

Cummins Westport
The Natural Choice



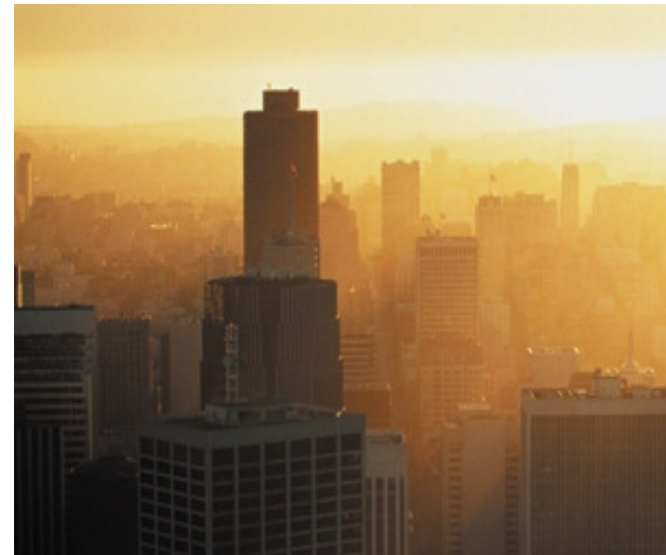
Near Zero Emissions

ISL G NEAR ZERO



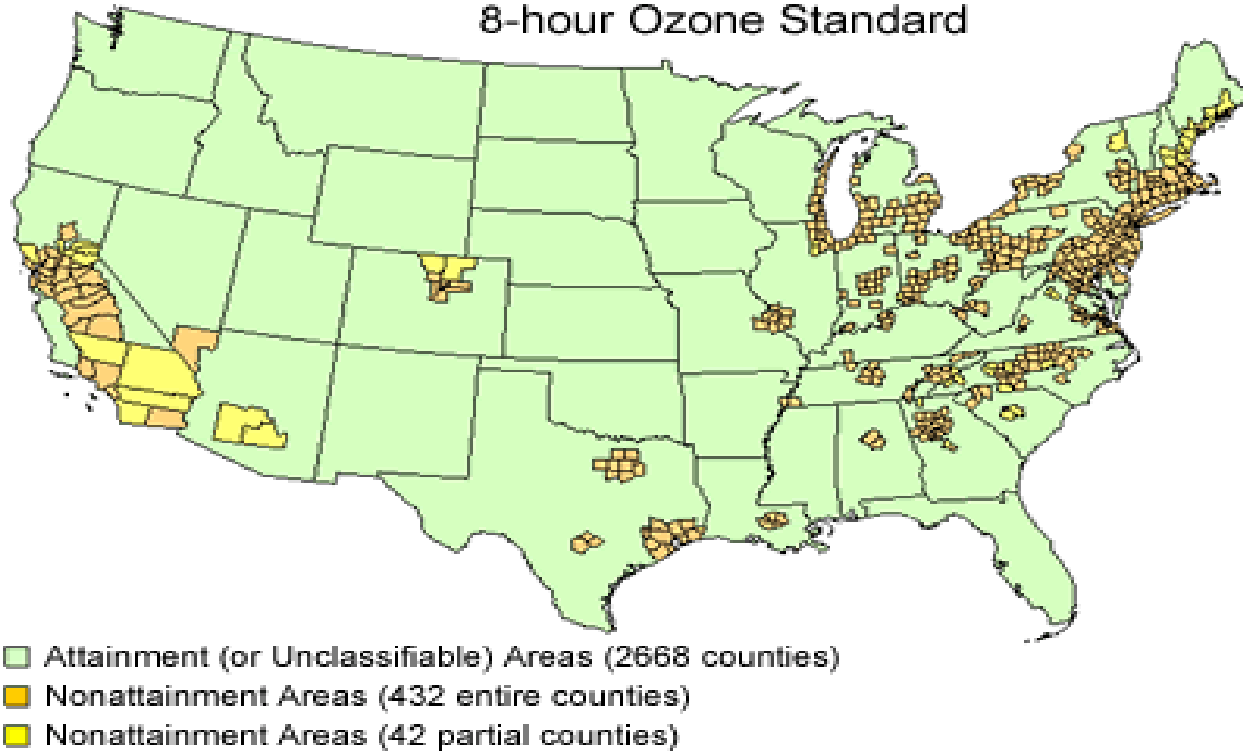
Why Lower NOx Emissions?

- High temperature engine combustion produces NO_x
- Via complex reaction with sunlight NO_x leads to NO₂
- This Conversion leads to ground level ozone formation
- Reactive hydrocarbons can speed the conversion process
- Natural Gas hydrocarbons are less reactive than diesel
- In most urban areas lower engine related NO_x will reduce ground level ozone



NOx is not Just a Southern California Issue


Attainment and Nonattainment Areas in the U.S.
8-hour Ozone Standard




California NOx Improvement.

- California's poor PM and Ozone air quality is pushing government to take significant steps for NOx improvement
 - Fund technology development and demonstration
 - Offer end-user incentives to offset incremental vehicle costs, customers will request product!

Additional Reductions Needed



- Health impacts still significant
- Localized impacts still remain
- Near and long term reductions still needed for air quality and SIP



Federal Non-attainment Areas Ozone

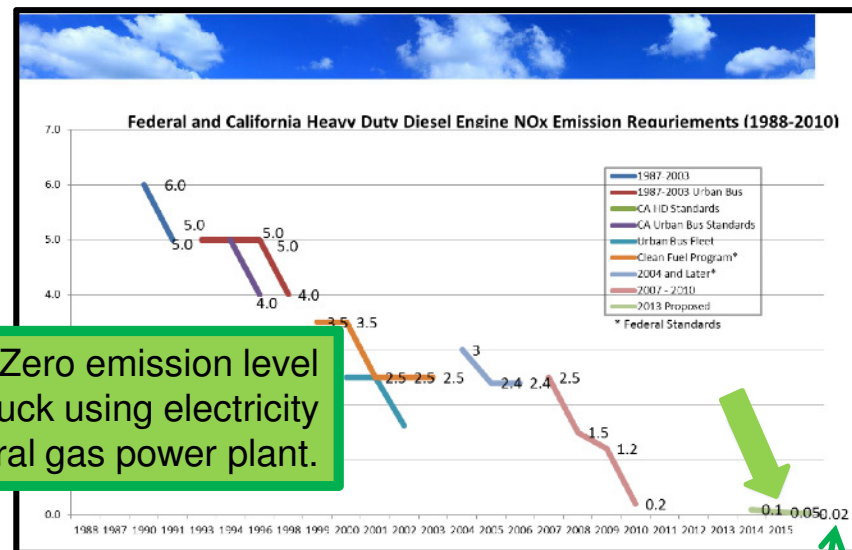
- If the entire on-road fleet complies with 2010 NO_x standards
 - NAAQS for PM and Ozone will still be exceeded
 - NOx creates Ozone
 - NOx contributes to secondary formation of PM (nitrates)

How California (ARB) Plans to Get There

- Already a 98% NOx reduction with current standards comparing 1985 to 2010 EPA
- Now ARB has established three optional low NOx emissions standards
 - 0.02 g ~ “Near Zero” NOx emissions, 90% reduction in NOx from current (2010) standards

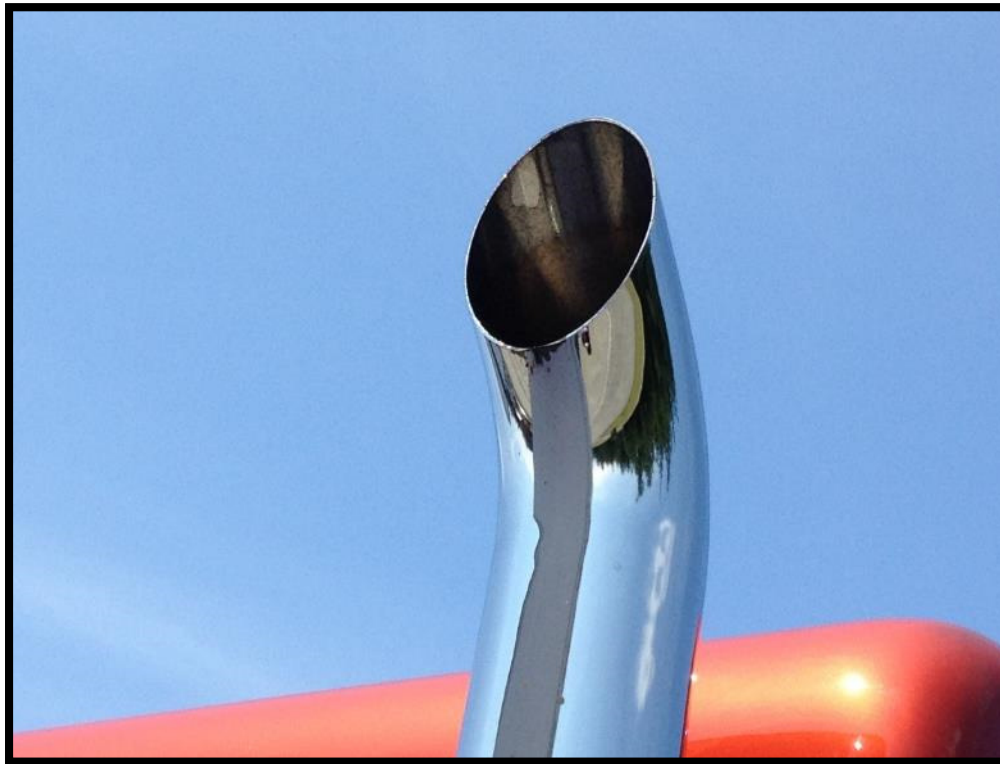
0.2 g/bhp-hr	Current NOx standard
0.1 g/bhp-hr	ARB optional low NOx standards
0.05 g/bhp-hr	
0.02 g/bhp-hr	

ARB has defined this certified Near Zero emission level as equivalent to a 100% battery truck using electricity from a modern combined cycle natural gas power plant.





Introducing Cummins Westport's Path to Lower Emissions



June 2016




Cummins Westport Inc



Near Zero Emissions Natural Gas Engine

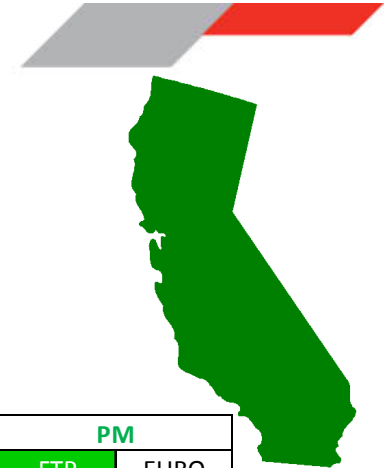
- CWI has been working on a project supported by the SCAQMD, CEC & SoCal Gas to develop technology that would reduce NOx emissions to below the 0.02 g/bhp-hr “Near Zero” level

- In 2014, CWI completed laboratory-based R&D, using prototype hardware, testing the ISL G for near zero emissions while maintaining current architecture

Emissions Criteria	Reduction	Near Zero
Particulate Matter (PM)	↓ 80% below EPA standards	
Nitrogen Oxides (NOx)	↓ 90% below EPA standards	
Engine related Methane (CH ₄)	↓ 70% reduction (crankcase and tailpipe)	
Greenhouse Gases (CO ₂ equivalent)	↓ 9% reduction (technology pathway for further reduction in 2019/2020)	

- 2015 work included
 - Component and engine design for high volume manufacture
 - Extensive component / system validation to demonstrate performance, reliability and durability, including field testing in California
 - Emissions certification
- 2016 Production begins

EPA and California ARB Certifications



Current ISL G certification

- PM is 80% below the EPA standard
- NOx is 35% below the standard

ISL G

	NMHC		NOx		CO		PM	
	FTP	EURO	FTP	EURO	FTP	EURO	FTP	EURO
STD	0.14	0.14	0.20	0.20	15.5	15.5	0.01	0.01
CERT	0.06	0.06	0.13	0.01	9.8	8.00	0.002	0.001

ISL G Near Zero certification

- PM is 90% below the EPA standard
- NOx is 50% below the NZ standard!
- CO2 is 16% below NZ Standard!

ISL G NEAR ZERO

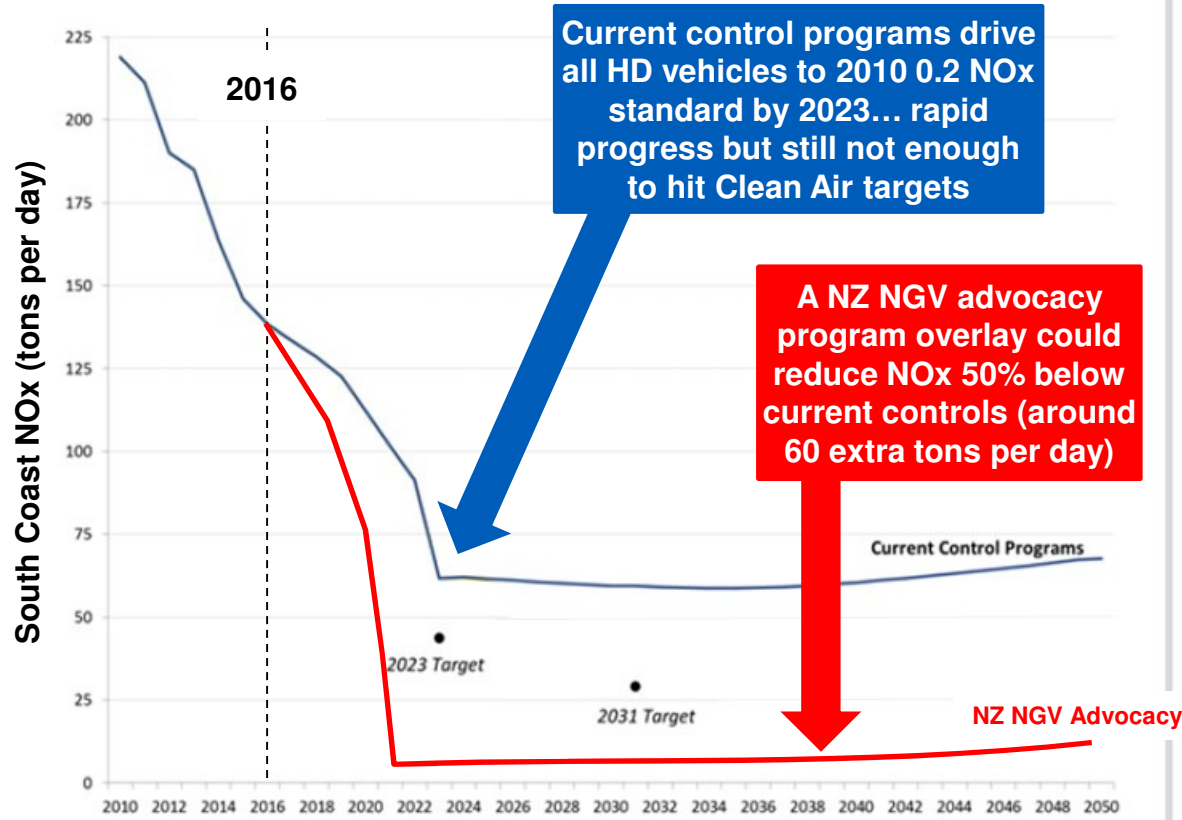
	NMHC		NOx		CO		PM	
	FTP	EURO	FTP	EURO	FTP	EURO	FTP	EURO
STD	0.14	0.14	0.02	0.02	15.5	15.5	0.01	0.01
CERT	0.01	0.000	0.01	0.004	1.5	0.3	0.001	0.000

In g/bhp-hr	EPA CERTIFICATE OF CONFORMITY		PRIMARY INTENDED SERVICE CLASS	
	CDL		VOCATIONAL	
	FTP	SET	DH	N/O
STD	655	*	0.10	0.10
FCL	476	*	*	*
FEL	450	*	0.65	*
CERT	405	*	0.56	0.02

In g/bhp-hr=grams per brake horsepower-hour; FTP=Federal Test Procedure; SET=Supplemental emissions testing; STD=standard or emission test spec; FEL=emission limit; FCL=heavy-duty emission level; CERT=certification level; CO=carbon dioxide; DH=diesel; N/O=non-diesel; VOCATIONAL=vocational engine; TRACTOR=tractor engine



Figure 6-2: The Importance of Federal Standards for Heavy Duty Vehicles*



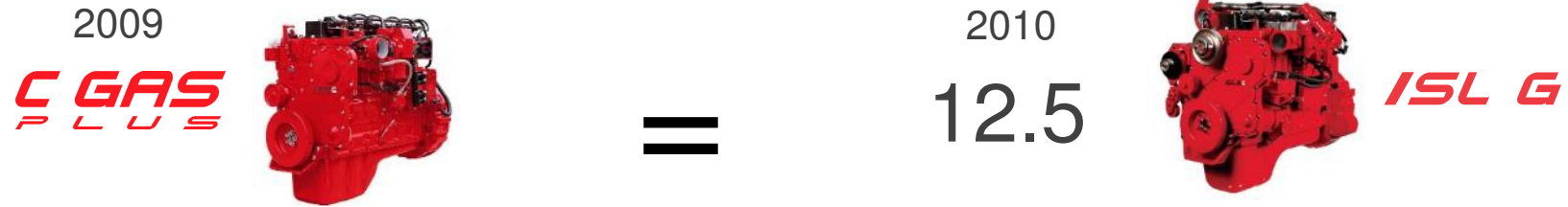
*The scenarios illustrated in this figure reflect natural turnover rates.
June 2016

	NMHC		NOx		CO		PM	
	FTP	EURO	FTP	EURO	FTP	EURO	FTP	EURO
STD	0.14	0.14	0.02	0.02	15.5	15.5	0.01	0.01
CERT	0.01	0.000	0.01	0.004	1.5	0.3	0.001	0.000

- NOx is 50% below STD
- PM is 90% below STD
- CO2 is 16% below STD
- RNG compatibility enables GHG emission reduction to near zero levels as well (landfills, dairies, waste water streams, etc.)
- NZ is ready now... how clean do you want to be and how fast?



Emissions Reduction Impact - NOx



	2009	2010	2016	ISL G NZ
NOx (g/hp-hr)	2.5	0.2	0.02	0.01
PM (g/hp-hr)	0.05	0.01	0.01	

Greenhouse Gas

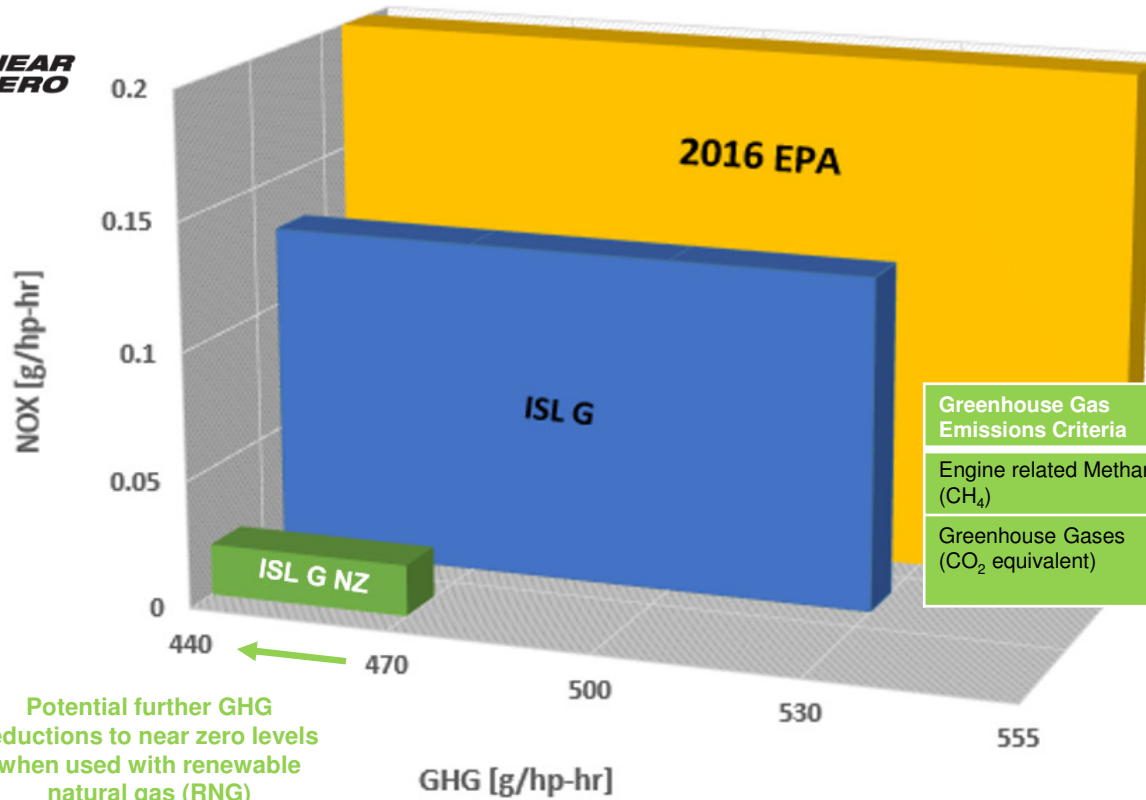
- Greenhouse gases are essential to maintaining the temperature of the Earth as they reduce the loss of heat into space and help control global temperatures through the greenhouse effect
- Increased emissions of greenhouse gases can cause global warming.
- Carbon Emissions are gaining in importance by government and industry
- Carbon dioxide, methane, nitrous oxide and three groups of fluorinated gases (sulfur hexafluoride HFCs, and PFCs) are the major greenhouse gases.

Natural gas is a low carbon fuel.

From GREET1_2015	CNG	LNG	Diesel	Gasoline
Fuel Carbon Content per Unit of Energy (gCO ₂ /MJ)	56.3	56.5	74.9	72.7
CNG compared to Petroleum			25% lower	22 % lower

Greenhouse Gas Reduction

ISL G NEAR ZERO



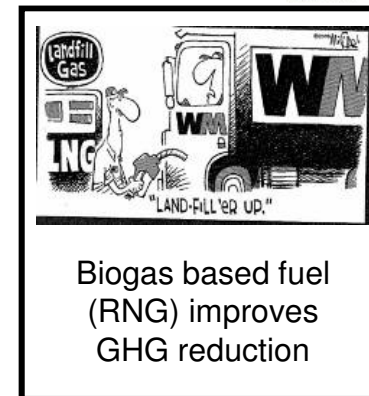
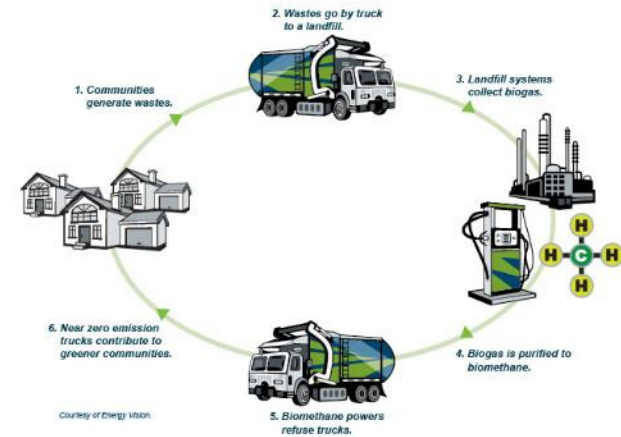
Greenhouse Gas Emissions Criteria	Reduction From Base ISL G
Engine related Methane (CH ₄)	↓ 70% reduction (crankcase and tailpipe)
Greenhouse Gases (CO ₂ equivalent)	↓ 11% reduction (technology pathway for further reduction in 2019/2020)

Potential further GHG reductions to near zero levels when used with renewable natural gas (RNG)

Use Renewable Natural Gas

- The use of renewable natural gas as a fuel reduces greenhouse gas emissions
- Biogas is a mixture of methane and other gases produced from the natural decomposition of organic materials in landfills, composting or agriculture.
- Purifying biogas to “pipeline quality” produces Renewable Natural Gas (RNG) or biomethane that is a pipeline-quality natural gas substitute.
- Converting the methane that leaks from landfills or other sources to biomethane fuel **has significant greenhouse gas emissions reduction benefits.**
- In addition, there's a **100% displacement of fossil fuels** as RNG is a renewable resource.

RENEWABLE NATURAL GAS CYCLE



Renewable Natural Gas (**RNG**) Improves GHG Profile

- Landfill gas and biogas that has been processed to “pipeline quality” is **RNG**
- ISL G can operate on up to 100% **RNG** or as it sometimes called, biomethane.
- ISL G / ISX12 G engines are currently in operation with renewable natural gas from landfills (landfill gas) & dairy farms (biogas)



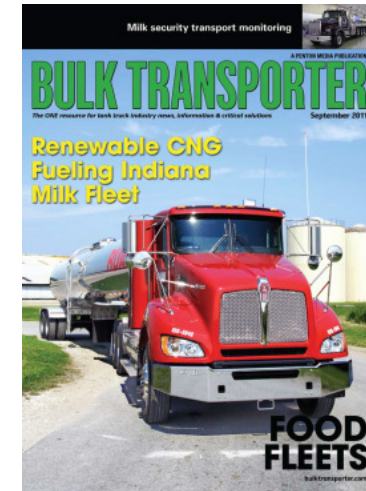
Waste Management,
Altamont Landfill,
California

June 2016



EBI Montreal Inc.
Quebec

Cummins Westport Inc



Fair Oaks Dairy
Indiana



14

Greenhouse Gas Reduction from RNG?

gm/kilometer	Extraction	Processing	Fueling, Transportation and Storage	Vehicle Operation	C in End Use Fuel from CO2 in Air (RNG)	Total gm/km	Change
Natural Gas (CNG)	124.7	118.4	58.4	1290.7	0	1592.2	-11.1 %
Natural Gas (CNG) ISL G NEAR ZERO	124.7	118.4	58.4	1214.7	0	1516.1	-15.3 %
Renewable Natural Gas (CNG - Landfill)	0	31.7	45.3	1214.7	- 1141.4	193.6	- 89.2 %
Diesel	103.2	328.1	9.3	1350.2	0	1790.8	Baseline

Source: GHG Emissions for Ontario Natural Gas Buses – GH Genius Feb 2016

- Baseline ISL G natural gas reduces GHG WTW emissions by 11%
- ISL G Near Zero improves WTW GHG reduction to 15%
- Use of **RNG** with ISL G Near Zero improves GHG reduction to 89%
 - **For every 50,000 miles save 128 metric tons of CO2**

Greenhouse gas (CO2) Measured in Metric Tons

One
Metric
Ton of
CO2

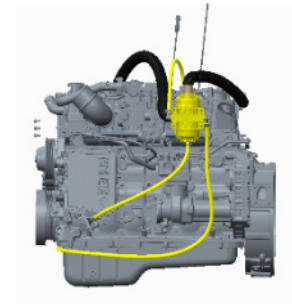
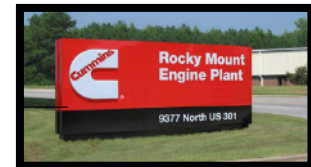
=



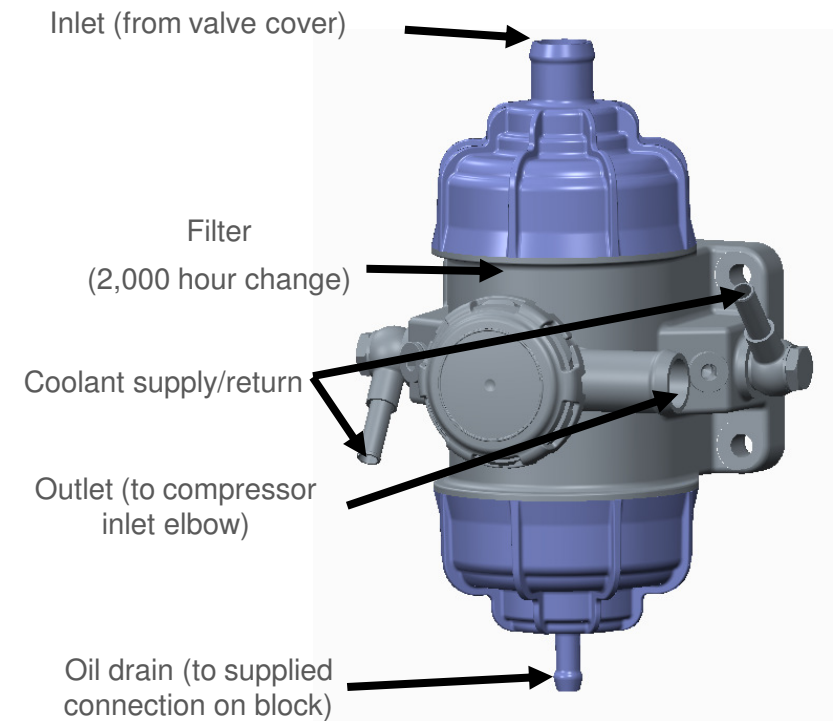
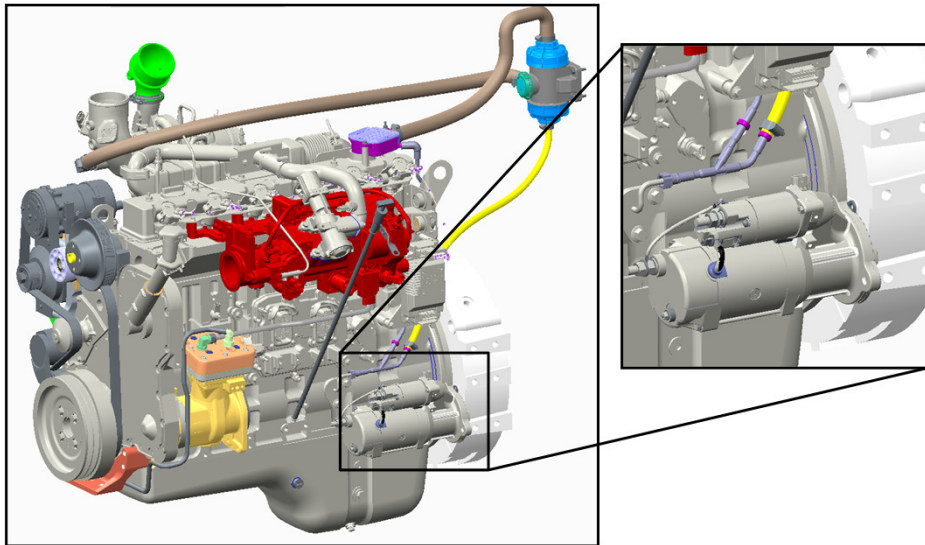
*One ISL G
Near Zero
running RNG
removes 512
trailers full of
CO2 per year*

ISL G **NEAR ZERO**

- Base ISL G engine design is the same
 - Engine will be factory built at Cummins Rocky Mount Engine Plant
 - Ratings, warranty and operational / maintenance procedures will be the same
 - No change in technician service certification requirements
- Closed Crankcase Ventilation (CCV) will be added to engine
 - CCV system reduces engine related methane emissions by 70%
 - CCV filter change required at 2,000 hours
- Three Way Catalyst will change to meet next level emissions
 - Remains maintenance free
 - Larger size catalyst with addition sensor added
 - New substrate composition for durability and emission performance



Closed Crankcase Ventilation (CCV) System



ISL G **NEAR ZERO**

Summary

- Cummins Westport has certified the ISL G Near Zero (NZ) NOx with EPA and California ARB for Bus and Truck applications
- Field testing is in progress in transit and refuse applications.
- ISL G NZ NOx engines will be factory built and available in 2016 for new Bus and Truck installations as well as for repowers of existing natural gas vehicles.
 - There are no plans for retrofit kits for existing engines
- **Zero Emission technology at conventional propulsion system values!**



Why ISL G Near Zero vs Current ISL G?

- ISL G Near Zero has 90% lower NOx and 9% better GHG profile
 - Lowest emission mid range engine in North America
 - 10 - ISL G Near Zero engine NOx emissions equal one ISL G
 - Tenfold decrease in emissions for new and existing fleets
- ISL G Near Zero is better qualified for Non Attainment funding
 - Cleanest ICE technology available.
- ISL G Near Zero features all the latest engineering improvements from the ISL G
 - Natural gas fleets looking to replace existing natural gas vehicles or engines will notice a dramatic improvement in reliability and uptime performance
- ISL G Near Zero affords fleets the opportunity to market “Near Zero” emissions.
- ISL G Near Zero is the “go forward” product for CWI
 - OBD in 2018 will obsolete base ISL G

Near Zero Product Plan – Feb 2016

(Certified to ARB Near Zero NOx standard - 0.02 gm/bhp.hr.)

Engine	2016	2017	OBD	2018	2019
ISB6.7G*	Available	Available		Available	Available
ISB6.7G NEAR ZERO	Not Available	Not Available		Development Program Not Funded	
ISL G	Available	Available		Not Available	Not Available
ISL G NEAR ZERO	Available	Available		Available	Available
ISX12G	Available	Available		Not Available	Not Available
ISX12G NEAR ZERO	Not Available	Not Available	Available	Available	

Legend

Available

Not Available

* ISB6.7 G will be certified at launch to California ARB optional Low NOx (0.1 gm/bhp-hr.)

Near Zero development funding for the ISB6.7 G has not be secured – no ISB6.7 G NZ in plan without funding

ISX12 G NZ will be available in 2018

Base ISL G and ISX12 G engines are not available post 2017 (not OBD compliant)



OEM Availability

June 2016

Cummins Westport Inc



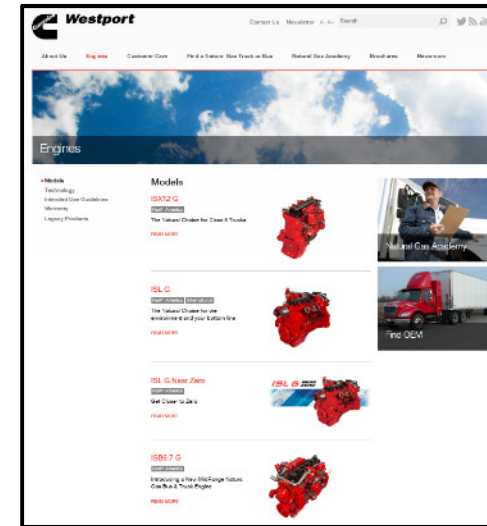
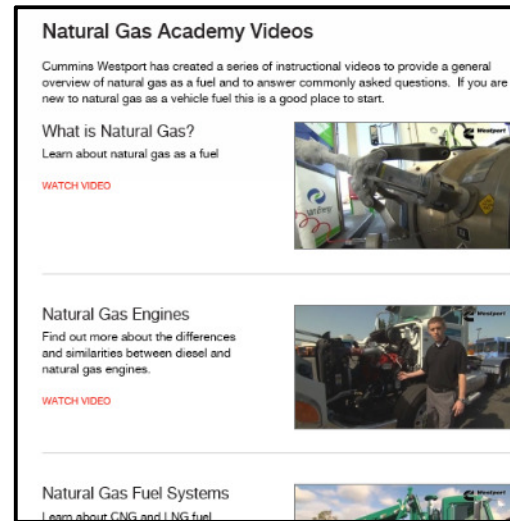
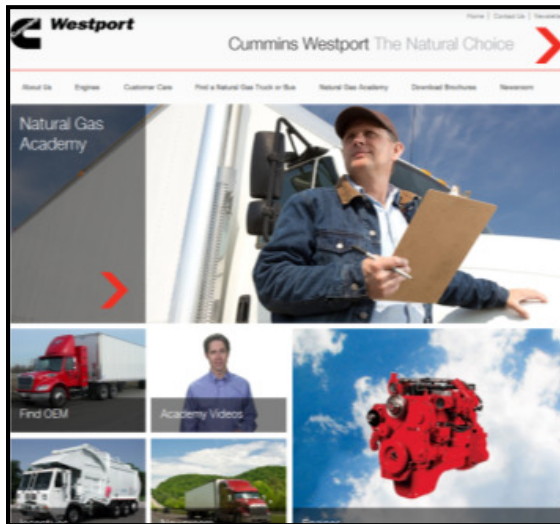
OEM Availability

	OEM	ISL G	ISX12 G
Conventional Truck	Freightliner	Yes	Yes
	International	Yes	-
	Kenworth	Yes	Yes
	Mack	-	Yes
	Peterbilt	Yes	Yes
	Volvo	Yes	Yes
	Western Star	-	-
Refuse Truck	Autocar	Yes	Yes
	Crane Carrier	Yes	-
	Mack	Yes	-
	Peterbilt	Yes	Yes
Coach	MCI		Yes

	OEM	ISL G	ISB6.7 G
Transit Bus	El Dorado	Yes	Pending
	Gillig	Yes	
	New Flyer	Yes	
	Nova	Yes	
School Bus	Blue Bird	Yes	
	IC Bus	-	
	Thomas Built	Yes	Yes

**ISL G NZ Availability
Pending OEM orders**

More information... www.cumminswestport.com



- Natural Gas Academy: great source of information about NG, technology, vehicles
- Series of instructional videos, including engine walk-arounds and service & driver training videos
- Engine information – specs, features, maintenance intervals
- Product Brochures & Bulletins available for download

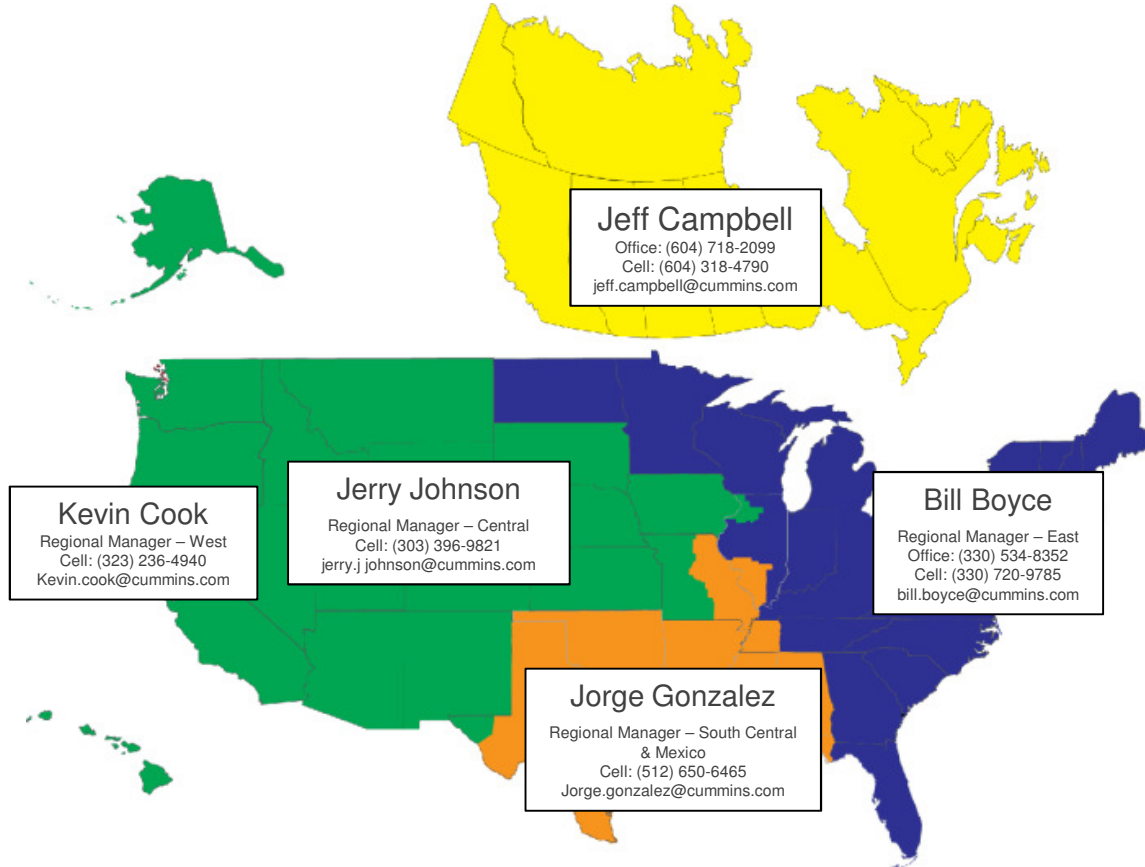
June 2016

Cummins Westport Inc



24

Cummins Westport Regional Managers



June 2016

Cummins Westport Inc

