LNG CANADA

Opportunity for British Columbia. Energy for the world

Joint venture companies

Mitsubishi Corporation

A Preliminary Well-to-wire Assessment of B.C. LNG: Report Overview

March 2015 Study

Agenda

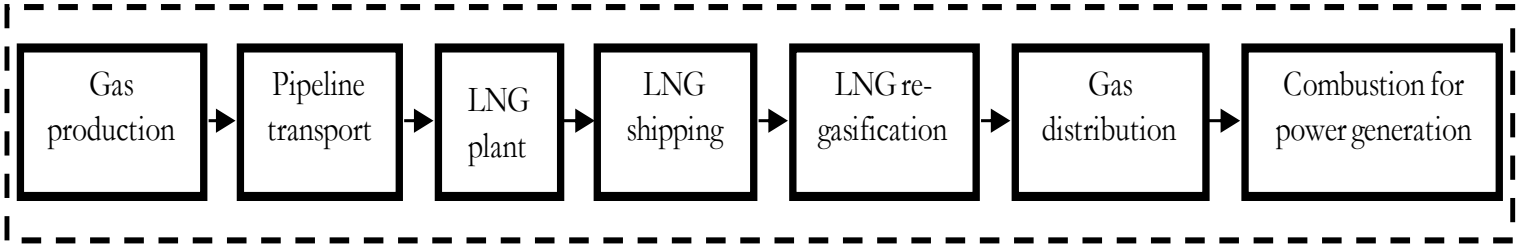
1. Study Overview
   - Goals
   - Scope
   - Methodology & data sources
   - Key assumptions and premises
2. Key findings and conclusions

1.0

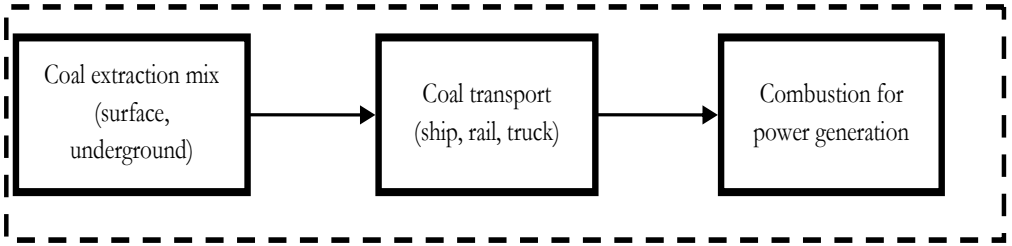
Study Goals

- To estimate the life-cycle greenhouse gas (GHG) performance of a generic BC LNG facility case on a well-to-wire basis, relative to competing hydrocarbon sources in the destination markets (well-to-wire analysis).
- To complete a benchmarking analysis comparing the performance of the proposed BC LNG facilities to leading global competing facilities
- To provide credible life cycle GHG emissions data on BC's proposed LNG industry to the public domain to inform LNG project development, government policy and stakeholder dialogue.

Study Scope



LCA done for LNG from British Columbia, LNG from Eastern and Western Australia, and LNG from US Gulf Coast. LNG destination proposed as China for production of electricity.



LCA done for domestic coal production in China used for power (subcritical power plant) and Australian imported coal used for power production in China (new supercritical power plant).

Methodology & data sources

General Methodology

- For all pathways considered in this study an inventory of GHG emissions was developed from publicly available information. Spreadsheet analysis was used for developing the inventories and calculating the impacts. The life cycle inventories are limited to a GHG comparison.

LCA data sources and bases of estimation

- The life cycle inventory data sources vary considerably depending on the geographic location and the availability of data for existing projects. The data sources, basis of estimates and uncertainties for each activity in the study boundary is documented within the report.

Study assurance and execution

- Research and review of publicly available information performed by Shell Greenhouse Gas Intensity Analysis team with support from the Pembina Institute
- Calculation of GHG emissions intensity for various LNG projects and comparison pathways performed by Shell analysis team
- Independent assurance panel convened and facilitated by the Pembina Institute provided input to the scoping of this study, methodology, and data sources, and reviewed and commented on the study results

Panelists

- Joule Bergerson, University of Calgary
- Matt Horne, Pembina Institute
- Tom Pedersen, Pacific Institute for Climate Solutions
- David Pumphrey, Centre for Strategic and International Studies
- Garry Wouters, Coastal First Nations

Key assumptions and premises

BC Upstream Gas Intensity

- The study assumed 70% Montney, 20% Horn River Gas and 10% Alberta Grid
- GHG intensity for BC upstream was derived from publicly reported data and using GHGenius … intensity was also checked against Shell internal intensity data.

Pipeline Compression

- Gas Turbine compressor drives

BC Facilities

- Four large LNG facilities that had filed a Project Description with the BC EAO were chosen to represent the BC LNG sector.
- Did not assume full electrification but rather a suite of technologies that could be used by LNG proponents in BC. Intensity range was 0.10 tonnes CO2/tonne of LNG to 0.26 tonnes CO2/tonne of LNG

2.0

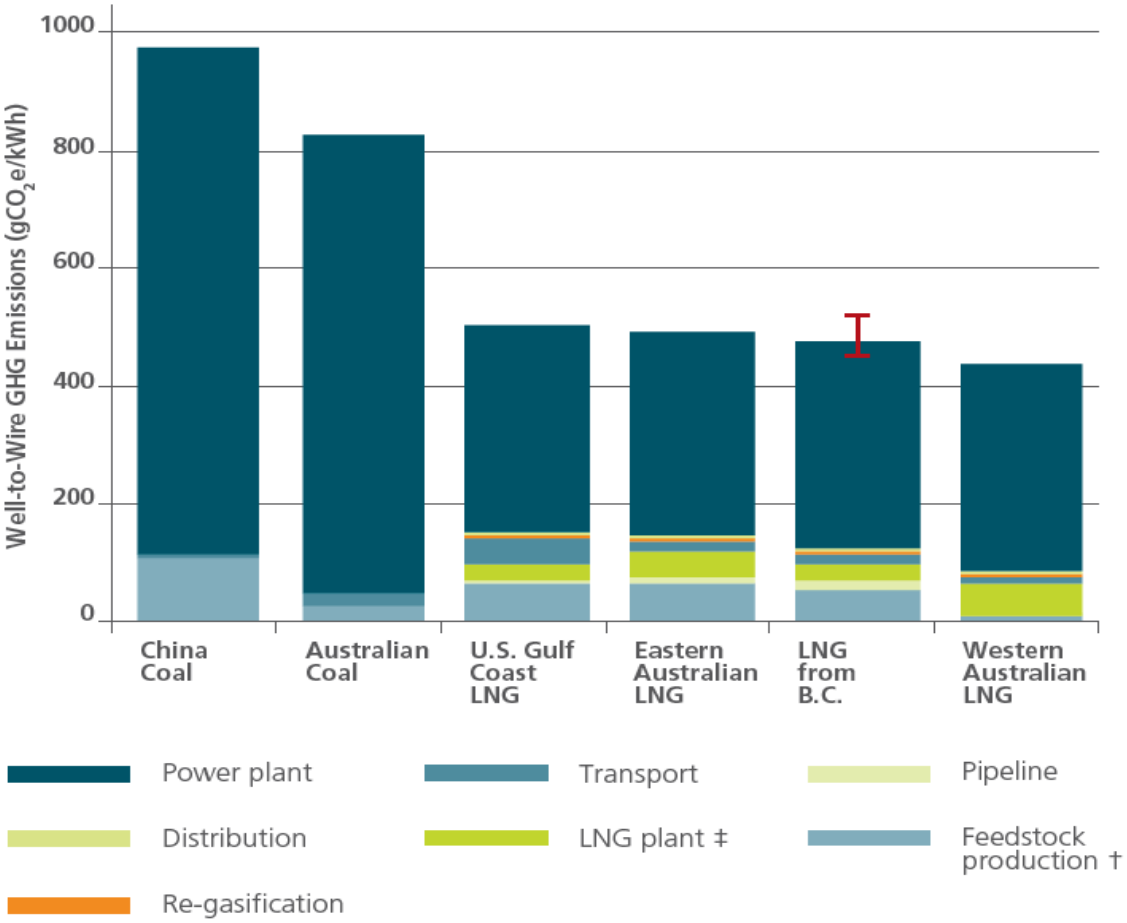
Key Findings – LCA Comparison

LNG from BC fares well on a life-cycle basis

- The Life Cycle GHG emissions of LNG produced and shipped from BC to China for production of electricity are 40 to 50 % less than the life cycle emission of coal used to produce electricity in China.
- Consistent with findings from other LCA studies comparing gas to coal
  - Pace Global Report
  - USNETL report

Life Cycle Assessment of BC LNG vs Coal
LNG Canada – March 2015

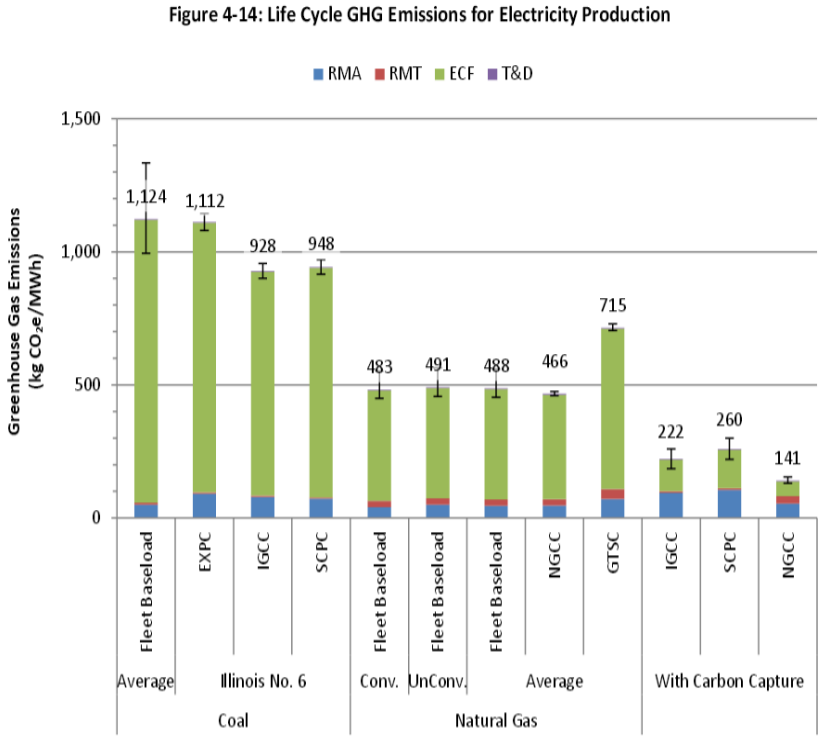
Figure 1 GHG Life Cycle Analysis for B.C. LNG Industry, Coal and other Global LNG



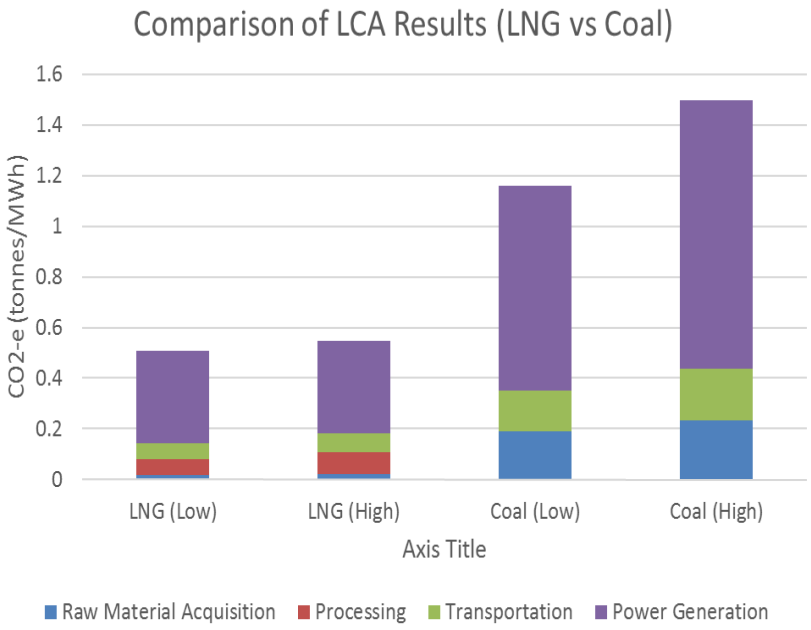
Other Global LCA Studies

GHG emissions of Natural Gas are 40 to 50% less than coal on a Life Cycle basis.

Source - US Dept. of Energy - May, 2014
LCA of Natural Gas Extraction and Power Generation



Source – PACE Global – Oct 2015
LNG & Coal – LCA of GHG Emissions



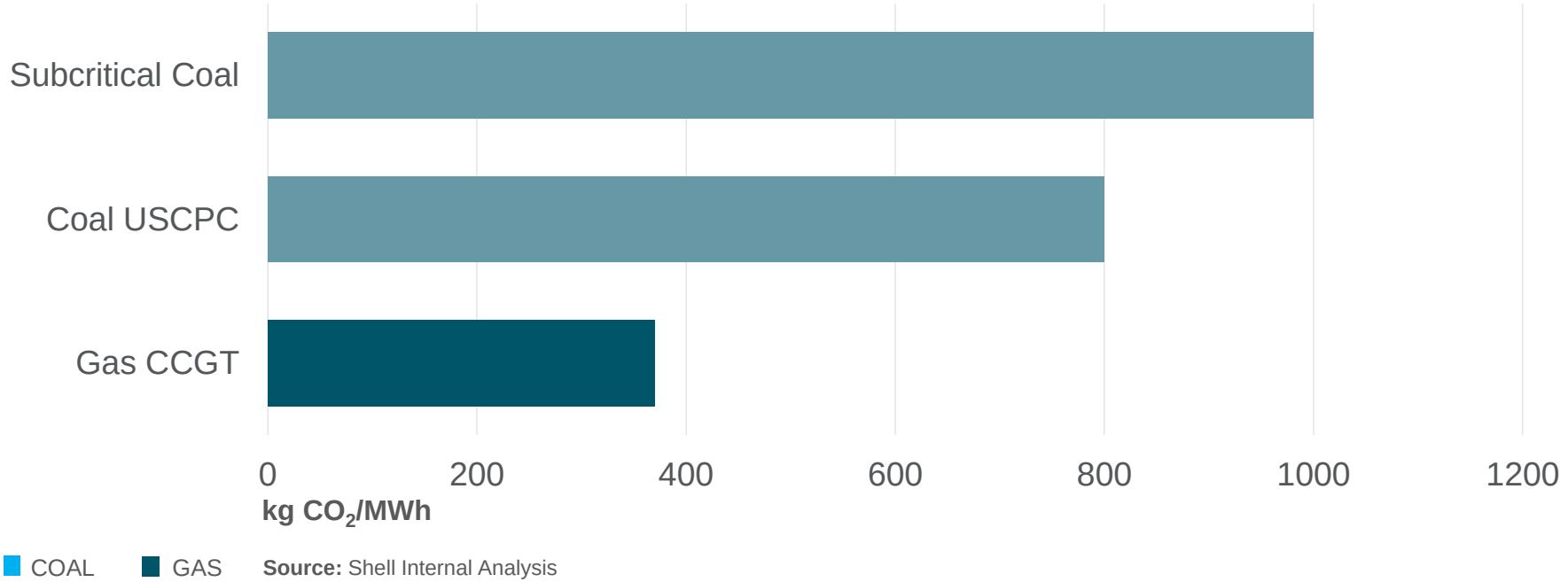
Replacing Coal With Gas – Roughly 50% less CO_2

Gas plants emit:

- Around half the CO_2 of coal
- Up to 70% less CO_2 in the case of an old coal plant

There are still hundreds of old coal plants in operation today

CO_2 Emissions



Source: Shell Internal Analysis

Sensitivities and Uncertainties

Methane emissions

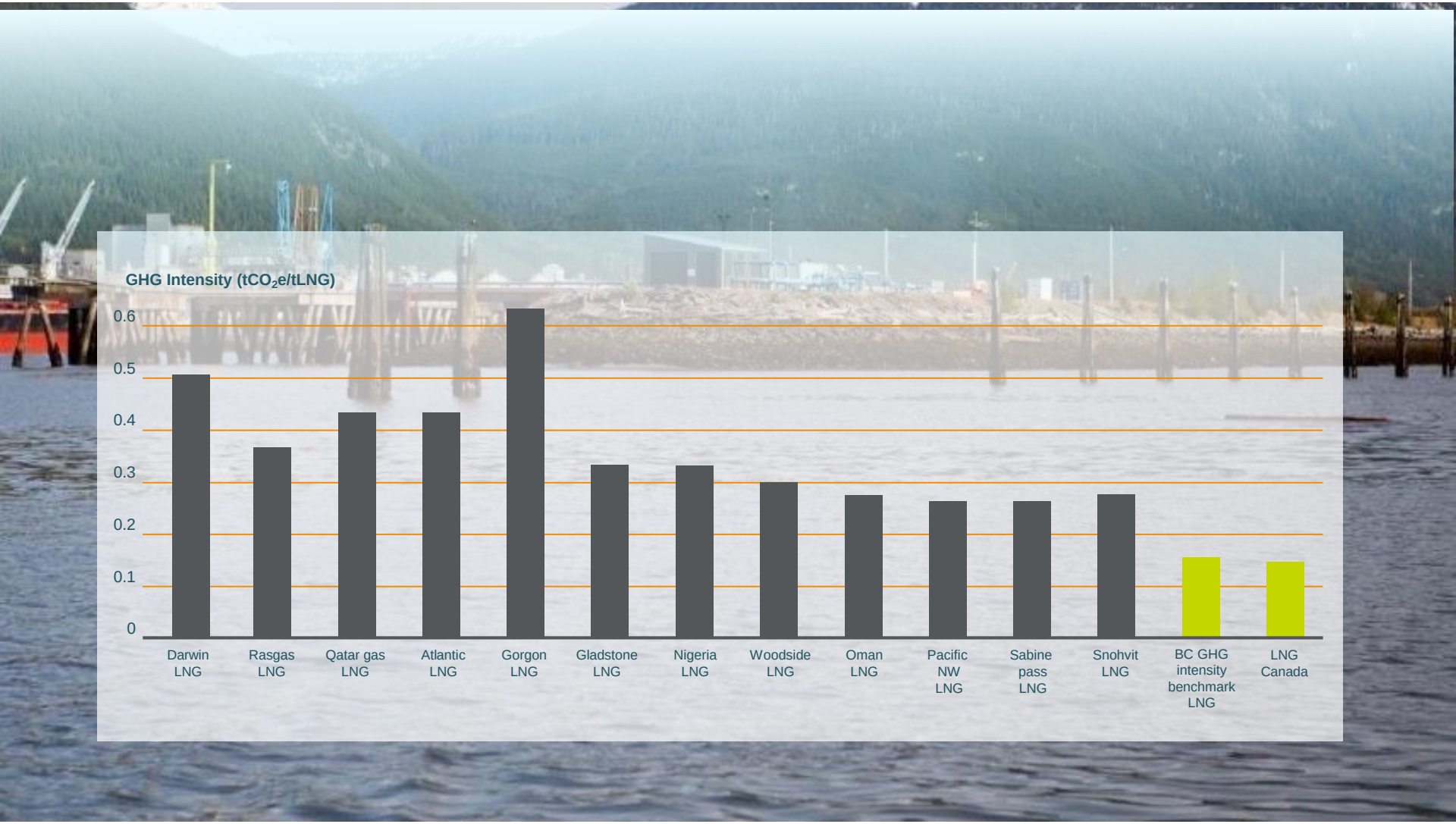
- Upstream estimates based on BC reported methane emissions for the upstream sector
- New methane regulations requiring a 45% reduction in upstream methane emissions
- Improvement in measurement of methane emissions ongoing
- An area for further study … also need to consider methane emissions for the coal pathway and other LNG pathways … a differentiator for Canadian LNG

LNG End Use and Displacement

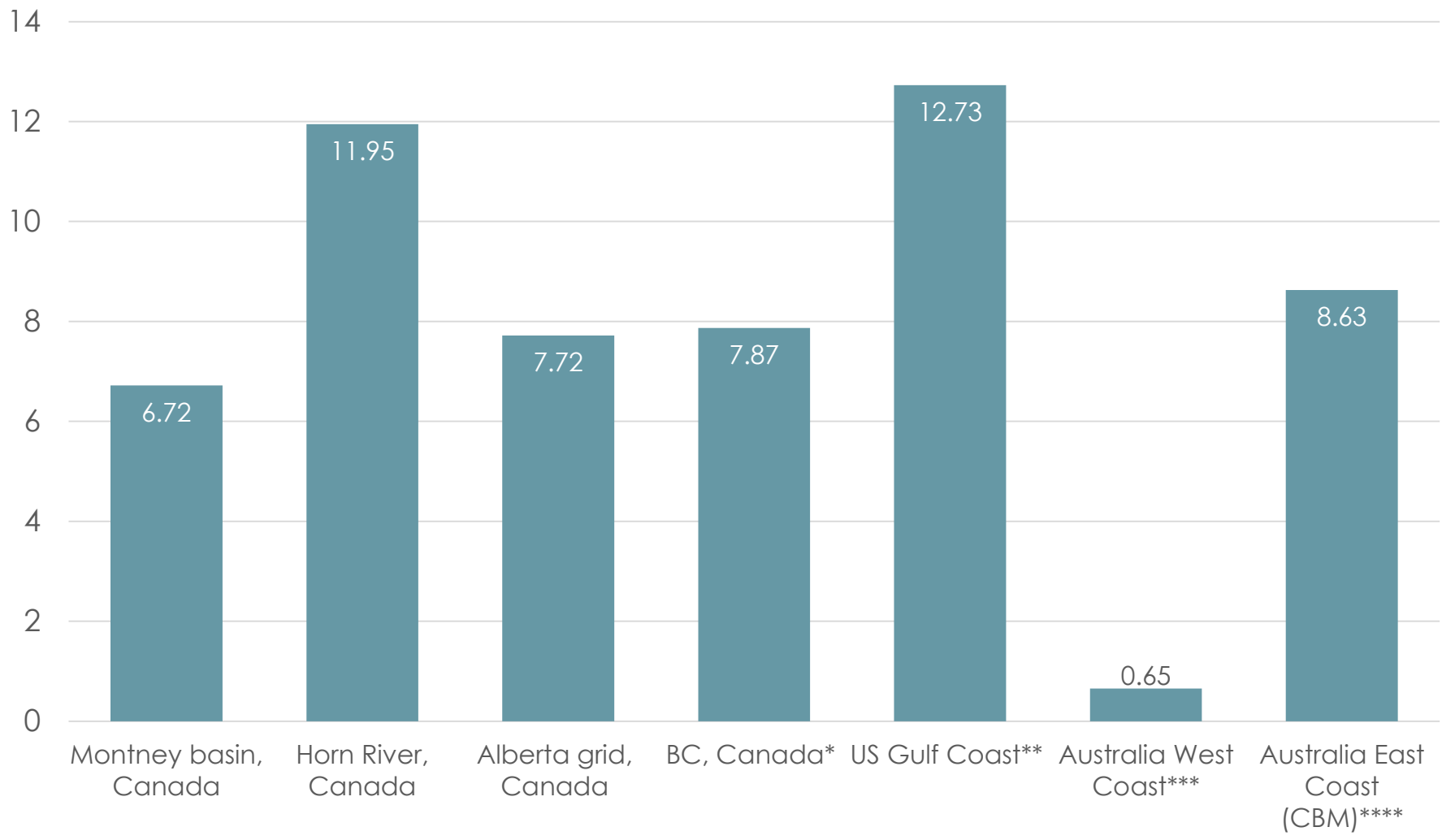
- Study compares LNG for power in China vs coal fired power in China … further work needed to understand what energy sources LNG will back out
- Recent information showing that natural gas is used for district heating and commercial heating in cities … displacing coal … a targeted policy to clean up the airshed in major cities
- End use for LNG and displacement is different for each country

ADDITIONAL SLIDES

LNG Facility Benchmarking – Delphi Consulting 2018



Upstream gas production GHG emissions estimates



Western Canada gas production

Three scenarios for CO_2 content:

- **Upper case:** assumes all feed gas from Horn River (1.5 mol%)
- **Most representative case:** assumes blend of feed gas consists of 70% Montney, 20% Horn River and 10% Alberta production (0.75 mol%)
- **Lower case:** assumes all feed gas from Montney (0.5 mol%)

Pipeline transport

- Emissions estimated based on a linear model from NETL
- Average U.S. natural gas pipeline distance of 971 km assumed
- pipeline GHG emissions intensity of 2.7 gCO_2e/MJ HHV
- Gas loss of 1.45% (includes combustion and fugitive losses)

LNG plant

GHG emissions intensity varies considerably due to:

- Variation in the level of vented CO_2
- Variation in facility design
- Variation in annual average ambient temperatures

Facility	Upper Case		Most Likely Case		Low Case	
	$tCO_2e/tLNG$	gCO_2e/MJ	$tCO_2/tLNG$	gCO_2e/MJ	$tCO_2/tLNG$	gCO_2e/MJ
B.C. LNG (generic)	0.26	5.10	0.170	3.49	0.10	1.92
US Gulf Coast	0.29	5.80	0.260	5.10	0.22	4.40
Western Australia LNG	–	–	0.395	7.90	–	–
GLNG/APLNG	–	–	0.353	7.06	–	–

LNG Shipping

- Modeled based on a tank carrier with capacity of 138,000 m^3 (conservative size)
- Shipping distances for LNG from various jurisdictions to China estimated using marine distance calculators
- For LNG from East Coast Australia, emissions taken from published literature

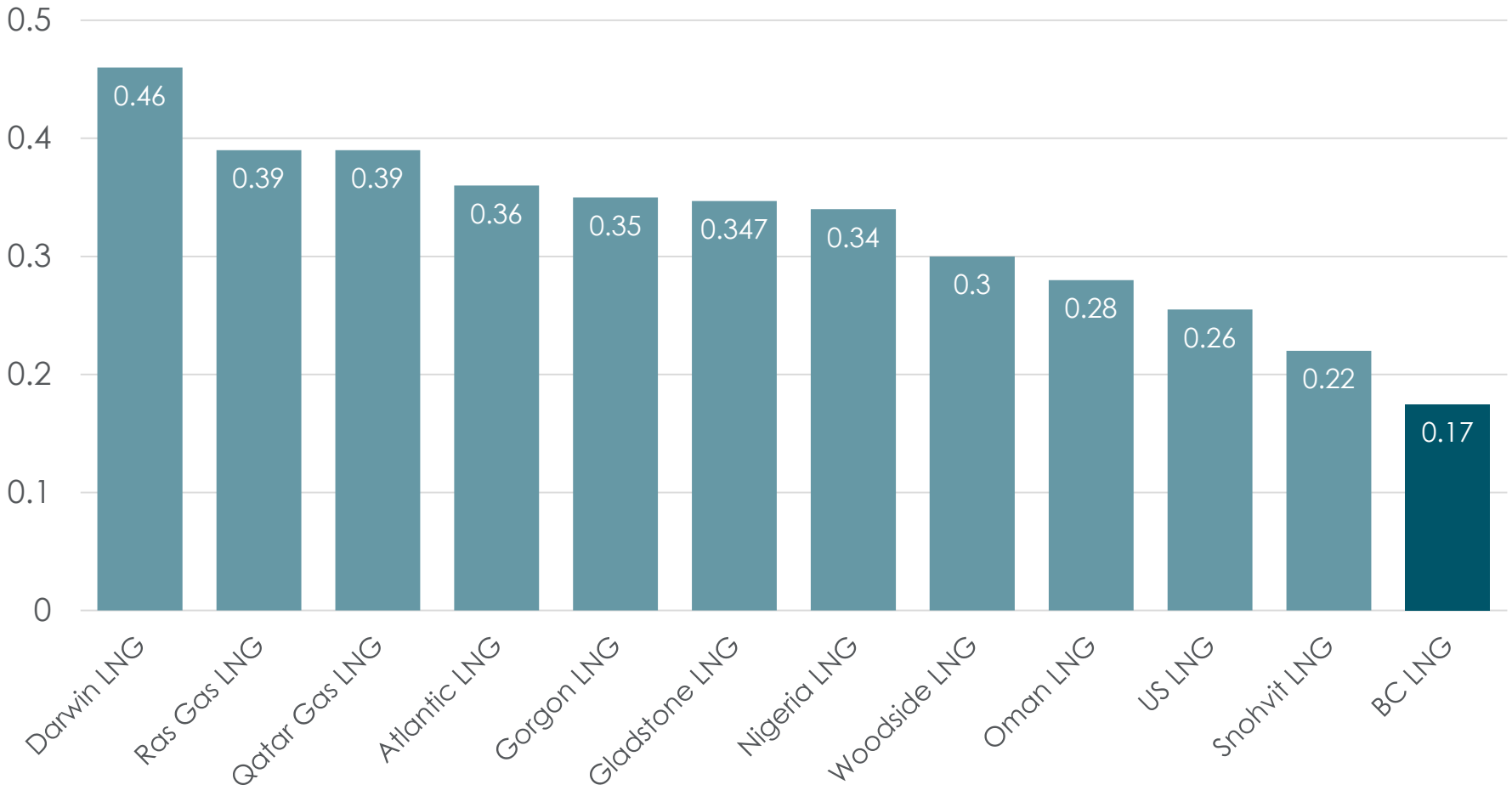
Re-gasification, pipeline distribution and combustion for power generation

- **Re-gasification:** study assumes submerged combustion vaporizer (SCV) to produce heat needed to vaporize the LNG before it can be distributed to the pipeline
- **Pipeline distribution:** assumed distance of 150 km between re-gasification terminal and natural gas power plant for all pathways
- **Combustion for power generation:** a performance range for power generating facilities was assessed based on a WorleyParsons assessment

4.0 Facility Benchmarking

B.C. LNG facilities can have world-class GHG intensity

LNG plant intensity ($tCO_2e/tLNG$)



BC LNG - Reducing global greenhouse gases

How much energy does 1 large BC LNG facility deliver to China, and how much power is produced?

Energy and Power from 1 large BC LNG facility (24 mtpa of LNG)

- Energy content of 1 tonne of LNG = 51.455 GJ (14.29 MWh of energy)*
- Energy content of 24 million tonnes of LNG = 342,960 GWh power
- Annual Power production from 24 mtpa of LNG = 188,970 GWh power (assumes 5% losses in transport and 58% power plant efficiency)

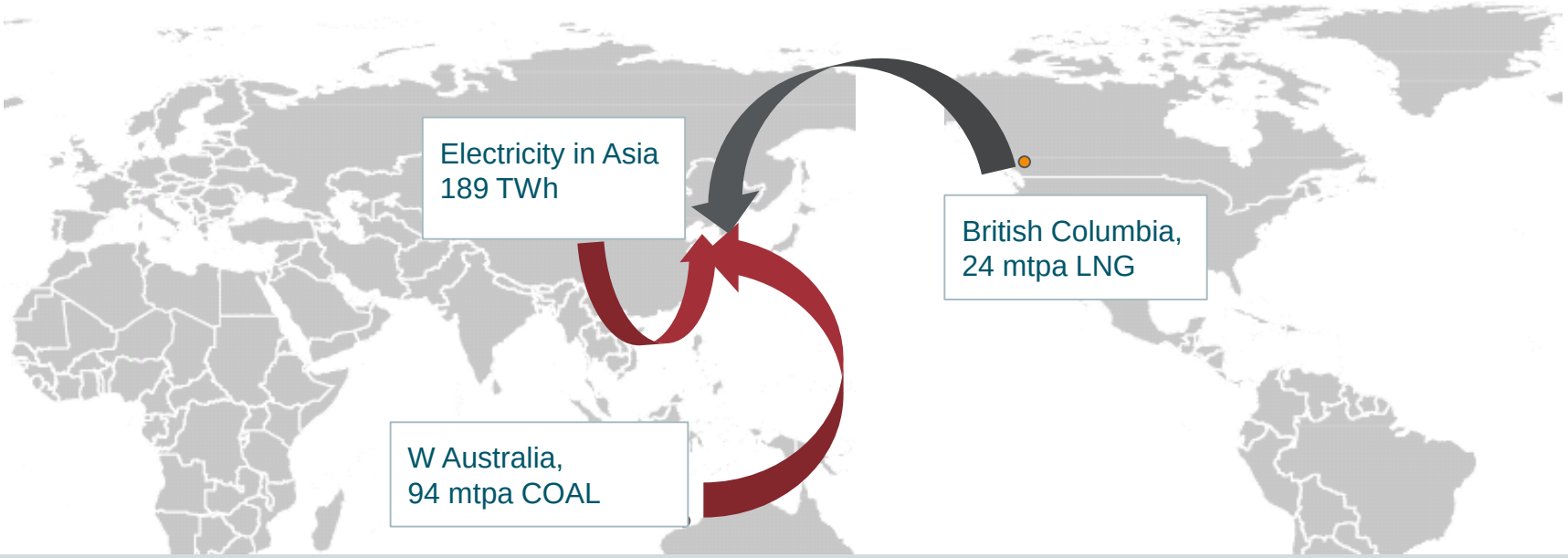
How many power plants does this take

- 21.5 GW installed power needed to generate 188,970 GWh of energy in a year
- 43 Power Plants of 500 MW Capacity needed to generate 21.5 GW or 188,970 GWh in one year

* Source – NEB Canada

BC LNG - Reducing global greenhouse gases

How much less global CO2 for power from 24 mtpa of BC LNG delivered to Asia vs equivalent power from domestic or imported Coal to China on an Annual basis?

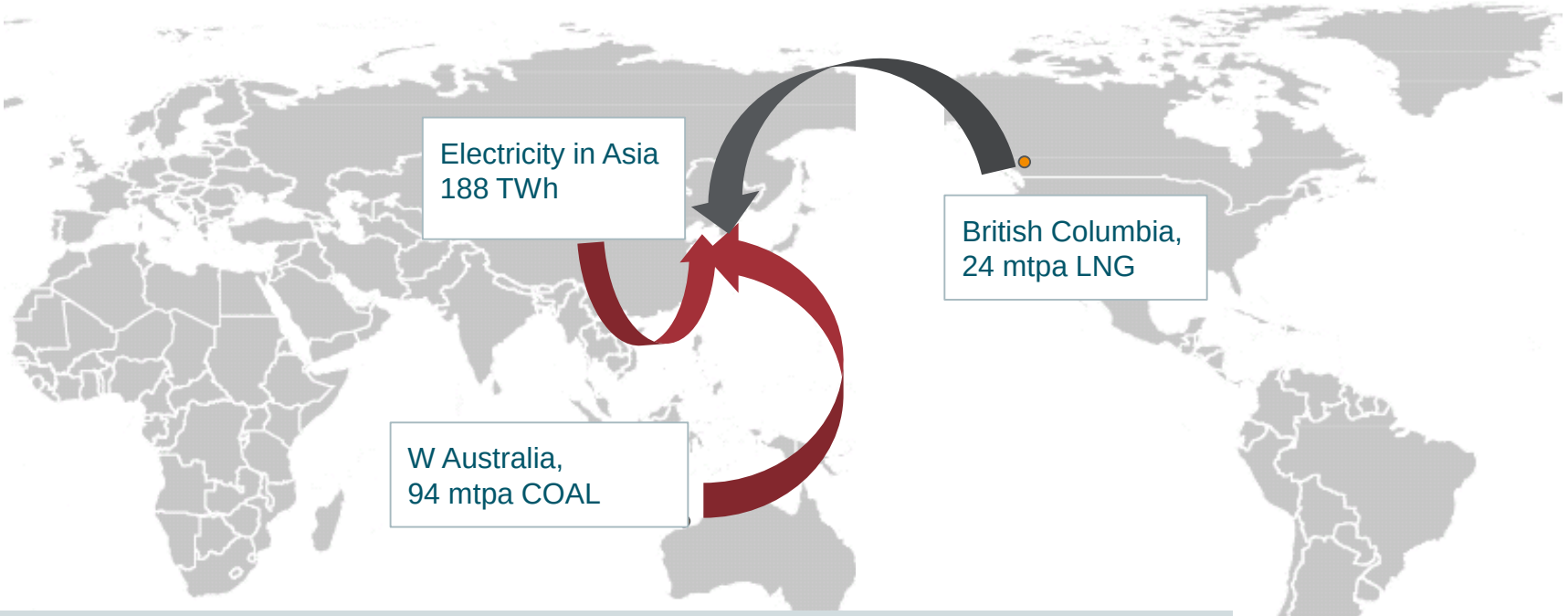


Difference in GHG Emissions Based on 189 TWh of electricity produced from LNG and Coal

- **Coal LCA Emission = 0.9 to 1.1 tonnes CO2e/MWh**
- **LNG LCA Emissions = 0.5 to 0.55 tonnes CO2e/MWh**
- **Low Differential (Low Coal LCA - High LNG LCA) = 0.9 - 0.55 tCO2e/MWhX189TWh= 66 Million tonnes/yr**
- **Medium Differential (Avg Coal LCA – Avg LNG LCA) = 1.0 – 0.525 tCO2e/MWhX189 TWh = 90 million tonnes/yr**
- **High Differential (High Coal LCA – Low LNG LCA) = 1.1 – 0.5 tCO2e/MWhX189 TWh = 113 Million tonnes/yr**

Reducing global greenhouse gases

LNG produces 66 - 90 million tonnes/yr less CO_2 than Coal for equivalent power produced in Asia from one large BC LNG plant



66 – 90 million tonnes in GHG reduction represents:

- More than all of British Columbia's annual GHG emissions
- Approximately 10% of Canada's GHG emissions
- Equivalent to taking 2/3 of all cars in Canada off the road!

Reducing global greenhouse gases

One large BC LNG facility produces 66 - 90 million tonnes/yr less CO_2 than Coal for equivalent power produced in Asia

This is equivalent to :

- **Reducing over 100% of British Columbia's total GHG emissions (62 Mt/yr est'd in 2016)**
- **Reducing approximately 10 % of Canada's GHG emissions (716 Mt/yr est'd in 2017)**
- **Taking 14 to 21 Million cars off the road (66 – 100 % of all the cars in Canada based on StatCan data)**
- **Equivalent of replacing 20 to 40 Coal Fired Power plants (500 or 1000MW units) with Natural Gas**

B.C. LNG advantages

- Ability to use the latest technology
- Opportunity to use low-carbon hydroelectricity from the B.C. grid (93% renewable energy) for a portion of power needs
- Colder ambient temperatures that improves LNG process efficiency
- Relatively low CO_2 content in the natural gas (feed gas) supplying the B.C. LNG facilities (maximum allowable CO_2 content of 2 mol%)

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