Liquefied Natural Gas Export: Markets and Environmental Implications

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Introduction

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- With new abundance of natural gas, investors seeking new markets with liquefied natural gas (LNG).
- A lot to discover regarding the life cycle emissions of LNG export as global natural gas markets evolve.
- Increasing attention on fugitive methane (and other) emissions.
- Goal: review LNG export challenges and opportunities, then analyze the emissions implications of increasing export from the US and Canada.

Global imports/exports of natural gas (2014)

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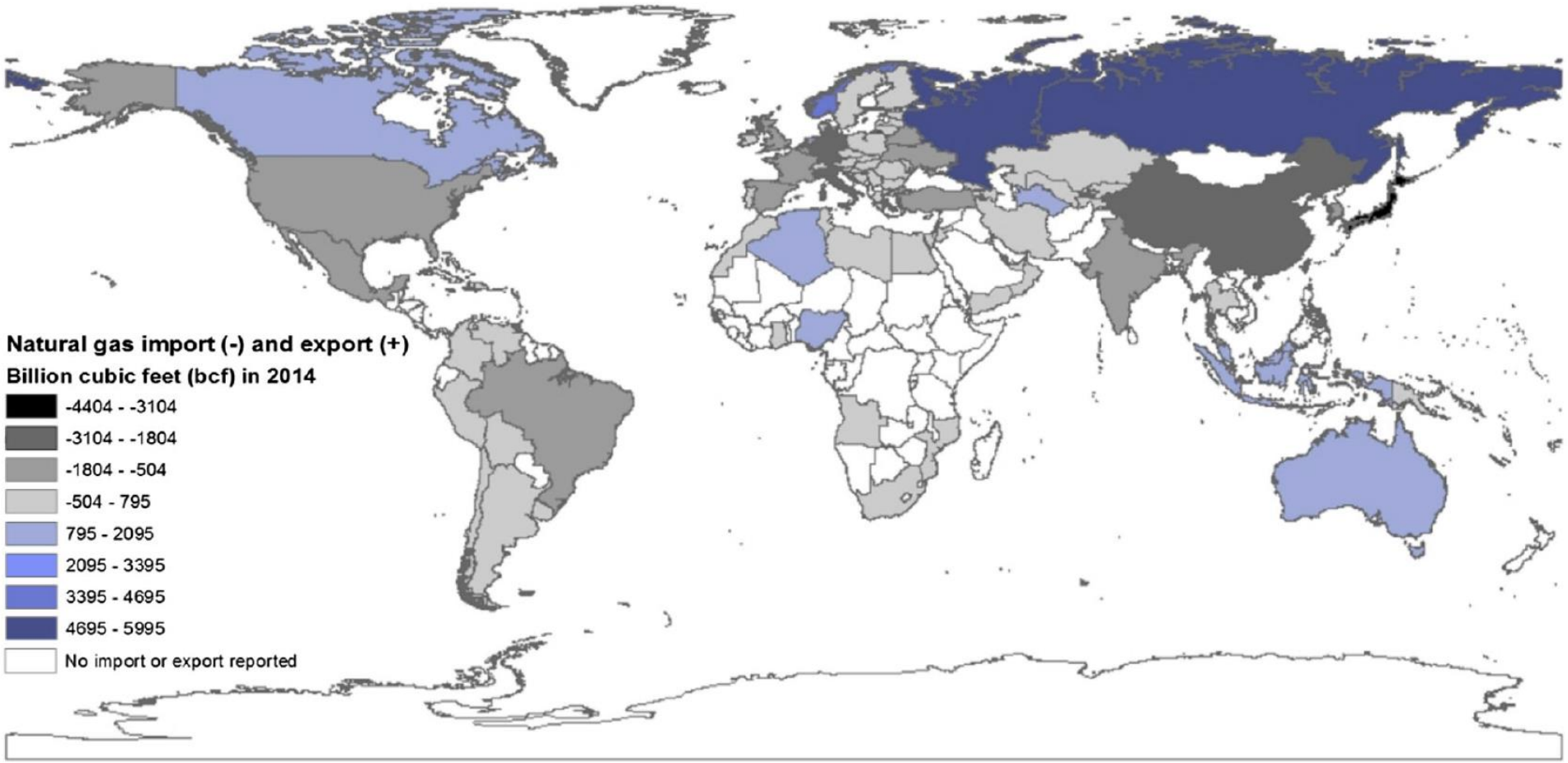
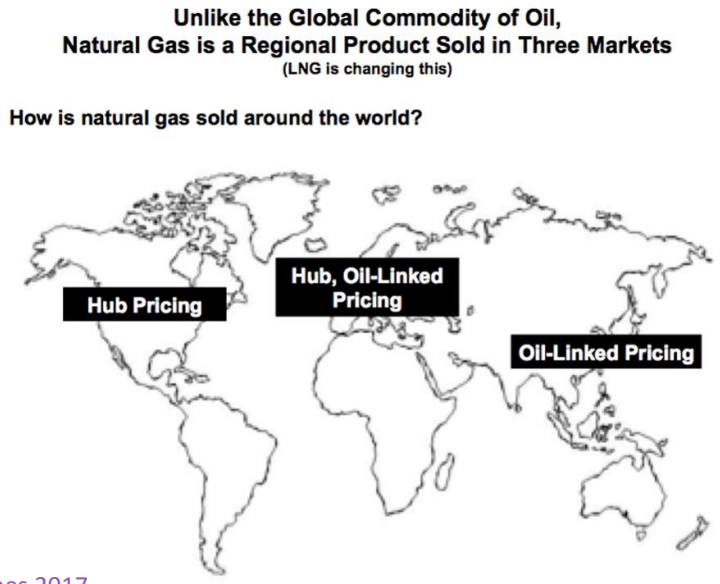


Boersma and Jordaan (2017) - https://link.springer.com/article/10.1007/s41825-017-0005-4

Market evolution

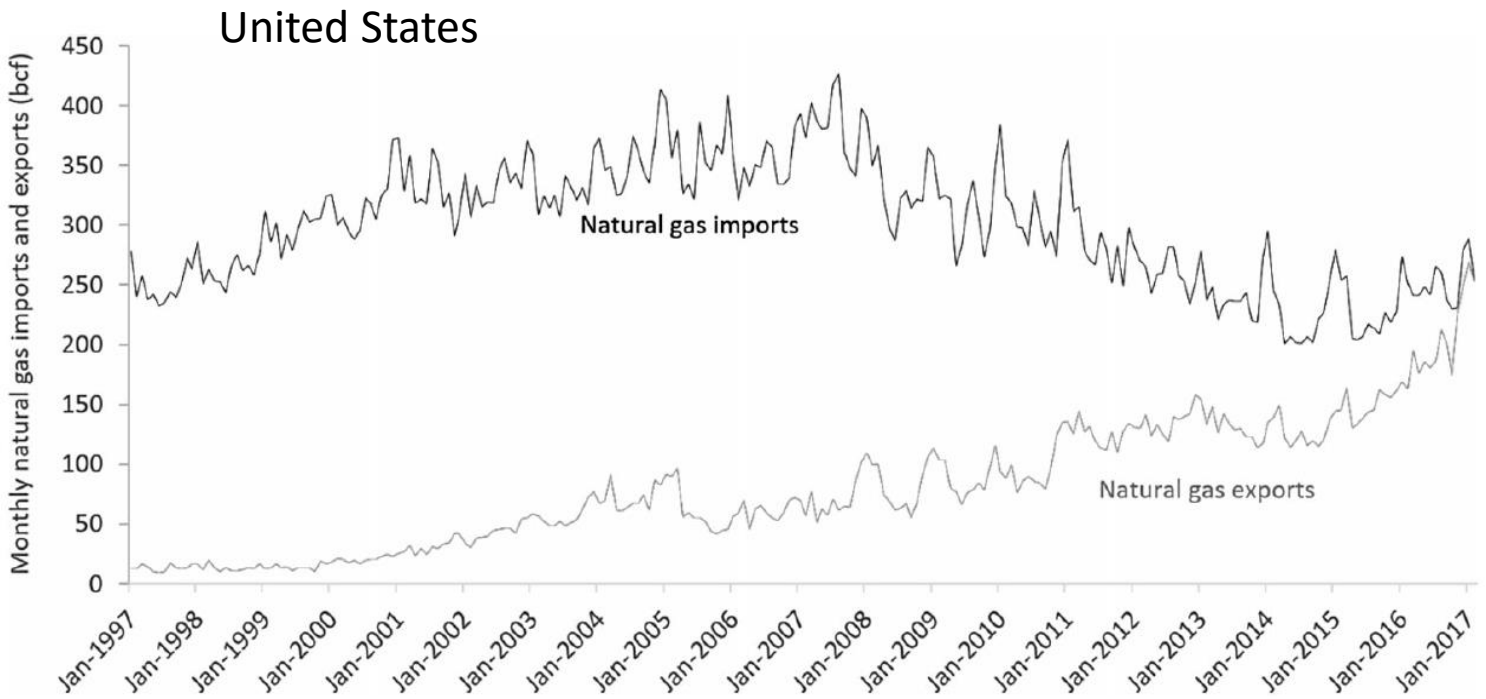


Forbes 2017

- Three separate markets traditionally, with different pricing structures.
- More connected markets and inter-market trade are influencing their evolution.

- Specific landed prices jump to different markets.
- Decrease in prices across markets since 2015.
- Appears to be reflective of increased market connectivity, supply glut, recovery from shock.

Export of natural gas continues to grow



North American Import	# plants	Capacity (Bcfd)
Proposed	2	0.5
Approved	4	3.4
Existing	16	21.9

www.ferc.gov/

North American Export	# plants	Capacity (Bcfd)
Proposed	13	23.1
Pre-filing	5	6.2
Approved	15	23.2
Existing	2	2.3

www.ferc.gov/

Boersma and Jordaan (2017)

Whatever happened to the Golden age of natural gas?

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- Supply-side abundance
  - U.S. shale boom reversed assumptions regarding supply (and changed reserve estimates, globally).
  - North America emerging as an energy superpower.
  - EU reliant on Russia, hesitant to scale shale potential.

- Demand-side uncertainty
  - Price volatility in non-OECD Asia – seeking alternatives.
  - OECD Asia face competing goals: energy security, environment, energy access.

Boersma and Jordaan (2017)

What is Life Cycle Assessment?

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- Life Cycle Assessment (LCA) is ‘cradle to grave’ assessment, in this case of greenhouse gas emissions (GHG).
- Several different methods – process LCA, EIO-LCA.
- LCA and the fuel cycle (supply chain).

How to undertake an international LCA?

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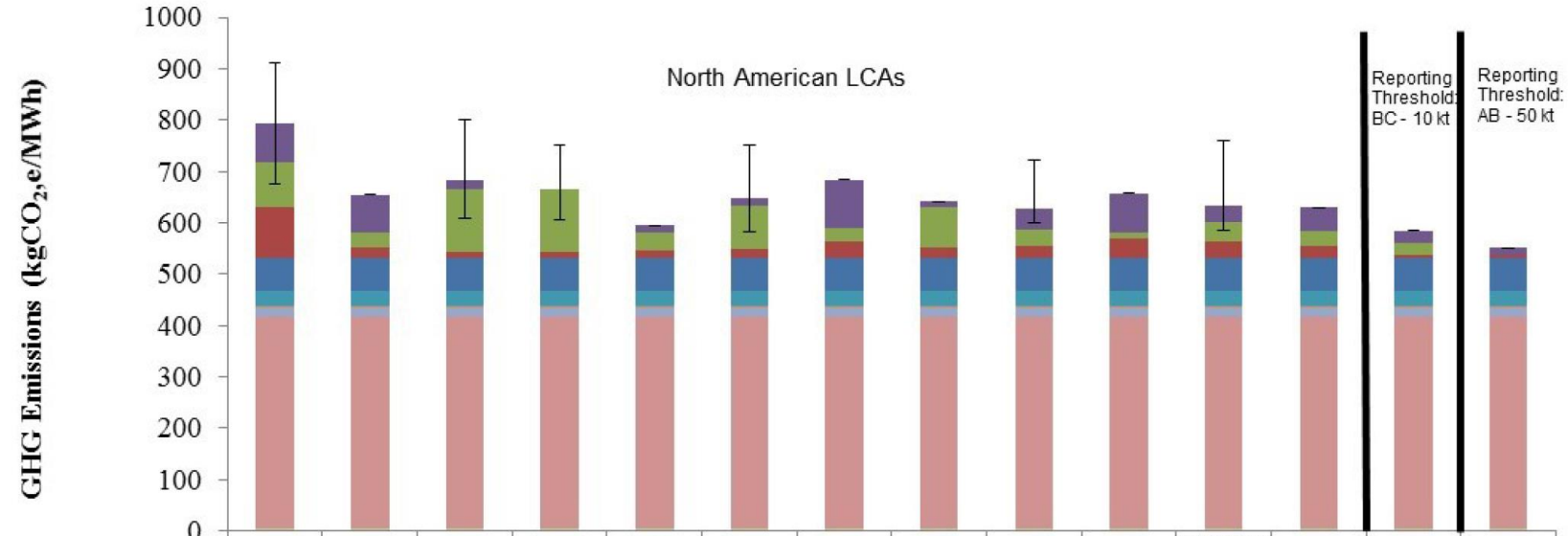
- LCA is typically undertaken within a country's or defined sub-region's borders.
- A calibrated LCA is required that accounts for boundaries on regulatory jurisdiction and alternative uses for LNG.
- Presently, there is no comprehensive, interjurisdictional LCA database that employs the same methodology across shale basins in the US, Canada, and globally.

Upstream data collection and calibration



	Howarth	Burnham	Jiang	Venketash	Stephenson	Weber	Fulton	NETL	JISEA	Laurenzi & Jersey	DOE/NETL N-O to Shanghai	GHGenius	BC	AB
Production	75.7	73.6	16.1	0.0	14.7	15.0	93.9	10.9	42.3	77.1	33.3	44.3	23.2	14.2
Processing	86.9	29.1	122.7	122.7	33.1	84.7	25.8	78.0	31.1	10.8	37.0	30.5	23.6	0.0
Transportation	99.6	19.9	12.3	12.3	15.4	18.2	33.2	21.7	23.6	38.0	32.0	22.9	6.6	5.5
Liquefaction	64.7	64.7	64.7	64.7	64.7	64.7	64.7	64.7	64.7	64.7	64.7	64.7	64.7	64.7
LNG Transport	29.4	29.4	29.4	29.4	29.4	29.4	29.4	29.4	29.4	29.4	29.4	29.4	29.4	29.4
Tanker Berthing & Deb.	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
LNG Regasification	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7
Power Plant Ops	415	415	415	415	415	415	415	415	415	415	415	415	415	415
Electricity Trans.& Dist.	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3

Figure 2: Comparison of different studies for life cycle greenhouse gas emissions of shale gas production

Coleman et al (2015) - https://prism.ucalgary.ca/retrieve/44157/LNG-OP49.pdf

LNG compared to average generation mix

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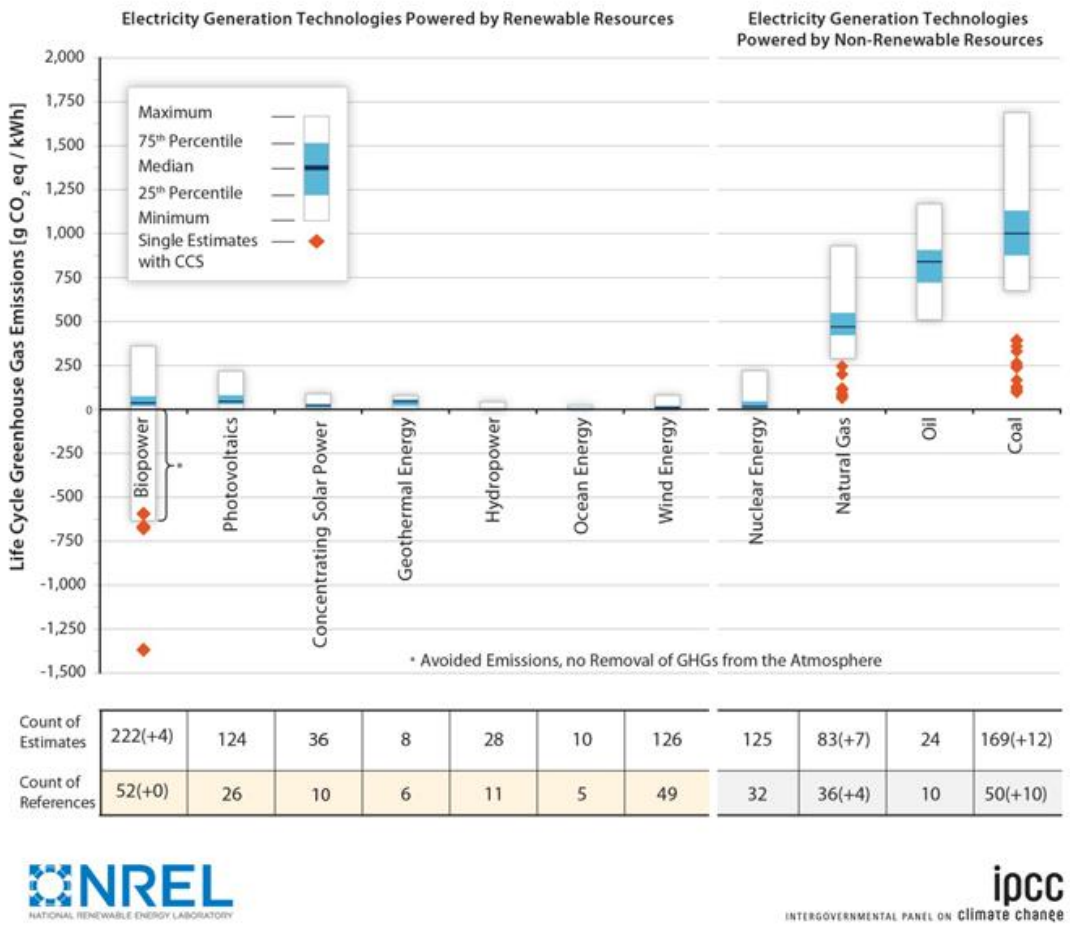


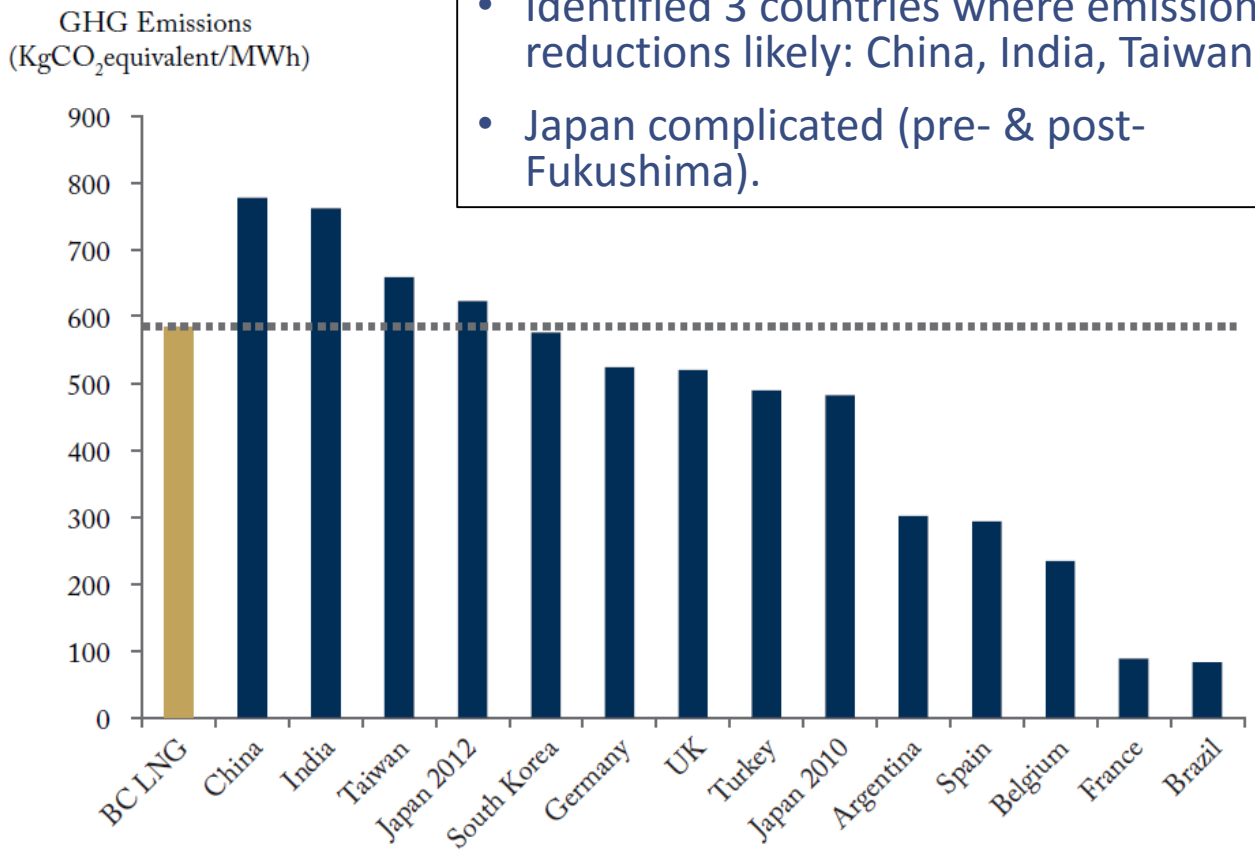
	Biopower	Photovoltaics	Concentrating Solar Power	Geothermal Energy	Hydropower	Ocean Energy	Wind Energy	Nuclear Energy	Natural Gas	Oil	Coal
Count of Estimates	222(+4)	124	36	8	28	10	126	125	83(+7)	24	169(+12)
Count of References	52(+0)	26	10	6	11	5	49	32	36(+4)	10	50(+10)

NREL NATIONAL RENEWABLE ENERGY LABORATORY

ipcc INTERGOVERNMENTAL PANEL ON climate change

https://www.nrel.gov/analysis/life-cycle-assessment.html

- C.D.Howe report: compared to average electricity generation mixes.
- Identified 3 countries where emissions reductions likely: China, India, Taiwan.
- Japan complicated (pre- & post-Fukushima).



Coleman and Jordaan (2015) – posted on C.D. Howe

Ongoing research

Improving results to include country-level infrastructure and power plant efficiencies in importing nations.

Key recommendations

Industry

- Promote consistent reporting across jurisdictional boundaries
- Participate in the international standardization of LCA, measurement, and reporting related to regions and nations involved with natural gas import/export
- Participate in measurement studies

Governments

- Similarly, to participate in the international standardization of LCA, measurement, and reporting related to regions and nations involved with natural gas import/export
- Promote the use of LNG in coal-using countries through trade agreements

Concluding remarks and future research

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- Global markets have evolved from the Golden Age to an era of potential market convergence, supply glut, and demand uncertainty.
  - Yet, the LNG export continues to grow.

- Much left to discover related to the development of inter-regional and international LCA.
  - Infrastructure and end uses in importing countries presently not well accounted for.
  - Power dispatch and markets presently not well modeled.

- Comprehensive datasets data by region and country to develop standardized but accountable LCA.

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