

GREET Model Expansion for Well-to-Wheels Analysis of Heavy-Duty Vehicles

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HDVs represent a wide range of Gross Vehicle Weight Rating (GVWR)

Gross Vehicle Weight Rating: The maximum operating weight/mass of a vehicle

Gross Vehicle Weight Rating (lbs)									
	6,000	8,500	10,000	14,000	16,000	19,500	26,000	33,000	60,000
Federal	LDV		MDPV	-	-	-	-	-	-
	LDT		HDV / HDE						
	LLDT	HLDT	LHDDE			MHDDE		HHDDE / Urban Bus	
	LDT 1 & 2 ^a	LDT 3 & 4 ^b	HDV2b	HDV3	HDV4	HDV5	HDV6	HDV7	HDV8a HDV8b

GREET
incorporated

HDVs

U.S. EPA

Why do we study HDVs?

- 2nd largest and fastest growing share of transportation energy demand
 - **23%** of total energy use of the U.S. transportation sector
- 2nd largest source of transportation GHG emissions
 - **23%** of total GHG emissions of the U.S. transportation sector
- HDVs remain an important source of NO_x and PM
 - **20%** and **6%** of total U.S. **NO_x** and **PM** emissions in 2011



New GREET HDV module developed to evaluate the AFVs' potential to reduce fuel use, GHGs, & air pollutants

- **12 HDV subcategories included to cover diverse U.S. HDV market**
 - Class 2b to Class 8b trucks and buses
 - Targeted the key vehicle type for each HDV subcategory
- **11 alternative fuels & powertrain technologies examined**
 - Biodiesel, CNG, LNG, electric hybrids, hydraulic hybrids, battery electric, DME, LPG, ethanol, renewable diesel, renewable gasoline
- **Energy use, GHG emissions, criteria air pollutants, and water use evaluated, for HDVs covering MY 1990 to MY 2020**
 - Per mile and per ton-mile WTW results are available for trucks
 - Per mile and per passenger-mile WTW results are available for buses
- **It is now available in the Excel GREET, and will become available in the .net platform next year**



Selection of highest-fuel-consuming HDV subcategories

Engine Fuel	Regulatory Category	Vehicle Subcategory	Vehicle Type	Fuel Consumption
Diesel	Combination trucks	Combination long-haul	Van, Class 8b	36.1%
		Combination short-haul	Van, Class 8b	6.9%
	HD pickups and vans	—	Pickup, Mini & Light Van, SUV, Class 2b	1.7%
	Vocational vehicles	Heavy heavy-duty vocational vehicles	Dump <=50 mi, Class 8b	1.3%
		Medium heavy-duty vocational vehicles	Van, Class 6	2.6%
		Light heavy-duty vocational vehicles	Van, Class 4	0.7%
		Refuse trucks	Trash/Garbage/Recycling, Class 8a	1.3%
Gasoline	HD pickups and vans	—	Pickup, Mini & Light Van, SUV, Class 2b	3.2%
	Vocational vehicles	Medium heavy-duty vocational vehicles	Van, Class 6	0.5%

Body Types and Vocational Purposes Vary

Class 8b LH combination



Class 8a refuse truck



Class 8b dump truck



Class 6 delivery truck



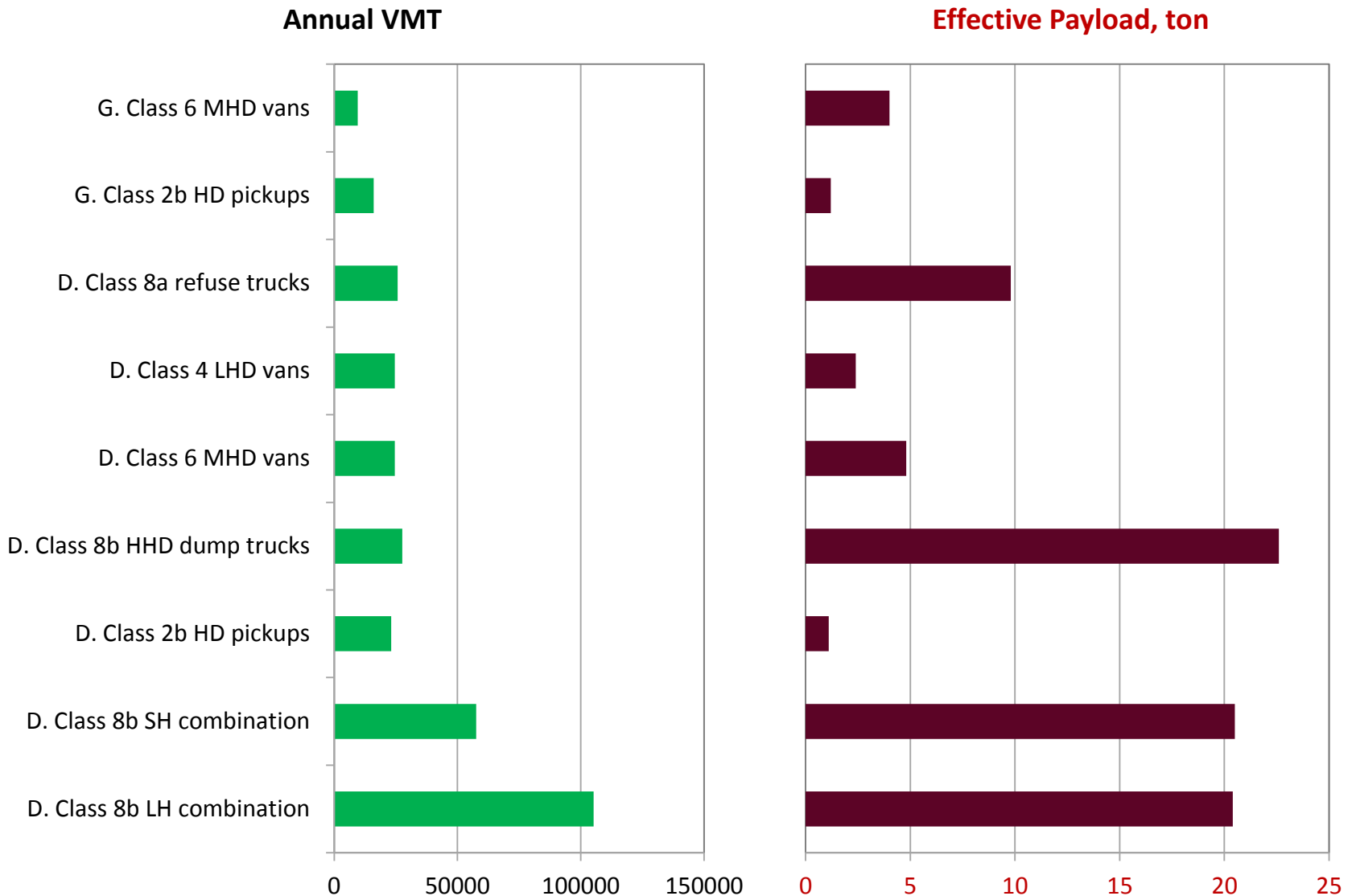
Class 4 delivery truck



Class 2b HD pickup truck



Very different use intensities and work performed



School buses, transit buses, and intercity buses are included



National Renewable Energy Laboratory, 2014; U.S. Department of Energy, 2013; Shutterstock, 2013

GREET HDV module: Now and future

	BD	EtOH	CNG	LPG	LNG, SI	LNG, DPI	DME	HHV	HEV	BEV	PHEV	FCV
D. Class 8b LH Combination												
D. Class 8b SH Combination												
D. HD pickups and vans												
D. HHD trucks												
D. MHD trucks												
D. LHD trucks												
D. Refuse trucks												
G. HD pickups and vans												
G. MHD trucks												
School buses												
Transit buses												
Intercity buses												



Included, high
fidelity



Included,
good fidelity



To be
considered

Features and Functionalities of GREET HDV module

- **Well-to-Wheels energy consumption, GHG emissions, criteria air pollutants emissions, and water consumption of 12 HDV types**
 - Energy consumption includes fossil energy and its breakdown into coal, NG and petroleum use
 - GHG emissions, including short-lived climate forcers, e.g. black carbon
 - Six criteria air pollutants: NO_x , PM_{10} , $\text{PM}_{2.5}$, SO_2 , CO, and VOC
 - Water consumption associated with fuel cycles
- **Energy-saving and emission-reduction potentials of major AFV technologies and applications in the heavy-duty vehicle sector can be evaluated**
- **Functional units include per mile, per ton-mile, per passenger-mile**
 - Cargo payload is set as an individual parameter to account for actual work performed
- **Vehicle model year-specific results, ranging from MY1990 to MY2020, to allow for evaluation of the effect of vehicle technology advancement on various environmental metrics**



The GREET HDV Module User Interface

GREET1_2015.xlsm - Microsoft Excel

File Home Insert Page Layout Formulas Data Review View

RSESelect_HDV_Su... Select Heavy-Duty Vehicle Subcategory

Home WTW Results Menu Select a vehicle type from a pink drop down menu, then press "Go"

Inputs Heavy-Duty Vehicles Select Heavy-Duty Vehicle Subcategory Go

Back to Top Select Fuels and Vehicle Technologies

WTW Results Unit Selection: Select units from a pink drop down menu for the Results

WTW Changes Per Vehicle Distance Travelled or Cargo Distance Transported Per Energy in Fuels

Energy Unit: Btu Emission Unit: g Service Functional Unit for Heavy-Duty Vans and Trucks: mile Energy Unit: Btu Emission Unit: g Service Functional Unit for Buses: mile Energy Functional Unit: mmBtu

Per Vehicle Distance Travelled

Energy Unit	Btu	mBtu	J	kJ
	1.000	0.001	1055	1.055
Emission Unit	g	mg	kg	lb
	1.000	1000	0.001	0.002
Functional Unit	mile	km		
	1.000	1.609		

Well-to-Wheels Energy Consumption, Water Consumption, and Emissions of Heavy-Duty Vehicles
CIDI Combination Long-Haul Trucks: Conventional and LS Diesel

Item	Btu/mile or Gallon/mile or g/mile				Btu/mmBtu or Gallon/mmBtu or g/mmBtu			
	Feedstock	Fuel	Vehicle Operation	Total	Feedstock	Fuel	Vehicle Operation	Total
Total Energy	1,361	2,076	16,817	20,254	80,954	123,446	1,000,000	1,204,400
Fossil Fuels	1,294	2,046	16,817	20,157	76,976	121,672	1,000,000	1,198,648
Coal	191	88	0	279	11,373	5,222	0	16,595
Natural Gas	858	1,336	0	2,194	50,998	79,440	0	130,439
Petroleum	246	622	16,817	17,685	14,604	37,010	1,000,000	1,051,614
Water Consumption	0	0	0	0	19	11	0	30
CO2 (w/ C in VOC & CO)	103	133	1,329	1,565	6,139	7,919	79,016	93,074
CH4	1	0	0	1.776	68.619	16.451	20.524	105.595
N2O	0	0	0	0.006	0.111	0.152	0.122	0.385
GHGs	138	142	1,340	1,620	8,227	8,453	79,664	96,344
VOC: Total	0.064	0.068	0.413	0.544	3.785	4.034	24.545	32.364
CO: Total	0.136	0.093	1.424	1.652	8.070	5.506	84.682	98.258
NOx: Total	0.243	0.161	3.485	3.890	14.472	9.603	207.264	231.339
PM10: Total	0.015	0.014	0.117	0.146	0.867	0.860	6.974	8.700
PM2.5: Total	0.011	0.011	0.057	0.080	0.677	0.657	3.396	4.730
SOx: Total	0.099	0.135	0.009	0.243	5.869	8.033	0.545	14.446
BC Total	0.002	0.001	0.007	0.010	0.111	0.060	0.418	0.589
OC Total	0.004	0.002	0.012	0.018	0.244	0.146	0.687	1.077
VOC: Urban	0.011	0.039	0.177	0.228	0.665	2.343	10.554	13.562
CO: Urban	0.005	0.038	0.612	0.655	0.303	2.249	36.413	38.965
NOx: Urban	0.011	0.068	1.499	1.579	0.683	4.068	89.124	93.874
PM10: Urban	0.001	0.007	0.050	0.059	0.065	0.439	2.999	3.502
PM2.5: Urban	0.001	0.006	0.025	0.031	0.040	0.330	1.460	1.831
SOx: Urban	0.016	0.078	0.004	0.098	0.952	4.639	0.234	5.825
BC: Urban	0.000	0.000	0.003	0.004	0.005	0.029	0.180	0.214
OC: Urban	0.000	0.001	0.005	0.006	0.013	0.076	0.295	0.384

Select Heavy-Duty Select Fuels and Vehic

Combination Long-Hi Combination_Long_Haul_
Combination Short-H Combination_Short_Haul_
Heavy Heavy-Duty \ Heavy_Heavy_Duty_Voc
Medium Heavy-Duty Medium_Heavy_Duty_Vo
Light Heavy-Duty Vc Light_Heavy_Duty_Vocal
Heavy-Duty Pick-Up Heavy_Duty_Pick_Up_Tr
Heavy-Duty Pick-Up Heavy_Duty_Pick_Up_Tr
Medium Heavy-Duty Medium_Heavy_Duty_Vo
Refuse Trucks Refuse_Trucks
School Buses School_Buses
Transit Buses Transit_Buses
Intercity Buses Intercity_Buses

Select Fuels and Vehicle Technologies

CIDI Vehicle: Diesel RNAV_LHT_CIDI_Diesel
SI Vehicle: CNG RNAV_LHT_SI_CNG
SI Vehicle: LNG RNAV_LHT_SI_LNG
CIDI Vehicle: Biodies RNAV_LHT_CIDI_BD
CIDI Vehicle: Renew RNAV_LHT_CIDI_RD
CIDI Vehicle: DME RNAV_LHT_CIDI_DME
CIDI Vehicle: LNG w RNAV_LHT_CIDI_LNG

Select Fuels and Vehicle Technologies

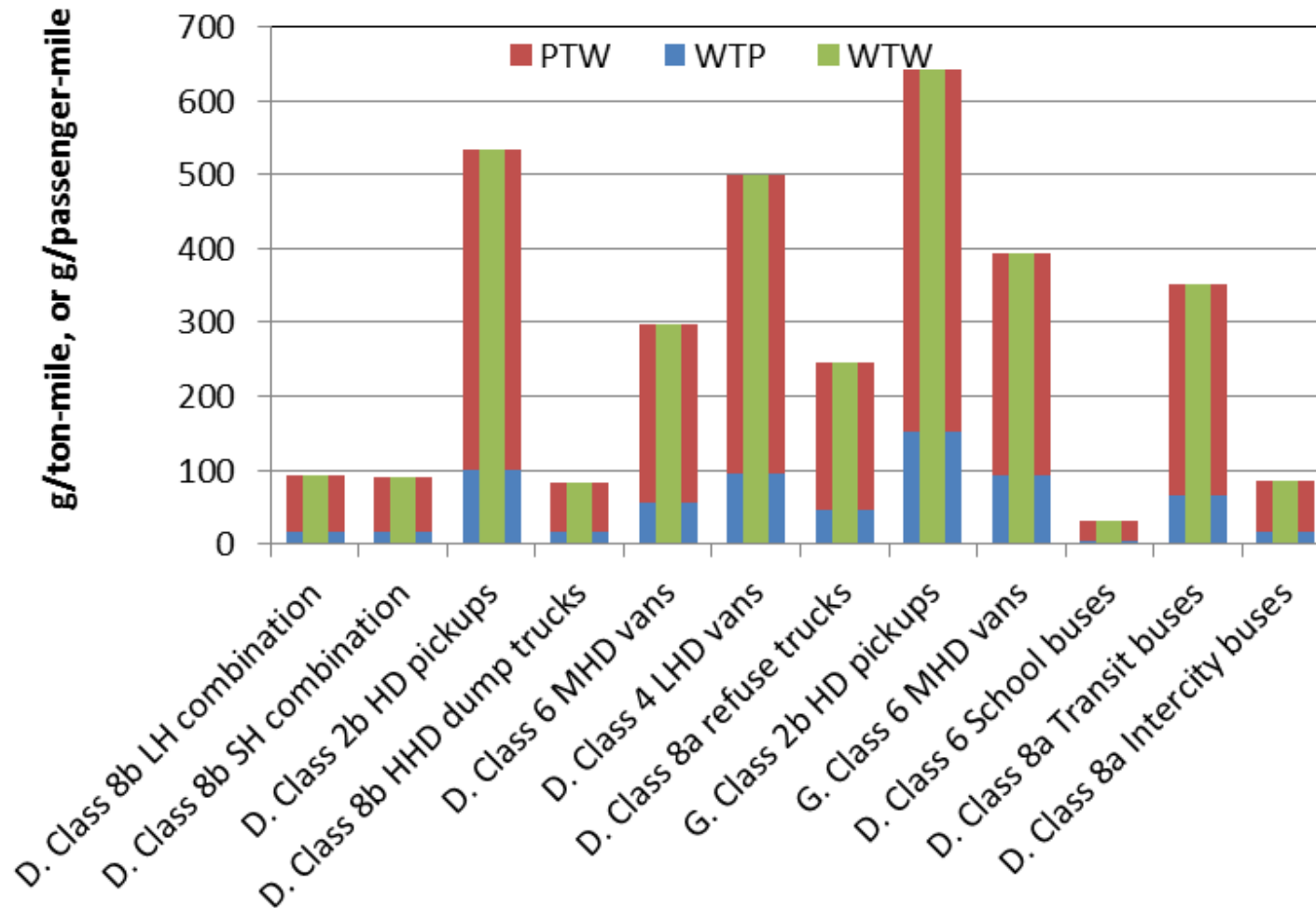
CIDI Vehicle: Diesel RNAV_SHT_CIDI_Diesel
SI Vehicle: CNG RNAV_SHT_SI_CNG
SI Vehicle: LNG RNAV_SHT_SI_LNG
CIDI Vehicle: Biodies RNAV_SHT_CIDI_BD
CIDI Vehicle: Renew RNAV_SHT_CIDI_RD

HDV_TS HDV_WTW JetFuel_WTP JetFuel_PTWa JetFuel_WTWa Rail_PTW Rail_WTW MarineFuel_PTH MarineFuel_WTH Dist_Spec Forecast_Spec Forel

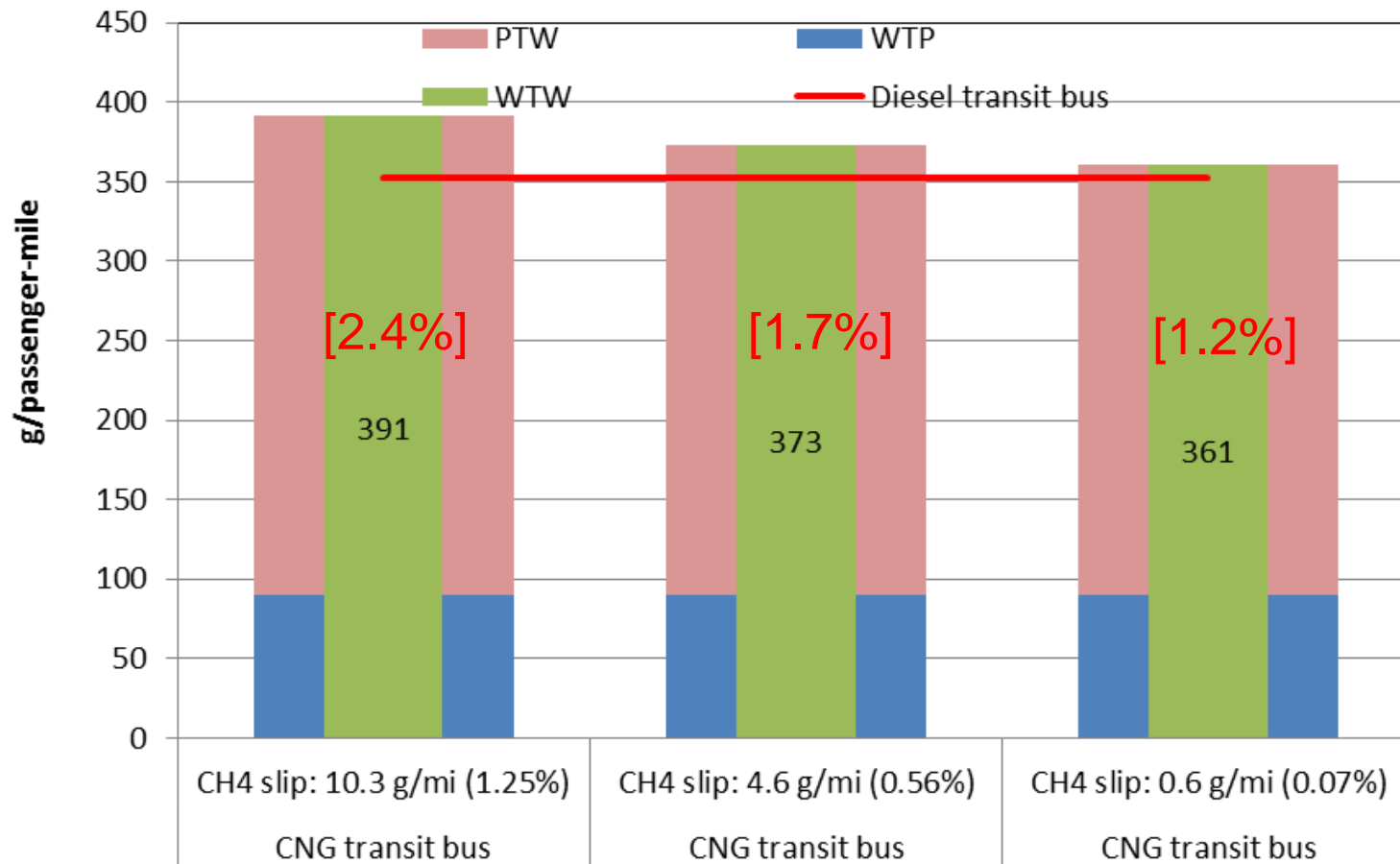
Ready Calculate 85%

GREET 2015

Fuel economy and carried payload/passengers dictate WTW GHG emissions of conventional HDV subcategories



Case study: Impact of vehicle CH₄ slip on WTW GHG emissions of CNG transit buses



15% fuel economy penalty for CNG transit buses

Summary

- **REET includes 12 HDV subcategories and their various alternative fuel counterparts to cover the diverse HDV sector**
- **Well-to-Wheels energy consumption, GHG emissions, criteria air pollutants emissions, and water consumption of various HDV technologies can be evaluated on a consistent scope and platform**
- **Energy-saving and emission-reduction potentials of major AFV technologies and applications in the heavy-duty vehicle sector overtime can be evaluated for the actual work performed**
- **Argonne keeps analyzing the impacts of new HD vehicle technologies and regulations on the environmental performances of the HDV sector. The findings of such efforts will be incorporated to update the REET HDV module**



Thank You!

Questions & Comments?

For additional information

**Please check the Argonne report: The GREET Model Expansion
for Well-to-Wheels Analysis of Heavy-Duty Vehicles,
<https://greet.es.anl.gov/publication-heavy-duty>
or contact:**

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