



LNG Mining Truck - Launch Review

May CIM Conf Edmonton

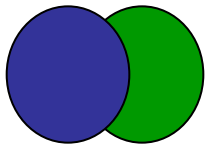
WHEREVER THERE'S MINING



LNG Drivers for Mining

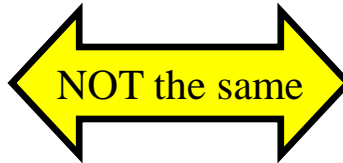
- **Alternate Fuels Drivers:**
 - Price of oil – natural gas price remains stable
 - Security of fuel energy supply – abundance of natural gas
 - GHG – public perceptions drive political and legislative agendas
- **LNG**
 - Stable in the liquid form
 - Of gas options, provides largest fuel per unit volume (minimum tank size)
- **Several Fuel System Alternatives to Accomplish Combustion**
 - Fumigation
 - Inlet Port Injection
 - Direct Injection
- **Mining Truck Customer Benefits**
 - Lower fuel costs (>16% savings), lower emissions (-40% NOx, -60% PM, -20% CO2)
 - Lessens impact of CO2 taxation (\$25 USD/ton being discussed)

What is Clean & Green



Clean

- NO_x – Nitrogen Oxides
- PM – Particulate Matter
- HC – Hydro Carbons
- CO – Carbon Monoxide



Green

- CO₂ – Carbon Dioxide
- CH₄ – Methane / Natural Gas
- N₂O – Nitrous Oxide

North American
regulatory
requirements

Australian carbon
tax, Alberta GHG
reduction
initiative

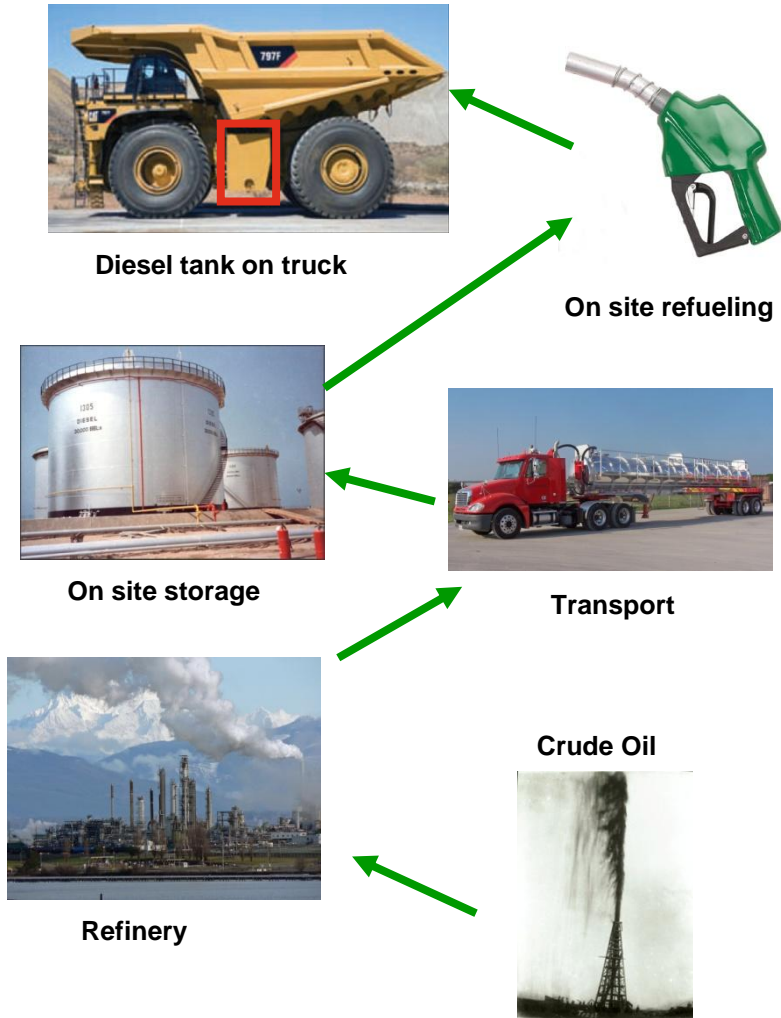
Mining customers need GREEN solutions
•Direct Injection Natural Gas technology
can address both clean & green

Cat Mining Truck LNG Program Objectives

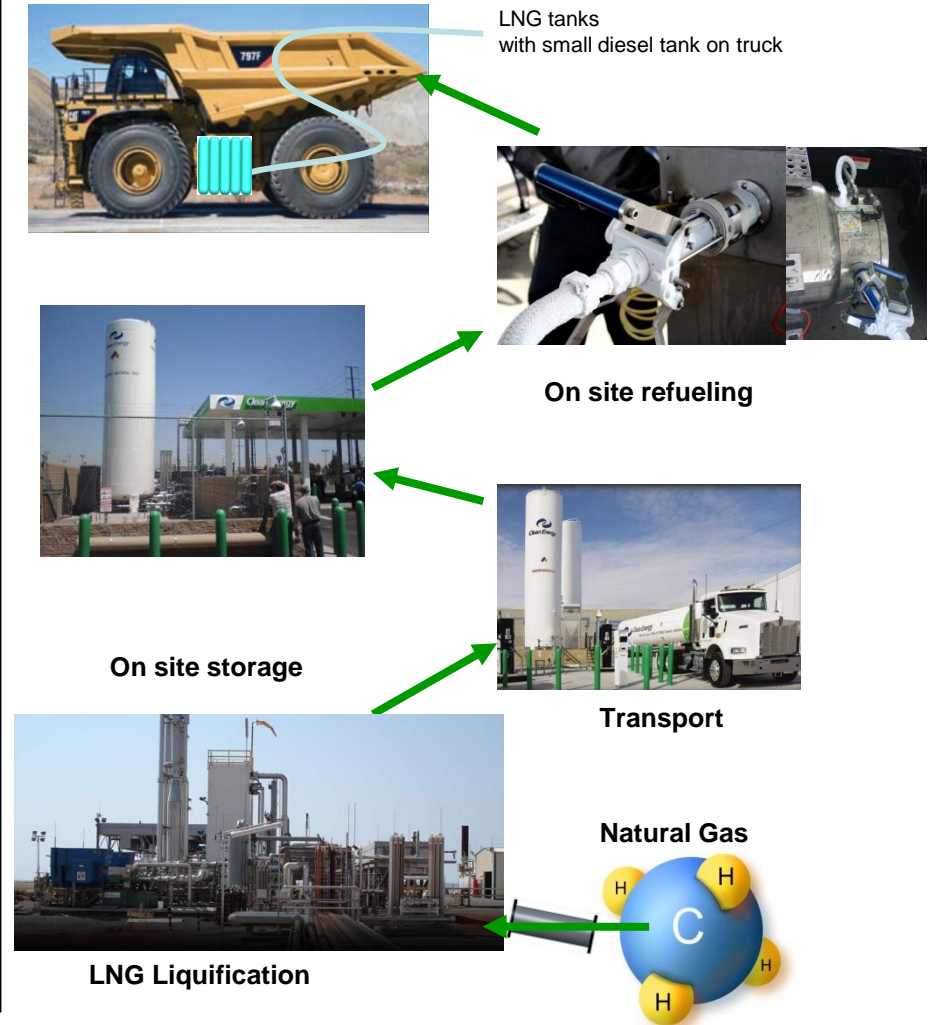
- Develop direct injection twin-fuel system that will provide positive benefits in emissions and GHG
- Evaluate fumigation alternatives trade-offs, Understand potential markets
- Equivalent engine performance vs. diesel
- Ensure Diesel only Mode with partial power
- Develop within the same footprint on the truck as the diesel equivalent
- Minimum of 12 hour fuel storage on the truck
- Target trucks: Phase 1. 793, 795, 797 Phase 2. 785, 789
- Accept wide range of LNG fuel quality
- Same or lower sound levels as diesel powered truck
- Similar reliability of diesel truck
- Understand site implementation requirements and best practices

LNG vs Diesel Supply Chain

Current Diesel Fueling Model



Future LNG Fueling Model



2012 Activities

- Single Cylinder Test Engine (SCTE)
 - Optimize the emissions and fuel consumption of the Twin-Fuel combustion system; reduce PM, lower and higher power ratings, low GHG Tier 2 calibration
 - Injector evaluation
- Multi Cylinder Test (MCTE)
 - Build and Test Multicylinder
 - Finalize single cylinder results
- Fuel Systems
 - TF2 (Twin Fuel) design on SCTE
 - Design & procurement of system bench
 - Pump development
 - Fuel system controls
- Machine Development
 - Detailed project plan
 - Gather voice of customer, develop functional & technical specifications
 - Safety & regulations, FMEA
 - Develop (tank, accumulators, heat exchangers, etc.)
 - Develop mule truck concepts and finalize designs
 - Establish field follow validation

LNG Safety

Rod Zehrung

Safety comparison LNG to diesel and gasoline

Hazard	LNG	LPG	Diesel	Gasoline
Toxic	No ¹	No ¹	Yes	Yes ¹
Carcinogenic	No ¹	No ¹	Yes	Yes ¹
Asphyxiant	Yes, in confined spaces ¹	Yes, in confined spaces ¹	No	No ¹
Flammable	Yes ¹	Yes ¹	Yes	Yes ¹
Forms Vapor Clouds	Under special conditions ¹	Yes ¹	Somewhat	Yes ¹
Other health hazards	Cryogenic temp exposure	No ¹	Eye irritant, narcosis, nausea, others	Eye irritant, narcosis, nausea, others ¹
Flammability limits in air %	5-15 ¹	2.1-9.5 ¹	0.6 - 7.5 ³	1.3-6 ¹
Autoignition temperature °C	540 ²	482 ²	315 ²	257 ²
Stored pressure	Pressurized	Pressurized ¹	Ambient	Ambient ¹
Behavior if spilled	Evaporates forming visible "cloud" that disperses readily ¹	Evaporates forming "explosive" vapor cloud ¹	Forms a flammable pool. Environmental cleanup required ¹	Forms a flammable pool. Environmental cleanup required ¹

¹ From "LNG Facilities - The Real Risk" by William W. Lewis, James P. Lewis, and Patricia A. Outtrim from the GASTECH Conference in

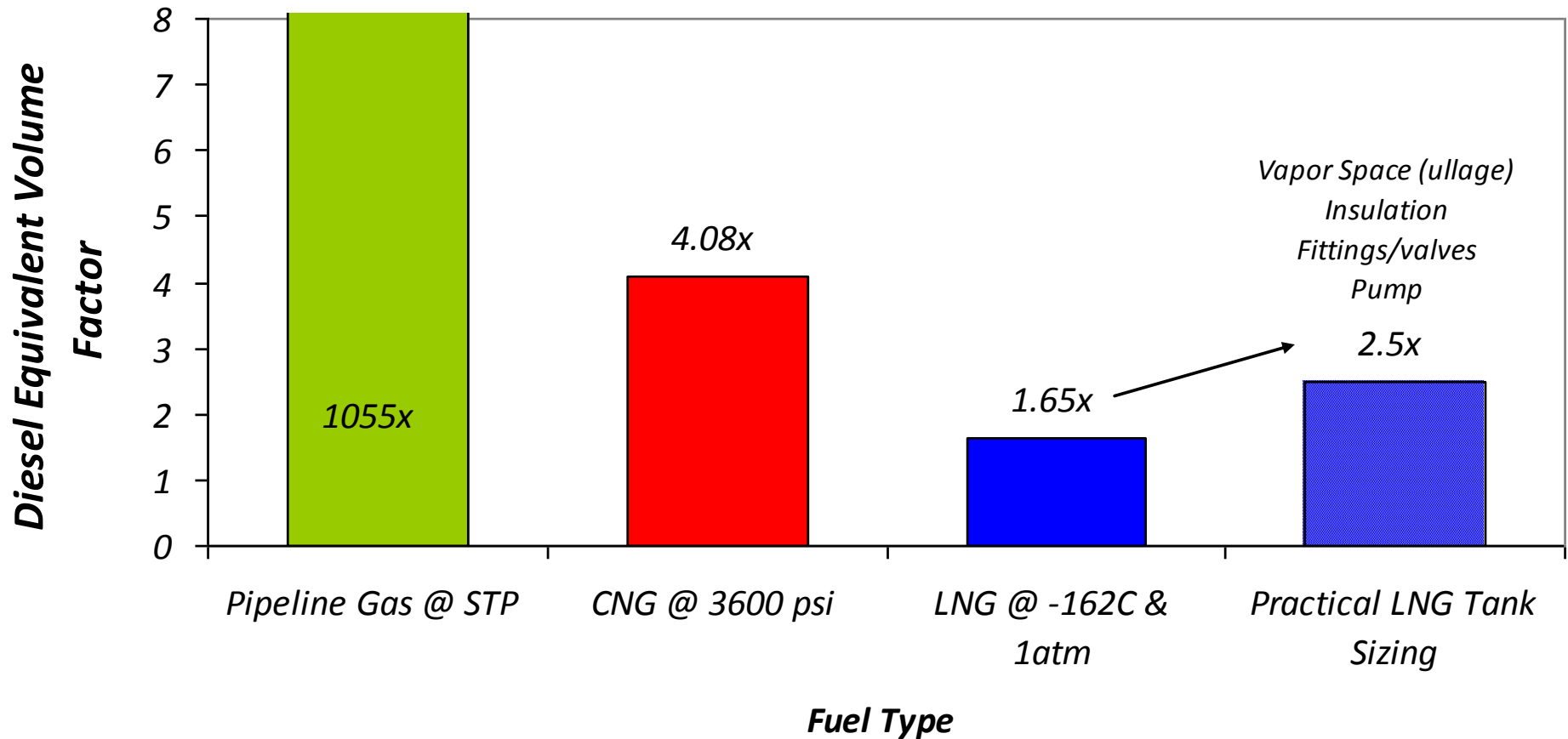
² "LNG Safety and Security Security" by Michelle Michot Foss, Center for Energy Economics 2006

³ "Flammability Limit" en.wikipedia.org/wiki/flammability_limit

Energy Density

Natural Gas Energy Density

Diesel Equivalent Volume Factor



LNG Tank Sizing (Diesel Equivalent)

