differences in lifecycle results for pathways assessed due to:
  - Allocation rules (Energy vs. Displacement):

    Δ 7-12 gCO_2e/MJ for HEFA pathways – no impact on FT results since no non-fuel co-products

  - System boundaries, including land-use change:

    Δ 55 gCO_2e/MJ for camelina, if camelina becomes subject to ILUC factor in EU (relevant for all oily crops)

  - Agricultural inputs

    Δ 2-9 gCO_2e/MJ for HEFA pathways, 0.7 gCO_2e/MJ for FT pathways

BUT: Not all differences are indicative of a need for harmonization (systematic vs. parametric differences)

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- Work presented may not represent the views of the sponsors

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Robert Malina
rmalina@mit.edu

Website: LAE.MIT.EDU
Twitter: @MIT_LAE