

NATURAL RESOURCES CANADA - INVENTIVE BY NATURE

Greenhouse Gas (GHG) Emissions from Underground Mining Diesel Engines

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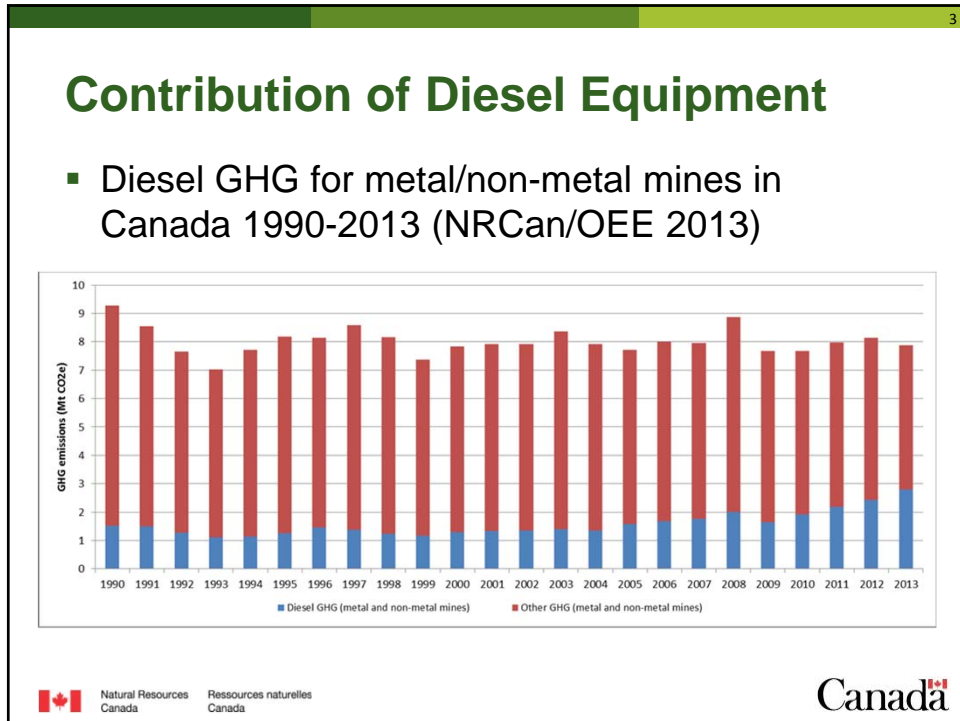
GHGs and Mining in Canada

- Most mining operations contribute to GHG emissions in Canada.
- Proposed cap-and-trade systems will place a strong incentive on mines to track all sources of GHG and look for possible reduction strategies.
- All sources of GHGs will be reviewed including diesel equipment.

Sector	Percentage	GHG Emissions (Mt)
Oil and gas	25%	179
Transportation	23%	170
Buildings	12%	86
Electricity	12%	85
Emissions-intensive and trade-exposed industries	11%	76
Agriculture	10%	75
Waste and others	7%	54

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GHG and Equivalents from Diesel

- CO₂ is the most recognized GHG from diesel but N₂O and DPM (black carbon) are also significant.
- N₂O and black carbon have very high CO₂ equivalencies which makes them significant even at engine-out emission levels lower than CO₂.

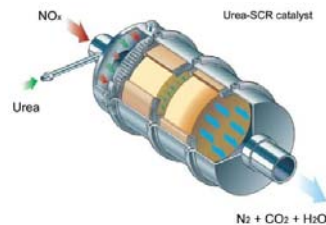
Greenhouse Gas	Time Horizon	
	20 years	100 years
Carbon dioxide	1	1
Methane	72	25
Nitrous oxide	289	298
Black Carbon	2000 [§]	350 - 1500*

Table 1: Global Warming potentials
 CO₂, methane and N₂O data from IPCC, 2007
[§] Bond (2007)
 * Jacobson (2007) reports 1500 - 2240

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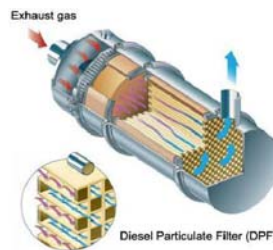
N₂O – Nitrous Oxide

- N₂O is formed in some diesel emission control systems.
- Not part of the CSA vent rate calculation.
- Not routinely measured during certification in the past however we are starting now.
- N₂O from existing certified engines may be estimated based on the specific emission control technology and factors derived from the literature.
- N₂O will contribute to an overall CO₂e equivalency estimate.



Black Carbon from DPM

- DPM is part of the vent rate calculation and is routinely measured during certification tests.
- DPM is composed of elemental (black carbon) and organic carbon. Only the elemental portion is considered to be a significant GHG with a very high CO₂e equivalency.
- Factors for black carbon derived from DPM measurements were developed from MSHA and CANMET internal reports.
- Retrofit of diesel particulate filters (DPF) can result in a significant reduction in CO₂e



How could this contribution be tracked?

- CanmetMINING already performs mining engine emissions testing to the CSA M424.1-16 and M424.2-16.
- This includes measurement of CO₂ and some CO₂ equivalents like DPM and reporting of an emissions-based mine ventilation rate.

Engine Manufacturer: Detroit Diesel
 Engine Model: 6063-WK32/6063-EK32, 11.1L, Series 60, Tier 1
 Governing Standard: CSA M424.2-90 (Non-Gassy Mines)

Certificate Number	Engine Rating and Maximum Fuel Rate at Sea Level	Sulphur in Fuel - % wt.	Ventilation Prescription	
			CFM	m ³ /min
1007	325 HP @ 2100 RPM 115.7 lb/hr	0.05	22 000	623.0
		0.10	24 000	679.6
		0.20	28 000	792.9
		0.25	29 900	846.7
		0.50	39 800	1 127.0



Internal Project – GHG Development

- Development of an internal project to investigate GHG from mining engines and certification data.
- Literature review on existing approaches to calculate GHG emission from diesel engines.
 - Carbon dioxide (CO₂)
 - Nitrous oxides (N₂O)
 - Black carbon from diesel particulate matter (DPM)
- Estimate GHG from currently approved mining engines (2016-17).
- Estimate GHG from mining vehicles (2017-18)
- White paper on GHGs from mining engines.
- Solicitation of comments from industry stakeholders.
- Incorporate GHG equivalency measurements and calculations into CSA testing and certification process.

White Paper GHG Mining Diesels

- Development of proposed equivalencies and calculation methods.
- Trial runs with existing certified engines.

Protected Business Information

Greenhouse Gas (GHG) Emissions from Underground Mining Diesel Engines

By

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Greenhouse Gas Emissions from Underground Mining Diesel Engines

Proposed cap and trade regulations for greenhouse gases (GHG) in some Canadian jurisdictions have created a renewed interest in documenting all sources of GHGs for underground mining operations.

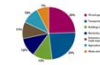


Figure 1: Sources of GHG Emissions by Industry

Diesel engines are a major source of GHGs in underground mining operations and are used for drilling, ore haulage, personnel transport, reclamation and development. The underground mining sector is considered fully-exposed industry.




Figure 2: Diesel Mining Vehicle

APCC's jurisdiction-based RED programs to reduce/minimize diesel emissions in mines and tests and certifies new diesel engines intended for use in underground equipment according to the relevant

CSA standards and maintains a list of approved engines with associated ventilation rates on a website available to industry. Several jurisdictions require the use of certified diesel engines in their underground mines.

There exists an opportunity to increase the value of this list to industry by adding information on GHG emissions for climate change alongside the current information on ventilation rates for health and safety.

Engine Manufacturer: Detroit Diesel

Engine Model: 6063-WK32/6063-EK32

Governing Standard: CSA M424.2-16

Engine Model	Power Rating (kW)	Ventilation Rate (m³/s)	GHG Emissions (kg/h CO2e)
242 kW @ 2100 RPM	52.6 kg/h	10.4	101

Figure 3: Proposed Approved Engine Table

In the majority of cases, this information can be mined from existing engine test data and new test procedures can be developed for future emissions testing.

The new information would allow mining companies to compare and select engines that are not only the cleanest in terms of toxic emissions but also select those that minimize GHG emissions.

Data from the list could also be used to estimate GHG contributions of a mine's underground diesel fleet for cap and trade reporting purposes.

For further information, please contact David A. Young, Chief Diesel Emissions Research, CMRI, (513) 943-9205.

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CO2e Reporting

- It is feasible to calculate a GHG emission rate in CO₂e during engine certification and report it next to the prescribed vent rate.

Engine Manufacturer: **Detroit Diesel**
 Engine Model: **6063-WK32/6063-EK32, Tier 1**
 Governing Standard: **CSA M424.2-16**

Certificate Number	Engine Rating and Fuel Rate at Sea Level	Ventilation m³/s	GHG kg/h CO ₂ e
1007	242 kW @ 2100 RPM 52.6 kg/h	10.4	101



GHG Consultations - MDEC

- CanmetMINING has produced a white paper on its proposed GHG measurement and reporting strategies and released it to industry stakeholders for comments.
- This paper is available by request:
brent.rubeli@canada.ca
- 15-20 written comments received to date. CanmetMINING welcomes all comments and suggestions.
- MDEC 2017 has provided time during the roundtable forum on Thursday, Oct 5th at 3:00pm for discussion with stakeholders and any interested parties.

Sample of Initial Comments:

- Battery equipment is still only 5-10% of orders so CO₂ from diesel is going to be important for a while.
- Tier IV engines have lowered CO_{2e} and Tier V may target CO₂ directly.
- CO_{2e} is generally decreased for aftertreatment systems even though CO₂ may increase.
- CO₂ is shown on many ambient air quality monitors but what about CO_{2e}? Could this be used for VOD?
- Cost effectiveness needs to be part of the work. CO₂ is costly to reduce while DPM is comparatively easy perhaps initial work could focus on DPM

Future steps

- Analysis of stakeholder comments and suggestions.
- Development of definitive GHG measurement and calculation procedures.
- Extrapolation to common vehicle cycles and underground fleet populations.
- Engagement with the CSA for incorporation into future versions of the standards.

Questions?

- Hope to see you at the roundtable forum tomorrow on October 5th at 3:00pm.
- Brent.Rubeli@Canada.ca