Laboratory for Aviation and the Environment

Massachusetts Institute of Technology

Worldwide Lifecycle Analysis of Greenhouse Gas Emissions from Petroleum Fuels

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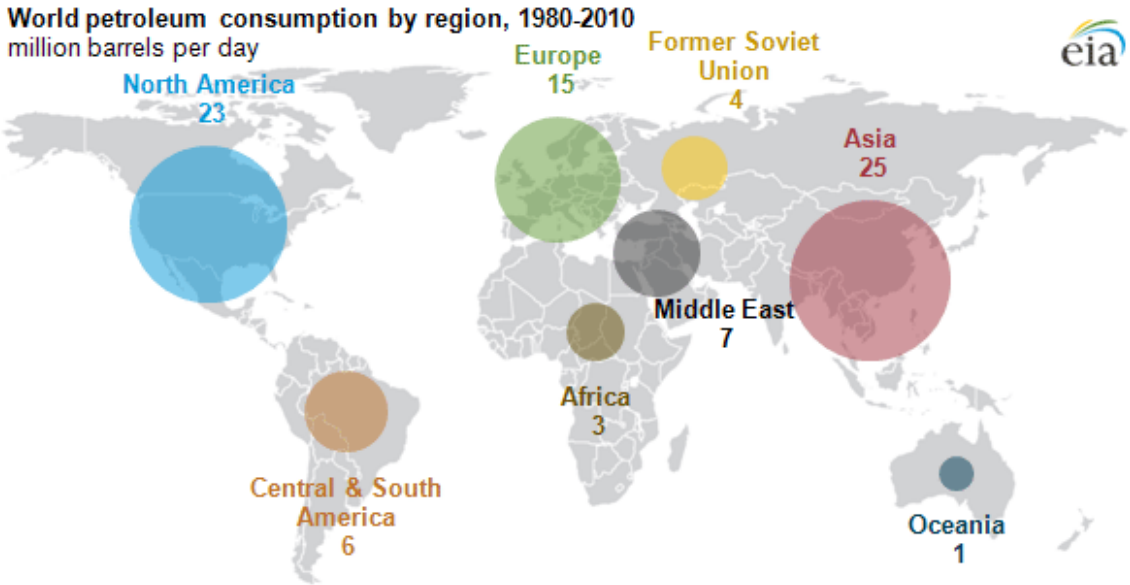
Objectives

- Estimate global and world-region specific lifecycle greenhouse gas emissions for petroleum-derived transportation fuels, with a particular focus on jet fuel

- **Temporal dimension:**
  - Retrospective analysis for 2005 and 2012
  - Near-term projection for 2020
  - Long-term scenarios for 2050

- **Spatial dimension:**
  - Global
  - World-regions – Energy Information Administration (EIA) definitions

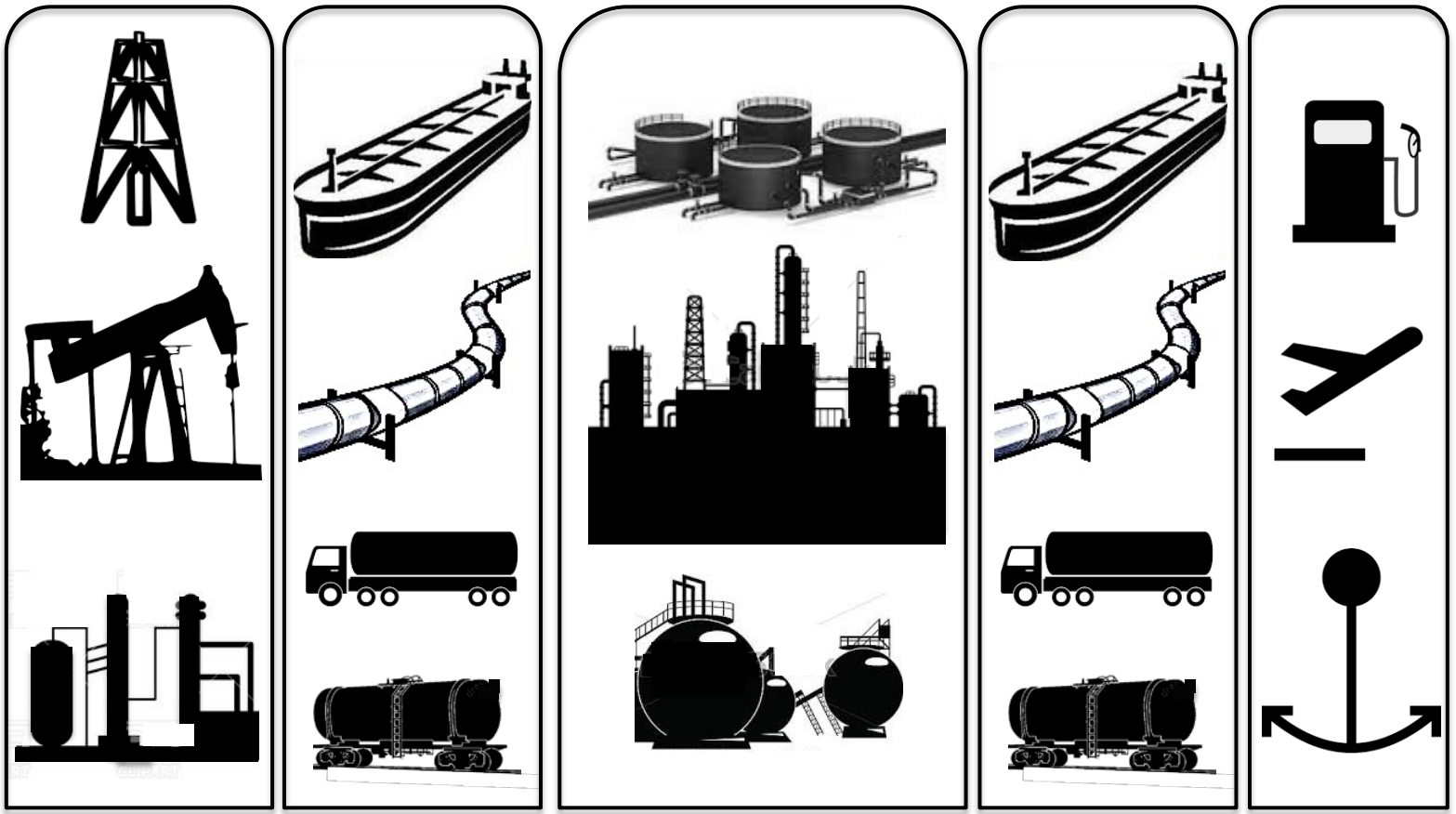


Oil Supply Chain

Well-to-Pump Emissions ?

~72 g CO_2/ MJ

Stage 1	Stage 2	STAGE 3	STAGE 4	STAGE 5
Extraction	Crude Movement	Refining	Products Movement	Combustion



Challenges

- Large number of (small) emissions across a wide range of activities
- Wide range of technologies used for the same task
- Wide geographical distribution:
  - Crude is produced in 91 countries
  - Refined products are produced in 112 countries
  - Refined products are used in 218 countries/ territories
- Scarcity, sparsity, and aggregation of data:
  - Well and reservoir characteristics
  - Crude grades produced/ consumed
  - Refinery intake streams and outputs
  - Variation in outputs of refinery units
  - Import/ export data of crude and refined products

Approach

- Data collection from many sources
- Estimation of missing data points based on regional or world averages when specific values are not available
- Categorization based on best practice
- Aggregation of data at country level
- Inferences based on material balances
- Uncertainty analysis

Emission Sources Included in LCA

1. Production

- ❑ **Drilling**
  - Prime movers
  - Hydraulic fracturing
- ❑ **Mining**
- ❑ **Artificial Lift**
  - Rod pumps
  - Gas lift
- ❑ **Surface Processing**
  - Heater/ treater
  - Crude stabilizer
  - Wastewater treatment
  - Water re-injection
  - Flaring, venting, fugitive
- ❑ **Enhanced Oil Recovery**
  - CO_2 flooding
  - Steam injection
  - Gas injection

2. Crude Movement

- ❑ **Transportation Mode**
  - Tankers
  - Pipeline
  - Rail
  - Trucks
  - Barge

3. Refining

- ❑ **Distillation**
  - Atmospheric
  - Vacuum
- ❑ **Reforming**
- ❑ **Hydrotreating**
- ❑ **Catalytic Cracking**
  - FCC
  - Hydrocracking
- ❑ **Thermal Cracking**
  - Vis breaking
  - Coking
- ❑ **Alkylation**
- ❑ **Isomerization**
- ❑ **Cogeneration**

4. Product Movement

- ❑ **Transportation Mode**
  - Tankers
  - Pipeline
  - Rail
  - Trucks
  - Barge

FCC: Fluid Catalytic Cracking
VOC: Volatile Organic Compounds

Additional factors: Land use change (vegetation & soil carbon), flaring & fugitive emissions, VOC emissions

Data Inventory

1. Production

- ❑ Crude & NGL production, consumption, trade
- ❑ Crude assays
- ❑ Type of oil fields (conventional/ heavy/ tight/ oil sands), by field
- ❑ Location of (major) oil fields,
- ❑ Number of active rigs
- ❑ Number, average depth of producing wells drilled
- ❑ Gas-to-oil and water-to-oil ratios, by country
- ❑ Gas flaring
- ❑ Enhanced oil recovery practices

2. Crude Movement

- ❑ Crude pipelines length and diameter
- ❑ Tanker fleet size and age distributions
- ❑ Intra-country movements of crude by rail, truck, and barge

3. Refining

- ❑ Refinery intake (crude, NGL, unfinished oils, oxygenates, additives)
- ❑ Refinery unit capacities
- ❑ Refined products slate, consumption, trade

4. Product Movement

- ❑ Refined products pipelines length and diameter
- ❑ Tanker fleet size and age distributions
- ❑ Intra-country movements of refined products by rail, truck, and barge

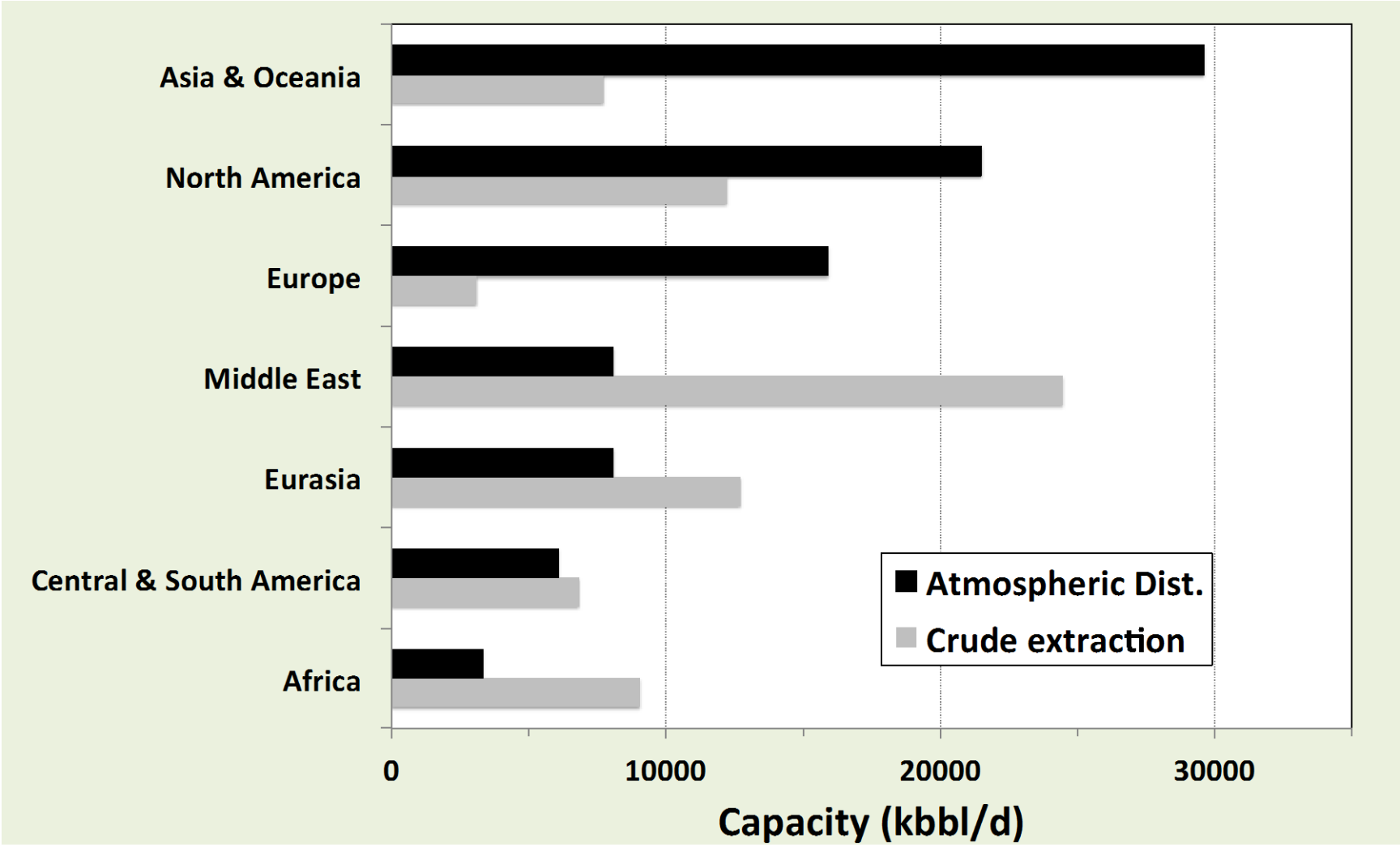
NGL: Natural Gas Liquids
EOR: Enhanced Oil Recovery

Emission factors for electricity, hydrogen, heat, steam, natural gas, and other fuels

Refinery Emissions: Methods

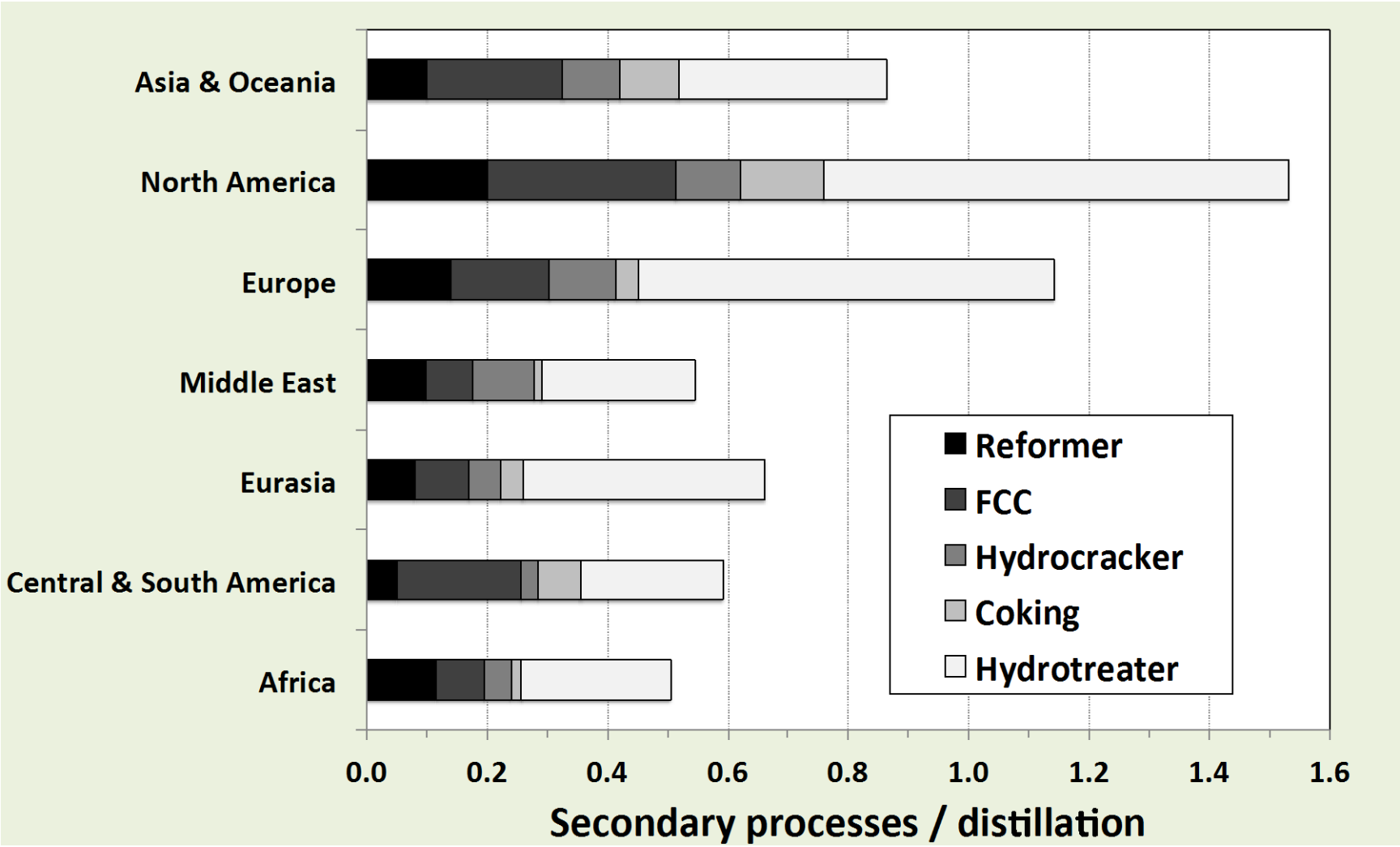
- Refinery by refinery process unit capacity data was collected and compiled from various sources (Global Data, BP, Oil & Gas Journal, OPEC, etc.).
- Data includes 18 process types in 687 refineries, corresponding to full coverage of the global refining capacity.
- The inputs to the model include:
  - Refinery by refinery unit capacities
  - Process unit heat, steam, electricity, and hydrogen consumption/ generation
  - Emission indices of utilities and hydrogen
  - Process unit output mix
  - Refinery utilization factors
  - Average refinery fuel use by each country
  - Crude grades refined in each country, based on production and import data
  - Country's product slate

Regional Distillation Capacities



Preliminary results – Please do not cite or quote.

Regional Secondary Process Capacities



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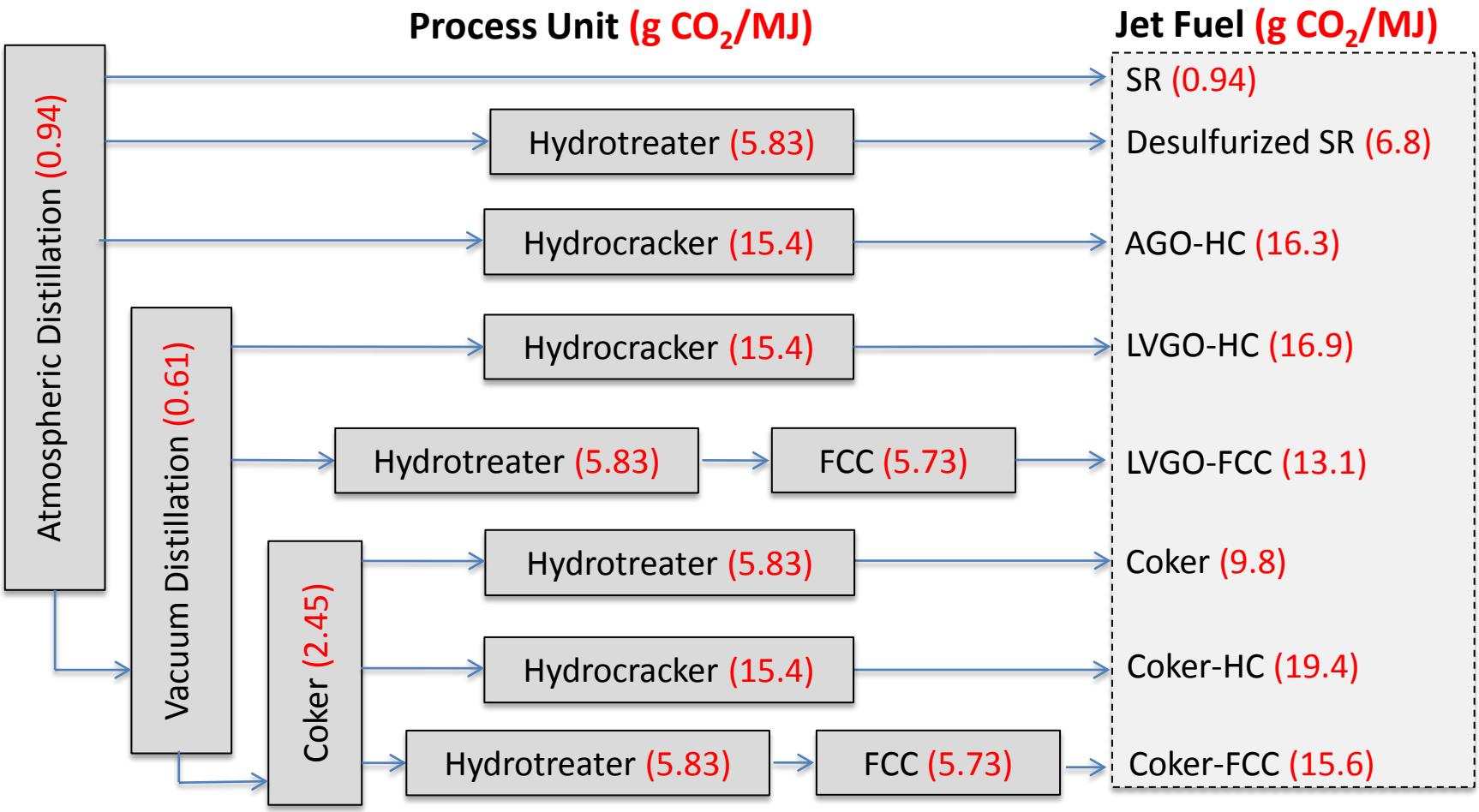
Example: Jet Fuel Production Pathways



SR: Straight Run
HC: Hydrocracked

AGO: Atmospheric Gas Oil
LVGO: Light Vacuum Gas Oil

Preliminary results – Please do not cite or quote.

Example: Jet Fuel Refinery Emissions

Emissions per unit throughput

Atmospheric Distillation (0.94)
Vacuum Distillation (0.61)
FCC (5.73)
Hydrocracker (15.4)
Hydrotreater (5.83)
Coker (2.45)
Flaring (0.09)
Co-generation (-0.55)

Values in (g CO_2/MJ)

× 0.11 Relative capacity

× 0.11 Kerosene output share

× 0.55 Jet/Kerosene ratio

÷ 0.08 Jet fuel product fraction

Emissions per unit jet fuel

Atmospheric Distillation (0.94)
Vacuum Distillation (0.30)
FCC (0.26)
Hydrocracker (1.28)
Hydrotreater (2.40)
Coker (0.13)
Flaring (0.09)
Co-generation (-0.55)

Jet Fuel (4.85 g CO_2/MJ)

Straight-Run & Cracked MD

Component	North America		Europe		World	
(mmbbl/ d)	SR	Cracked	SR	Cracked	SR	Cracked
Middle distillates	5.3	4.2	4.0	1.7	23.0	12.0
- Kerosene (intermediate)	2.4	0.5	1.8	0.2	10.5	1.5
- Jet fuel (product)	1.6		0.8		5.4	
- Kerosene (product)	0.0		0.2		1.5	

Straight-run (SR) middle distillate cuts:

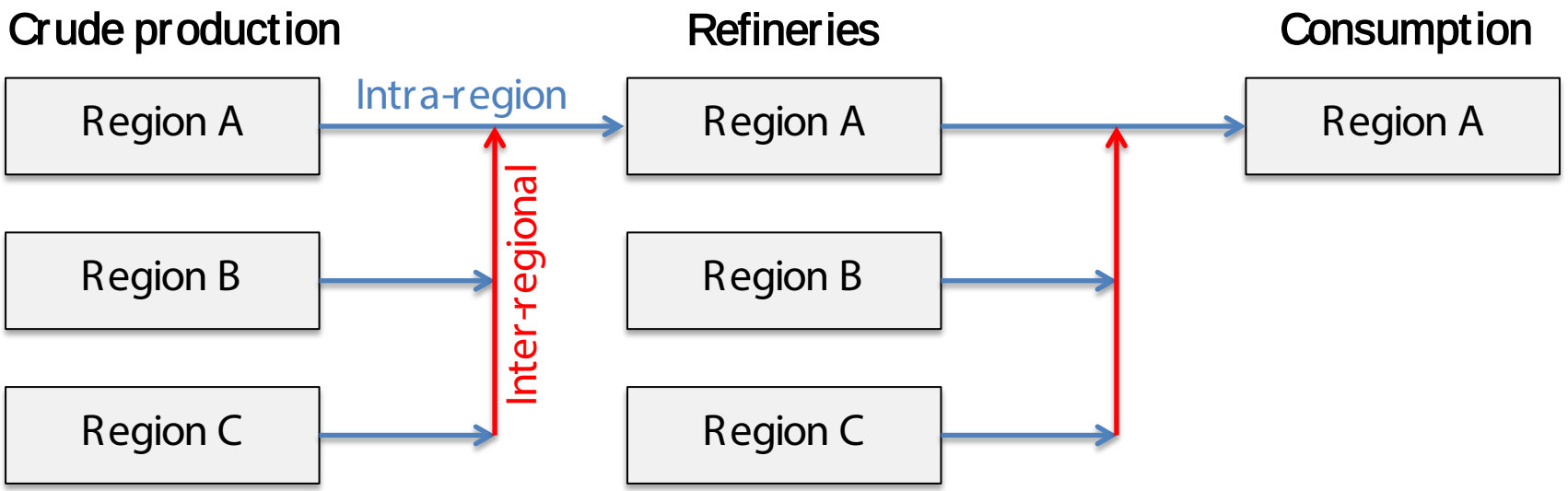
- Naphtha/ Kerosene swing
- Kerosene
- Kerosene/ Diesel swing
- Diesel
- Light VGO

Cracked middle distillate from:

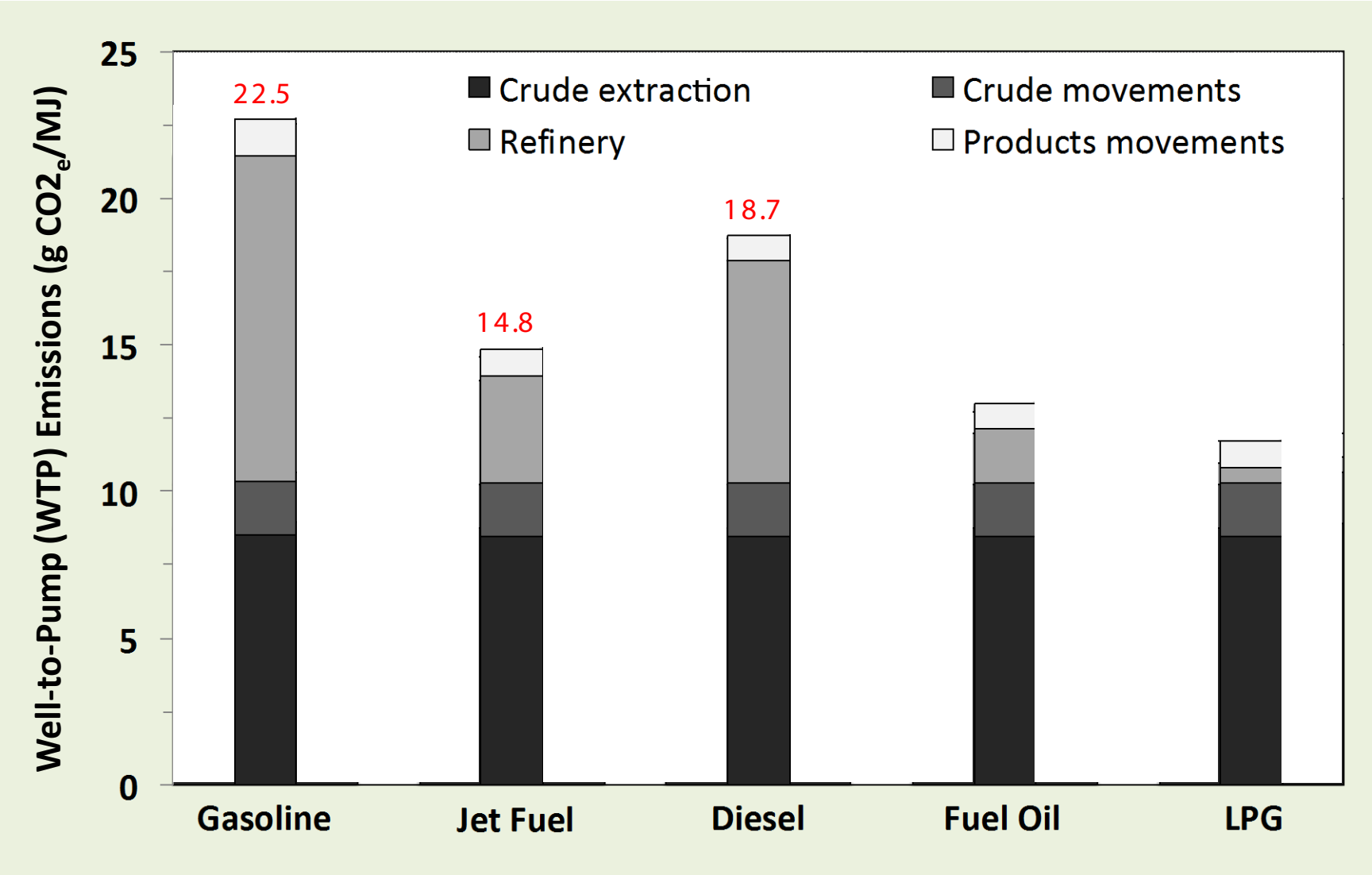
- FCC
- Hydrocracker
- Coking
- Visbreaker

Regional Material Balance

- Objective is to calculate the emission of petroleum fuels **consumed** at each world region.
- Follow EIA's definition of world regions, i.e. North America, Central and South America, Europe, Eurasia, Africa, Middle East, Asia and Oceania.



WTP Emissions by Product



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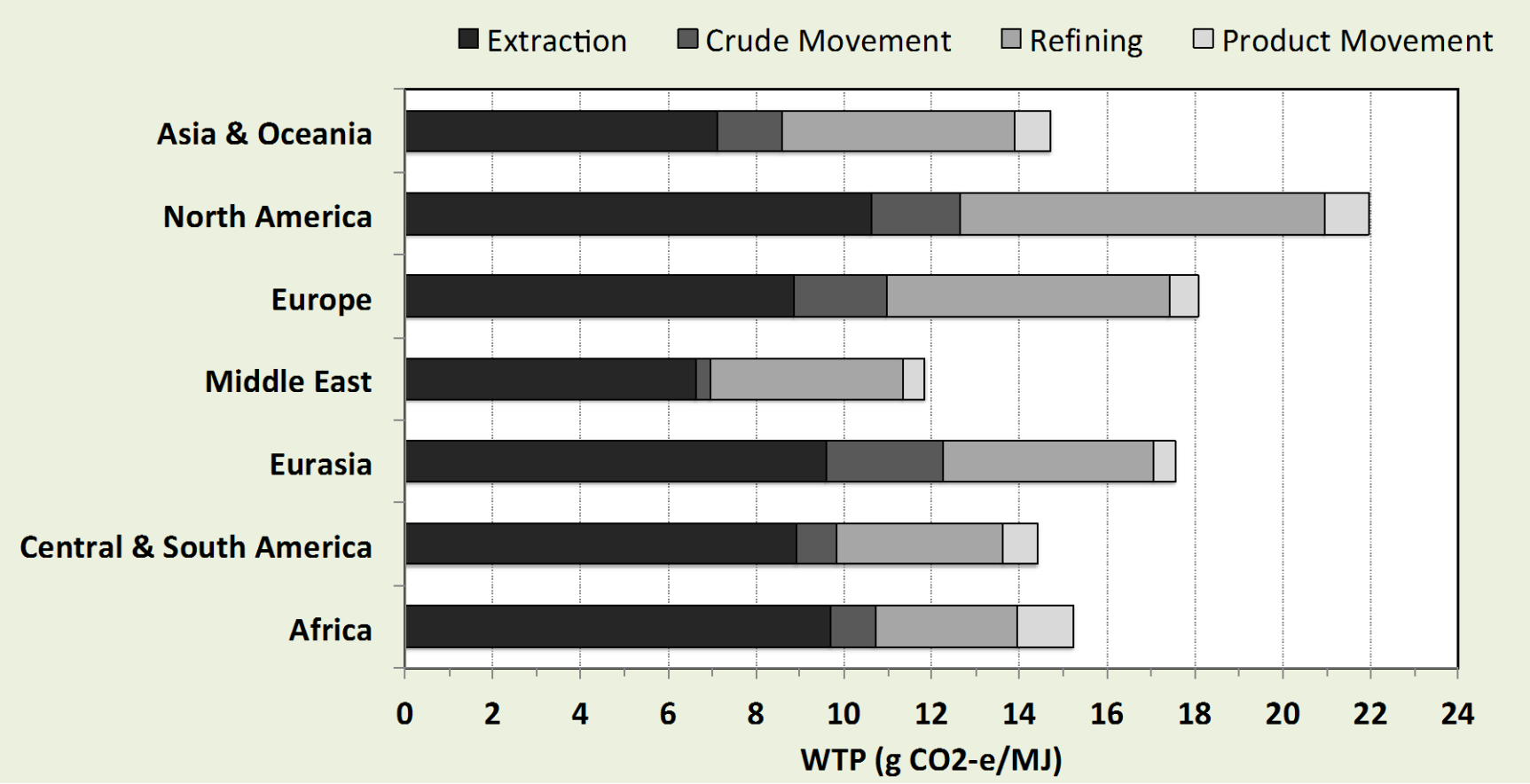
World Region-Specific Results

- WTP GHG emission of **Average Refinery Product** consumed in each region.



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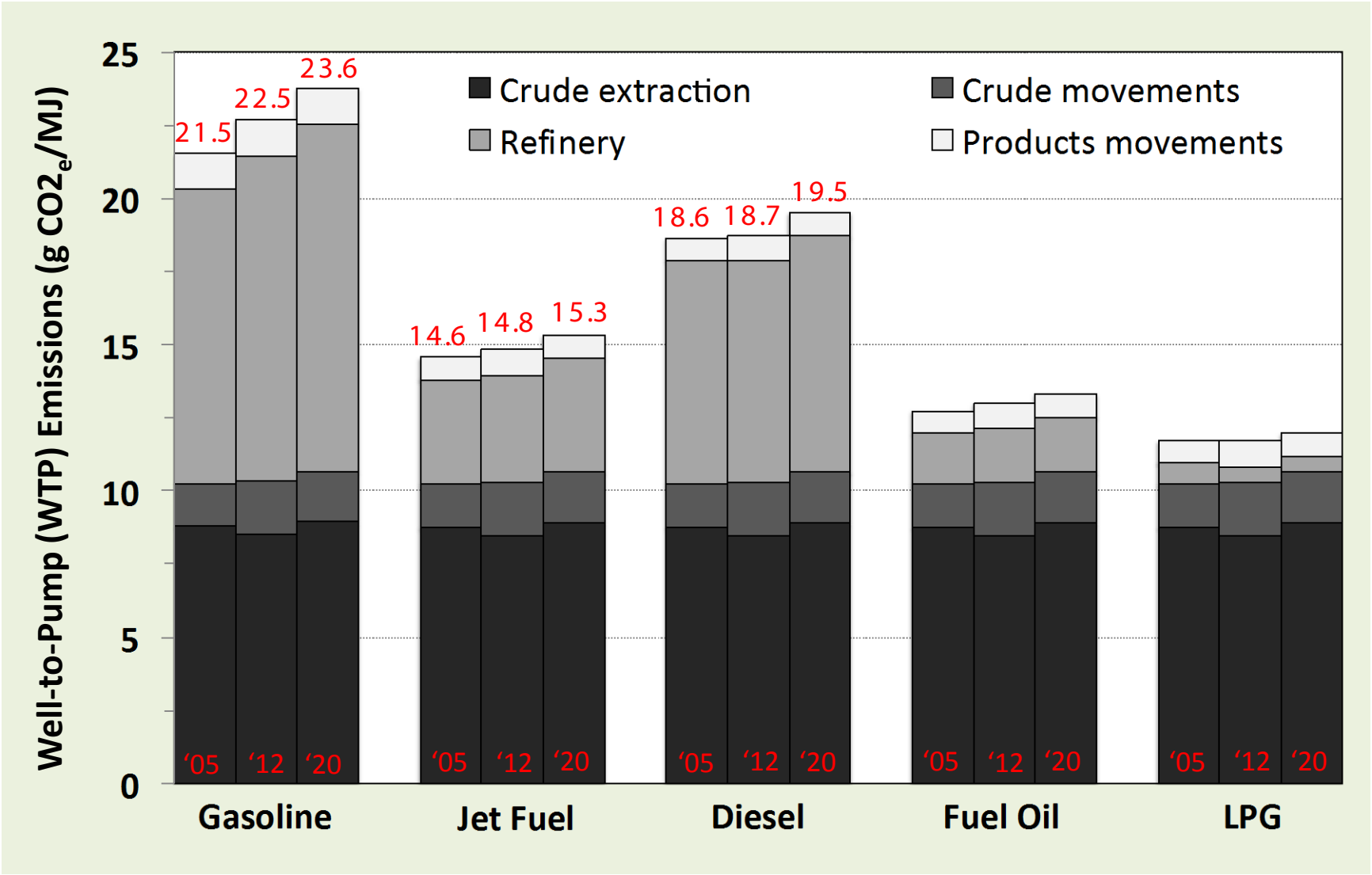
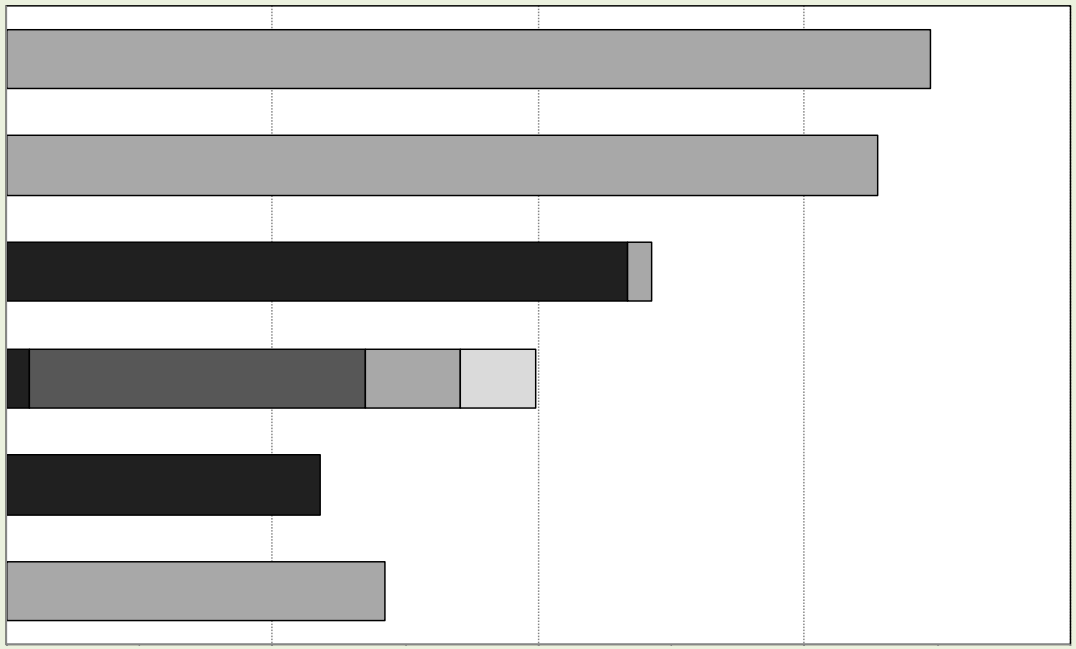
2005, 2012, and 2020 WTP Results



Preliminary results – Please do not cite or quote.

Sensitivity Analysis



Preliminary results – Please do not cite or quote.

Next Steps

- Product-specific uncertainty analysis
- Scenarios for global and word-region-specific emissions in 2050
- Opportunities for reductions of GHG emissions from petroleum-derived transportation fuels

Acknowledgments

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- Work presented may not represent the views of the FAA

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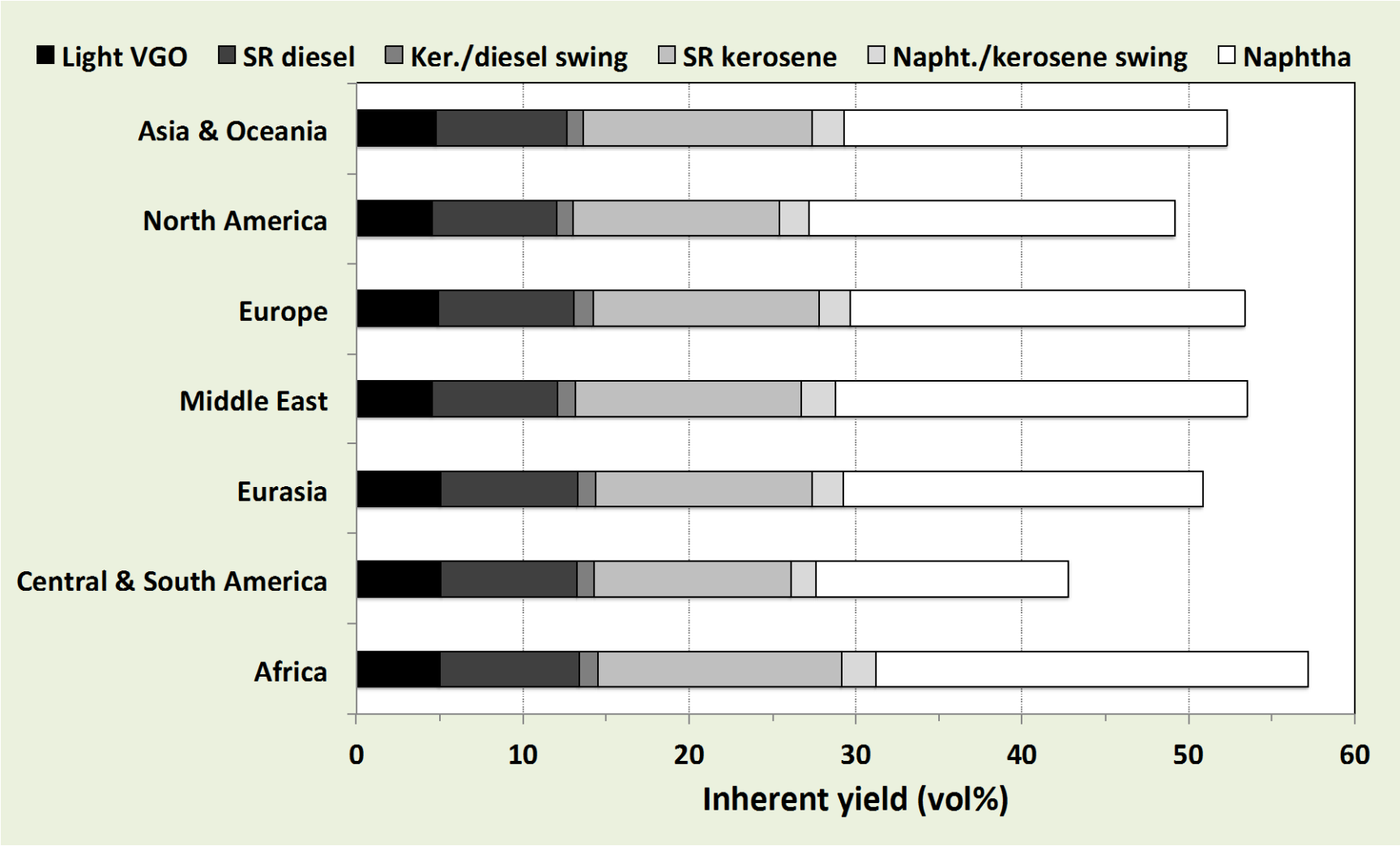
Glossary

- AGO: Atmospheric Gas Oil
- EOR: Enhanced Oil Recovery
- FCC: Fluid Catalytic Cracking
- HC: Hydrocracker
- LPG: Liquefied Petroleum Gas
- LVGO: Light Vacuum Gas Oil
- NGL: Natural Gas Liquids
- OGJ: Oil & Gas Journal
- OPEC: Organization of Petroleum Exporting Countries
- PTW: Pump to Wheels/ Wake
- SR: Straight Run
- VGO: Vacuum Gas Oil
- WTP: Well to Pump
- WTW: Well to Wheels/ Wake

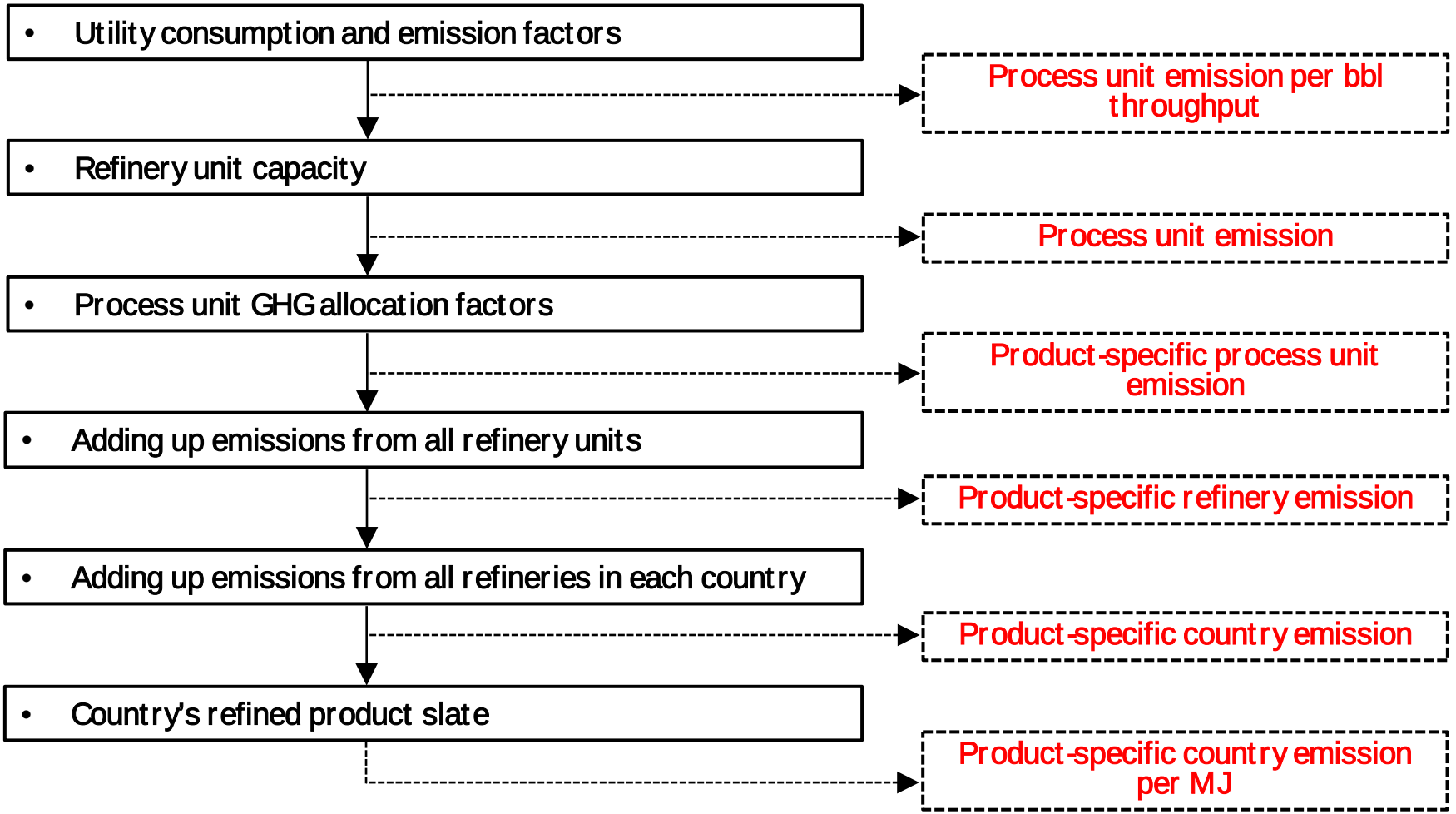
Regional Inherent Yields



Other cuts not shown here: gas, heavy VGO, vacuum residue.

Preliminary results – Please do not cite or quote.

Refinery Emission: Methods



2005

World Average (2005)		Emission Points	Product Allocation	Average WTP			Product-specific Emissions (g CO2-e/MJ)					
LCA stage	Subgroup			Tonne CO2-e/d	g CO2-e/MJ	Total	Gasoline	Jet fuel	Diesel	Fuel oil	LPG	Others
Crude extraction	Drilling	1	Product share	1.7E+04	0.04	8.71	0.04	0.04	0.04	0.04	0.04	0.04
	Land use change	2	Product share	2.7E+04	0.06		0.06	0.06	0.06	0.06	0.06	0.06
	Production	2	Product share	2.2E+05	0.51		0.51	0.51	0.51	0.51	0.51	0.51
	Surface processing	4	Product share	5.4E+05	1.24		1.24	1.24	1.24	1.24	1.24	1.24
	Flaring	2	Product share	1.3E+06	3.00		3.00	3.00	3.00	3.00	3.00	3.00
	Venting + Fugitive	3	Product share	1.4E+06	3.14		3.14	3.14	3.14	3.14	3.14	3.14
	EOR	3	Product share	1.9E+05	0.44		0.44	0.44	0.44	0.44	0.44	0.44
	Fracking + Horz. dril.	2	Product share	0.0E+00	0.00		0.00	0.00	0.00	0.00	0.00	0.00
	Oil sands	3	Product share	1.3E+05	0.29		0.29	0.29	0.29	0.29	0.29	0.29
Crude movements	Tankers	4	Product share	2.0E+05	0.45	1.46	0.45	0.45	0.45	0.45	0.45	0.45
	Pipeline	1	Product share	4.4E+05	1.00		1.00	1.00	1.00	1.00	1.00	1.00
	Inland water	1	Product share	5.4E+02	0.00		0.00	0.00	0.00	0.00	0.00	0.00
	Rail	1	Product share	1.7E+03	0.00		0.00	0.00	0.00	0.00	0.00	0.00
	Truck	1	Product share	3.4E+03	0.01		0.01	0.01	0.01	0.01	0.01	0.01
Refinery	Distillation	2	Product share	5.1E+05	1.17	6.23	1.17	1.17	1.17	1.17	0.95	1.17
	Hydrotreating	8	Unit-level	1.1E+06	2.52		3.11	1.79	4.09	0.83	0.00	0.64
	Cracking	2	Unit-level	9.7E+05	2.21		4.78	0.83	2.34	0.00	0.00	0.00
	Thermal Operations	2	Unit-level	8.4E+04	0.19		0.07	0.05	0.28	0.00	0.00	0.65
	Upgrading	3	Unit-level	3.7E+04	0.09		0.29	0.00	0.00	0.00	0.00	0.00
	Flaring + Fugitive	2	Product share, Unit-level	6.0E+04	0.14		0.09	0.08	0.08	0.08	0.11	0.49
	Co-generation	1	Product Share	-1.4E+05	-0.32		-0.32	-0.32	-0.32	-0.32	-0.32	-0.32
	NGL	1	Unit-level	1.1E+05	0.24		0.81	0.00	0.00	0.00	0.00	0.00
Products movements	Tankers	4	Product share, Unit-level	7.9E+04	0.18	0.88	0.21	0.17	0.17	0.17	0.17	0.17
	Pipeline	1	Product share	1.3E+05	0.29		0.29	0.29	0.29	0.29	0.29	0.29
	Truck	4	Product share, Unit-level	9.7E+04	0.22		0.30	0.19	0.19	0.19	0.19	0.19
	Rail	4	Product share, Unit-level	2.3E+04	0.05		0.07	0.04	0.04	0.04	0.04	0.04
	Inland water	4	Product share, Unit-level	3.2E+04	0.07		0.08	0.07	0.07	0.07	0.07	0.07
	Storage+Fill.+Refuel.	3	Product share	3.0E+04	0.07		0.22	0.00	0.00	0.00	0.11	0.00
Total		71			Subtotal before losses	17.3	21.4	14.5	18.6	12.7	11.8	13.6
					WTP Emission	**17.4**	**21.5**	**14.6**	**18.6**	**12.7**	**11.8**	**13.6**
					PTW	73.2	72.5	73.6	72.6	77.4	63.1	73.3
					WTW	**90.4**	**93.9**	**88.1**	**91.2**	**90.1**	**74.9**	**86.9**

2012

World Average (2012)		Emission Points	Product Allocation	Average WTP			Product-specific Emissions (g CO2-e/MJ)					
LCA stage	Subgroup			Tonne CO2-e/d	g CO2-e/MJ	Total	Gasoline	Jet fuel	Diesel	Fuel oil	LPG	Others
Crude extraction	Drilling	1	Product share	3.0E+04	0.07		0.07	0.07	0.07	0.07	0.07	0.07
	Land use change	2	Product share	4.5E+04	0.10		0.10	0.10	0.10	0.10	0.10	0.10
	Production	2	Product share	2.6E+05	0.58		0.58	0.58	0.58	0.58	0.58	0.58
	Surface processing	4	Product share	5.6E+05	1.24		1.24	1.24	1.24	1.24	1.24	1.24
	Flaring	2	Product share	1.1E+06	2.33	8.47	2.33	2.33	2.33	2.33	2.33	2.33
	Venting + Fugitive	3	Product share	1.4E+06	2.99		2.99	2.99	2.99	2.99	2.99	2.99
	EOR	3	Product share	2.2E+05	0.49		0.49	0.49	0.49	0.49	0.49	0.49
	Fracking + Horz. dril.	2	Product share	7.6E+04	0.17		0.17	0.17	0.17	0.17	0.17	0.17
	Oil sands	3	Product share	2.4E+05	0.52		0.52	0.52	0.52	0.52	0.52	0.52
Crude movements	Tankers	4	Product share	2.3E+05	0.52		0.52	0.52	0.52	0.52	0.52	0.52
	Pipeline	1	Product share	5.7E+05	1.26		1.26	1.26	1.26	1.26	1.26	1.26
	Inland water	1	Product share	5.6E+02	0.00	1.79	0.00	0.00	0.00	0.00	0.00	0.00
	Rail	1	Product share	1.9E+03	0.00		0.00	0.00	0.00	0.00	0.00	0.00
	Truck	1	Product share	4.6E+03	0.01		0.01	0.01	0.01	0.01	0.01	0.01
Refinery	Distillation	2	Product share	5.3E+05	1.17		1.17	1.17	1.17	1.17	0.96	1.17
	Hydrotreating	8	Unit-level	1.1E+06	2.50		2.95	1.77	3.75	1.12	0.00	0.62
	Cracking	2	Unit-level	1.2E+06	2.71		5.57	1.11	2.72	0.00	0.00	0.00
	Thermal Operations	2	Unit-level	1.1E+05	0.24	6.73	0.09	0.06	0.35	0.00	0.00	0.72
	Upgrading	3	Unit-level	4.7E+04	0.10		0.33	0.00	0.00	0.00	0.00	0.00
	Flaring + Fugitive	2	Product share, Unit-level	6.5E+04	0.14		0.09	0.09	0.09	0.09	0.12	0.50
	Co-generation	1	Product Share	-2.5E+05	-0.55		-0.55	-0.55	-0.55	-0.55	-0.55	-0.55
	NGL	1	Unit-level	1.9E+05	0.41		1.33	0.00	0.00	0.00	0.00	0.00
Products movements	Tankers	4	Product share, Unit-level	1.0E+05	0.23		0.27	0.22	0.22	0.22	0.22	0.22
	Pipeline	1	Product share	1.3E+05	0.28		0.28	0.28	0.28	0.28	0.28	0.28
	Truck	4	Product share, Unit-level	120446	0.27	0.99	0.34	0.23	0.23	0.23	0.23	0.23
	Rail	4	Product share, Unit-level	3.5E+04	0.08		0.10	0.07	0.07	0.07	0.07	0.07
	Inland water	4	Product share, Unit-level	3.3E+04	0.07		0.08	0.07	0.07	0.07	0.07	0.07
	Storage+Fill.+Refuel.	3	Product share	3.1E+04	0.07		0.21	0.00	0.00	0.00	0.11	0.00
	Total	71			Subtotal before losses	18.0	22.3	14.8	18.7	13.0	11.7	13.6
					WTP Emission	18.1	22.5	14.8	18.7	13.0	11.7	13.6
					PTW	73.0	72.5	73.6	72.6	77.4	63.1	73.3
					WTW	91.0	94.9	88.4	91.3	90.4	74.8	86.9

Preliminary results – Please do not cite or quote.

2020

World Average (2020)		Emission Points	Product Allocation	Average WTP			Product-specific Emissions (g CO2-e/MJ)					
LCA stage	Subgroup			Tonne CO2-e/d	g CO2-e/MJ	Total	Gasoline	Jet fuel	Diesel	Fuel oil	LPG	Others
Crude extraction	Drilling	1	Product share	3.3E+04	0.07		0.07	0.07	0.07	0.07	0.07	0.07
	Land use change	2	Product share	5.1E+04	0.10		0.10	0.10	0.10	0.10	0.10	0.10
	Production	2	Product share	3.0E+05	0.61		0.61	0.61	0.61	0.61	0.61	0.61
	Surface processing	4	Product share	6.1E+05	1.24		1.24	1.24	1.24	1.24	1.24	1.24
	Flaring	2	Product share	1.1E+06	2.14	8.89	2.14	2.14	2.14	2.14	2.14	2.14
	Venting + Fugitive	3	Product share	1.5E+06	3.04		3.04	3.04	3.04	3.04	3.04	3.04
	EOR	3	Product share	2.5E+05	0.52		0.52	0.52	0.52	0.52	0.52	0.52
	Fracking + Horz. dril.	2	Product share	1.9E+05	0.39		0.39	0.39	0.39	0.39	0.39	0.39
	Oil sands	3	Product share	3.8E+05	0.78		0.78	0.78	0.78	0.78	0.78	0.78
Crude movements	Tankers	4	Product share	2.2E+05	0.44		0.44	0.44	0.44	0.44	0.44	0.44
	Pipeline	1	Product share	6.1E+05	1.25		1.25	1.25	1.25	1.25	1.25	1.25
	Inland water	1	Product share	6.2E+02	0.00	1.70	0.00	0.00	0.00	0.00	0.00	0.00
	Rail	1	Product share	2.2E+03	0.00		0.00	0.00	0.00	0.00	0.00	0.00
	Truck	1	Product share	5.3E+03	0.01		0.01	0.01	0.01	0.01	0.01	0.01
Refinery	Distillation	2	Product share	5.7E+05	1.17		1.17	1.17	1.17	1.17	0.96	1.17
	Hydrotreating	8	Unit-level	1.3E+06	2.63		3.10	1.86	3.94	1.17	0.00	0.65
	Cracking	2	Unit-level	1.5E+06	3.02		6.21	1.24	3.04	0.00	0.00	0.00
	Thermal Operations	2	Unit-level	1.2E+05	0.24	7.17	0.09	0.06	0.35	0.00	0.00	0.72
	Upgrading	3	Unit-level	5.1E+04	0.10		0.33	0.00	0.00	0.00	0.00	0.00
	Flaring + Fugitive	2	Product share, Unit-level	7.1E+04	0.14		0.09	0.09	0.09	0.09	0.12	0.50
	Co-generation	1	Product Share	-2.7E+05	-0.55		-0.55	-0.55	-0.55	-0.55	-0.55	-0.55
	NGL	1	Unit-level	2.0E+05	0.41		1.33	0.00	0.00	0.00	0.00	0.00
Products movements	Tankers	4	Product share, Unit-level	1.1E+05	0.23		0.28	0.22	0.22	0.22	0.22	0.22
	Pipeline	1	Product share	1.3E+05	0.25		0.25	0.25	0.25	0.25	0.25	0.25
	Truck	4	Product share, Unit-level	110898	0.23	0.91	0.29	0.20	0.20	0.20	0.20	0.20
	Rail	4	Product share, Unit-level	3.3E+04	0.07		0.08	0.06	0.06	0.06	0.06	0.06
	Inland water	4	Product share, Unit-level	3.3E+04	0.07		0.07	0.06	0.06	0.06	0.06	0.06
	Storage+Fill.+Refuel.	3	Product share	3.1E+04	0.06		0.19	0.00	0.00	0.00	0.10	0.00
	Total	71			Subtotal before losses	18.7	23.4	15.3	19.4	13.3	11.9	13.9
					WTP Emission	18.8	23.6	15.3	19.5	13.3	12.0	13.9
					PTW	73.0	72.5	73.6	72.6	77.4	63.1	73.3
					WTW	91.7	95.9	88.8	92.1	90.7	75.0	87.2

Preliminary results – Please do not cite or quote.

Refinery Emissions per barrel

- Steam, heat, electricity, and hydrogen consumption of common refinery process units are obtained from literature.
- Then, the emission of each process unit per barrel input is calculated using emission indices of utilities and hydrogen.
- Total emission from each refinery process unit is obtained by multiplying unit emission by unit capacity and refinery overall utilization factor.

Sample calculation of process unit GHG emission per bbl throughput

Unit	Steam (MJ/ bbl)	Electricity (MJ/ bbl)	Heat (MJ/ bbl)	Hydrogen (MJ/ bbl)	CO_2 (kg/ bbl)
P_1	16.2	3.2	52.8		6.2
P_2	122.2	46.8	189.6	575	92.1
P_3		3.6	211		18.5

Refinery Emission Allocation Factors

- Emissions / credits at process unit level are allocated to different products based on the ultimate use of the output mix from that unit.
- The basis for the GHG allocation can be energy content, volume, mass, or economic value of the products.
- Inherent yields from crude assays are used to estimate straight-run yields and make adjustment for the final product slate.

Sample GHG allocation factors based on unit output mix

Unit	Gasoline	Jet fuel	Diesel	Fuel oil	LPG	Others
a_1	Relative to final product slate					
a_2	10%	5%	45%		10%	30%
a_3	100%					

Stage 3: Product Allocation Factors

Unit	Gasoline	Jet fuel	Diesel	Residual fuel oil	Others
Atm. distillation	Relative to final product slate				
Vac. distillation	Relative to product slate from atm. residue				
Catalytic cracking	71%	2%	27%		
Reforming	100%				
Coking	12%	5%	50%		33%
Hydrocracking	58%	11%	31%		
Alkylation	100%				
Isomerization	100%				
Hydrotreating					
Naphtha	100%				
Kerosene		100%			
Diesel			100%		
VGO	71%	2%	27%		

Values are from NETL (2008), Petroleum Refining by Gary et al., and AFPM (2014)

Preliminary results – Please do not cite or quote.

Commercial Crudes

- Production volume and properties of commercial crudes produced by each country are needed to calculate the properties of crude produced (and consumed) within each region.

- Current database include production volume, density (API) , and sulfur content of 187 commercial crudes, covering ~90% of global production.

Country	Crude Name	API Gravity	Sulfur %	Volume (kbbl/d)	Average API	Average S%
UAE	Abu Bukhoosh	31.5	1.9	30	37.3	1.15
	Zakum	40.2	1.01	250		
	Murban	39.6	0.73	1,200		
	Umm Shaif	36.5	1.39	300		
	Upper Zakum	32.9	1.78	550		
	Dubai	30.4	2.13	90		
Algeria	Algerian Condensate	63.3	0.01	445	49.9	0.08
	Saharan Blend	45.7	0.1	1,350		
	Zarzaitine	42.8	0.06	30		
Angola	Cabinda	32.5	0.13	270	30.3	0.37
	Dalia	22.6	0.49	250		
	Girassol	30.8	0.34	250		
	Hungo	27.8	0.65	250		
	Kissanje Blend	30.5	0.38	250		
	Kuito	19	0.68	57		
	Nemba	39.9	0.2	140		
	Palanca Blend	37	0.21	125		
	Xikomba	34.4	0.41	70		
Argentina	Medanito	34.9	0.48	260	34.9	0.48
Australia East Timor	Bayu Undan	55.9	0.07	56	55.9	0.07
Australia	Cossack	47.7	0.05	107	48.2	0.27
	Enfield	21.7	0.13	40		
	Gippsland	48.7	0.91	80		
	Northwest Shelf Conden	61.2	0.01	82		
Azerbaijan	Azeri (BTC)	34.8	0.15	400	35.6	0.14
	Azeri Light	34.9	0.15	200		
	Shah Deniz Condensate	47	0.03	40		

Inherent Yields of Commercial Crudes

- Crude assays were obtained from Aspen PIMS library.

Country	Crude Name	API Gravity	Sulfur %	Volume (kbbl/d)	Average API	Average S%
UAE	Abu Bukhoosh	31.5	1.9	30	37.3	1.15
	Zakum	40.2	1.01	250		
	Murban	39.6	0.73	1,200		
	Umm Shaif	36.5	1.39	300		
	Upper Zakum	32.9	1.78	550		
	Dubai	30.4	2.13	90		

cont. →

Gas (IBP - 30C)	Light Naphtha (30 - 93.3C)	Heavy Naphtha (93.3 - 193.3C)	Whole Naphtha (30 - 193.3C)	Naph/Ker Swing (193.3 - 204.4C)	Kerosene (204.4 - 282.2C)
3.96	6.11	18.26	24.37	2.09	14.19
0.05	4.50	30.93	35.43	2.53	12.43
0.01	3.55	33.38	36.93	3.15	17.12
0.00	10.14	20.63	30.77	2.16	14.56
3.37	6.47	16.33	22.80	1.78	13.61

cont. →

Ker/Diesel Swing (282.2 - 287.8C)	Diesel (287.8 - 332.2C)	Atmospheric Res. (332.2C - FBP)	Light Vac GO (332.2 - 360C)	Heavy Vac GO (360 - 565.5C)	Vac Redisue (565.5C - FBP)
1.00	8.00	46.39	4.94	28.14	13.30
1.05	10.01	38.49	5.19	24.29	9.01
2.11	8.01	32.67	4.37	22.55	5.74
0.63	8.35	43.52	4.62	27.81	11.09
1.10	8.82	48.53	5.48	31.05	12.01

weighted average → Country-specific yields → weighted average → Region-specific yields

Comparison with NETL

	NETL	MIT	Unit
Origin	US refineries+ Virgin Island+ Imports	Global refineries	
NGL emissions	All products based on vol. share	Only to gasoline	
Reformer emission/credit allocation	Reformer emission is on produced H2	Refomer emission & credit is on gasoline	N/A
Electricity emission	211	225	g CO2/MJ
Hydrogen emission	74	99	g CO2/MJ
Average Refinery fuel emission	78	68	g CO2/MJ
NGL WTP emission	1.9	17.2	g CO2/MJ