Exhibit 2

OILCHANGE INTERNATIONAL

JANUARY 2018

JORDAN COVE LNG AND PACIFIC CONNECTOR PIPELINE GREENHOUSE GAS EMISSIONS BRIEFING

FACTS AT A GLANCE

Total Annual GHG Emissions:	**36.8 million metric tons**
Emissions Equivalent:	**15.4 times the 2016 emissions of Oregon's last remaining coal-fired power plant (the Boardman plant) – or 7.9 million passenger vehicles**
Pipeline Project Name:	Pacific Connector Gas Pipeline
LNG Export Terminal Project Name:	Jordan Cove Energy Project
Ownership:	Pembina Pipeline Corporation
Operator:	TBD
Pipeline Length:	229 miles
Pipeline Diameter:	36 inches
Pipeline Capacity:	1.2 billion cubic feet per day (cf/d)
LNG Export Capacity:	7.8 million metric tons of gas per year (MMT/Y)
Project Cost:	$10 billion
Land Affected:	5,146 acres
States Directly Affected:	Oregon
Counties Affected:	Coos, Douglas, Jackson, and Klamath
Gas Source:	The Rocky Mountain states of Utah, Wyoming, and Colorado and the Montney Basin in British Columbia
Claimed Destination Markets:	Primarily Asia – Japan and China
Intended Permit and Project Schedule (Est.):	Final Environmental Impact Statement (August 2018); FERC order granting authorization and state permits (November 2018); Construction (first half of 2019); In-service date (first half of 2024)

SUMMARY

The proposed Pacific Connector Gas Pipeline and Jordan Cove Energy Project would transport and process into liquefied natural gas (LNG) around 430 billion cubic feet of fossil gas annually.[a] The greenhouse gas (GHG) emissions triggered by the project will be significant, but to date the scope of these emissions has not been well understood.

This paper provides an estimate of the full lifecycle emissions of the project, calculating a reference and high case estimate using the best available information. It finds that the project would add significantly to greenhouse gas emissions both globally and within the state of Oregon.

The emissions estimate includes an estimated range of methane leakage along the supply chain and finds that even a conservative estimate of methane leakage undermines claims that the gas supplied to global markets via the project would lead to a net reduction in GHG emissions. The paper also finds that there is no evidence to support an assumption that gas supplied by the project would replace coal in global markets.

In order to address the global climate crisis, emissions from all sources of fossil fuel must be reduced to zero by mid-century. Building and operating this project will undermine that goal. This paper provides the clear climate rationale against the project going ahead.

a We use the term fossil gas to mean natural gas produced from fossil fuel sources.

Above: LNG Tanker ©Smit Ebro , Grace Dahlia & Fairplay 21

PACIFIC CONNECTOR GAS PIPELINE MAP

PROJECT OVERVIEW

The Pacific Connector Gas Pipeline (PCGP) is a proposed 36-inch fracked gas pipeline that would run 229 miles across southern Oregon to a proposed liquefied natural gas export terminal at Jordan Cove, near Coos Bay, OR. The pipeline would start in southern Klamath County in the farming community of Malin, OR.

The proposed route of the pipeline crosses the Cascade mountains, threatening public and private lands, traditional tribal territories, and more than 2,000 acres of forest. Close to 400 rivers and streams would be crossed, including the Rogue, Klamath, Umpqua, Coos, and Coquille Rivers.

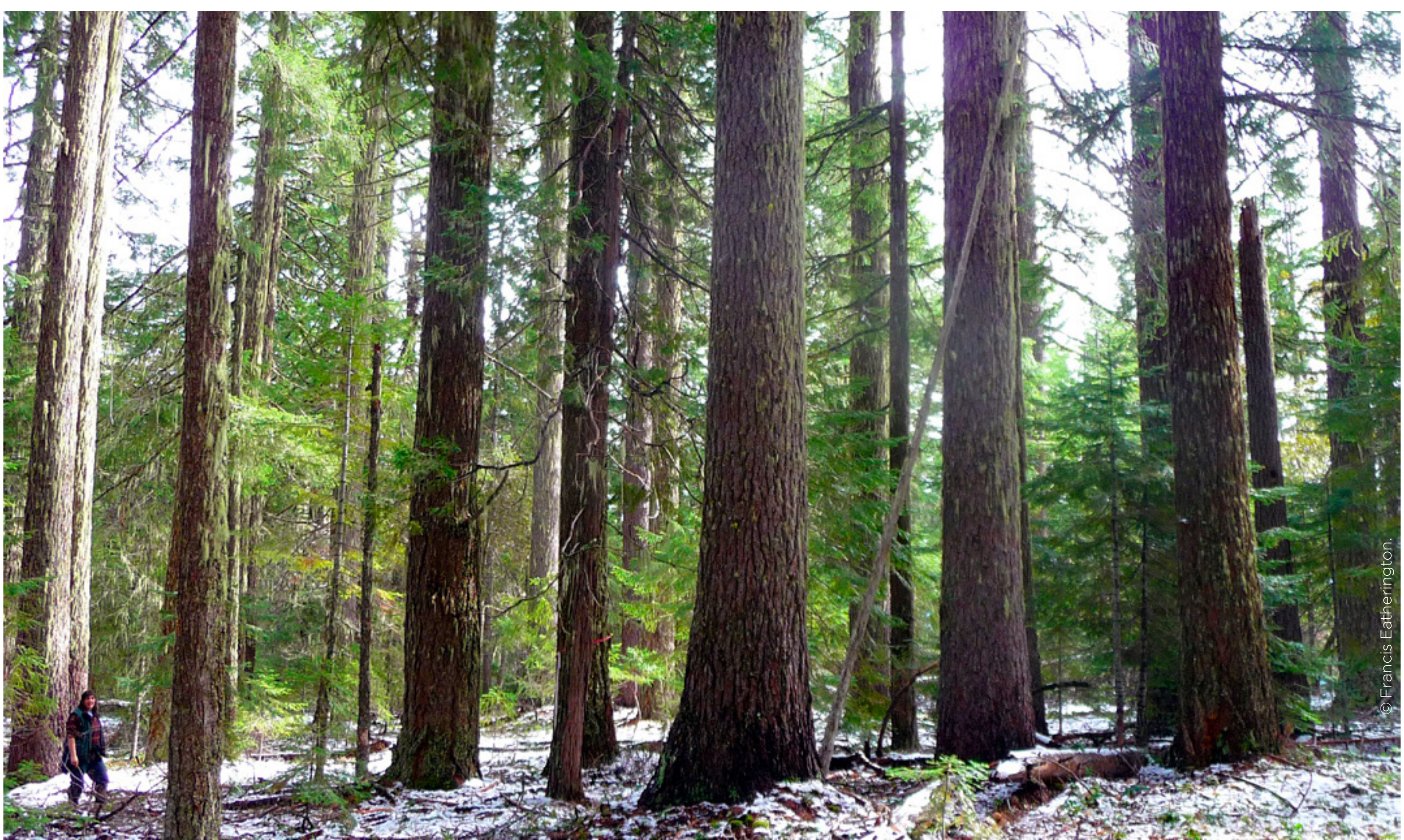
The project is facing significant opposition from indigenous communities along the pipeline route, including the Klamath Tribes, as well as the Yurok and Karuk Tribes along the Klamath River. The construction of the pipeline and the terminal would disturb sacred sites, burial grounds, and cultural resources and could also impact critical runs of salmon and steelhead. The Jordan Cove LNG export terminal would be built on traditional Coos tribal territory. There are also over 500 landowners along the pipeline route that would be impacted by the pipeline, and many will face eminent domain proceedings for the private project if it moves forward. More than 400 landowners, organizations, tribal members, and concerned citizens have filed motions to intervene with the Federal Energy Regulatory Commission (FERC) in opposition to the project, with only five interventions filed in support.[1]

The project backer is the Canadian company Pembina Pipeline Corporation, a fossil fuel giant that recently merged with Veresen, the original proponent of the pipeline proposal. The pipeline would be fed by either of two existing pipelines – the Ruby Pipeline that runs from the Rocky Mountains in Wyoming to Malin, or the Gas Transmission Northwest pipeline that runs from British Columbia. Each pipeline is capable of carrying 100 percent of Pacific Connector's capacity of 1.2 billion cubic feet per day. This creates a unique situation in which Canadian and U.S. fracked gas could compete for export, and opens the possibility that Jordan Cove could provide export service for 100 percent Canadian-sourced fracked gas.

The Pacific Connector Pipeline and the Jordan Cove Energy Project were first proposed in 2005 as a gas import project. The original project was vacated in 2012 and replaced with a LNG export proposal in 2013. In a rare federal decision, FERC denied the project application in 2016, stating that, "because the record does not support a finding that the public benefits of the Pacific Connector Pipeline outweigh the adverse effects on landowners, we deny Pacific Connector's request for certificate authority to construct and operate its project."[2] In early 2017, project backers reapplied under the Trump administration, which has stacked FERC with new appointees.

Pembina plans to complete the federal and state permit process by November 2018. It plans to begin construction in the first half of 2019 and bring the export terminal online by the first half of 2024.

Proposed path of pipeline through Umpqua National Forest, south of Tiller, MP 109.



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FOSSIL GAS AND CLIMATE CHANGE

Climate science clearly indicates the need to reduce consumption of all fossil fuels and make a just transition to a clean energy economy.[3] Building major fossil gas infrastructure today undermines action to protect our climate. Increasing access to fossil gas spurs its use, locking us into releasing more emissions when we must progressively produce and use less of all fossil fuels, including gas.

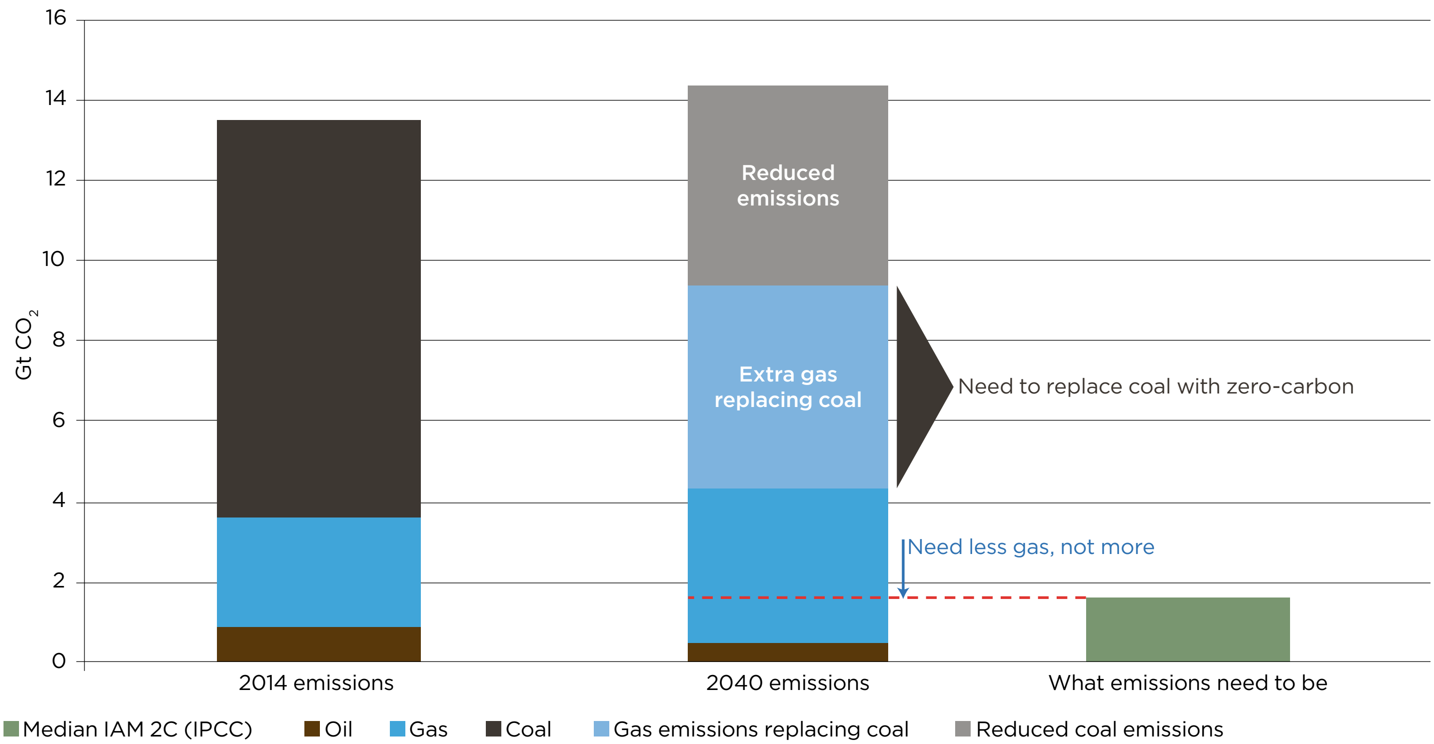
Much of the debate on fossil gas and climate has focused on measuring and reducing the leakage of methane, a potent greenhouse gas, to the atmosphere. But focusing on methane leakage alone distracts from the core issue at hand. To meet climate goals, fossil gas production and consumption must, like that of other fossil fuels, be phased out. Reducing methane leakage, even to zero, does not alter that fact.

Fossil gas proponents also argue that more gas capacity is needed to complement renewable energy sources. Several factors undermine this case, summarized as follows:[4]

1. **No Room for New Fossil Gas:** Climate goals require the power sector to be decarbonized by mid-century. This means gas use must be phased out, not increased (see Figure 1).
2. **New Gas is Holding Back Renewable Energy:** Wind and solar are now cheaper than coal and gas in many regions. This means new gas capacity often displaces new wind and solar rather than old coal.
3. **The Wrong Gas at the Wrong Time:** Claims that gas supports renewable energy development are false. The cheapest gas generation technology, Combined Cycle Gas Turbines (CCGT), is designed for base load operation, not intermittent peaking. In any case, most grids are a long way from renewable energy penetration levels that would require back up. Storage and demand response will be ready to step in by the time they are really required.
4. **New Gas Locks in Emissions for 40+ Years:** Companies building multibillion-dollar gas infrastructure today expect to operate their assets for around 40 years. Emissions goals mean this expectation cannot be met.
5. **Too Much Gas Already:** The coal, oil, and gas in the world's currently producing and under construction projects, if fully extracted and burned, would take the world far beyond safe climate limits. Opening new gas fields is inconsistent with the Paris climate goals.

The fact that methane leakage cannot be reduced to zero, and therefore emissions from fossil gas are in fact higher than is often accounted for, only makes the phasing out of fossil gas more urgent. By enabling an increase in production and consumption of fossil gas, the Jordan Cove LNG terminal and Pacific Connector Gas pipeline will contribute significant amounts of greenhouse gas emissions that will exacerbate climate change.

Figure 1: We Need Less Gas, Not More: Global Emissions from Power Generation (2014 and projected 2040 in IEA New Policies Scenario) Compared to Median IPCC 2040 Power Emissions Consistent With a Likely 2°C Scenario



Source: Oil Change International analysis, see Endnote 4.

PROJECT EMISSIONS ESTIMATED AT 36.8 MILLION METRIC TONS ANNUALLY

The lifecycle greenhouse gas emissions of the project depend on the amount of gas exported through it, and the methane and carbon emissions associated with extracting, piping, processing, transporting, and burning that volume of gas.

The Jordan Cove LNG terminal is expected to export 7.8 million tons of LNG per year.[5] This would require around 85 percent of the 1.2 billion cf/d capacity of the Pacific Connector pipeline.[6] However, the Jordan Cove Energy Project has signed agreements to use 95.8 percent of the pipeline's capacity. This allows for an additional 10 percent of pipeline capacity for seasonal fluctuations and to carry gas to run equipment at the LNG terminal. The greenhouse gas emissions estimate is therefore based on delivering 1.15 billion cf/d to Jordan Cove.

In our reference case, which utilizes a mean methane leakage rate of 1.77 percent across the gas supply chain, we estimate the total lifecycle emissions caused by the project to be over 36.8 million metric tons (MMT) of carbon dioxide equivalent (CO_2e) per year. This is equivalent to over 15.4 times the 2016 emissions from Oregon's only remaining coal plant, the Boardman coal plant, or equivalent to the annual emissions from 7.9 million passenger vehicles. The Boardman plant is scheduled to close in 2020 because of climate and air pollution concerns.[7]

Based on a peer-reviewed study of methane leakage for gas production in three Rocky Mountain states,[8] a high-end estimate brings the overall leakage rate to just over 4 percent. This would raise the annual lifecycle emissions from the project to nearly 52 million metric tons. This would be nearly 22 times the emissions from the Boardman coal plant, or equivalent to the annual emissions from 11.1 million passenger vehicles.

For Oregon's emissions inventory, emissions savings from shutting down Boardman will be cancelled out by this project.

Annual emissions within Oregon would be over 2.2 MMT, which is slightly less than the 2016 emissions from the Boardman plant. For Oregon's emissions inventory, emissions savings from shutting down Boardman will be cancelled out by this project. In fact, in-state emissions could be higher if the project leads to additional gas being transported on the GTN pipeline from Canada. This would increase emissions at GTN compressor stations located in Oregon.

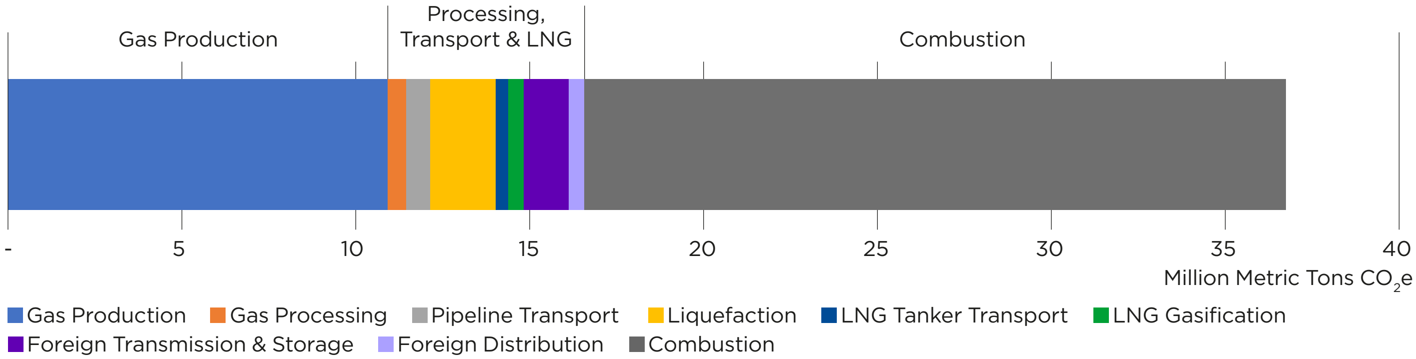
Outside of Oregon, emissions come from fracked gas production and processing, pipeline transport to the state line, tanker transport from Jordan Cove to destinations in Asia, transmission, distribution, and storage between the regasification facility

Table 1: Lifecycle GHG Emissions from Jordan Cove LNG and Pacific Connector Pipeline

Lifecycle Stage	Reference Case (MMT/Y)	High Case (MMT/Y)
Gas Production	10.9	26.0
Gas Processing	0.51	0.52
Pipeline Transport to Jordan Cove	0.78	0.78
Gas Liquefaction	1.8	1.8
Tanker Transport	0.44	0.44
LNG Gasification	0.40	0.40
Foreign Transmission & Storage	1.3	1.3
Foreign Distribution	0.43	0.43
Combustion	20.2	20.2
Total	36.8*	52.0*

*Figures may not add due to rounding.
Source: Oil Change International – See Appendix for details.

Figure 2: Full Lifecycle Emissions from Jordan Cove LNG and Pacific Connector Pipeline - Reference Case



Source: Oil Change International – See Appendix for details.

and points of final use, and finally the combustion of gas.

For methane leakage rates in the production zone, we reference a study published in *Environmental Science & Technology* in June 2017 by researchers from University of Wyoming and Colorado State University. That study quantified atmospheric methane emissions from active natural gas production sites in normal operation in four major U.S. basins/plays: Upper Green River (Wyoming), Denver-Julesburg (Colorado), Uintah (Utah), and Fayetteville (Arkansas).[9] The difference between our reference and high case estimates is primarily based on the difference between the middle and high measurements in the range of figures presented in this paper. However, we did make some downward adjustments to leakage rates in Colorado in both cases, in acknowledgment of new methane regulations in that state (see the Appendix for more details on leakage rates).[10]

For the pipeline and liquefaction emissions of the Jordan Cove and Pacific Connector project, we used emissions data from the latest project application.[11] Elsewhere in the supply chain, we used methane leakage rates based on EPA national averages where we did not have project-specific data. These figures likely underestimate leakage, leading to a conservative estimate of total emissions in our analysis.

We used a 20-year global warming potential factor of 86 to convert methane to carbon dioxide equivalent. For more details on methane assumptions and full details of sources and methods, please see the Appendix.

LNG EXPORTS WOULD HAVE NO EMISSIONS ADVANTAGE OVER COAL

As climate science indicates we must move as quickly as possible toward zero emissions, replacing coal with gas is clearly not a climate solution.[12] Nonetheless, the gas industry and its supporters continue to use this as a talking point, claiming that doing so would lead to a net reduction in emissions. However, even in the hypothetical scenario that every molecule of gas exported from Jordan Cove replaces coal in the destination market, the emissions associated with this project suggest that no net saving in greenhouse gas emissions would occur. In fact, the project could lead to higher net greenhouse gas emissions.

In 2014, the U.S. Department of Energy (DOE) released a "Life Cycle Greenhouse Gas Perspective on Exporting Liquefied Natural Gas from the United States."[13] The report, conducted by the National Energy Technology Laboratory (NETL), found that "compared to domestically produced and combusted gas, there is a significant increase in the lifecycle GHG emissions that are attributed to the LNG supply chain, specifically from liquefaction, tanker transport, and regasification processes."

Domestically, the current climate "break-even" point for lifecycle methane leakage is about 2.7 percent when switching from coal to gas for electricity over a 20-year lifecycle. That means that new gas combined cycle power plants reduce climate impacts compared to coal plants only when leakage remains under 2.7 percent.[14] Other estimates have put the domestic break-even point at 2.8 percent.[15]

When exporting LNG to Asia, the methane leakage rate must be significantly lower to have a "break-even" climate impact. The DOE/NETL report found that when comparing the climate impacts of LNG to coal-fired electricity in China, the lifecycle methane leakage rate would have to stay below 1.4 percent – when exporting LNG from New Orleans to Shanghai – to produce benefits over a 20-year timeframe.

NETL did not model lifecycle greenhouse gas emissions resulting from exporting LNG from the West Coast of the United States to Asian markets. Presumably, the climate break-even point would be slightly higher when exporting LNG from Oregon's Jordan Cove to Asia, given the closer geographic proximity. For comparison, the report found that the break-even point for LNG exports from New Orleans to Europe is 1.9 percent. Therefore, based on the DOE/NETL estimates, the climate break-even point for LNG exported from Jordan Cove to Asia is likely somewhere between 1.4 and 1.9 percent.

Our reference case estimate of methane leakage along the project's entire chain of supply is 1.77 percent. This is likely a conservative estimate as a number of factors could mean the real leakage rate is significantly higher (see Appendix). Even at this relatively low methane leakage rate, claims that greenhouse gas emissions are reduced by replacing coal in Asia with LNG exports from Jordan Cove are unsubstantiated, in part because the methane leakage associated with the project will likely be above the break event point.

FERC'S INADEQUATE CLIMATE ANALYSIS

The Federal Energy Regulatory Commission (FERC) is the primary federal agency that assesses the need for and impacts of interstate gas pipelines and LNG facilities, and it issues permits for construction and operation.[16]

FERC has yet to conduct an updated analysis of the Jordan Cove project, but we know FERC has repeatedly failed to fully assess and analyze the greenhouse gas emissions of the projects it permits. In August 2017, the Sierra Club together with landowners successfully overturned FERC's approval of the Southeast Market Pipelines Project, an interstate fossil gas pipeline project proposed through Alabama, Georgia, and Florida, based on inadequate information on greenhouse gas emissions in the project's environmental impact statement (EIS).[17] Although the project is already completed, the U.S. Court of Appeals vacated and remanded FERC's permits and ordered the agency to issue a supplemental EIS (SEIS) quantifying the project's downstream emissions.

FERC issued a draft of the SEIS in September 2017[18] and the Sierra Club filed detailed and scathing comments on the draft in November.[19] The Sierra Club comments not only call out the continuing inadequacy of FERC's climate emissions analysis, but also add clarity to the case for fully accounting for the entire emissions profile of fossil gas projects.

As in many of FERC's EIS documents, FERC preempts its discussion of greenhouse gas emissions and climate change in the draft SEIS with an assertion that the gas delivered by the project will replace dirtier fossil fuels, namely coal-fired power generation. The Sierra Club raises a number of points regarding this assumption that have salience for Jordan Cove LNG and similar proposed fossil gas infrastructure.

The Sierra Club argues that, to demonstrate that a project is instrumental to the retirement of other fossil fuel capacity, FERC must compare future scenarios with and without the project, rather than simply "juxtapos(ing) past conditions with a future in which the pipeline is built."[20]

A paper published in the international journal *Energy* in November 2017 discussed this issue in detail, specifically examining scenarios in which U.S. LNG is exported to Asia.[21] The paper found that the displacement of coal by LNG exports is far from a given, and that, as a result of U.S. exports of LNG, "emissions are not likely to decrease and may increase significantly due to greater global energy consumption, higher emissions in the US, and methane leakage."[22]

The Sierra Club comments also point out that accelerating projections of renewable energy adoption indicate that retiring coal capacity is not necessarily replaced with gas. Further, much of the coal generation capacity slated for retirement is old and inefficient. It is therefore typically operating far below capacity and likely to be retired whether a new gas pipeline is built or not. In this way, comparisons between retiring installed coal capacity and building new gas-fired capacity are misleading. For power plant emissions to be reduced by retiring coal and adding gas, new gas capacity would have to be run at similarly low utilization rates, which would likely not be economical. With no concrete analysis to back up its assumptions, FERC's attempt to discount gas pipeline emissions based on the offset of dirtier energy sources has no basis in fact.

The Jordan Cove Energy Project makes similar assertions regarding gas replacing coal, claiming that, "(n)atural gas is the cleanest-burning hydrocarbon available, and its transportation to other markets will allow consumers to move away from higher-emission fuels such as coal."[23] The company provides no evidence to support this.

Finally, as the "Climate and Fossil Gas" section explains, the premise that replacing coal with gas leads to positive climate outcomes is flawed. Emissions from fossil fuels need to be close to zero by mid-century to ensure a safe climate. Therefore, any new gas infrastructure built today will need to be replaced with zero emissions energy sources before it reaches the end of its economic life. With Jordan Cove currently scheduled to come online in 2024, investors would expect it to still be operating long after the transition to clean energy should be complete.

There is no evidence that the project would reduce emissions in line with the climate goals established by science - in fact, existing analyses point to the opposite. The 36.8 million tons of annual GHG emissions associated with the project must therefore be viewed as additional pollution that cannot be squared with any greenhouse gas reduction strategy.

There is no evidence that the project would reduce emissions in line with the climate goals established by science - in fact, existing analyses point to the opposite.

OREGON'S CLIMATE GOALS

In 2007, the Oregon legislature adopted goals to reduce climate pollution to 10 percent below 1990 levels in 2020 and at least 75 percent below 1990 levels by 2050.[24] According to these goals, Oregon's greenhouse gas emissions should be below 14.1 MMT in 2050. The state legislature is currently considering the "Clean Energy Jobs Bill," which creates a mechanism to reduce climate pollution in line with state goals.

These goals may fall below the targets set in the UNFCCC's Paris Agreement, which Governor Kate Brown committed to after President Donald Trump withdrew in 2017. The Paris Agreement commits to keeping global temperature rise "well below" 2 degrees Celsius (C) compared to pre-industrial levels and aims for a maximum temperature rise of 1.5°C. The latter goal requires global greenhouse gas emissions to fall to zero by around 2050, while the former (2°C) goal requires emissions to reach zero by about 2065.[25] According to the Oregon Global Warming Commission 2017 Report, Oregon is currently not on track to reach statutorily mandated emission reduction goals in 2020 or 2050.[26]

The total in-state annual emissions of the Jordan Cove Project, which only includes emissions from the LNG terminal, compressor stations, and leakage along the pipeline route, would be over 2.2 MMT, while the total lifecycle emissions of this project are over 36.8 MMT. The LNG terminal alone would emit over 1.8 MMT of greenhouse gas pollution a year, becoming the largest single source of climate pollution in the state of Oregon after 2020. If Oregon reaches its 2050 climate reduction goals, the in-state emissions of Jordan Cove will be equal to 16 percent of Oregon's total emissions, while the lifecycle greenhouse gas emissions will be over 261 percent.

In 2016, the Oregon legislature passed SB-1547, which requires investor-owned utilities to eliminate coal-fired power from Oregon by 2035 because of pollution and climate concerns. Only considering in-state emissions, the Jordan Cove LNG Export Terminal and the Pacific Connector Pipeline would be roughly equivalent to the Boardman coal plant, which is set to close in 2020 in order to meet emissions goals. Considering the total life cycle emissions, this project would be equivalent to over 15.4 Boardman coal plants.

If the state of Oregon's climate policies progress toward alignment with the goals of the Paris Agreement, as Governor Brown has stated she intends,[27] then the project's in-state emissions will constitute an increasingly large proportion of remaining allowable emissions, while providing no actual energy supply for the state. By mid-century, the project will have to be shut down – decades before investors expect the project's economic life to end. Finally, Oregon's commitment to climate leadership would be undermined by hosting a facility that supports unsustainable global emissions and undermines climate action in other regions.

The project's in-state emissions will constitute an increasingly large proportion of remaining allowable emissions, while providing no actual energy supply for the state.

Table 2: GHG Emissions of the Jordan Cove Energy Project as a Percentage of Oregon's GHG Emissions

		Jordan Cove Energy Project		
		LNG Terminal Emissions	Total Project In-State Emissions	Total Project Lifecycle Emissions
	MMT CO_2e per year	1.8	2.2	36.8
Oregon 2015 Emissions	63.4	2.9%	3.5%	58%
Oregon 2050 Goals (75% below 1990)	14.1	13%	16%	261%
Under 2 MOU[b] (2 MT per capita by 2050[c])	11.2	16%	20%	329%

Source: Oil Change International

b The Under 2 MOU, signed by Oregon Gov. Kate Brown in 2015, is a commitment by sub-national governments to reduce GHG emissions towards net-zero by 2050. Central to this is the public commitment by all signatories to reduce GHG emissions by 80-95% below 1990 levels, or to 2 metric tons of carbon dioxide-equivalent per capita, by 2050.
c Based on 5,588,500 Oregon estimated population in 2050. http://www.oregon.gov/das/OEA/Pages/forecastdemographic.aspx

CONCLUSIONS

This briefing provides a calculation and discussion of the greenhouse gas emissions of the Pacific Connector Gas Pipeline and Jordan Cove LNG Export Terminal proposed in the state of Oregon. It clearly shows that the project would add significantly to greenhouse gas emissions both in the state of Oregon and globally.

The analysis shows that methane leakage along the project's supply chain undermines any claim that the project would supply destination markets with cleaner fuel. In addition, the remaining global carbon budget has no room to replace coal with gas, even if methane leakage were zero. In fact, the expansion of fossil gas undermines renewable energy development.

The project would increase the flow of fossil gas to the global market and in doing so would run counter to the goals of the Paris Agreement on climate change. The project would undermine Oregon's potential to play a leadership role in addressing global climate change.

APPENDIX: METHODS AND SOURCES FOR ESTIMATING JORDAN COVE LNG GREENHOUSE GAS EMISSIONS

GENERAL OVERVIEW OF LIFECYCLE EMISSIONS

Lifecycle greenhouse gas emissions include a combination of combustion emissions from burning fossil gas, emissions from producing, processing, and transporting the gas, and methane leakage – the intentional or unintentional leakage of fossil gas into the atmosphere along the full supply chain. In the case of liquefied natural gas export, additional combustion and leakage emissions from liquefaction, tanker transport, regasification, and transport from the import terminal to the ultimate point of consumption must also be included.

Developing any estimate of potential lifecycle greenhouse gas emissions from a proposed project requires using a variety of sources and assumptions. An emissions factor of 117.1 pounds of CO_2 per thousand cubic feet for the combustion of fossil gas is well established and this comprises the largest proportion of total emissions.[28]

Estimates of emissions occurring upstream of the proposed project include the production and processing of fossil gas and are based on available peer-reviewed and government data. For the Pacific Connector pipeline and Jordan Cove terminal, emissions estimates for equipment to be installed, such as compressors and engines, or electricity to be consumed, are supplied in the project applications and environmental impact statement. Emissions occurring downstream or after the defined project's parameters must be determined using other available sources.

The production, processing, and transport of fossil gas requires energy. For example, diesel, gasoline, fossil gas, or electricity are consumed to run drilling rigs, trucks for materials transport, compressors for pipeline pressure, and many other processes that require engines, turbines, and other equipment. Much of the emissions estimates for these stages are derived from expectations of the fuel such equipment is expected to consume based on projected utilization rates and operating times.

In addition to these fuel-based emissions, the production and handling of fossil gas leads to significant quantities of the gas being emitted to the atmosphere uncombusted. Some of this is emitted as part of standard processes such as the blow down of pipelines during maintenance. These intentional emissions of fossil gas are considered 'venting.' Some gas escapes from valves and seals as a result of equipment wear and tear or malfunction and these emissions are considered 'fugitive.'

Fossil gas is primarily made up of methane (CH_4), a hydrocarbon that, pound for pound, is a more powerful heat-trapping gas than carbon dioxide (CO_2), the primary GHG that is causing global temperatures to rise and the climate to change. Because the measurement and analysis of GHGs is based on much more abundant CO_2, the impact of methane on the atmosphere is expressed as a carbon dioxide equivalent (CO_2e) according to its global warming potential (GWP).

CALIBRATING CH_4 WITH CO_2

The study of methane's impact on warming has evolved in the past decade and estimates of the GWP of methane have increased as more has been learned. Methane lasts about 12 years in the atmosphere while CO_2 lasts for centuries. To calibrate methane's impact with that of CO_2, two time horizons have been used: 20 years and 100 years.

We use the 20-year GWP timeframe and 86 GWP for methane from the Intergovernmental Panel on Climate Change's (IPCC) most current *Assessment Report 5* (AR5), because whereas CO_2 accumulates in the atmosphere over the long term, the impact of methane is felt in the short term. Its most important contribution to total warming occurs at the time of peak atmospheric CO_2 concentrations (i.e. net zero CO_2 emissions) – that is, when CO_2 has its greatest warming effect, and methane potentially adds to that maximum amount of warming. According to analyses of IPCC scenarios, net CO_2 emissions need to reach zero around 2050 to have a 50 percent chance of limiting warming to 1.5 degrees Celsius, and around 2065 to have a likely chance of staying below 2 degrees Celsius of warming.[29]

With those scenarios in mind, if the Jordan Cove plant operates from 2024 to 2064, the average molecule of methane will be emitted in 2044 – respectively six years or twenty-six years before peak CO_2 concentrations. As those molecules will have their greatest impact in the period immediately prior to or beyond the point at which CO_2 concentrations should peak, the shorter range GWP is the more relevant measure for the project's methane emissions.[30]

The 100-year GWP is most commonly used by government and industry. It calibrates the GWP of methane at 34 times that of CO_2. However, according to the IPCC: "There is no scientific argument for selecting 100 years compared with other choices. The choice of time horizon is a value judgement because it depends on the relative weight assigned to effects at different times."[31]

The U.S. Environmental Protection Agency (EPA) generally uses the 100-year metric.[32] We strongly urge the EPA and all federal government agencies assessing the impact of fossil gas systems to use the 20-year GWP to properly measure the impact of methane leaked to the atmosphere. This is particularly important at a time when the production of gas is growing so fast, driving increased gas consumption.

STAGES AND SOURCES FOR THE JORDAN COVE GHG ESTIMATE

The estimate of lifecycle emissions begins with fossil gas production and runs the entire journey of the gas through to combustion. In the case of the Jordan Cove LNG terminal, gas would be primarily produced from shale plays in either the Canadian or U.S. Rockies and be transported by pipeline to Malin on the southern Oregon border where the Pacific Connector pipeline would begin.

Project application documents were used for the emissions estimates for the Pacific Connector pipeline and the Jordan Cove LNG plant. The only change we made to these estimates was to convert CH_4 to CO_2e using the 20-year GWP discussed in the previous section.

Methane leakage estimates at the production stage were based on the latest available peer-reviewed science for gas produced in the Rocky Mountain states of Colorado, Utah, and Wyoming.[33] While gas for the project may also be sourced from Canada, data for Canadian production were not available.

The stages, rounded figures, emissions assessed, and data sources for the full lifecycle GHG emissions of the Jordan Cove Energy Project are summarized in Table A1. Calculations are based on producing 7.8 million tons of LNG per year (374.4 Bcf/y), the maximum the project can produce. Fossil gas reaching the project was set to 431.4 Bcf/y, or 95.8% of the maximum 1.2 Bcf/d capacity of the Pacific Connector pipeline, which is how much capacity the company has reserved. The initial volume of gas needed from the wellhead to supply that volume of gas to the project is 437.7 Bcf/y (after factoring in methane leakage). All GHG emissions are shown in million metric tons per year (MMT/Y).

The leakage rates from Table A3 and Table A4 were applied to the Production, Gas Processing, Foreign Transmission and Storage, and Foreign Distribution stages, and resulting emissions are shown as 'Reference Case' and 'High Case' emissions per lifecycle stage in Table A1. Data for combustion and leakage emissions for the Pacific Connector Pipeline and Jordan Cove liquefaction facility were taken from the respective FERC applications. Emissions from the Ruby Pipeline, which would feed gas to the Pacific Connector, were based on 77 percent (1.15 Bcf/d) of the total estimated emissions (0.523 MMT/Y) described in the project's FERC order.[34]

METHANE LEAKAGE RATE ESTIMATE

The gas arriving for liquefaction at Jordan Cove would be delivered by the proposed Pacific Connector Pipeline, which would connect to the Ruby and Gas Transmission Northwest Pipelines. While it is not known at this point exactly where that gas would come from, for purposes of estimating methane leakage, this analysis assumes that 100 percent of the gas will be sourced from the Rocky Mountains region – specifically from Colorado, Wyoming, and Utah, the three most productive Rocky Mountain states for natural gas.[35] This choice was made because, while gas could also come from the Montney Basin in British Columbia, there is a lack of peer-reviewed data sources about fugitive methane emissions from natural gas production in British Columbia.

Table A1: Lifecycle Stages, Emissions, and Sources for the Pacific Connector Pipeline and Jordan Cove Energy Project

Lifecycle Stage	Reference Case (MMT/Y)	High Case (MMT/Y)	Emissions Assessed	Sources
Gas Production	10.9	26.0	Methane emissions resulting from normal operations, routine maintenance, and system upset – mainly from gathering stations, pneumatic controllers, liquids unloading, and offshore platforms; and CO_2 emissions from fuel combustion.	Methane Leakage: Robertson, et al. in *Environmental Science & Technology*, June 2017. http://pubs.acs.org/doi/abs/10.1021/acs.est.7b00571 CO_2: International Institute for Sustainability Analysis and Strategy. http://iinas.org/tl_files/iinas/downloads/GEMIS/2014_Fracking_analysis_comparison.pdf
Gas Processing (dry-wet gas separation)	0.51	0.52	Methane emissions resulting from normal operations, routine maintenance, and system upsets – mainly fugitive emissions from compressors and seals.	Based on national EPA data in "Inventory of U.S. Greenhouse Gas Emissions and Sinks": https://www.epa.gov/sites/production/files/2017-02/documents/2017_complete_report.pdf
Transmission to Jordan Cove	0.78	0.78	CO_2, CH_4, and N_2O emissions from compressor station, pipeline, and meter stations associated with Pacific Connector and Ruby pipelines. Includes fugitive emissions, venting, and combustion-related emissions.	Emissions for PCGP based on project application. http://pacificconnectorgp.com/wp-content/uploads/2017/09/1.1-PCGP-Application-and-Exhibit.pdf For Ruby pipeline, estimate based on FERC certificate order. https://www.ferc.gov/CalendarFiles/20100405150436-CP09-54-000.pdf
LNG Liquefaction	1.8	1.8	CO_2, CH_4, and N_2O emissions from liquefaction operations, fugitive emissions, and on-site vessel fuel combustion.	Figures from Jordan Cove application. http://pacificconnectorgp.com/wp-content/uploads/2017/09/1.1-PCGP-Application-and-Exhibit.pdf
Tanker Transport	0.44	0.44	CO_2 emissions from fuel combustion.	Based on distance to Tokyo and Shanghai, and Jaramillo et al. http://www.ce.cmu.edu/~gdrg/readings/2005/10/12/Jaramillo_LifeCycleCarbonEmissionsFromLNG.pdf
LNG Gasification	0.40	0.40	CO_2 emissions from fuel combustion.	Based on: Jaramillo et al http://www.ce.cmu.edu/~gdrg/readings/2005/10/12/Jaramillo_LifeCycleCarbonEmissionsFromLNG.pdf
Foreign Transmission & Storage	1.3	1.3	Methane emissions resulting from normal operations, routine maintenance, and system upsets – fugitive emissions from compressor stations and venting from pneumatic controllers account for most of the emissions from this stage.	Based on EPA estimates in U.S. "Inventory of U.S. Greenhouse Gas Emissions and Sinks": https://www.epa.gov/sites/production/files/2017-02/documents/2017_complete_report.pdf
Foreign Distribution	0.43	0.43	Methane emissions resulting from normal operations, routine maintenance, and system upsets – mainly from fugitive emissions from pipelines and stations.	Based on EPA estimates in U.S. "Inventory of U.S. Greenhouse Gas Emissions and Sinks": https://www.epa.gov/sites/production/files/2017-02/documents/2017_complete_report.pdf
Combustion	20.2	20.2	CO_2 emissions from fuel combustion.	EPA Fuel Emissions Factors Assumptions https://www.epa.gov/sites/production/files/2015-08/documents/chapter_11_other_fuels_and_fuel_emission_factors.pdf
Total	36.8*	52.0*		

*Figures may not add due to rounding

Table A2: EPA Methane Leakage Rate Estimates from 2017 U.S. GHG Inventory

Lifecycle Stage	Leakage Rate
Field Production leakage	0.79%
Processing leakage	0.08%
Transmission and Storage leakage	0.25%
Distribution leakage	0.08%
Total leakage	1.20%

Source: Oil Change International

Table A3: Reference Methane Leakage Rate for Jordan Cove GHG Lifecycle Analysis

Lifecycle Stage	Leakage Rate
Field Production leakage	1.36%
Processing leakage	0.08%
Transmission and Storage leakage	0.25%
Distribution leakage	0.08%
Total leakage	1.77%

Source: Oil Change International

Table A4: High-End Methane Leakage Rate for Jordan Cove GHG Lifecycle Analysis

Lifecycle Stage	Leakage Rate
Field Production leakage	3.66%
Processing leakage	0.08%
Transmission and Storage leakage	0.25%
Distribution leakage	0.08%
Total leakage	4.08%

Source: Oil Change International

For stages of the process for which we did not have access to project-specific estimates for leakage – Processing, Foreign Transportation and Storage, and Foreign Distribution (see Table A1) – we used national level data from the U.S. EPA. Data from the EPA's latest GHG inventory would indicate that the U.S. national methane leakage rate is 1.2%.[36] That figure is a blended composite of all fossil gas production nationally, and does not account for regional variation. Table A2 shows the breakdown of EPA's methane emission estimates from all stages of the domestic fossil gas lifecycle.

For U.S. Rocky Mountain-specific methane leakage figures, this analysis looked to a recent peer-reviewed study published in *Environmental Science & Technology* in June 2017. The study was conducted by researchers from University of Wyoming and Colorado State University and quantified atmospheric methane emissions from active gas production sites in normal operation in four major U.S. basins/plays: Upper Green River (Wyoming), Denver-Julesburg (Colorado), Uintah (Utah), and Fayetteville (Arkansas) (Robertson et al. 2017).[37]

The emissions were measured within the basins on randomly chosen days in 2014 and 2015 from the University of Wyoming Mobile Laboratory utilizing the EPA's Other Test Method (OTM) 33a. The median methane leakage rates measured from the three Rocky Mountain basins during the field production stage were 0.18 percent (0.12–0.29%) in Wyoming, 2.1 percent (1.1–3.9%) in Colorado, and 2.8 percent (1.0–8.6%) in Utah.

The mean average of those field production leakage rates is 1.69 percent, with a high-end average of 4.26 percent, but it was determined for this study to make an adaptation. Since 2014, Colorado has implemented rules to reduce oil and gas methane emissions through air pollution control practices and technologies, including leak detection and repair (LDAR) requirements.[38] Therefore, the low-end of the range measured by the study in Colorado may be a fairer assessment of expected methane emissions for fossil gas production in the Denver-Julesburg basin than the median rate used for the other two states. Using the low end of the methane leakage range for Colorado, the average field production leakage rate in the Rocky Mountain states, as reported in Robertson et al., would be 1.36 percent, with a high-end average of 3.66 percent. The high end for Colorado was assumed to be the median leakage rate in the study (2.1 percent).

Based on national EPA data, but regionalized to account for field production methane emissions measured in the Rocky Mountains, the reference methane leakage rate for gas exported from Jordan Cove is 1.77 percent. The high-end methane leakage rate for gas exported from Jordan Cove is 4.08 percent.

CONSERVATIVE ASSUMPTIONS BAKED INTO LEAKAGE ESTIMATE

The leakage rate estimates presented in the preceding section are conservative in at least two ways. First, several studies have found that EPA emissions factors for leakage from existing fossil gas systems are too low. For example, a July 2015 study published in *Environmental Science & Technology* by researchers from University of Arkansas – Fayetteville, University of Houston, Purdue University, Aerodyne Research, Inc., Colorado State University, Carnegie Mellon University, and Environmental Defense Fund found that anthropogenic methane emissions from the oil and gas industry were 50 percent higher than estimates derived from the EPA inventory.[39]

More recent studies have measured leakage rates of between 4.2 and 8.4 percent in the Bakken shale region.[40] If domestic fossil gas processing and transmission emissions are higher than EPA estimates, the lifecycle leakage rate for Jordan Cove's LNG would be higher than this paper presents.

Second, this analysis used EPA's relatively low domestic leakage rate estimates for the transmission and storage and distribution stages, rather than rates in Asia, where those two stages of the fossil gas lifecycle would take place in the case of the Jordan Cove project. If the pipelines in Asian countries importing Jordan Cove's gas leak at higher rates than the EPA estimates for U.S. pipelines, the actual lifecycle leakage rate for Jordan Cove's LNG would be higher than our estimate.

Tanker emissions estimates were based on a paper from the Civil and Environmental Engineering Faculty at Carnegie Mellon University and amended based on the shipping distance between Jordan Cove and Shanghai and Tokyo. We assumed a 50/50 split of shipments between these two ports.

ENDNOTES

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The full calculations can be found in the spreadsheet available at http://bit.ly/JCLNG-GHGs.

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