ASCENT 32
Worldwide life-cycle analysis of GHG emissions of petroleum-derived jet fuels

Motivation and Objectives

Substantial research has been funded by the Federal Aviation Administration through FAA Centers of Excellence (COE) to quantify the lifecycle greenhouse gas (GHG) emissions of alternative jet fuels, for example, through Projects 17, 28 and 47 of the Partnership of Air Transportation Noise and Emissions Reduction (PARTNER) COE, and Project 1 of the Aviation Sustainability Center (ASCENT) COE. The impact of using alternative fuels in terms of GHG emissions can be described in relative terms compared to using petroleum-derived jet fuel. In order to do so, a **"baseline" GHG** value for **petroleum-derived jet fuel** needs to be established.

To date, only a limited number of analyses of GHG emissions for jet fuel from petroleum sources exist, limited to the United States and the European Union. To the best of our knowledge, no baseline value for jet fuel from petroleum has been established in other world regions.

The **main objective** of this project is to calculate **GHG emissions estimates** for petroleum jet fuels for the **recent past** and **for future scenarios** in the coming decades. Results will be reported globally and broken out by world regions, and the impact of changes in future demand for certain petroleum products and of changes in crude properties will be quantified. Opportunities for reductions in GHG emissions along the supply chain will be estimated.

The results from this work can be used as a **petroleum baseline** for future alternative jet fuel analyses both within the US Government and in support of U.S. efforts at the International Civil Aviation Organization's Committee on Aviation Environmental Protection (CAEP).

Summary

Global average lifecycle GHG emissions from conventional jet fuel are calculated at **15.1, 15.7** and **16.0 gCO_2e/MJ** (well-to-pump), and **88.0, 88.6** and **88.9 gCO_2e/MJ** (well-to-wake) for the years 2005, 2012 and 2020, respectively (**Figures 2** and **3**).

Well-to-pump jet fuel emissions are found to vary among world-regions from **10.8 to 18.5 gCO_2e/MJ** in 2012 **(Figure 4)**. Emissions vary among world-regions, inter alia, with the world-region crude consumption mix and the share of jet fuel required to go through **secondary processing** (**Figure 5**).

For the year **2050**, emission scenarios were built that capture possible internally-consistent states of the world. Depending on scenario, global well-to-pump emissions are estimated to change **by -2.7 to +2.9 gCO_2e/MJ**, compared to the 2020 value (**Figures 6** and **7**).

Methods and Materials

We develop a region-specific life cycle model encompassing data on each lifecycle stage and estimate world-region-specific emissions for the years 2005, 2012 and 2020. The GHG life cycle model developed for **extraction of crude** from conventional and tight resources encompasses the following modules: well drilling, artificial lift, water re-injection, heater-treater, crude stabilization, waste water treatment, land use change, venting and flaring of associated gas, enhanced oil recovery, and fracking.

On the **refinery side**, by refinery process unit capacity data was collected and compiled from various sources (Global Data, BP, OGJ, OPEC, etc.). Data includes 18 process types in 687 refineries, corresponding to full coverage of the global refining capacity. The inputs to the refinery model include, refinery by refinery unit capacities, process unit heat, steam, electricity, and hydrogen consumption/generation, emission indices of utilities and hydrogen, refinery utilization factors, average refinery fuel use by each country, crude grades refined in each country, based on production and import data, process unit output mix and each country's product slate.

Transportation emissions from both crude and jet fuel are estimated using empirical information and projections on product flows by transportation mode at the world-region level and estimates for emission indices associated with each mode of transportation. Combustion emissions are calculated using **empirical estimates.**

For **long-term projections**, **emission scenarios** were constructed that represent possible and consistent future states of the world. Core drivers of emissions are varied according to scenario as shown in **Figure 1** and **Table 1**.

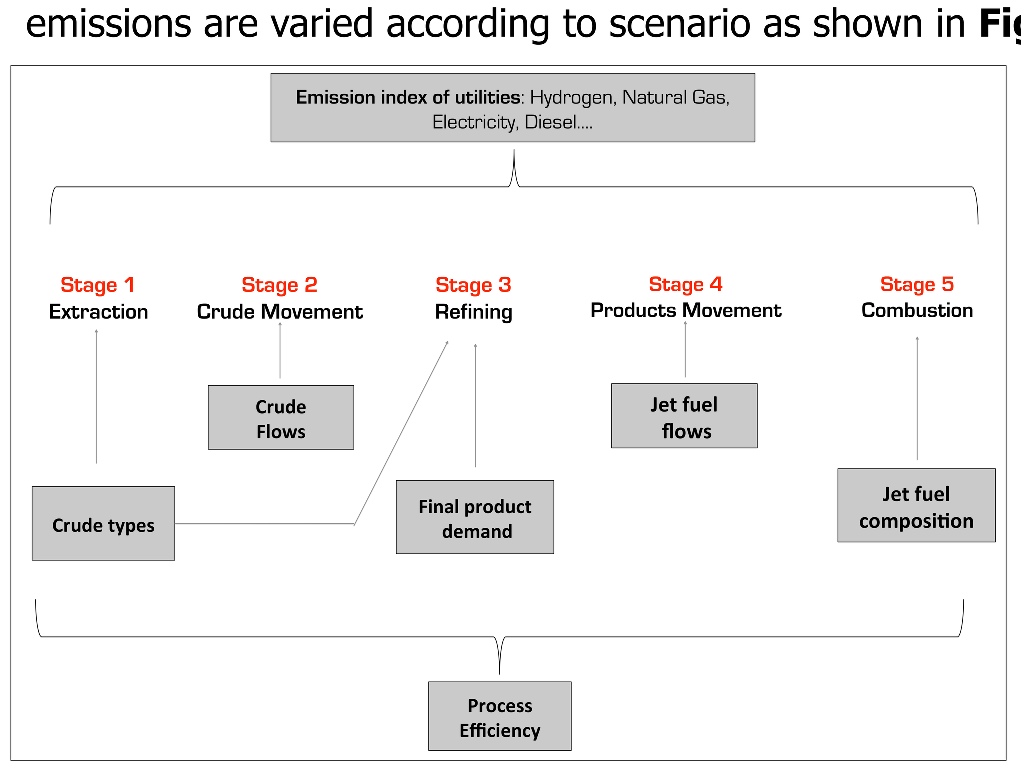

Figure 1: Factors varied in the 2050 analysis compared to 2020 analysis.

Category	Factor	MIT 2020	Business As Usual	Moderate Policies	Strong Policies
Extraction	Tight Oil EI [g CO_2 / MJ]	MIT 2020 (6.3)	Medium (6.3)	Medium (6.3)	Low (1.8)
	Tight Oil Production [kbbl / d]	MIT 2020 (5.2%)	High (12.2%)	Medium (5.9%)	Low (3.5%)
	Heavy Oil EI [g CO_2 / MJ]	MIT 2020 *	Medium *	Medium *	Low *
	Heavy Oil Production [kbbl / d]	MIT 2020 (6.0%)	High (9.6%)	Baseline (8.0%)	Low (4.9%)
Utilities	Electricity Generation EI [g CO_2 / MJ]	MIT 2020 **	MIT 2020 **	Jazz **	Symphony **
	Hydrogen Production EI [g CO_2 / MJ]	MIT 2020 (0.099)	MIT 2020 (0.099)	Baseline (0.063)	Low (0.028)
Refinery	Share of Jet Fuel in Middle Distillates	MIT 2020 (0.30)	Low (< 0.3)	High (0.38)	Moderate (0.31)

** Varies with extraction method* *** Varies with world region*

Table 1: 2050 scenario construction.

Lead investigators: R. Malina & S.R.H. Barrett
Massachusetts Institute of Technology
Project manager: D. Williams, FAA

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Results and Discussion

Preliminary results – Please do not cite or quote.

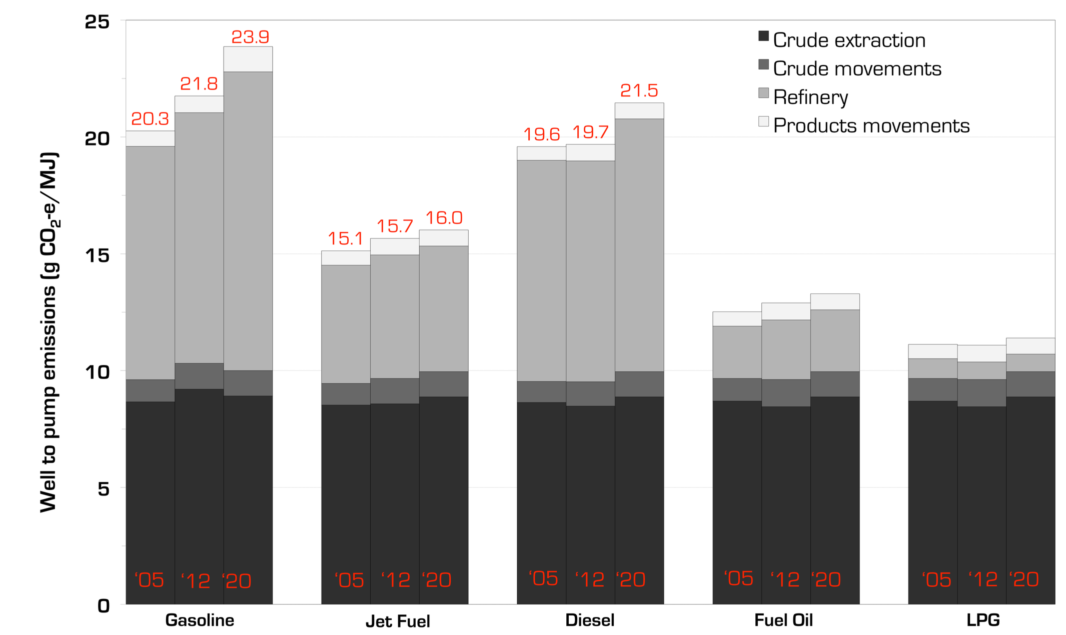

Figure 2: Global average well-to-pump GHG emissions (gCO_2e/MJ) of petroleum-derived jet fuel in 2005, 2012 and 2020, broken out by life cycle step. Other fuel types shown for comparison purposes.

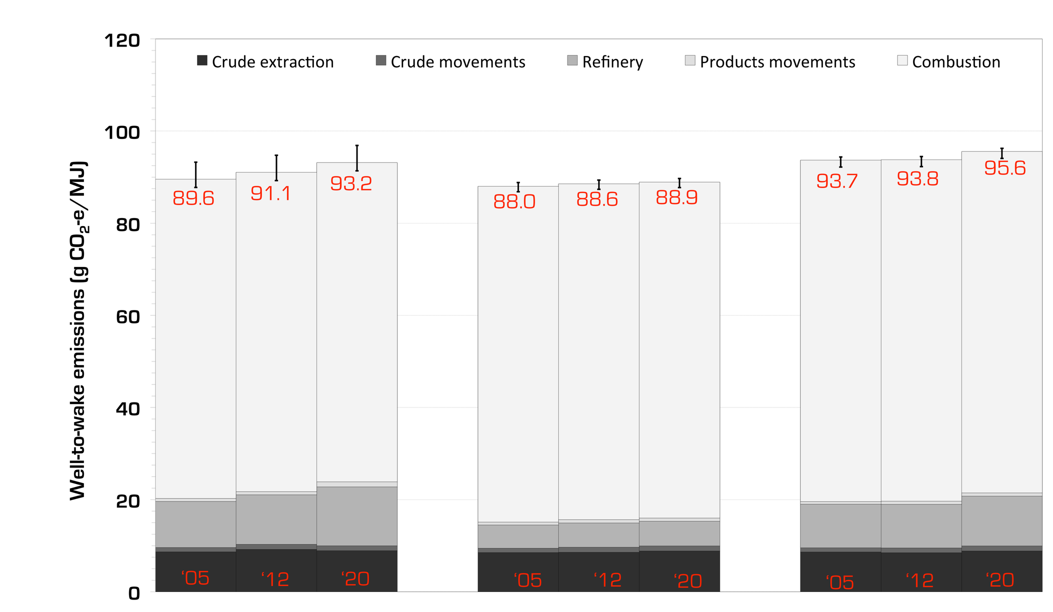

Figure 3: Global average well-to-wake GHG emissions (gCO_2e/MJ) of petroleum-derived jet fuel in 2005, 2012 and 2020, broken out by life cycle step. Other fuel types shown for comparison purposes. Uncertainty ranges due to variation in combustion emissions by unit of fuel.

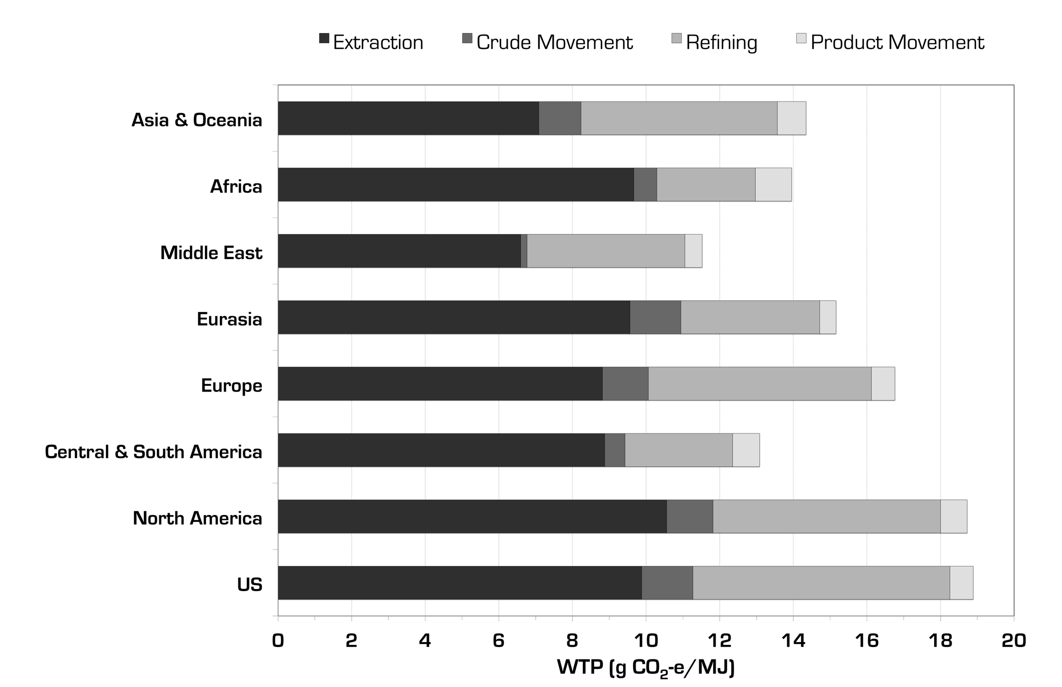

Figure 4: Average Well-to-pump GHG emissions (gCO_2e/MJ) of petroleum-derived jet fuel in 2012, by world region and broken out by life cycle step.

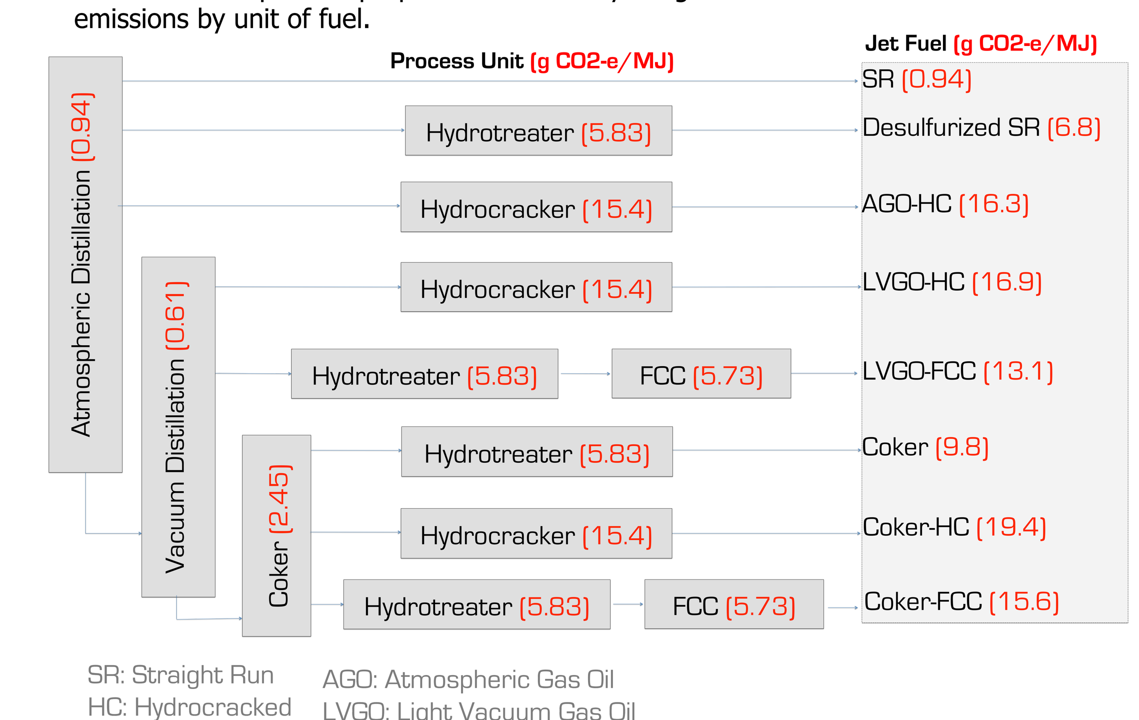

Figure 5: Contribution of primary and secondary processing emissions to refining emissions of petroleum-derived jet fuel (global average, for 2012).

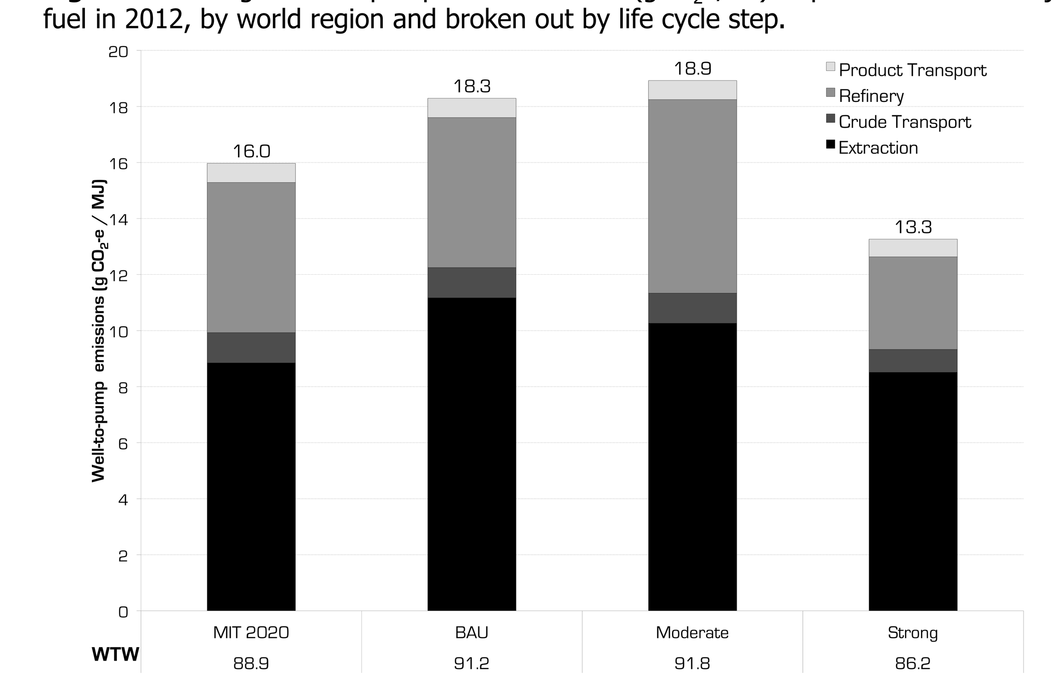

Figure 6: Global scenario-specific average well-to-pump and well-to-wake GHG emissions (gCO_2e/MJ) of petroleum-derived jet fuel in 2050, broken out by life cycle step

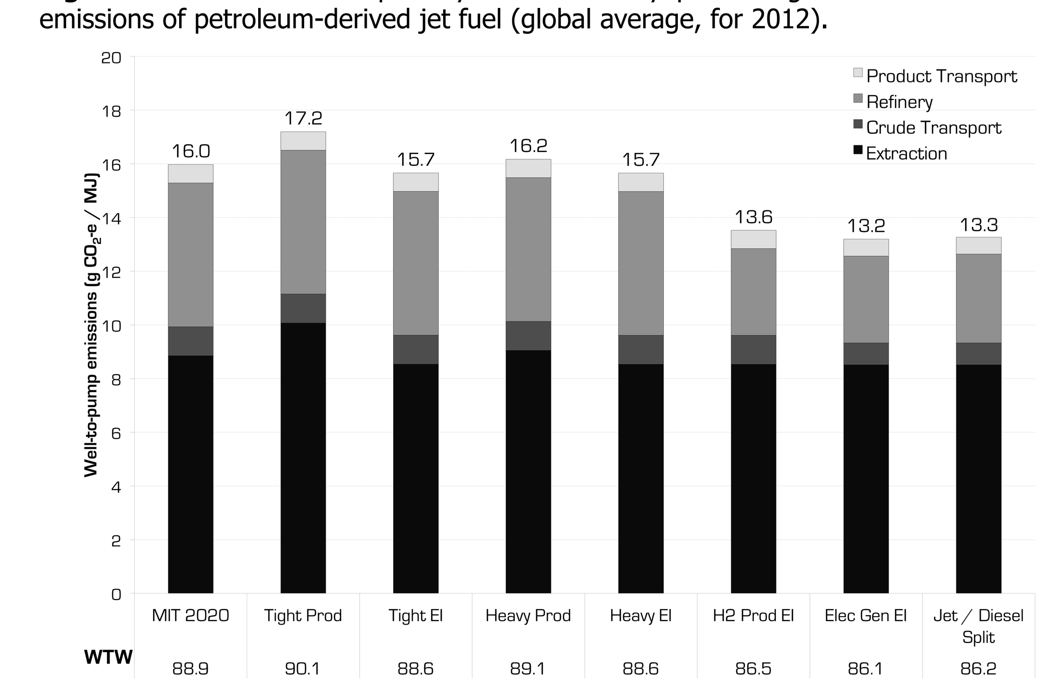

Figure 7: Development of well-to-pump life cycle emissions (gCO_2e/MJ) of petroleum-derived jet by scenario in 2050 for the strong policies scenario, broken out by contributing factor

Conclusions and Next Steps

Significant variability was found in the well-to-pump emissions of petroleum-derived jet fuel between world regions. Temporal variability could be identified as well, but is shown to be lower than world-region variability.

Next steps include the continuation of 2050 scenario analyses by adding resolution to the refining emission step and by including temporal variation in combustion emissions. In parallel, the research team will quantify opportunities for reduction in GHG emissions along the supply chain

Contributors to the project: Pooya Azadi, Cassandra Rosen, Raymond Speth, Steven Barrett and Robert Malina (all MIT)

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