DEPARTMENT OF ECOLOGY
State of Washington

Kalama Manufacturing and Marine Export Facility
Draft Second Supplemental Environmental Impact Statement

Washington State Department of Ecology
Olympia, Washington

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Contact Information

Rich Doenges, Regional Director
Southwest Regional Office
P.O. Box 47600
Olympia, WA 98504-7600
Phone: 360-407-6300

Website: Washington State Department of Ecology

- Headquarters, Olympia 360-407-6000
- Northwest Regional Office, Bellevue 425-649-7000
- Southwest Regional Office, Olympia 360-407-6300
- Central Regional Office, Union Gap 509-575-2490
- Eastern Regional Office, Spokane 509-329-3400

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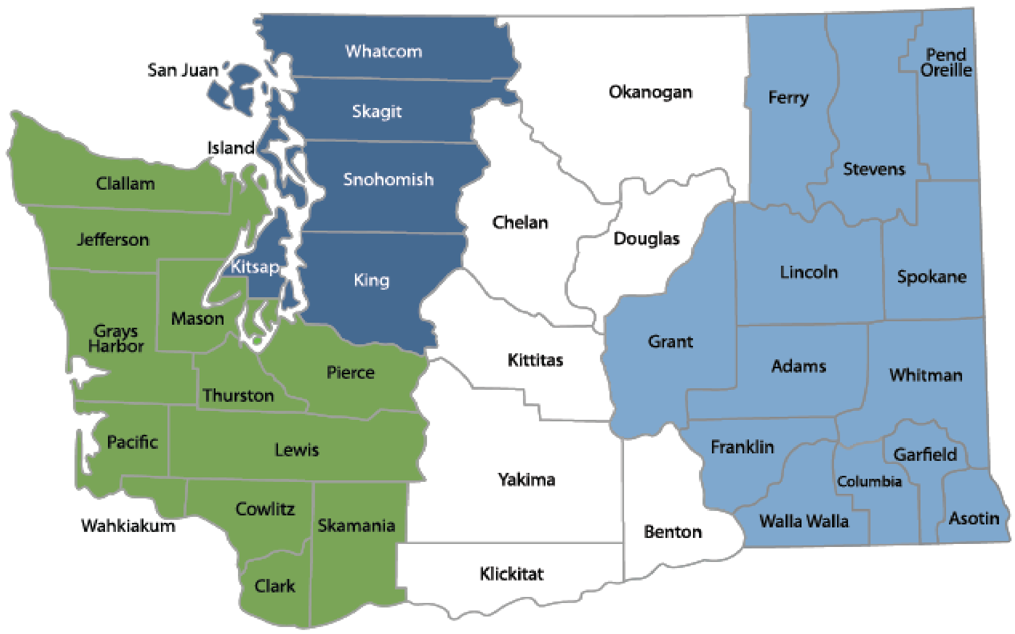

Southwest Region 360-407-6300	Northwest Region 425-649-7000	Central Region 509-575-2490	Eastern Region 509-329-3400

Region	Counties served	Mailing Address	Phone
Southwest	Clallam, Clark, Cowlitz, Grays Harbor, Jefferson, Mason, Lewis, Pacific, Pierce, Skamania, Thurston, Wahkiakum	PO Box 47775 Olympia, WA 98504	360-407-6300
Northwest	Island, King, Kitsap, San Juan, Skagit, Snohomish, Whatcom	3190 160th Ave SE Bellevue, WA 98008	425-649-7000
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Headquarters	Across Washington	PO Box 46700 Olympia, WA 98504	360-407-6000

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List of Abbreviations and Acronyms

Abbreviation/Acronym	Definition
BACT	best available control technology
BEVS	battery-electric vehicles
BNSF	Burlington Northern Santa Fe Rail Line
Board	Shorelines Hearings Board
CECC	Shanghai Bi Ke Clean Energy Technology Co, Ltd.
CFR	Code of Federal Regulations
CH_4	methane
CIG	Climate Impacts Group
CO_2	carbon dioxide
CO_2e	CO_2 equivalent
Cowlitz PUD	Cowlitz County Public Utility District No. 1
CR	combined reforming
CUP	Conditional Use Permit
Ecology	Washington State Department of Ecology
EIA	Energy Information Agency (Department of Energy)
EIS	Environmental Impact Statement
FEIS	Final Environmental Impact Statement
FERC	Federal Energy Regulatory Commission
First SEIS	First Supplemental Environmental Impact Statement
GHG	greenhouse gas
GREET	Greenhouse Gases, Regulated Emissions, and Energy
GWP	global warming potential
I-5	Interstate 5
IPCC	Intergovernmental Panel on Climate Change
KMMEF	Kalama Manufacturing and Marine Export Facility
LCA	lifecycle analysis
LPG	liquefied petroleum gas
MeOH	methanol
MMT	million metric tons
MT	metric tons
N_2O	nitrous oxide
NEPA	National Environmental Policy Act
NOAA	National Oceanic and Atmospheric Administration
NCCV	National Climate Change Viewer
NDC	nationally-determined contributions
NEPA	National Environmental Policy Act

Abbreviation/Acronym	Definition
NHPA	National Historic Preservation Act
NMFS	National Marine Fisheries Service
Northwest	Northwest Pipeline LLC
NWIW	NW Innovation Works, LLC
PIK	Potsdam Institute for Climate Impact Research
PORT	Port of Kalama
RCW	Revised Code of Washington
RM	river mile
SCUP	Shoreline Conditional Use Permit
SDP	Shoreline Substantial Development Permit
Second SEIS	Second Supplemental Environmental Impact Statement
SEEP	State Efficiency and Environmental Performance
SEIS	Supplemental Environmental Impact Statement
SEPA	State Environmental Policy Act
SHB	Washington State Shoreline Hearings Board
SWCAA	Southwest Clean Air Agency
ULE	ultra-low emissions
UNFCC	United Nations Framework Convention on Climate Change
U.S.	United States
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
USGCRP	U.S. Global Change Research Program
USGS	U.S. Geological Survey
WAC	Washington Administrative Code
WDFW	Washington Department of Fish and Wildlife
WRI	World Resources Institute
ZLD	zero liquid discharge

FACT SHEET

Project Name

Kalama Manufacturing and Marine Export Facility (KMMEF)

Description of Proposed Project and Alternatives

NW Innovation Works, LLC – Kalama (NWIW) and the Port of Kalama (Port) are planning to construct the KMMEF, which would consist of a methanol manufacturing facility and a new marine terminal on approximately 100 acres on the Columbia River at the Port's North Port site (the project site). In a connected action, Northwest Pipeline LLC (Northwest) is proposing to construct and operate the Kalama Lateral Project (the proposed pipeline), a 3.1-mile natural gas pipeline to the proposed project, and Cowlitz County Public Utility District No. 1 (Cowlitz PUD) is proposing to upgrade electrical service to provide power to the proposed project.

The proposed methanol manufacturing facility would convert natural gas to methanol, which would be stored on site and transported via marine vessel to global markets, primarily in Asia. The project proponents state that methanol manufactured at the proposed facility is intended to be used for the production of olefins, which are primary components in the production of such consumer products as medical devices, glasses, contact lenses, recreational equipment, clothing, cell phones, furniture, and many other products. NWIW signed a dock use agreement (described below) with the Port of Kalama in which NWIW covenants not to sell methanol for the use as fuel. However, the dock use agreement does not prevent importers of methanol produced at the KMMEF from selling it as fuel. Therefore, this Second SEIS considers the potential emissions of using the export product as fuel.

The proposed marine terminal would accommodate oceangoing vessels that would transport methanol to destination ports. It would also be designed to accommodate other vessel types and, when not in use for loading methanol, would be made available for use as a lay berth where vessels could moor while waiting to use other Port berths or for other purposes.

The alternatives evaluated in the previously published FEIS and first SEIS include four action alternatives and a no-action alternative. The action alternatives included two methanol production technology alternatives (Technology Alternatives), and two marine terminal design alternatives (Marine Terminal Alternatives). The FEIS and SEIS also evaluated a No Action Alternative wherein the proposed project would not be constructed.

Project Proponents

NW Innovation Works, LLC – Kalama and the Port of Kalama

Location

The KMMEF would be located at the Port of Kalama's North Port site at 888 Tradewinds Road in unincorporated Cowlitz County, Washington. The North Port site is located at approximately RM 72 along the east bank of the Columbia River. The BNSF rail line and Interstate 5 (I-5) lie immediately to the east. The project site is approximately 100 acres in size, and lies within Sections 31 and 36, Township 7 North, Range 2 West Willamette Meridian.

Supplemental Greenhouse Gas Analysis

This Second Supplemental EIS (Second SEIS) includes a greenhouse gas (GHG) lifecycle analysis covering the following sources of GHG emissions:

- GHG emissions attributable to construction and decommissioning of the proposed project;
- On-site, direct GHG emissions from operations of the proposed project;
- GHG emissions from purchased power, including consideration of the potential sources of generation that would satisfy the new load;
- GHG emissions potentially attributable to the proposed project from natural gas production, collection, processing, and transmission;
- GHG emissions from shipping methanol to a representative Asian port; and
- GHG emissions associated with changes in the methanol industry and related markets that may be induced by the proposed project's methanol production.

In addition, the lifecycle analysis includes GHG emissions associated with the manufacture of olefins from methanol, as well as the potential to use methanol as fuel. The approach to the analysis is presented in Section 3.4.

The results of the analysis are summarized in Section 1.5.1 and presented in full in Section 3.5, which includes analysis of both global and in-state emissions. Section 3.6 presents a sensitivity analysis.

The Second SEIS is limited to addressing project-related GHG emissions, the global potential for the proposed project to substitute for other sources, and the consequent impact on climate change. Analysis of impacts and mitigation associated with other elements of the environment are not the subject of the Second SEIS and remain unchanged from those identified in the previously published FEIS and First SEIS. Readers are encouraged to consult the FEIS and First SEIS for detailed information about the proposed project.

Lead Agency

Washington Department of Ecology (Ecology)

SEPA Responsible Official

Rich Doenges, Regional Director
Southwest Regional Office
300 Desmond Drive SE, Lacey, WA 98503
RDOE@ECY.WA.GOV
(360) 407-6307

Ecology Contact

Meg Bommarito, Regional Planner
Northwest Regional Office
3190 160th Ave SE, Bellevue, WA 98008
Meg.bommarito@ecy.wa.gov
(425) 649-7128

Authors and Principal Contributors

This Second SEIS has been prepared under the direction of Ecology, and in consultation with Cowlitz County, the Port of Kalama, and other relevant agencies.

Authors and principal contributors for the draft Second SEIS include:

- TRC Environmental: technical input, project and document management, greenhouse gas lifecycle analysis technical input and overall management
- Keramida: greenhouse gas emissions and lifecycle analysis
- Greene Economics: greenhouse gas emission substitution and lifecycle analysis

Dates of Issue

Draft Second Supplemental EIS: September 2, 2020

Date Comments are Due

October 2, 2020

Public Comment and Hearings on the Draft Second Supplemental Environmental Impact Statement

Comments on this document will be accepted during the comment period, September 2 through October 2, 2020. Comments can be submitted in the following ways.

By mail to:

Rich Doenges
Department of Ecology
Kalama SSEIS
PO Box 47775, Olympia, WA 98504-7775

Online:

Submit comments through Ecology's eComments site at
http://admin.ecology.commentinput.com/?id=kG9ji

During online public hearings, verbally:

- September 17 at 1:00 p.m.
- September 22 at 10:00 a.m. and 6:00 p.m.

Meeting information will be posted on Ecology's website at https://ecology.wa.gov/kalamamethanol

List of Permits and Approvals

Government	Permit/Authorization/Approval	Agency
Federal	Rivers and Harbors Act Section 10/ Clean Water Act Section 404 Permit	U.S. Army Corps of Engineers (USACE)
Federal	Endangered Species Act Section 7 Consultation	National Oceanic and Atmospheric Administration (NOAA)/U.S. Fish and Wildlife Service
Federal	Marine Mammal Protection Act	NOAA Fisheries
Federal	Private Aids to Navigation Permit	U.S. Coast Guard
Federal	Section 106 of the National Historic Preservation Act	USACE
State	Hydraulic Project Approval	Washington State Department of Fish and Wildlife
State	Shoreline Conditional Use Permit	Ecology
State	401 Water Quality Certification	Ecology
State	Air Containment Discharge Permit	Southwest Clean Air Agency/Ecology
State	National Pollutant Discharge Elimination System (NPDES) Construction Stormwater Permit	Ecology
State	NPDES Industrial Stormwater General Permit	Ecology
Local	Shoreline Substantial Development and Conditional Use Permit	County
Local	Critical Areas Permit	County
Local	Floodplain Permit	County
Local	Engineering and Grading	County
Local	Building, Mechanical, Fire, etc.	County

Ecology Action and Projected Date for Action

Once Ecology determines the Second Supplemental EIS to be complete and final, Ecology will make a final decision on the Shoreline Conditional Use Permit. Ecology's decisions and actions will be made as expeditiously as possible consistent with applicable law. No Ecology decisions will be made until at least seven days after the issuance of the Final Second SEIS.

Subsequent Environmental Review

No subsequent environmental review of the proposed project is planned.

Availability of the Draft Second Supplemental EIS

The Draft Second SEIS is posted on the following websites:

- Ecology website at https://ecology.wa.gov/kalamamethanol
- SEPA register at https://apps.ecology.wa.gov/separ/Main/SEPA/Search.aspx

Copies of the Draft Second SEIS on CD may be requested from Ecology.

Availability of Background Materials

The original Draft and Final EIS for the project, the First SEIS are available at https://kalamamfgfacilitysepa.com/

1.0 Summary

1.1 Introduction

NW Innovation Works, LLC – Kalama (NWIW) and the Port of Kalama (Port) are proposing to construct the Kalama Manufacturing and Marine Export Facility (KMMEF or proposed project) on the Columbia River at the Port's North Port site (the project site). The proposed project will manufacture methanol for sale and export to destination ports, primarily in Asia, where the methanol is intended to be converted to olefins as a feedstock for fabrics, plastics, and other manufactured products. It is possible, however, that the methanol could be used as a fuel once it is acquired by importers in Asia and elsewhere.

Review of the proposed project is required under the State Environmental Policy Act (SEPA). The SEPA environmental review process helps state and local agencies identify and consider possible environmental impacts that could result from government actions, including the issuance of permits.

The Port and Cowlitz County (County) completed a SEPA environmental impact statement (EIS) for the proposed project in September 2016. After publication of the EIS and the issuance of a Shoreline Substantial Development Permit (SDP, issued by Cowlitz County) and a Conditional Use Permit (CUP, issued jointly by Ecology and the County), the permits were appealed to the Washington State Shorelines Hearing Board (Board). The Board, and later Cowlitz County Superior Court, determined that SEPA required additional review of the impacts of the KMMEF's greenhouse gas (GHG) emissions. In August 2019, the Port and the County issued a Supplemental EIS (First SEIS) in response to the Board and the Court's rulings. In November 2019, Ecology issued a SEPA Notice of Determination for a Second Supplemental EIS (Second SEIS) for the proposed project. This chapter provides an overview of the proposed project and SEPA review, including this Second SEIS.

1.2 Purpose of Second SEIS

This document supplements the First SEIS issued for the proposed project in August 2019. Ecology determined that its comments on the draft of the First SEIS warranted additional discussion of the impacts of the proposed project's GHG emissions, as well as the mitigation proposed to address those impacts. This discussion and analysis is necessary for Ecology to determine whether the CUP for the KMMEF should be approved, modified, conditioned, or denied under the Shoreline Management Act, as required by Cowlitz County Superior Court's July 12, 2018, Order Affirming in Part and Reversing in Part the Shorelines Hearings Board Order dated September 15, 2017 (Case No. 17-2-01269-08). This draft Second SEIS provides the required additional technical GHG lifecycle analysis (LCA) and a global emissions displacement analysis to address the requirements identified above. This draft also reviews and revises mitigation proposed by NWIW to address the KMMEF's in-state GHG emissions impacts.

1.3 Second SEIS Process

Ecology is the lead agency for the Second Supplemental SEPA environmental review process, which includes the following activities:

- Gathering data and information, and developing a scope of work and models to complete a global lifecycle analysis that assesses the range of potential end uses of methanol generated and transported by the project based on economic considerations and the range of potential GHG generation associated with those potential end uses in comparison with alternate cases in which existing methanol and fuel sources control GHG generation for those end uses.
- Analyzing and reviewing scenarios
- Identifying potential GHG emissions attributable to various scenarios
- Identifying ways to reduce the effects of significant GHG emissions
- Publishing a Draft Second SEIS
- Conducting public review and commenting on the Draft Second SEIS
- Compiling and responding to substantive public comments received
- Releasing the Final Second SEIS

Ecology will use the Second SEIS in its review of the CUP under the Shoreline Management Act, Revised Code of Washington (RCW) 90.58, and consistent with the requirements of the Cowlitz County Superior Court Order Affirming in Part and Reversing in Part the Shorelines Hearings Board Order dated September 15, 2017 (Case No. 17-2-01269-08). Ecology must wait a minimum of seven days after publication of the Final Second SEIS to take action.

Online copies of this Draft Second Supplemental EIS are available on Ecology's website at https://ecology.wa.gov/kalamamethanol, and https://fortress.wa.gov/ecy/publications/summarypages/2006011.html.

The First SEIS and the FEIS that it supplements are available at https://kalamamfgfacilitysepa.com/.

Paper copies of the document are available for review at the locations noted in section 1.6.

1.3.1 Information required

Ecology has determined that a supplemental analysis is needed of the proposed project's global lifecycle GHG emissions from the project under a range of scenarios. Accordingly, this draft Second SEIS contains a revised quantitative analysis of the content originally included in Chapter 3 and Appendix A of the First SEIS. All assumptions, data, emissions values, and conclusions of those parts of the First SEIS have been reevaluated and are reused only after careful reconsideration and validation of the previous work.

GHG emissions are expressed in metric tons of each GHG and in carbon dioxide equivalents (CO_2e) for each scenario. This includes emissions from all applicable GHGs listed in WAC 173-441-040. Ecology's December 28, 2018 and October 9, 2019 letters to the Port and the County contain more details on the scope of this analysis (Ecology 2018, Ecology 2019a). These letters outline key scenarios, conditions, emissions, and pathways that are included in this draft Second SEIS.

A sensitivity analysis providing a range of possible GHG emissions is also provided. The range includes both conservative and protective assumptions whenever possible to facilitate lower bound, upper bound, and mid-range scenarios.

The analysis addresses all GHG emissions related to the proposed project at the proposed project site, in the State of Washington, in the United States, and globally. It includes all GHG emissions directly released by the proposed project as well as indirect upstream and downstream GHG emissions related to products made by the proposed project and model inputs used by the proposed project.

Total gross emissions by category, scenario, and location of the emissions, together with net emissions are also addressed (see Section 3.5). Calculation methods are based on WAC 173-441 whenever possible. Topics addressed include:

- Extraction, processing, and transmission of the natural gas used by the proposed project. This analysis includes a sensitivity analysis of emissions rates, considering the rates used in the discussion brief prepared by the Stockholm Institute (cited in Ecology's December 28, 2018 comments on the 2018 Draft First SEIS) as well as 40 CFR Part 98.
- Evaluation of whether and to what extent the proposed project would substitute for other sources of methanol rather than supplement them.
- Global supply and demand for methanol, as well as such other factors as government policies (e.g., potential China policies regarding the phasing out coal-to-methanol plants) over the proposed project's 40+ year expected lifespan.
- Scenarios for both methanol and olefins products. Modeling and quantitative analysis specify the assumptions, conditions, and uncertainty parameters for all scenarios.
- Technologies that would be displaced by substitution and related changes in global GHG emissions, accounting for economic and regulatory factors
- Non-methanol-based olefin production technologies, in addition to methanol-based olefin production. These include natural gas-to-methanol-to-olefin; naphtha-to-olefin; and coal-to-methanol-to-olefin processes.
- Cradle-to-grave GHG emissions associated with using the proposed project's methanol to make olefin-based consumer products are estimated, together with cradle-to-grave GHG emissions associated with using the proposed project's methanol as a fuel.

Other factors considered include onsite emissions; electricity used by the proposed project; transportation emissions; and construction, startup, and maintenance.

1.4 Background & History

1.4.1 Regulatory and legal review

Initial SEPA and Shoreline Permitting Process for the Project. In September 2016, the Port and County, acting as SEPA co-leads, issued an EIS for the KMMEF Project. That EIS concluded that the proposed project would emit more than one million metric tons of greenhouse gas emissions annually but would have no significant unavoidable adverse impacts related to air quality or greenhouse gas emissions. This conclusion was based on Ecology SEPA guidance that has since been withdrawn.

In March 2017, the County issued a Shoreline SDP and CUP for the proposed project. Under Washington State shoreline permit regulations (WAC 173-27-200(1)), Ecology has 30 days to review a CUP and either approve, approve with conditions, or deny the permit. During this 30-day period, Ecology can also request additional information from local government and project applicants if it determines the permit application is incomplete (WAC 173-27-130(5)). Ecology cannot make a final permitting decision until the requested information is provided to the department.

Requesting additional information is a common practice to help ensure efficient, effective review of shoreline permits. To that end, in April 2017, Ecology requested additional information from the County regarding the proposed project's site plan, shoreline narrative, and greenhouse gas emissions. In its initial review of the CUP, Ecology had identified an apparent omission in the EIS's calculation of the proposed project's total annual carbon dioxide emissions (CO_2) and explained that the information needed to be provided by May 19, 2017, or else the department would return the permits to the County as incomplete.

Subsequently, the County, the Port, and NWIW met with Ecology and provided some of the requested information, Ecology deemed the application complete, and on June 8, 2017, Ecology approved the CUP for the proposed project, with conditions. Condition 4 of the CUP required NWIW to reduce the proposed project's annual greenhouse gas emissions by 1.7 percent annually, an amount similar to the reductions required by the state Clean Air Rule, WAC 173-442. Ecology included Condition 4 because it had determined that the proposed project's greenhouse gas emissions were significant under SEPA and believed Condition 4 could mitigate for those emissions.

Several stakeholders then appealed the decision to the Board, and the Board reversed the shoreline permits. The Board found that the EIS was inadequate due to insufficient analysis of the environmental impacts of the proposed project's greenhouse gas emissions, and that the EIS improperly relied on Ecology's guidance in concluding that the project would have no significant impacts. Accordingly, the Board remanded the matter back to the County and the Port to conduct additional analysis of the proposed project's greenhouse gas emissions under SEPA.

The proponents appealed the Board's decision to Cowlitz County Superior Court. The Court affirmed the Board's determination that the EIS was inadequate and found that additional analysis of the proposed project's greenhouse gas emissions was necessary in the form of a supplemental EIS (SEIS). The Court reinstated the shoreline permits but remanded them to the County and Ecology "for additional review of greenhouse gas emissions. The only issue the permitting agencies must address on remand is how any new SEPA analysis of greenhouse gas emissions affects their decision-making under the applicable statutes." The Court ordered, "Cowlitz County and Ecology must review the SEIS and determine whether, or not, the Permits must be modified, conditioned, or denied based on the analysis in that document."

Port of Kalama and Cowlitz County Draft Supplemental EIS. In January 2018, the Port and the County issued a Scoping Notice for the SEIS. Ecology offered technical assistance to the SEPA co-leads on greenhouse gas calculations and significance determinations and, in November 2018, met with the Port and the County to review a draft lifecycle analysis of the proposed project's greenhouse gas emissions. The Port and the County issued a Draft SEIS for the proposed project in the same month, again concluding that the proposed project would have no significant adverse environmental impacts. The SEIS found that the proposed project would reduce greenhouse gas emissions globally by between 12 and 14 million metric tons annually. This conclusion was based on the assumption that the methanol produced by the proposed project would displace an equal quantity of methanol derived from coal in China because it is more expensive to make methanol from coal, and because China has a national policy of reducing coal processing and greenhouse gas emissions. The Draft SEIS also stated that NWIW proposed to voluntarily mitigate for the proposed project's in-state greenhouse gas emissions. In December 2018, Ecology met with the SEPA co-leads to discuss the contents of the Draft SEIS. Before the meeting, Ecology provided the Port and County with questions regarding the lifecycle analysis in the SEIS and NWIW's proposed mitigation.

Comments on the Draft SEIS. Ecology submitted detailed comments on the Draft SEIS, focusing on three issues: (1) proposed mitigation, (2) production alternatives addressed in the Draft SEIS's sensitivity analysis, and (3) assumptions and methodologies generally employed in the lifecycle analysis of the proposed project's greenhouse gas emissions. Among other things, Ecology questioned the Draft SEIS's conclusion that the proposed project would have no significant adverse environmental impacts. To support the Draft SEIS's determination that the proposed project would reduce 12 to 14 million metric tons of greenhouse-gas emissions annually, Ecology believed that additional production alternatives should be evaluated in the final SEIS's sensitivity analysis. Ecology also made several recommendations for improving the proposed mitigation for the proposed project’s in-state greenhouse gas emissions so mitigation would be verifiable, enforceable, and would result in actual emissions reductions. Finally, Ecology noted that because methanol is commonly burned as fuel, the SEIS should assume that at least some of the methanol produced by the proposed project would be used as mobile or stationary fuel. After submitting comments on the Draft SEIS, Ecology met with representatives of the Port, County, and NWIW five times over the next eight months, and provided technical advice on the Draft SEIS's analysis of greenhouse gas emissions and proposed voluntary greenhouse gas mitigation. Other comments on the SEIS addressed the potential for the proposed project’s methanol product to be sold as fuel for marine and ground transportation, and industrial boilers.

Ecology Directed to Continue its Review. In May 2019, Governor Inslee directed Ecology to continue conducting “a thorough and objective review of proposed projects to ensure they meet the state's environmental standards.”

Port of Kalama and Cowlitz County Final Supplemental EIS. On August 30, 2019, the SEPA co-leads released the Final SEIS for the Project, which continued to maintain that the proposed project would have no significant adverse environmental impacts. In arriving at this conclusion, the Final SEIS evaluated and concluded that the proposed project would displace between 12 and 14 million metric tons of greenhouse gas emissions annually, and did not consider the use of methanol as fuel in determining the significance of the proposed project's environmental impacts under SEPA. The final SEIS also included a Voluntary Greenhouse Gas Mitigation Program Framework that describes NWIW's proposed commitment to mitigate for in-state greenhouse gas emissions.

Cowlitz County Reapproval of Project's Shoreline Permits. On September 11, 2019, the County determined "no further County action or decision on the existing shoreline permits [for the proposed project] was warranted". The County based this determination on the SEIS's conclusion that the proposed project "would result in a net reduction of global [greenhouse gas] emissions due to anticipated global methanol market displacement." The County found that based on this displacement, "the project does not have any significant unavoidable adverse impacts." The County acknowledged that NWIW "voluntarily agreed to mitigate for all in-state [greenhouse gas] emissions attributable to their project," but did not include this mitigation as a condition of the CUP. Per state shoreline permit regulations, and consistent with this Court's prior order, Ecology had 30 days from the County's decision to determine whether to modify, condition, or deny the CUP for the Project. WAC 173-27-200(1).

Litigation Prior to Ecology Decision on Shoreline Permits. Shortly after Ecology began its review, stakeholders filed an administrative appeal of the final SEIS with the Cowlitz County Hearing Examiner and subsequently with the Board. The assumed jurisdiction over the matter. Because Ecology had not yet rendered a final decision on the CUP, the Board granted the parties' joint motion to extend preliminary deadlines in the case so that dates fell outside of the 30-day CUP review period.

Ecology Requests Additional Information to Complete Its Review of the Project's Shoreline Permits. On October 9, 2019, Ecology sent a letter to the County requesting additional information to complete the department's review of the CUP. Consistent with its previous comments on the draft SEIS, Ecology requested additional information regarding the Voluntary Mitigation Program, and the SEIS's conclusion that the proposed project would have no significant adverse environmental impacts. Specifically, Ecology requested (1) an improved explanation of how the proposed project would displace (i.e., reduce) coal-to-methanol production in China, given that the SEIS also acknowledges global demand for methanol is projected to increase beyond what the proposed project would put into the market; (2) a more detailed sensitivity analysis calculating the proposed project's emissions if the final end use of the methanol were for fuel; (3) analysis of the proposed project's upstream emissions using the natural gas leak rates previously recommended by Ecology; and (4) a comparison of other displacement technologies. Ecology asked that the information be remitted by November 7, 2019, or Ecology would return the CUP to the County as incomplete. Although a response was received, Ecology did not receive the information needed to satisfy its questions.

Ecology Issues a SEPA Notice of Determination for Second SEIS. On November 22, 2019, Ecology issued a SEPA Notice of Determination for a Second Supplemental EIS (SEPA Notice) because it concluded that its written comments on the [draft EIS] warranted additional discussion for purposes of rendering a final permitting decision, as provided under WAC 197-ll-600(3)(c). In a letter to the County (with the Port and NWIW copied), Ecology explained that a Second SEIS is necessary because Ecology's written comments on the 2018 Draft SEIS were not adequately addressed in the Final SEIS or other communications. Ecology explained that the Second SEIS would supplement the analysis contained in Chapter 3 and Appendices A and C of the Final SEIS (respectively, the greenhouse gas emissions analysis and mitigation plan).

RCW Chapter 70.235, Limiting Greenhouse Gas Emissions, established GHG reduction goals compared to a 1990 baseline and directed Ecology and other state agencies to undertake specific tasks related to GHG emissions. The intent of the chapter, as specified in RCW 70.235.005(3), was to:

(a) Limit and reduce emissions of GHGs as stated in RCW 70.235.020;
(b) minimize the potential to export pollution, jobs, and economic opportunities; and
(c) reduce emissions at the lowest cost.

The statute does not specify regulatory requirements to reduce or limit GHG emissions that are applicable to individual projects (including the proposed project), industries, or sectors. RCW 70.235.050 does impose requirements for state agencies to develop plans to reduce their GHG emissions to meet the adopted reduction targets. In its 2019 update prepared under RCW 70.235.040, Ecology recommended the following updated statewide reduction goals for GHG emission limits:

- By 2020, reduce overall emissions of greenhouse gases in the State to 1990 levels
- By 2035, reduce greenhouse gas emissions in the State to 45 percent below 1990 levels
- By 2040, reduce greenhouse gas emissions in the State to 70 percent below 1990 levels
- By 2050, reduce greenhouse gas emissions in the State to 95% below 1990 levels and achieve net zero greenhouse gas emissions in the State

The most recent statewide GHG emission inventory (Ecology 2019b) indicated that the state's total GHG emissions in 2017 were 97.5 million metric tons CO_2e, which is 7.0 million metric tons higher than the 2020 target. To achieve the goal by 2020, a reduction of approximately 7.7 percent is required from 2015 levels.

1.5 Supplemental Analysis

1.5.1 GHG emissions and substitution scenarios

This Second SEIS calculates GHG emissions generated by the production and use of methanol from KMMEF. Activities associated with the KMMEF evaluated in this Second SEIS include:

- Upstream emissions associated with natural gas to be used by the KMMEF
- Emissions generated by the construction of the KMMEF, including emissions from the production of construction materials
- Emissions from the operation of KMMEF, including emissions from the production of methanol, electricity purchased by KMMEF from the local utility, and transportation of methanol from Kalama to China
- Emissions from two potential end uses of KMMEF methanol (olefins and fuel).

This Second SEIS also includes an economic evaluation of whether the methanol produced by KMMEF would substitute for or replace other sources of methanol in the global market. GHG emissions associated with any likely alternate substitution pathway are calculated based on the outcome of the economic evaluation. Alternate methods of methanol production (or olefin production) that are evaluated in this document include:

- Use of coal within China to produce methanol
- Use of natural gas within China to produce methanol
- Methanol imported by China from producers around the world
- The use of naphtha (derived from oil refining) to produce olefins

1.5.2 Mitigation measures

Ecology has determined that the total instate greenhouse gas emissions that are directly or indirectly attributable to the NWIW Kalama methanol facility are significant and capable of being mitigated. Section 3.7 and Appendix D discuss the proposed mitigation framework, consistent with Washington's existing GHG reporting program (WAC 173-441). In summary, the mitigation framework would establish an annual greenhouse gas emission reduction obligation equal to instate emissions as determined by Ecology's GHG reporting rule, to the extent possible.

2.0 Proposed Project and Alternatives

2.1 Introduction

NWIW and the Port are planning to construct the KMMEF (the proposed project), which would consist of a methanol manufacturing facility and a new marine terminal on approximately 100 acres on the Columbia River at the Port's North Port site (the project site). The location of the project site is shown on Figure 2-1. In a connected action, Northwest Pipeline LLC (Northwest) is proposing to construct and operate the Kalama Lateral Project (the proposed pipeline), a 3.1-mile natural gas pipeline to the proposed project, and Cowlitz PUD is proposing to upgrade electrical service to provide power to the proposed project.

The proposed methanol manufacturing facility would convert natural gas to methanol, which would be stored on site and transported via marine vessel to global markets, primarily in Asia. According to NWIW, the methanol manufactured at the proposed facility would be used for the production of olefins, which are primary components in the production of such consumer products as medical devices, glasses, contact lenses, recreational equipment, clothing, cell phones, furniture, and many other products.

The proposed marine terminal would accommodate ocean-going vessels that would transport methanol to destination ports. It would also be designed to accommodate other vessel types and, when not in use for loading methanol, would be made available for use as a lay berth where vessels could moor while waiting to use other Port berths or for other purposes.

2.2 Project Site

The proposed project would be located at the Port of Kalama's North Port site at 888 Tradewinds Road in unincorporated Cowlitz County, Washington (Figure 2-1). Existing Port facilities are located along the Columbia River between approximately River Mile (RM) 72 and RM 77. The North Port site is located at approximately RM 72 along the east bank of the Columbia River. The BNSF rail line and Interstate 5 (I-5) lie immediately to the east.

The proposed project site lies within Sections 31 and 36, Township 7 North, Range 2 West Willamette Meridian. The project site consists of portions of tax parcels 63302, 63304, 63305, 60822, 60831, 63301, and WH2500003. A portion of the proposed project site consists of state-owned lands that are subject to a Port Management Agreement between the Port and the Washington State Department of Natural Resources.

The project site is bounded by the Columbia River to the west; by Tradewinds Road, the Air Liquide industrial facility, and the Port's industrial wastewater treatment plant to the east; by Port property primarily used for open space, recreation, and wetland mitigation to the north; and by the existing Steelscape manufacturing facility to the south.

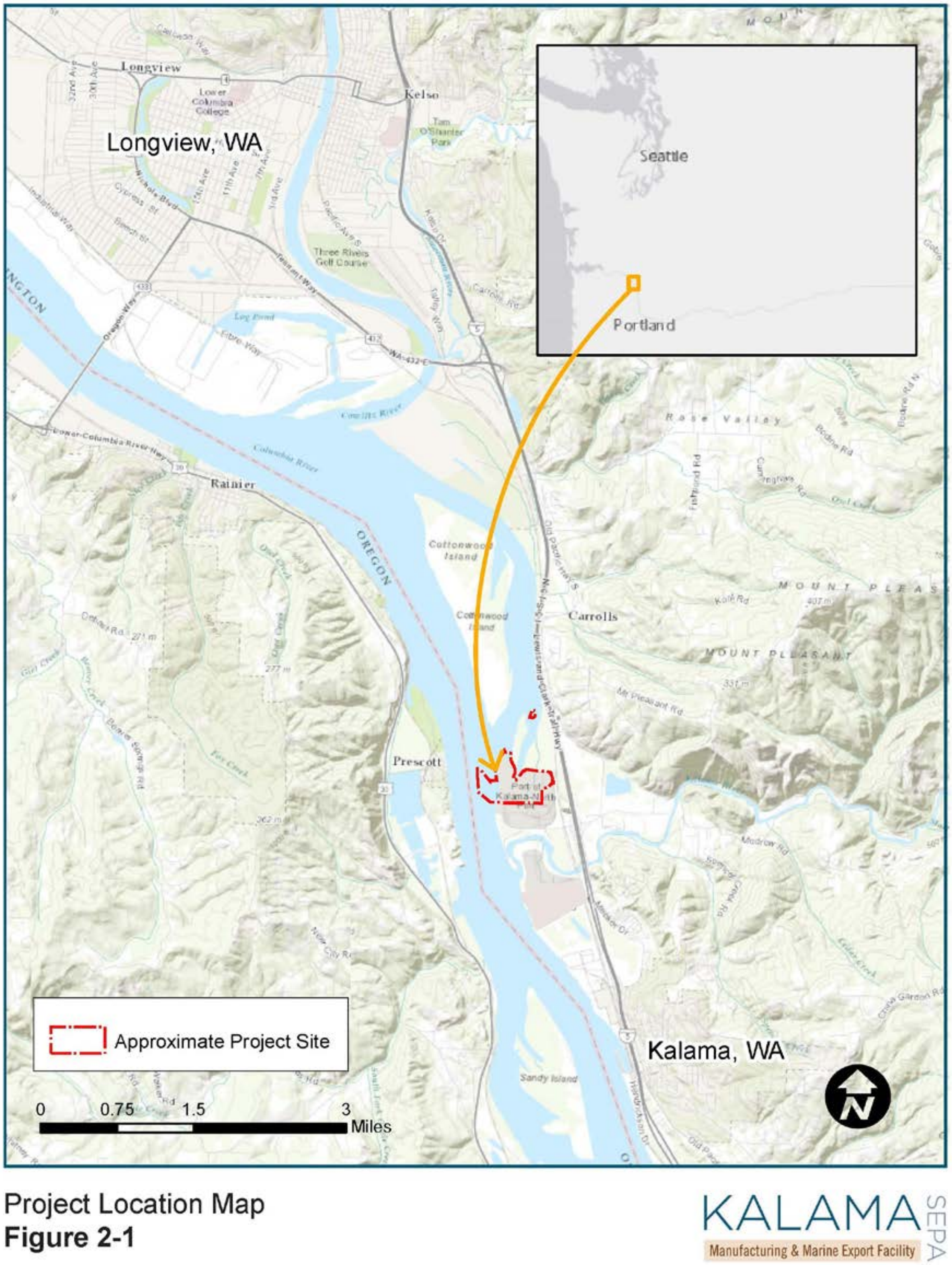

Figure 2-1. Project Location Map

The Port is the owner of the project site and has leased approximately 90 acres of the 100-acre North Port site to NWIW for construction and operation of the proposed facility. The Port would construct the proposed marine terminal to accommodate the shipping of methanol. The Port would also improve existing access roads, construct a new access road, and develop water supply, recreation areas, and other elements to support the proposed project in the remaining 10 acres of the project site.

2.3 Project Proponents

The project proponents (NWIW and the Port) seek to construct the KMMEF on the Columbia River at the Port's North Port site.

NWIW is a multinational partnership formed to produce methanol to meet global methanol demands. The parent company of NWIW is CECC (Shanghai Bi Ke Clean Energy Technology Co., Ltd.), a technology commercialization and project development firm operating in the gas, synthesis gas, chemicals, and fuels industries.

The Port of Kalama operates according to the provisions of Title 53 of the RCW Chapter 53.04. Port districts are specifically authorized by RCW 53.04 to acquire, construct, maintain, operate, and develop harbor improvements; rail or motor vehicle transfer and terminal facilities; water transfer and terminal facilities; air transfer and terminal facilities, or any combination of such transfer and terminal facilities; other commercial transportation, transfer, handling, storage, and terminal facilities; and industrial improvements.

2.4 Project Objectives

The project purpose as defined by the project proponents is to manufacture competitively priced methanol from natural gas at the Port's North Port site using an ULE technology that would generate lower GHG emissions during manufacture than traditional GTM CR technology, and to construct a new marine terminal at the site for methanol shipment to Asian markets in light of Chinese methanol demand. The proposed project marine terminal would provide the infrastructure needed to load NWIW methanol to export via ocean-going vessels and would also provide general lay berth needs for the Port of Kalama. Construction and operation of the marine terminal would support the Port of Kalama's desire to provide economic benefit to the region, create jobs, and improve access to recreational resources.

2.4.1 Project alternatives

Information on the project alternatives is included in the previously published Final EIS and the subsequent First SEIS. They are not further evaluated in this Second SEIS.

2.5 Anticipated Permit Requirements

2.5.1 Proposed project

The proposed project would require federal, state, and local permits and authorizations. Table 2-1 lists the permits that are anticipated to be required and their current status. Additional permits or approvals may be identified as the design and environmental review processes proceed. Permit that have been applied for will be obtained prior to and closer to actual construction.

Table 2-1. Permits and Authorizations Required for the Proposed Project

Level of Government	Agency	Permit/Authorization	Status
Federal	USACE	Rivers & Harbors Act Section 10/Clean Water Act Section 404	Issued: 3/28/2019 (Permit No. NWP-2014-177/2) (approved pending appeal)
Federal	National Oceanic and Atmospheric Administration (NOAA)	Marine Mammal Protection Act Incidental Harassment Authorization	Issued: 10/19/2018
Federal	NOAA Fisheries/ USFWS	Endangered Species Act Section 7 Consultation	NOAA Biological Opinion issued: 10/10/2017 (Reference No. WCR-2015-3594) USFWS Biological opinion issued 11/14/2016 (Reference No. 01EWFW00-2016-F-0065 and 0066)
Federal	USACE, NOAA	NEPA	USACE –Included in USACE permit noted above NOAA – Environmental Assessment issued 10/2016 Finding of No Significant Impact issued 10/24/2016
Federal	U.S. Coast Guard	Private Aids to Navigation Permit	Not applied for

Level of Government	Agency	Permit/Authorization	Status
Federal	USACE	Consultation under Section 106 of the National Historic Preservation Act if the project would affect historic properties	Addressed in USACE permit noted above
State	WDFW	Hydraulic Project Approval	Issued 10/16/2016 (Permit No. 2016-5-150+01)
State	Ecology	Shoreline Conditional Use Permit	Approved 6/8/2017 (CUP No. 1056)
State	Ecology	401 Water Quality Certification	Issued: 2/15/2017 (Order No. 13925; USACE # NWP-2014-177/2)
State	SWCAA	Air Discharge Permit	Issued: 6/7/2017 (Permit No. ADP 16-3204)
State	Ecology	NPDES Construction Stormwater Permit	Not applied for
State	Ecology	NPDES Industrial General Stormwater Permit	Not applied for
Local	County	Shoreline Substantial Development Permit	Issued (Permit# SL 16-0975)3
Local	County	Critical Areas	Issued: 4/5/2017 (Permit # 16-07-3712)
Local	County	Floodplain Permit	Issued: 4/5/2017 (Permit # 16-07-3712)
Local	County	Engineering and Grading	Not applied for
Local	County	Building, Mechanical, Fire, etc.	Not applied for

2.5.2 Connected actions

A natural gas pipeline to transport feedstock to the site and an electric transmission line have been approved and permitted as related actions.

3.0 GHG LCA Emissions, Displacement Analysis & Climate Change

3.1 Introduction

This chapter provides additional analysis of potential GHG emissions and impacts of the proposed project, consistent with the Ecology determination that a Second SEIS is required to adequately identify and analyze the greenhouse gas emissions and impacts before rendering a decision on the shoreline conditional use permit necessary to construct and operate the KMMEF.

3.2 Affected Environment for GHG Emissions

The First SEIS provides a detailed discussion of the general environmental setting and existing conditions with respect to presence and effects of GHG in the atmosphere emissions and associated climate change. The reader is referred to that discussion and to the reports of the Intergovernmental Panel on Climate Change (IPCC) cited below for this background:

https://kalamamfgfacilitysepa.com/wp-content/uploads/2019/08/FSEIS_August2019.pdf

https://www.ipcc.ch/reports/

Although the specific effects of climate change vary regionally, they result from GHG emissions that accumulate on a global basis. Carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) are primary GHGs that are circulated and well-mixed throughout the atmosphere. As such, they cause climate change irrespective of the location of the emission (USGCRP 2017). Thus, equivalent GHG emissions originating from the proposed project would have the same effect as those from any other location (and vice versa). The consensus of science is that anthropogenic GHG emissions are causing climate change (USGCRP 2017). It is not meaningful to link a specific climate change directly to a specific emissions source (USFS 2009; USEPA 2009; California Air Pollution Control Officers Association 2008; Council on Environmental Quality 2016; USFWS 2008; IPCC 2007; NMFS 2017).

The IPCC has identified the following general effects of climate change (IPCC 2018):

- Global temperature increases.
- A rise in sea levels affecting coastal areas and cities.
- Increased ocean acidification.
- Reduction in snow cover and sea ice.
- More intense and frequent heat waves, tropical cycles, and heavy precipitation.
- Impacts to biodiversity, drinking water, and food supplies.

The Climate Impacts Group (CIG) is a Washington State-based interdisciplinary research group that collaborates with federal, state, local, tribal, private agencies, organizations, and businesses, and studies impacts of natural climate variability and global climate change on the Pacific Northwest. CIG research and modeling indicates the following potential anthropogenic GHG impacts in the Pacific Northwest (May et al. 2018):

- Increased temperatures.
- Changes in water resources, such as decreased snowpack; earlier snowmelt; decreased water for irrigation, fish, and summertime hydropower production; increased conflicts over water; and increased urban demand for water.
- Changes in salmon migration and reproduction.
- Changes in forest growth and species diversity and increases in forest fires.
- Coastal changes, such as increased coastal erosion and beach loss due to rising sea levels, increased landslides due to increased winter rainfall, permanent inundation in some areas, and increased coastal flooding due to sea level rise and increased winter stream flow.
- Human and environmental health impacts resulting from these changes, including loss of biodiversity.

The Climate Science Special Report developed by the U.S. Global Change Research Program (USGCRP) predicts a similar set of impacts including (Mote et al 2014):

- Increased average annual temperatures.
- Change in average annual precipitation.
- Lower stream flows west of the Cascades.
- Increased wildfires, insect outbreaks, and diseases leading to widespread tree die-off.
- Continued sea level rise.

The U.S. Geological Survey (USGS) National Climate Change Viewer (NCCV) (USGS 2014) contains historical and future climate projections at county levels for the United States. The viewer indicates that, in Cowlitz County, minimum temperatures are likely to rise and that both increases and decreases in precipitation may occur, depending on other variables.

3.2.1 Washington State

Because Washington State policies and regulations address GHG emissions at the state level, emissions within this geography are assessed in this SEIS.

Ecology published its most recent reports to the Legislature on Washington GHG emissions and reduction limits in 2018 and 2019 (Ecology 2018, 2019). Information is also accessible on the web at https://ecology.wa.gov/Air-Climate/Climate-change/Climate-change-the-environment/Science. Total Washington GHG emissions were reported as 97.5 million metric tons (MMT) CO_2e in 2017. Ecology categorized GHG emissions into the following sectors:

- Transportation
- Electricity consumption (electricity generation/demand)
- Residential, commercial, and industrial (fuel combustion from space and/or process heating)
- Fossil fuel industry (leaks or venting from processing or distribution of fossil fuels
- Waste management
- Industrial processes (non-combustion sources)
- Agriculture

The State's total GHG emissions in 2017 were 97.5 MMT, which is 7.0 MMT higher than the State's 2020 target. The State's GHG emissions increased from 2012 to 2015 due to increased emissions from the electricity sector and the growth of Washington's economy (Ecology 2018).

As a percentage of total U.S. GHG emissions, Washington represents approximately 1.54 percent of the total 2015 GHG emissions of 6.6-billion metric tons estimated by the USEPA (USEPA 2019). Washington's per capita emission are also considerably lower than the U.S. average (Ecology 2012).

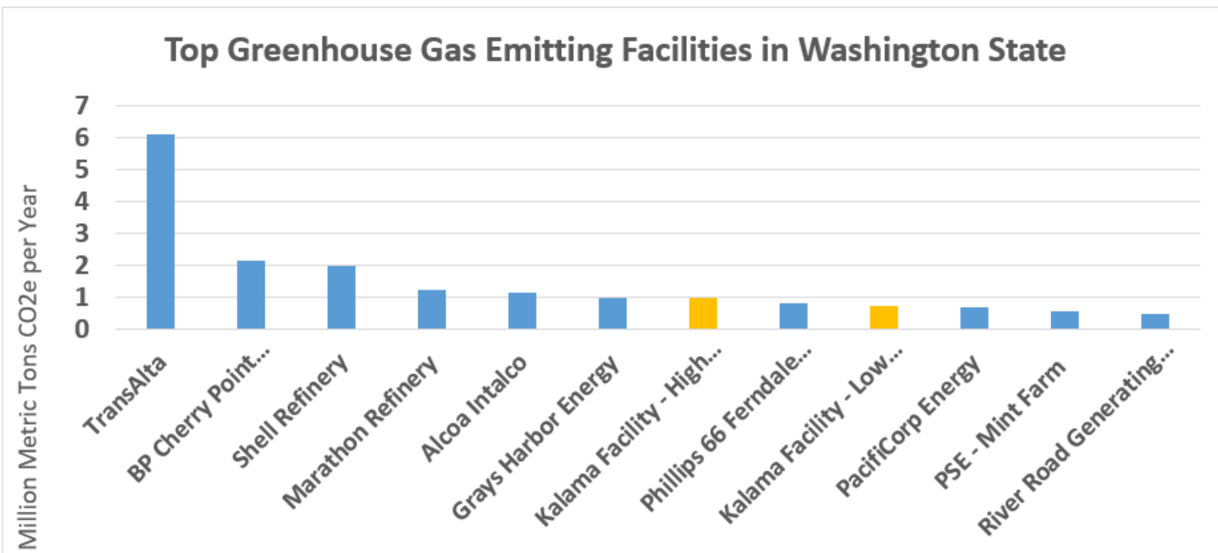

Figure 3-1. Washington State Top GHG Emitting Facilities

3.3 Regulatory Setting

This section consists of summaries of governmental laws, regulations, policies, and agreements that address GHG emissions.

3.3.1 International

Various international agreements have been established to address GHG emissions and climate change. This section does not provide an exhaustive summary of those agreements and includes only the most current and relevant.

3.3.1.1 Paris Agreement

The Paris Agreement is an international agreement intended to combat climate change by reducing emissions. In total, 197 parties (countries) agreed to the convention and 180 parties have ratified the agreement. The Paris Agreement aims to keep global temperature rise in this century well below 2 degrees Celsius beyond pre-industrial levels and strengthens the ability of countries to deal with the impacts of climate change (United Nations Framework Convention on Climate Change [UNFCC] 2018a).

In 2016, the United States joined the Paris Agreement, but under the current Administration has withdrawn. A key element of the agreement is nationally-determined contributions (NDCs). These are aspirational statements by each country of efforts to reduce national emissions and adapt to the impacts of climate change consistent with the agreement. The NDC submitted by the United States intended to achieve a reduction by 2025 of the level of its total GHG emissions by 26 to 28 percent below their 2005 level and to make best efforts to reduce its emissions by 28 percent (UNFCC 2018b). In August 2017, the United States stated its intent to withdraw from the Paris Agreement as soon as the country is eligible to do so (2020) (White House 2017). The United States continues to participate in negotiating the specific actions that will be taken by parties to the agreement and thus, until officially withdrawn is actively involved in activities supporting the Paris Agreement (United Nations 2017).

The Governor of Washington has joined other governors to form the U.S. Climate Alliance. The alliance has committed to meet their share of the Paris Agreement GHG emissions target by 2025 (U.S. Climate Alliance 2018).

3.3.2 Federal

3.3.2.1 Clean Air Act

The Clean Air Act (amended 1990) is the comprehensive federal law regulating emissions from both mobile and stationary sources of air pollution. In 2007, the U.S. Supreme Court ruled that GHGs were considered air pollutants under the Act.

In response to the fiscal year 2008 Consolidated Appropriations Act (H.R. 2764; Public Law 110-161), the USEPA issued "Mandatory Greenhouse Gas Reporting" the greenhouse gas reporting rule (40 CFR 23 Part 98) that requires reporting of GHG data and other relevant information by large sources and suppliers in the United States. The rule generally applies to activities that emit 25,000 metric tons of CO_2e or more per year. The rule requires only reporting and does not limit or require the reduction of emissions. The proposed project would be required to report direct project emissions under this program.

3.3.3 State

3.3.3.1 Limiting Greenhouse Gas Emissions (RCW 70.235)

RCW Chapter 70.235, Limiting Greenhouse Gas Emissions, established GHG reduction goals compared to a 1990 baseline and directed Ecology and other state agencies to undertake specific tasks related to GHG emissions. The intent of the chapter, as specified in RCW 70.235.005(3), was to:

(d) Limit and reduce emissions of GHGs as stated in RCW 70.235.020;
(e) minimize the potential to export pollution, jobs, and economic opportunities; and
(f) reduce emissions at the lowest cost.

The statute does not specify regulatory requirements to reduce or limit GHG emissions that are applicable to individual projects (including the proposed project), industries, or sectors. RCW 70.235.050 does impose requirements for state agencies to develop plans to reduce their GHG emissions to meet the adopted reduction targets. In its 2019 update prepared under RCW 70.235.040, Ecology recommended the following updated statewide reduction goals for GHG emission limits:

- By 2020, reduce overall emissions of greenhouse gases in the State to 1990 levels
- By 2035, reduce greenhouse gas emissions in the State to 45 percent below 1990 levels
- By 2040, reduce greenhouse gas emissions in the State to 70 percent below 1990 levels
- By 2050, reduce greenhouse gas emissions in the State to 95% below 1990 levels and achieve net zero greenhouse gas emissions in the State

3.3.3.2 Washington Clean Air Act (RCW 70.94)

The Washington Clean Air Act (RCW 70.94) establishes rules for reporting GHG emissions for sources that exceed 10,000 metric tons CO_2e emissions per year. Washington Administrative Code (WAC) 173-441 establishes the reporting rules. No specific reduction or mitigation requirements are included in the proposed project that would be required to report emissions under this rule.

3.3.3.3 Greenhouse Gas Emissions—Baseload Electric Generation Performance Standards (RCW 80.80)

RCW 80.80 establishes a maximum GHG emission rate of 1,100 pounds for each megawatt hour produced for certain baseload power generation facilities. RCW 80.80 would not apply to the proposed project because it is not a baseload facility, but the on-site power generation would meet the standard. CO_2 mitigation for certain fossil-fueled electric generation facilities is also required but mitigation for CO_2 emissions would not apply to the project.

3.3.3.4 Washington State Efficiency and Environmental Performance (Executive Order 18-01)

This executive order from Governor Jay Inslee was established in 2018 for the purpose of increasing the energy efficiency of state government operations and thereby reducing spending on energy costs, reducing harmful pollution from burning fossil fuels, and strengthening Washington's economy by promoting investment in renewable energy. The executive order outlines emission reduction initiatives when making purchasing, construction, and other decisions by state government, including utilizing battery-electric vehicles (BEVs), constructing buildings to be zero-energy capable, and pursuing zero-emission electricity sources. A cross-agency Governing Council adopts and implements workable standards, measures, and targets for agencies making emissions-reducing choices. The office of State Efficiency and Environmental Performance (SEEP) will guide the executive order and Governing Council. The order superseded Executive Order 04-04 (Washington Carbon Pollution Reduction and Clean Energy Action).

3.3.3.5 Washington’s Leadership on Climate Change (Executive Order 09-05)

This executive order from then-Governor Christine Gregoire was established after the adoption of RCW 70.235 and ordered the state to continue to participate in the Western Climate Initiative, estimate emissions, quantify emission reductions, and identify strategies and actions that could be used to meet the 2020 target for emission reductions adopted by RCW 70.235 in 2008, as well as other directives to Ecology and the Washington State Department of Transportation for specific emissions reduction efforts.

3.3.3.6 Executive Order 07-02

Governor Christine Gregoire established this executive order, which articulated statewide GHG reduction goals that are consistent with those subsequently established as law by RCW 70.235.020. The order also included directives to reduce GHGs, including increasing vehicular emission standards, retrofitting diesel vehicles, energy efficient buildings, and other similar activities.

3.3.3.7 Senate Bill 5116 (Chapter 288, Laws of 2019)

This legislation was signed by Governor Jay Inslee during the 2019 Regular Session of the Washington State Legislature. The intent of Senate Bill 5116 is to phase out the use of fossil fuels for power generation in Washington State. This legislation requires all electric utilities in Washington State to eliminate coal-fired resources from their electricity allocation on or before December 31, 2025. In addition, all sales of electricity to retail electricity customers must be GHG neutral by January 1, 2030. By January 1, 2045, the official state policy under Senate Bill 5116 is that every electric utility in the state receives 100 percent of their retail electric load from non-emitting or renewable resources.

3.3.3.8 Shoreline Management Act

The purpose of Washington's Shoreline Management Act (SMA) is to protect the shorelines of the state, which the SMA recognizes are “among the most valuable and fragile of its natural resources.” RCW 90.58.020. Thus, developments within state shoreline jurisdiction must be consistent with the policies of the SMA, state shoreline regulations, and the local Shoreline Master Program (SMP).

The SMA establishes a local/state partnership regulating State shorelines. Local governments have the primary responsibility for initiating the planning required by the act and administering the local regulatory and permitting program. The Department of Ecology's role is twofold:

1. Act primarily in a supportive and review capacity, with an emphasis on providing assistance to local governments.
2. Ensure compliance with the policies and provisions of the SMA by reviewing and approving permits and enforcing shoreline regulations.

The SMA establishes three types of shoreline permits: substantial development permits (SDP), conditional use permits (CUP), and variance permits. Most developments that meet a specific dollar threshold are considered substantial developments and require an SDP. A development requires a CUP if a proposed use is listed as a "conditional use" in the local SMP, or if the use is not addressed in the SMP.

CUPs may be required even if a proposed use is otherwise exempt from the requirement to obtain a substantial development permit. Some proposals may require both an SDP and a CUP, as is the case with the Kalama facility.

The local jurisdiction (e.g., Cowlitz County) bears the primary responsibility for receiving, reviewing, and then approving or denying a shoreline permit application. The local jurisdiction then sends approved CUPs to Ecology for the department to either approve, approve with conditions, or deny. Ecology must issue its decision within 30 days of receiving a complete permit package from the local government.

3.3.4 Local

3.3.4.1 Cowlitz County

Cowlitz County is required by RCW 36.70.320 to develop and adopt a comprehensive plan to guide the orderly physical development of the County. The plan is intended to guide the policy decisions related to the physical, social, and economic growth of the County and provide a framework for future growth and development, including development in shoreline areas.

The County updated its comprehensive plan in 2017 and the plan does not contain any specific policy direction regarding GHG emissions or climate change. In addition, the County recently updated its SMP (including receiving approval by Ecology) and it also does not include provisions related to GHG emissions or climate change. Current county code and other policy documents do not contain specific policy or regulatory requirements related to GHG emissions and/or climate change. The county does have specific regulations regarding the protection of critical areas including wetlands and shoreline areas.

3.4 Methods and Approach

3.4.1 Introduction

The Global GHG Lifecycle Assessment (LCA) Emissions and Economic Substitution Analysis covers two major elements:

- **GHG Emissions Analysis:** Lifecycle GHG emissions were calculated for methanol production and a number of potential end-uses, showing plausible low, medium, and high emission scenarios together with a sensitivity analysis of the scenarios.
- **Economic Analysis:** A market-based evaluation was conducted to assess whether methanol produced by the project would substitute for or replace other sources of methanol, rather than supplement them.

This section describes the methods and approach used in the GHG emissions and the economic analyses. In general, the analyses are based on a wide-ranging review of information sources, including the 2016 Final EIS, the First SEIS, peer-reviewed literature regarding emissions associated with global methanol production and end use, and market analyses documenting the global trade and disposition of methanol. Independent calculations and GREET model results were used to supplement emission values from the previous SEIS, validate values found in literature, and provide quality assurance and quality control.

The GHG analysis focuses on determining GHG emissions from sources associated with the KMMEF. For most sources, low, medium, and high emission factors were developed to provide a range of plausible inputs for the overall analysis. Low, medium and high estimates (scenarios) were run to better understand of how uncertainties inherent to the prediction of lifecycle emissions from a complex project can influence end results. Emissions from the following general categories of sources are included in this analysis:

- Upstream emissions associated with natural gas to be used by the KMMEF
- Emissions generated by the construction of the KMMEF, including emissions from the production of construction materials
- Emissions from the operation of KMMEF, including emissions from the production of methanol, electricity purchased by KMMEF from the local utility, and transportation of methanol from Kalama to China
- Emissions from alternate methods of methanol production available in the global market that have the potential to be replaced by the methanol that would be produced by the KMMEF.
- Emissions from potential end uses of KMMEF methanol.

Emissions in this study are presented from a gross and a net viewpoint. Gross emissions are calculated for the KMMEF and each alternate case for producing methanol, and net emissions represent the difference between the two. For the net perspective, results are the difference (or change) in emissions between KMMEF and alternate scenarios. Emission results will be primarily presented from a gross perspective but in certain instances it will be beneficial to see the net emissions impact due to the project. Emissions are presented both ways to provide a complete picture of the GHG impact of KMMEF. For example, even though net emissions may show less emissions for KMMEF compared to a reference case, it may not necessarily mean that global GHG emissions are becoming lower. Due to growing methanol demand, global emissions from increasing methanol use will be increasing over the lifetime of the proposed project. However, based on the results of this study it is likely that reference case emissions will be larger than emissions from the proposed project, which means a smaller increase to the gross global GHG emission footprint than what would happen absent the proposed project. Whether or not increasing methanol use results in a change in overall global emissions (taking into consideration all sectors of the global economy) is a different question having to do with what substitutes would be used in the market if the supply of methanol were constrained. That question is outside the scope of this analysis.

The economic analysis describes the global economic setting for methanol, including factors that influence methanol supply and demand as well as expectations for how the global methanol market will evolve in the future. This economic analysis provides the basis for projecting the degree to which KMMEF-produced methanol may substitute for other sources of methanol produced globally.

Finally, this section also describes the Emissions Sensitivity Model (ESM) developed to integrate results from the GHG Emissions analysis and the Economic Analysis in order to estimate overall GHG emissions from the KMMEF during its 40-year lifespan.

3.4.2 Upstream emissions

Greenhouse gases would be released during the extraction, production and transmission of natural gas delivered to the proposed KMMEF for conversion into methanol. These are characterized as “upstream emissions.” GHG emissions from the local natural gas distribution system are not attributable to the project because KMMEF will have its own dedicated high-pressure connection. As described in the First SEIS, natural gas will be supplied to KMMEF from the existing interstate transmission pipeline via a new 24-inch 3.1-mile lateral interconnection pipeline. Northwest Pipeline LLC is proposing to construct and operate this interconnection pipeline, which is known as the Kalama Lateral Project. Potential source regions for the natural gas supplied to KMMEF include northern British Columbia (BC) and the northern Rockies within the U.S.

Figure 3.4-1 below shows the regional interstate transmission pipeline routes expected to supply natural gas to KMMEF.

The primary GHGs from upstream gas emissions are carbon dioxide (CO_2) and methane (CH_4). A small amount of nitrous oxide (N_2O) is also emitted. Carbon dioxide is a combustion product emitted when natural gas is flared during extraction and processing and when there is combustion during flaring of gas that cannot be used or recovered economically. Carbon dioxide emissions also result from fossil fuels used during the production, processing, and transportation of natural gas. Methane emissions occur when gas is vented during extraction and processing, which often occurs for operational or safety reasons, as well as from unintentional leaks that occur during well drilling, processing, and transmission. Methane is also emitted when flaring of gas occurs in sub-optimal conditions that include variation in the heat content of the gas or instability of the flame. Nitrous oxide and methane are also emitted as byproducts from the combustion of natural gas or other fossil fuels.

Methane is a far more potent GHG than CO_2, raising concerns regarding methane emissions from upstream gas sources. A summary of several analyses was included in Table B.3 in Appendix B of the First SEIS. That summary showed methane emission rates (expressed as a percent of gas delivered), ranging from 0.32 to 2.3 percent.

Generally, available analyses indicate that Canadian natural gas sources exhibit lower methane emission rates than do U.S. natural gas sources. The natural gas supply for the NWIW project is expected to consist of 99.4 percent BC natural gas and 0.6 percent U.S. Rocky Mountain natural gas. In the First SEIS, the GHGenius model was used to estimate upstream emissions for natural gas from BC (S&T Squared 2013). The GREET model was used to provide estimates for the U.S. Rocky Mountain natural gas source (ANL 2017). As shown in the emission calculations in Appendix A, the methane emission rate using this approach is estimated to be 0.71 percent of the delivered natural gas. This methane emission rate, together with CO_2 and N_2O emission values corresponding to a BC/Rocky Mountain natural gas mix, are considered the “low emissions scenario” used in the LCA for this Second SEIS.

It should be noted that the upstream greenhouse gas emission rate from US sources is based on studies with higher methane emission rates than those used in GHGenius. Emission factors in the GREET model are routinely updated; the most recent update (Burnham 2019) includes options for using “EPA Conventional”, “EPA Shale” or “Environmental Defense Fund (EDF)” methane emission factors. The two USEPA emission factors are based on USEPA’s Greenhouse Gas Inventory (GHGI) updated through 2017. The USEPA GHGI is used in GREET as it is the best data source that provides the process-level emission details utilized in GREET.

The USEPA methane emission factor that is most appropriate for KMMEF is the “EPA Shale” factor, as the potential source regions for KMMEF natural gas (BC and Rocky Mountains) extract natural gas from shale deposits. The “EPA Shale” factor equates to a methane emission rate of approximately 0.97 percent of delivered natural gas. This methane emission rate, together with CO_2 and N_2O emission values from GREET presented in the First SEIS comprise the “mid missions scenario” defined for this Second SEIS.

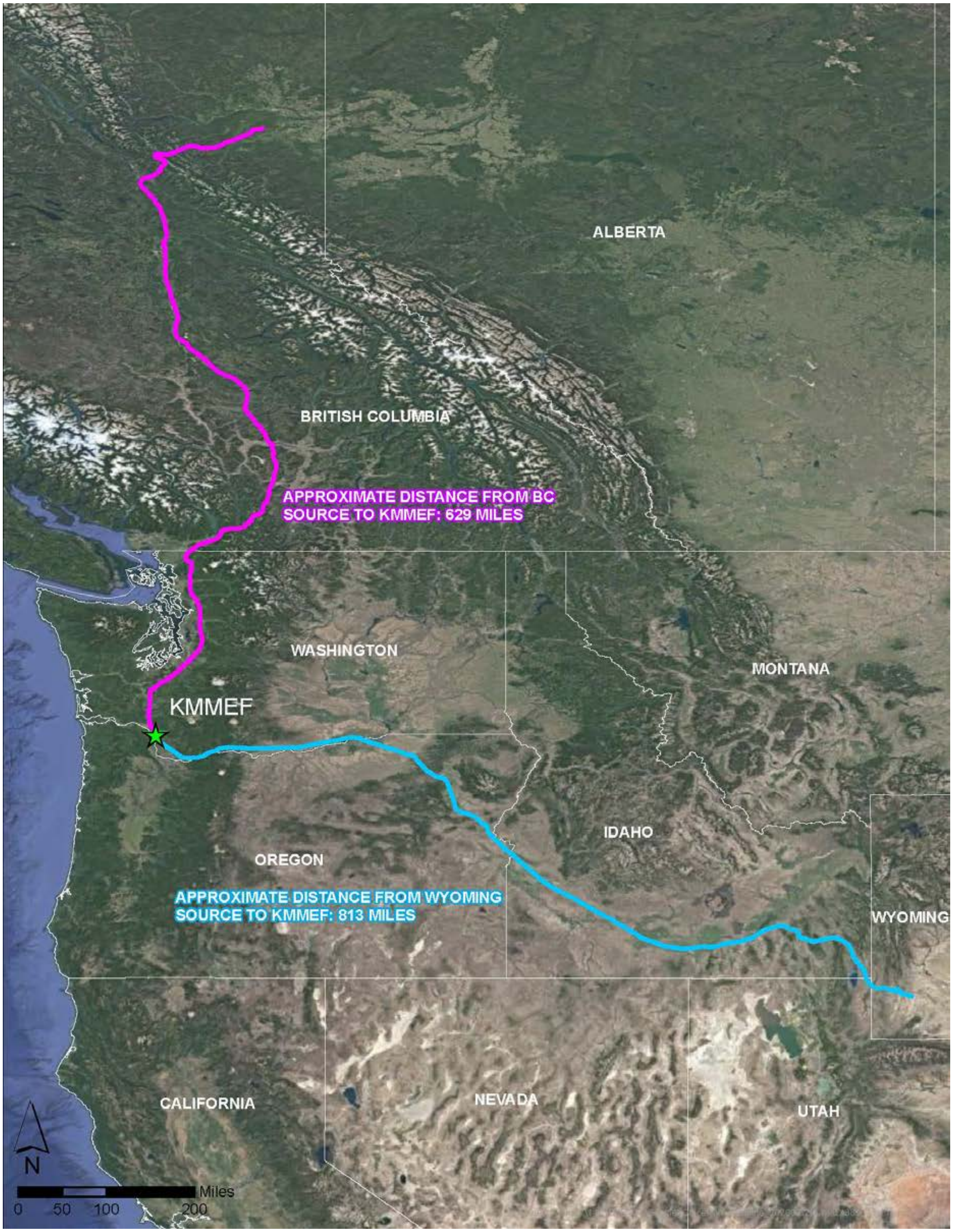

Figure 3.4-1. Regional Natural Gas Transmission Pipelines

The EDF methane emission factors are based on Alvarez et al.'s 2018 study in which methane emissions from ground-based, facility scale measurements (bottom-up emissions) were validated using aircraft observations (top-down emissions). Alvarez found good agreement between both bottom-up and top-down approaches to estimating methane emissions, and found a combined estimate for methane emissions to be approximately 60 percent higher than USEPA's emission inventory estimate. This difference is considered by Alvarez to likely result from releases that occur under abnormal fossil fuel drilling and natural gas pipeline system operating conditions that are not captured in USEPA's emission inventory. Alvarez's study concluded that the methane emission rate was not able to differentiate between natural gas and oil production emissions in its analysis. Therefore, ANL applied Alvarez's conclusion (60 percent higher emissions than USEPA's emission inventory-based estimate) to the USEPA emission factors for natural gas production for use in the GREET model (Burnham 2019). The resulting methane emission rate using this approach is approximately 1.46 percent of delivered natural gas. Estimates based on this EDF methane emission factor together with CO_2 and N_2O emission values from GREET are used to create the "high emissions scenario" for this Second SEIS.

The upstream methane emission rates described above and used in this Second SEIS represent a higher range in emission rates than were used in the First SEIS. Table 3.4-1 below presents these upstream methane emission rates for comparison. GHG emissions from upstream natural gas sources are presented in Section 3.5 and calculations are documented in Appendix A.

While the low, medium, and high emission scenarios described above represent a plausible, literature-supported range in upstream methane emission rate estimates, significant uncertainty exists regarding whether these estimates are truly accurate. Many studies document large variations in emissions both between individual natural gas production areas and at different times when emission rates are measured (Alvarez et al. 2018; IEA 2020). Additionally, gaps can exist in bottom-up studies or emission inventories that allow some sources to remain uncounted. Studies in the US, such as Alvarez et al., have identified methane emission sources operating under abnormal conditions that result in high methane emissions. These so-called "super emitters" are thought to be small in number but potentially contribute a significant portion of the total methane emissions from natural gas production. The variability in emissions in both time and space, potential for gaps in accounting for all sources in bottom-up emission inventories, and impact of "super emitters" are cited as a key reasons for the differing estimates of methane emission rates that exist in scientific literature.

Due to this uncertainty, this study has included a fourth upstream methane emission rate of 3 percent within the sensitivity study that is described in Section 3.4.7. This fourth emission rate estimate is significantly higher than the three values presented above and provides a useful mechanism to explore how the uncertainty that exists in upstream methane emission rates can impact the overall GHG lifecycle emissions for KMMEF.

Table 3.4-1. Upstream Methane Emission Rates from First and Second SEIS

3.4-1a. First SEIS

Emissions	Units	Low	Baseline	High
Upstream Methane Emission Rate	Percent of Natural Gas Used	0.71	0.71	0.97

3.4-1b. Second SEIS

Emissions	Units	Low	Medium	High
Upstream Methane Emission Rate	Percent of Natural Gas Used	0.71	0.97	1.46

3.4.3 Process emissions

GHG emissions will be generated by activities and operations at the KMMEF site. Emission sources evaluated in this Second SEIS include:

- KMMEF Construction. Emissions during construction are generated by construction equipment, construction worker commuting, the construction worker shuttle bus, material deliveries, organic material decomposition from dredging operations, and the manufacturing of materials used in construction.
- KMMEF Process Emissions. Process emissions include direct operating emissions from the conversion of natural gas to methanol, natural gas combustion emissions from the combined cycle power plant, and fugitive emissions from the methanol system and storage tank.
- Electrical Power. Emissions are associated with the portion of the electrical power to be used by the KMMEF that will be purchased from the local public utility.
- Methanol Transportation. Emissions will occur from the combustion of fuels used to power marine vessels transporting methanol from KMMEF to China, from helicopters used to transport bar pilots at the mouth of the Columbia River, and from tugboats used during marine vessel transit along the Columbia River.
- Fuel Production. Emissions are generated by activities associated with the production of the fuels used by various equipment, vehicles, and vessels during construction, operation, and transport of methanol.
- Waste Disposal. Emissions result from the transport of waste products (such as waste from raw water and process water treatment) from the project site to a landfill.
- Employee Commuting. Emissions are generated by the commuting of workers to KMMEF.
- Catalyst Replacement. Emissions result from manufacturing of the catalyst used in the methanol production process, from shipping the catalyst from the manufacturer, and from shipping the spent catalyst for recycling.

- Decommissioning. Emissions will be generated by equipment used to remove KMMEF structures during facility decommissioning.

A detailed description of the methods used to determine GHG emissions from the sources listed above is provided in Appendix C.

3.4.4 Downstream end ese emissions and emissions from substitute pathways

The downstream use of methanol produced by KMMEF will result in GHG emissions. This analysis recognizes that exported KMMEF methanol may substitute for current methanol production in China or elsewhere in the global methanol market. This section describes the methods used to estimate GHG emissions from alternate pathways of methanol production as well as from the ultimate end use of methanol regardless of source.

3.4.4.1 Review of previous SEIS

Results of the GHG life cycle emissions study from the First SEIS were analyzed and verified to determine elements for use in the current analysis. The following emission life cycles for methanol pathways and end uses were analyzed:

Pathways:

- China coal to methanol: emissions associated with coal mining and processing, coal mine methane fugitive emissions, processing of coal to methane, and transportation.
- Oil to naphtha: emissions related to the extraction and processing of oil, the transporting of oil, and the refining of the oil to produce naphtha.

End-uses:

- Methanol to olefins: emissions related to the use of methanol as a feedstock in the production of olefins including power requirements.
- Naphtha to olefins: emissions related to the process of steam cracking (thermal cracking of hydrocarbon feedstock using steam) to convert naphtha to olefin.
- Fuel combustion: emissions related to the direct combustion of methanol as a fuel.

Analysis of downstream end use emissions included independent calculation verification, literature review, and GREET simulations. Excel files of the First SEIS analysis were reviewed, both for raw data inputs and calculation methodology, and results were then compared to the literature.

Although there is extensive research on the lifecycle emissions of pathways and end uses that are relevant to this study, model boundary conditions can vary, and care must be exercised when comparing lifecycle emissions. In order to compare published data to the previous study, adjustments are applied to account for differences in boundary conditions presented in the publication selected for comparison. GREET simulations were conducted to provide further data comparisons. Fuel combustion emission factors are taken from 40 CFR Part 98 Subpart MM, Table MM-1 for the combustion of methanol as a fuel source. Regardless of whether methanol is used to fuel mobile or stationary sources, the emission factors are the same. Therefore, these emission factors for methanol fuel combustion are suitable.

3.4.4.2 Calculation of new pathways

This Second SEIS considers lifecycle emissions for two additional pathways that were not analyzed in the First SEIS. These pathways are described below:

3.4.4.2.1 China-based natural gas to methanol

Emissions arising from China-based natural gas extraction, processing and conversion to methanol were not evaluated in the First SEIS. Although methanol sourced from Chinese natural gas currently contributes only a small percentage to the methanol market in China, it is included in the evaluation presented in this Second SEIS to provide a complete picture of all potential pathways for the introduction of methanol used in China. Literature review identified a narrow range of lifecycle emissions from the Chinese extraction of natural gas and subsequent production of methanol. Based on the published data, emission rates for the life cycle emissions of Chinese natural gas-based methanol were identified and used as ESM inputs. A detailed analysis of the comparison is shown in Appendix A.

Some insight into the comparison of upstream methane emissions from natural gas production between North America and China can be gained from a recent study by Gan et al. (2020). This study indicates that the average GHG intensity of Chinese domestic natural gas supplies is 15.5 grams CO_2e per megajoule (g CO_2e/MJ) for conventional methods and 21.5 g CO_2e/MJ for unconventional methods. Additional gas supplies from international pipelines and overseas LNG are expected to be needed by 2030 to meet the growing gas demand in China. The average GHG intensity for these supplies is 19.7 g CO_2e/MJ for overseas LNG and 35.9 g CO_2e/MJ for international pipelines. Thus, based on this study, both domestic and imported sources of China based natural gas have a higher GHG intensity than US-based sources, which average 12.1 g CO_2e/MJ (Table B.5, Appendix B, First SEIS) and corresponds to a methane emission rate of approximately 1%. This suggests that the assumed equivalence in upstream methane emissions between KMMEF and China is unlikely to hold, and any result that suggests higher upstream methane emissions for the KMMEF than for natural gas-based methanol production in China, may be unlikely. Due to the insufficiency of data regarding the appropriate magnitude of upstream methane emissions in China, the ESM does not incorporate differences in upstream emissions between the KMMEF and China.

3.4.4.2.2 Non-KMMEF imports of methanol into China

Imported methanol represents a higher share of Chinese methanol supply than does methanol derived from Chinese natural gas. An evaluation of the major importers of methanol into China was undertaken to identify sources of imported methanol. A weighted average GHG emission factor was calculated for foreign, non-China based, methanol manufacturers. A total of 29 manufacturing facilities around the world (located in the Middle East, North America, Southeast Asia, Africa, and South America), were accounted for to represent an overall emission factor for China methanol imports. These 29 facilities have the capacity to produce as much as 48 MMT of methanol annually, representing nearly half of current production.

Four potential GHG emissions sources for methanol imports were evaluated:

1. Upstream natural gas GHG sources: Upstream GHG emissions from methanol importers depend on natural gas production, processing and transportation methods. Location-specific data on upstream GHG emissions, including methane emission rates, for methanol importers to China is limited. One of the driving factors behind upstream natural gas emissions is the methane leakage rate. Literature has shown that there is high degree of uncertainty in the estimates of upstream methane emissions associated with natural gas extraction and processing, especially for foreign manufacturers (Gan et al. 2020). Due to the high uncertainty, the evaluation of upstream GHG emissions for non-KMMEF importers of methanol assumes that their upstream emission is equivalent to the upstream KMMEF emissions on a per MT of methanol produced basis.
2. Upstream power. To calculate GHG emissions associated with upstream power usage, local electricity GHG emission factors in kg CO_2 per kilowatt hour (Kwh) for the 29 manufacturers were obtained from the International Energy Agency (IEA) and the U.S. Environmental Protection Agency (USEPA). These electricity emission factors were compared to the electricity emission factor for KMMEF, and a ratio of the two electricity emission factors calculated. This ratio was then multiplied with the upstream electricity emissions for KMMEF and assigned as the GHG emission value for the respective manufacturer.
3. Direct emissions. The KMMEF facility is projected to have a lower direct GHG emission rate than current methanol importers to China. This is due to KMMEF's innovative ULE technology, which incorporates gas-heated and autothermal reforming methods (GHR+ATR), and the availability of low-carbon electricity. Ingram (2017) reported that the GHR+ATR technology could result in significant reductions in direct GHG emissions compared to combined reforming (CR), which has been viewed as the lowest GHG emitting technology for methanol production (EPA PSD permit PST-TX-1340-GHG, August 2014). Based on the emission calculations presented in Appendix A and as described in Appendix B of the First SEIS, it is assumed that the ULE technology provides a 38% reduction in CO_2e emission relative to combined reforming. Currently, most methanol importers to China use either CR or steam methane reforming (SMR) to produce methanol from natural gas (see Table 7 in Appendix A). SMR is associated with higher GHG emissions than CR. While it is likely that in the future, methanol production globally will move towards lower GHG emitting technologies (CR or ULE), it is not possible at this point to forecast the extent to which this may occur. Therefore, the direct emissions for methanol importers to China conservatively assume that the importer uses CR technology to manufacture methanol rather than either the higher emitting SMR or the lower emitting ULE.
4. Transportation to China. It is assumed that transportation related GHG emissions are proportional to travel distances between the manufacturers and China. Emissions were derived from the ratio of travel distances to China, comparing distances from various

methanol importers to the travel distance from the KMMEF site. Figure 3.4-2 below shows travel routes from KMMEF and methanol importers to China.

Total GHG emissions for each of the 29 methanol manufacturers were calculated by totaling the GHG emissions related to upstream natural gas production, upstream power utilization, direct methanol production emission, and product transportation to China. In order to obtain a single GHG emission rate for the ESM to represent emissions from non-KMMEF importers of methanol into China, the weighted average of GHG emission rates was calculated relative to each manufacturer's methanol production capacity. It is important to calculate emissions relative to production capacity to ensure that emissions from high and low producing plants are adequately accounted for. The difference in emissions between importers of methanol and KMMEF is primarily driven by the ULE technology being implemented at KMMEF. ULE technology is not widely adopted by the methanol industry and most of the manufacturers evaluated in this study employ combined reforming or steam methane reforming which typically result in higher GHG emissions.

Methanol Import Distances to Tianjin, China (NM)

Figure 3.4-2. Travel Routes from KMMEF and Methanol Importers to China

3.4.5 Economic analysis

To understand the potential GHG emissions attributable to KMMEF-produced methanol during the facility's lifetime, an understanding of the global economic setting for methanol production and end use is required. While the First SEIS addressed the economic setting, Ecology determined that more economic analysis was needed to adequately address stakeholder concerns, including:

- Based on a market analysis is it possible that some methanol from KMMEF would be used for fuel?
- How might different assumptions about the sources of methanol used influence the emissions analysis?
- Given the many sources of uncertainty in global methanol markets and international trade policies and the future of energy use, can the analysis of global GHG emissions be more flexible to consider alternative assumptions?

A key example of global uncertainty that has developed in recent months is the ongoing global economic recession related to the Covid-19 pandemic that has altered many forecasts for future conditions that were deemed reasonable in November 2019.

To address these concerns, a new economic analysis was conducted that utilizes the information identified in the First SEIS while gathering and analyzing additional information to provide a more expansive assessment of the KMMEF facility within the global economic market. This analysis is based on current policies and market trends. Scenarios with substantially different global policies (fossil fuel/plastics phase outs or bans for example) are too uncertain to include in this analysis.

Additional information was gathered from independent sources, including the Methanol Institute, the Methanol Market Services Asia, IHS Markit, and industry periodical literature. These sources were used to corroborate and supplement the information in the First EIS and SEIS. The results of this literature review are highlighted in Appendix B, Methanol Markets. Information from this review was critical to set up a framework for addressing the questions about global emissions.

3.4.5.1 Framework for the analysis

Assessing the impact of a new methanol facility on global GHG emissions requires an analysis of the impact of the facility's product on the existing and projected global methanol market, in this case with a particular emphasis on the Chinese market. To achieve this, it is necessary to assess the GHG emissions expected to occur in the absence of the project, given likely economic conditions. Such a scenario is often called the "baseline" scenario, or the "business as usual" scenario. In other types of analysis this is called the "without project" scenario, when a project like KMMEF is being analyzed. In that vernacular, the "without project" scenario is contrasted with the "with project" scenario. Sometimes the comparison is referred to as the "reference case." But irrespective of what this scenario is called, the calculated project emissions can then be compared to this baseline, reference, or business as usual conditions to evaluate how emissions from the proposed project would compare relative to a scenario without the project. For this analysis, we employ the phrase “alternate cases” and will develop three cases, with one being the best estimate called the reference case, or RC.

A review of relevant literature and, in particular, a review of the world methanol market, showed that the global methanol market grew rapidly through 2019, was competitive, and had many producers. Global annual methanol use was more than 98 million metric tons (MMT) and of that, just under 30 MMT was traded internationally (MMSA 2020). For example, China imported 10.9 MMT of methanol in 2019, from nine different exporting countries contributing 95 percent of this quantity (Iran, New Zealand, Trinidad and Tobago, Oman, Saudi Arabia, UAE, Malaysia, Venezuela, Brunei, in decreasing order of volume) (CCFGroup 2020). In addition, global capacity is estimated at 153 MMT, and there are regular reports of additional capacity expansions planned for the near future. The fact that capacity exceeds existing demand signifies that the market is not capacity-constrained. That is, facilities will be able to quickly respond with additional supply as demand grows.

Given the competitive structure of the industry, this analysis assumes that as global methanol demand increases over the next 40 years, some methanol producers will expand to meet that demand. KMMEF is assumed to be a “price-taker” (as is expected in a competitive commodity market), meaning that the facility would take the price offered; it is not expected to impact global supply in a way that could affect the price.

Consequently, GHG emissions from the production of methanol to meet global demand will occur with or without the KMMEF. However, if KMMEF sells 3.6 MMT per year to China, then the emissions for 3.6 MMT of methanol produced under alternate cases would be replaced with the emissions from the KMMEF-produced methanol each year. Therefore, the focus of this analysis is on the emissions associated with the 3.6 MMT of methanol produced annually by KMMEF. The analysis will compare emissions from 3.6 MMT of KMMEF methanol to the emissions of other sources of methanol that may be expected under alternate cases.

3.4.5.2 Alternate case in China

The following graphic (Figure 3.4-3) shows the Chinese market using solid lines, and the KMMEF addition to the market with a dotted line. Each of the elements essential to determining emissions is shown in the graphic, aligning with the emission pathways previously described. These pathways are:

- the feedstock used to produce the methanol
- the transportation of the methanol product, and
- the end use of the methanol

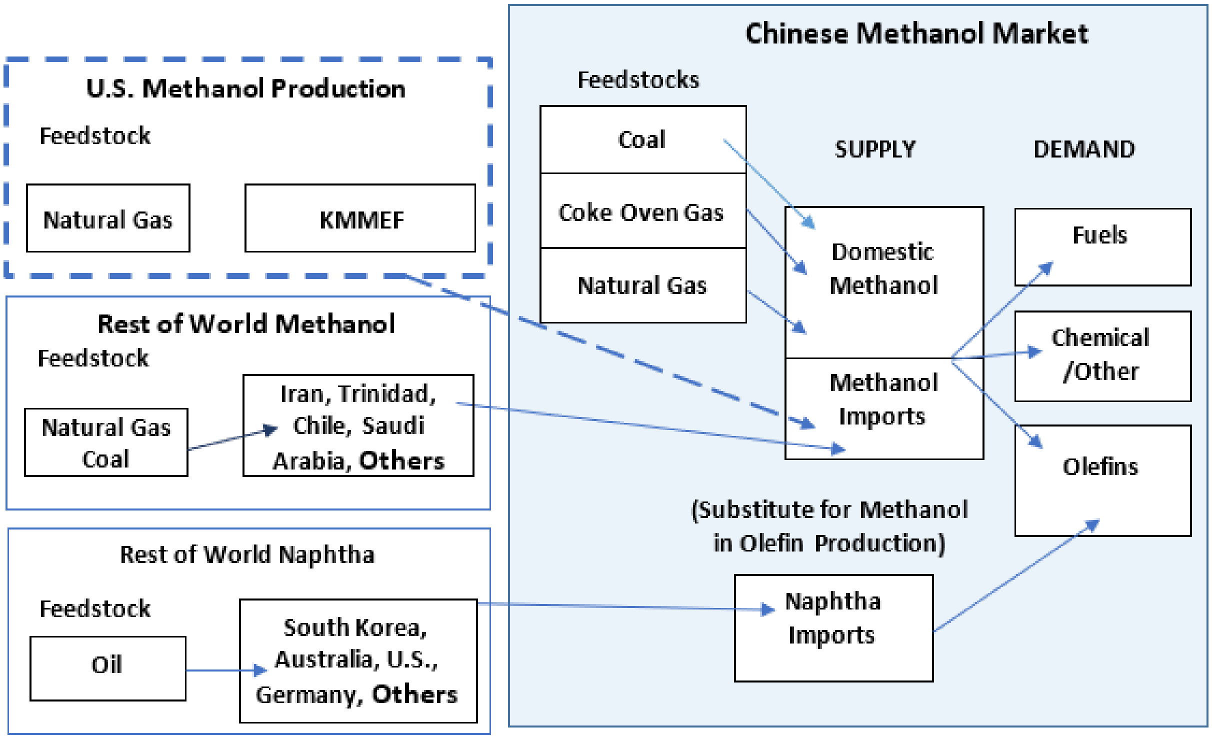

Figure 3.4-3. Current Chinese Methanol Market with KMMEF Project Represented with a Dashed Line

Each of the lifecycle emission pathways identified in the discussion of emissions in Chapter 3.4.2 is represented in Figure 3.4-3, as are the end uses (called "Demand" in this graphic). Each of the pathways results in a supply of methanol (shown in the middle column), either domestic methanol or methanol imports. Each of the pathways involves a feedstock that includes upstream emissions; a process including energy used to produce the methanol; and the transportation used to get the product to the Chinese market. Key drivers of increasing demand are expanding use for methanol to olefins (MTO) and a host of evolving technologies for using methanol for transportation and cooking fuels (highlighted in the graphic). Note that "Other" uses of methanol (formaldehyde, and various other industrial uses) make up approximately one third of all methanol use globally. This analysis does not focus on formaldehyde or other industrial uses, because in China, this "Other" sector makes up a small percentage of the total methanol use and other sectors such as olefins and fuels are expected to continue to grow faster (Dolan and Gregory 2019). Any growth for these "Other" uses is assumed to occur within the current suppliers to this sector. Consequently, the introduction of KMMEF is not expected to affect this sector. Additionally, coke oven gas is a bi-product from steel mills and its supply is tied to steel production. Coke oven gas is not tied to methanol production and is not subject to the forces of the methanol market. Therefore, this feedstock and sector is not expected to be influenced by KMMEF.

This analysis considers three likely alternate cases in China. Each case defines the sources of methanol that would likely be replaced by KMMEF production. The focus in this analysis is on how KMMEF methanol might serve as a substitute for, or temporarily replace another source of methanol. While there is uncertainty surrounding the pace of the growing methanol market, global nameplate capacity (i.e. the amount of methanol that could be produced by all global facilities if they were operating at full capacity) is much greater than current methanol use. Global production capacity is estimated to be 153 MMT. This suggests that there is ample capacity to increase production from existing facilities and still meet demand. The project will therefore be more cost competitive and win market share by virtue of cost, causing other operations to produce less while the project is in operation. Therefore, no plant shutdowns are anticipated as a result of KMMEF.

The three alternate cases were determined based on the best estimates of likely sources that will have their production levels impacted when KMMEF comes online. These are referred to as the RC, which is the best estimate of which suppliers would respond on a market without KMMEF, a lower coal-based production case (LCC), and a higher coal-based production case (HCC). The RC was designed to illustrate the most likely outcome, wherein 60 percent of the production that would come from the KMMEF would potentially be replaced by production from coal-based methanol in China (CCM), 10 percent would be from natural gas-based methanol from China (CNGM), and 30 percent would come from imports. The LCC represents a less likely but potentially realistic scenario that shows a lower percent of production coming from CCM (20 percent rather than 60 percent), and instead a majority of methanol coming from other international exporters. The HCC shows an equally plausible scenario where 80 percent of the production would come from low-cost CCM, none from CNGM, and 20 percent from other exporting nations. These are shown in table form below (see Table 3.4-3).

Table 3.4-3. Source Definition Under Three Alternate Cases

Scenario	Coal-based methanol production share	Natural gas-based methanol production share	Other methanol import share
RC	60%	10%	30%
LCC	20%	20%	60%
HCC	80%	0%	20%

3.4.5.3 Analysis through time

Because the KMMEF facility is a long-term investment that may be expected to operate for 40 years, it is important to consider the analysis of potential impacts (in this case, GHG emissions), throughout the life of the project. The market analysis also addresses expected changes throughout the life of the project and includes opportunities to explore the uncertainty and/or volatility of the markets going forward.

The methanol market is forecast to continue growing, having experienced an average annual growth rate of 4.5 percent per year between 2015 and 2020, even allowing for an anticipated flattening of the quantity demanded between 2019 and in the expected consumption for 2020 according to the Methanol Institute.

One market uncertainty is the evolving price of oil. If the price of oil goes up, then it is expected that the balance between olefin produced by methanol and olefin produced by naphtha will change, resulting in an increase in demand for methanol. Conversely if the oil price goes down, then naphtha will be viewed as a lower cost alternative for producing olefins and methanol demand will decrease. If oil prices remain unchanged, the assumption is that the balance between methanol and naphtha will remain constant throughout the study period, and the substitution of naphtha for methanol will not occur.

The demand for methanol for the next 40 years is further complicated by the uncertainty surrounding the Covid-19 pandemic. For these reasons, this analysis compares results across three different assumptions of pandemic recovery – slow, medium, and fast recovery of methanol markets.

It is important to note that emissions for global and Chinese methanol markets are expected to increase through time with increasing production and growing demand. Because methanol will increasingly replace higher-emission transportation fuels such as gasoline and bunker fuel for ships, it is likely that the increases in methanol production through time will also result in lower global emissions when compared with a future scenario that excludes methanol-based fuels.

3.4.6 Emission sensitivity model (ESM)

The Emissions Sensitivity Model (ESM) was developed to explore:

- Differing emission outcomes when methanol from alternate cases come from different sources
- The impact when the KMMEF methanol has different end uses
- Uncertainty surrounding market and other external forces

The ESM sums emissions for KMMEF and for alternate cases given different assumptions about the market. In addition, there are a number of options available for exploring the many factors associated with uncertainty in the methanol markets.

3.4.6.1 User-defined input values assumptions through time

The ESM is designed to explore two explicit questions:

- How might global emissions differ if the methanol from KMMEF was used for fuel?
- How might different assumptions about the sources of methanol under the alternate cases influence the emissions analysis?

The ESM dashboard is designed to allow users to specify the share of the KMMEF product (3.6 MMT/year) that will be used as fuel versus olefin. It also allows the alternate case sources (as defined above as RC, LCC, and HCC) to define what percent of the 3.6 MMT is produced by CCM, CNGM, and imports.

3.4.6.2 Assumptions through time

Given a distribution of end uses (split with 60 percent for olefins and 40 percent for fuel) set at the outset of the model, these shares of the total 3.6 MMT of methanol are held constant throughout the 40-year project timeline. The estimated split in end use represents the two growing markets for methanol in the future, with a slightly smaller share going to fuel since KMMEF has indicated that they are targeting the olefin market. The reason for the split is that market is very competitive, and all methanol demand will be met with or without KMMEF. If KMMEF sells to olefin producers and not fuel producers, other producers will sell methanol for fuel. And if KMMEF sells methanol to fuel producers (although this is not their stated intention), then other producers will sell methanol to the olefin producers. For the methanol source shares under the alternate cases, however, these fluctuate through time. Fundamentally, as demand increases in the global forecast, less of the KMMEF methanol will be replaced by CCM in the alternate cases because, while CCM is low cost and readily available, it is limited, and the expansion cannot continue indefinitely. Meanwhile in a competitive market, imports can be supplied with very few constraints. The slower the growth in demand – which may be modelled within the ESM through selection of a slow recession recovery or through the selection of a decrease in the price of oil – the longer the time period that coal maintains its initial share of the alternate case. However, in the event of an increase in oil prices, then the alternate case also includes a small portion of naphtha because methanol is then allocated to replacing some naphtha as demand for methanol increases. In this case the persistent coal share is also somewhat mitigated by the small naphtha share.

Once those two sets of parameters are set, the emissions are calculated as described below.

3.4.6.3 Measuring emissions in the ESM

Emissions from all methanol pathways and end uses evaluated in this study are used as inputs into the ESM. Emissions processes from each pathway and end use are assigned a low, medium, and high value based on results from the emissions evaluation of the various methanol pathways and end-uses. All emissions inputs must be normalized according to metric tons of methanol produced in order to see the impact of the 3.6 MMT of KMMEF methanol. In cases where olefin production is the end use, olefin to feedstock yields are applied to convert the emissions to units of metric tons of methanol.

3.4.6.4 ESM outputs

The ESM outputs show the total emissions for the 40-year period by lifecycle stage for KMMEF and for the alternate cases (RC, LCC, and HCC). Outputs also highlight the differences (relative reduction or increase) in global emissions between the KMMEF and alternate cases. Other outputs show the average annual emissions, initial first year emissions, and annual emissions through time for each case. Additional details regarding ESM inputs, outputs, and assumptions are provided in Appendix A.

3.4.7 Sensitivity

The ESM is designed to vary methanol sources in the alternate cases and to vary end uses. However, in addition to the three different alternate case examples analyzed (RC, LCC, and HCC) and the end uses of fuel and olefins, further sensitivity analysis was conducted to explore how results change when assumptions about other variables are modified. Additional variables considered in the sensitivity analysis include:

- Recession Recovery: The user can choose a fast, medium, or slow recovery rate;
- Oil price in 2030: The user can choose that the price will increase, stay the same, or decrease;
- Upstream Methane Emission Rate: The default is 0.97 percent, but the user can choose to make it lower (0.71 percent) or higher (1.46 percent or 3 percent);
- GWP Assumption: The default global warming potential (GWP) values used in this SEIS to calculate CO_2e are the 100-year values from AR4. However, other GWP values are included in the ESM. In addition to the 100-year AR4 values, the user can choose the 20-year AR4, 20-year AR5, or the 100-year AR5 values.

Additionally, the sensitivity analysis explores results when several variables are adjusted in combination. For example, what happens when the low, medium, and high ESM input values are evaluated for the LCC and the HCC? Some of the assumptions affect KMMEF emissions, some the emissions of the alternate cases, and some affect both. Finally, the sensitivity analysis describes two outlier cases. These represent two unlikely cases that could transpire, although they depend on a specific combination of input variable values. These outlier cases are intended to show what would happen in the lower probability scenarios.

3.5 GHG LCA Emissions and Economic Substitution Analysis Results

This section addresses the following questions regarding the lifecycle GHG emissions associated with the proposed KMMEF:

- What are the gross and net greenhouse gas emissions associated with the proposed KMMEF facility?
- To what extent might KMMEF methanol substitute for alternate sources of methanol produced for the Chinese market?
- How might the global gross and net GHG emissions change if KMMEF methanol is used for fuel and not for olefin production?
- What are the appropriate upstream methane emissions to use for this analysis?
- How will varying the input assumptions affect the results of this analysis?

Analysis was undertaken using the ESM as described in Section 3.4 Methods and Approach. Results from the GHG Emissions Analysis, which are used as inputs to the ESM, are provided in Section 3.5.1. Results from the Economic Analysis, which are also incorporated within the ESM, are presented in Section 3.5.2. In Section 3.5.3, ESM output results of gross GHG emissions associated with the project are presented. Section 3.5.4 explores the portion of total emissions expected to occur in Washington State, and Section 3.5.5 shows the net GHG emission results.

3.5.1 ESM input emissions and ranges

This section presents a literature review and results from an independent GHG emissions analyses and market analyses performed to determine input parameters for the ESM.

3.5.1.1 Upstream emissions

- Upstream GHG emissions associated with the proposed project include emissions for natural gas extraction, processing, and transmission. Table 3.5-1 shows upstream GHG emissions for natural gas that would be used in methanol production at KMMEF, along with the methane emission rate used to derive the methane emissions. The methane emission rate includes leaks, as described in Section 3.4.1. Natural gas emissions associated with electricity generation are accounted for in Section 3.5.1.2. To assess the potential range of upstream natural gas emissions, three upstream natural gas emission scenarios are identified and summarized below. A detailed description of the three scenarios is provided in Section 3.4.1.
- Low Emissions Scenario: Natural Gas Emission Mix of 99.4 percent British Columbia and 0.6 percent Rocky Mountain. This is equivalent to the "baseline scenario" presented in Table 3.9, Appendix A of the First SEIS, and uses GHG emission factors based on GHGenius model outputs.

Table 3.5-1. GHG Emission Rates from Upstream Natural Gas

GHG Emissions (MT/MT MeOH)	Low Emissions Scenario	Medium Emissions Scenario	High Emissions Scenario
CO_2	0.19	0.18	0.18
CH_4	0.003	0.006	0.008
N_2O	0.000	0.000	0.000
CO_2e	0.29	0.33	0.40
Methane Emission Rate (MT CH4/MT natural gas)[1]			
Percent of Natural Gas Used	0.71	0.97	1.46

1. Gas usage rate is 29.6 mmBTU/MT methanol. Methanol production rate is 3.6 million MT/year. Gas heat content is 23,180 Btu/lb.

Detailed emission calculations are included in Appendix A.

- Medium Emissions Scenario: North American Gas only. Emissions are based on the GREET model using USEPA Shale emission factors for the methane portion of emissions. These emission factors were derived from USEPA's 2019 update to GREET, which incorporate the inventory of GHG emissions and sinks for 1990 to 2017 prepared by the USEPA (Burnham 2019).
- High Emissions Scenario: North American Gas only. Emissions for CO_2 and N_2O are based on the GREET model and are identical to the emission factors used in the medium scenario. The methane emission factors used are the EDF emission factors presented in USEPA's 2019 update to GREET, which are based on results from Alvarez et al. (2018) adjusted to account for the portion of methane emissions from natural gas production (Burnham 2019).

3.5.1.2 KMMEF construction and process

GHG emissions from construction, operation, and decommissioning of the KMMEF are summarized in Table 3.5-2 below. A full description of the project's direct emissions, including a detailed accounting of each emission source, is provided in Appendix C. For this analysis one-time emissions were divided by the anticipated 40-year lifespan of the project and added to annual operating emissions totals.

Table 3.5-2. GHG Emissions from On-site Sources

Greenhouse Gas Emission Sources	Low Estimate (MT CO_2e/year[1])	Medium Estimate (MT CO_2e/year[1])	High Estimate (MT CO_2e/year[1])
KMMEF Construction[2]	15,055	15,055	15,055
KMMEF Decomissioning[2]	93	93	93
Purchased Power	526.7	187,112	372,752
ULE Methanol Production[3]	728,009	728,009	975,051
Catalyst Replacement	3074	3074	3074
Employee Commuting	903.9	903.9	903.9
Waste Disposal	22.1	22.1	22.1
Total	**747,683**	**934,268**	**1,366,951**

1. CO_2e calculated using 100-year AR4 GWPs.
2. Emissions shown for one-time sources (Construction and Decommissioning) are annualized by dividing the total emissions by 40 years.
3. For emissions from ULE Methanol Production, the Continuous Operation Scenario is used for the Low and Medium estimates, and the Maximum Potential to Emit Scenario is used for the High estimate.

3.5.1.3 Transportation of KMMEF methanol

Two scenarios were developed for the transportation of methanol from the KMMEF to ports in China. Scenario 1 assumes transport via 100,000 MT vessels; Scenario 2 assumes transport via 50,000 MT vessels. Scenario 1 is incorporated within the ESM for both the low and medium emission estimates, and Scenario 2 is incorporated as the high emission estimate in the ESM. Emissions from transportation include direct emissions from fuel use by the vessel, assist tugs, and pilot helicopters, as well as upstream emissions from the production of the fuels used. Return trips from empty vessels are also included in the transportation emissions. Table 3.5-3 presents the total transportation emissions associated with the two vessel size scenarios.

Table 3.5-3. Transportation Emissions

Transportation Emission Source	Emissions: Low Estimate[2] (MT CO_2e/yr[1])	Emissions: Medium Estimate[2] (MT CO_2e/yr[1])	Emissions: High Estimate[3] (MT CO_2e/yr[1])
Direct	165,928	165,928	249,230
Upstream	31,413	31,413	47,196
Total	**197,344**	**197,344**	**296,418**

1. CO_2e calculated using 100-year AR4 GWPs.
2. Low and Medium estimates assume transport by 100,000 MT vessels.
3. The High estimate assumes transport by 50,000 MT vessels.

3.5.1.4 Emissions from substitute pathways

The ESM considers the life cycle emissions of three alternate cases that include substitute pathways for methanol production (see Section 3.4.5.2). These three cases represent alternative means by which methanol may currently enter the Chinese market and are the potential pathways that could be partially replaced by the substitution of KMMEF methanol. The four current substitute pathways included in this study are:

- Chinese coal-based methanol;
- Chinese natural gas-based methanol;
- Imports of natural gas-based methanol into China from other countries. Most of the methanol imported into China use natural gas as a feedstock. Coal-based methanol production primarily occurs in China which is included in this evaluation.
- Naphtha to olefins

For the purposes of this section, results and ESM inputs are summarized as CO_2e using 100 yr AR4 GWPs (Global Warming Potential). The 100-year AR4 GWP values are currently set forth in 40 CFR Part 98 and Table A-1 of WAC 173-441-040. A detailed breakdown of the range of emissions used for each GHG (CO_2, CH_4, and N_2O) for each alternate case and end-use pathway are presented in Appendix A.

3.5.1.4.1 China Coal to Methanol

Coal is the dominant feedstock used in methanol production in China due to the country's rich inventory of coal and low supply of oil and natural gas (Xiang et al 2015). China is one of few countries who continue to use coal as a methanol feedstock, along with some manufacturing occurring in Africa. In 2019, China produced approximately 62 million tons of methanol, of which approximately 76% was produced from Chinese coal (http://market.chinabaogao.com/huagong/031TT2K2020.html). In the First SEIS, the GHG emissions arising from methanol production using China-based coal were calculated accounting for upstream (processing of coal and electricity requirements), direct process (methanol production from coal), and downstream (transportation) emission sources. A basic diagram of the process is shown in Figure 3.5-1.

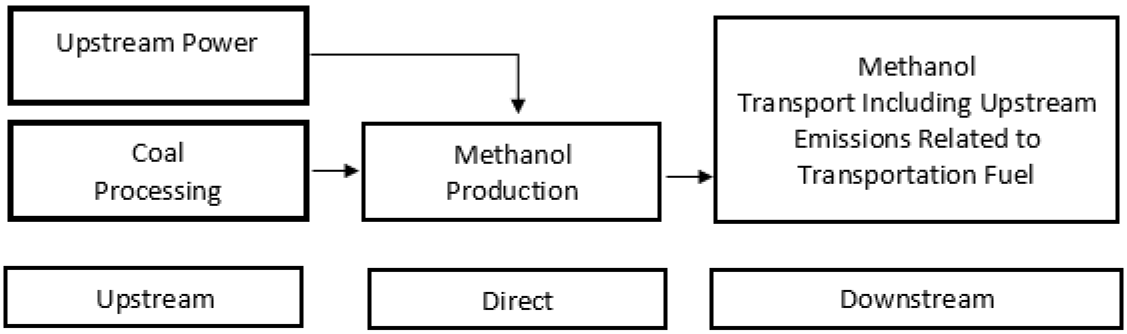

Figure 3.5-1. Life Cycle Steps of China Coal Based Methanol and Transport

The First SEIS provided a thorough literature review together with emissions calculations. This analysis aims to further compare calculated emission rates to published literature values, focusing on studies that conducted lifecycle emission calculations with boundary conditions and assumptions similar to the First SEIS. Emission rates from five studies were compared. The results from the studies are shown in Table 3.5-4.

Table 3.5-4. China Coal-Based Methanol Production Emissions (MT CO2e/MT MeOH)

Pathway	First SEIS	Qian et al (2015)	Chen at al. (2019)	Qin et al (2016)	Xiang et al. (2015)	Liu et al. (2020)
Life Cycle Emissions, China Based Coal to Methanol	3.4 - 4.1	2.86	2.67	2.97	3.84	3.48

The results from Qian et al. (2015) and Chen et al. (2019) for calculated emissions are slightly lower than the First SEIS; however, this can be explained by how the studies treated electricity, and to a lesser degree, transportation emissions. The emissions from the two studies are lower than the First SEIS primarily because they assume that electricity is imported from the grid. By contrast, the First SEIS assumed that electricity generation would be conducted on-site (a situation more common for coal-to-methanol production in China). Note that both studies assumed that methanol processing plants would be located near coal processing centers, thus reducing transportation emissions. Considering the overall uncertainty entailed in life cycle emissions estimates, especially for international processes, the two studies are reasonably close to the values calculated in the First SEIS.

The boundary conditions employed by Qin et al. (2016), Xiang et al. (2015) and Liu et al. (2020) were similar to those used in the First SEIS by assuming that a portion of electricity generation would occur on-site. The study by Qin et al. (2016) showed lower emission rates compared to the first SEIS as well as Xiang et al. (2015) and Liu et al. (2020). This lower emission rate was attributed to less of a reliance of on-site boilers. The Qin et al. (2016) study assumed that 20% of the total emissions are related to on-site electricity generation. The ASIACHEM study, which is the basis for the first SEIS, assumed that self-supplied electricity was 30% of the total GHG emissions. On-site generation of electricity typically results in higher GHG emissions due to the reliance of coal in electricity generation which is often the case in China.

Electricity is a sensitive parameter in the LCA of coal-based methanol production and discrepancies in the literature is driven by how electricity is delivered to the methanol plant. The GHG emission rates for electricity generation in China depends on the source of electricity, which will impact the result of the LCA. As indicated in the first SEIS and the ASIACHEM's report, a typical coal-to-methanol plant in China is equipped with coal-based boilers to generate a portion of electricity needed for methanol production. Literatures with similar systems were evaluated and were consistent with the results presented in the first SEIS. Based on this review of the published literature, it is concluded that the ranges of emission rates derived from the First SEIS for the lifecycle analysis of China coal-based methanol are justified and thus these emission rates are adopted for use in the ESM. The pathway of China coal-based methanol results in the highest GHG emitting pathway considered in this study. Any replacement of China coal-based methanol by any source of methanol, whether by KMMEF or imports, will result in a lower global GHG emission impact.

3.5.1.4.2 China Natural Gas to Methanol

Of the 62 million tons of methanol produced in China in 2019, 7 percent was produced from Chinese natural gas (Analysis of China Methanol Industry in 2020). The percentage of domestic natural gas-based methanol production is anticipated to decrease over time. Given the shortage of natural gas in China, the Chinese government issued a Natural Gas Utilization Policy in 2012, which prohibited using natural gas to produce methanol since December 2012. (Existing natural gas-based methanol plants in China were constructed before the restriction.) As total methanol production increases in China, it is anticipated that the share from natural gas will decrease as a result of this restriction.

Although Chinese natural gas-based methanol is expected to decrease and has not received attention in recent literature, it should be considered in a market analysis. This source was not included in the First SEIS analysis but is included here. Four papers related to Chinese natural gas-based methanol production were reviewed in this analysis that provide a narrow range of emission rates. Results are shown in Table 3.5-5.

The emissions from Chen et al. (2019) were selected as ESM inputs for China based natural gas to methanol production. The advantage of using the data by Chen et al. (2019) is that it presents results by CO_2, CH_4, and N_2O, whereas the other literature presents data as CO_2e which limits the ability to evaluate the impact of GWP on the emissions. The limitation to the studies evaluated is that it did not provide details on methane leakage rate during the extraction of natural gas; however, studies on international methane leakage rates are limited and uncertain (Gan et al. 2020). Being that the literature provided a narrow range of emission rates for this pathway, the ESM treats the emissions of this pathway as being independent of any other process.

Table 3.5-5. China Natural Gas-Based Methanol Production Emissions (MT CO_2e/MT MeOH)

Pathway	First SEIS	Chen et al. (2019)	Chen et al. (2017)	Li et al. (2018)
Life Cycle Emissions, China Based Natural Gas to Methanol	Not Quantified	1.2	1.4	0.9

3.5.1.4.3 China Imports of Methanol

China imported nearly 11 million tons of methanol in 2019 (http://finance.sina.com.cn/roll/2020-02-13/doc-iimxyqvz2471212.shtml), and has doubled imports since 2010, as shown in Figure 3.5-2. Although the current pandemic recession may temporarily slow the growth in methanol demand in China, it is expected to recover and continue to grow within a few years. This anticipated growth in demand for methanol in China will be met by combined imports and domestic production.

Methanol imported into China comes primarily from the Middle East, North America, Southeast Asia, Africa, and South America. The First SEIS did discuss methanol imports into China but did not account for the import pathway in the GHG analysis. In the current analysis, a weighted average life cycle emission rate for methanol imports into China was calculated using the emission rates of 29 existing facilities representing a total methanol production capacity of almost 50 million metric tons of methanol. The foreign facilities included in this study are characterized in Appendix A.

The total emissions for each manufacturer was calculated by summing emissions from upstream natural gas, upstream power, direct emission, and transportation emissions. Considering the production capacity of each of the 29 manufacturers, a weighted average was calculated to represent a single life cycle emission rate for methanol manufacturers that could potentially import into China. This calculation resulted in emission rates for non-KMMEF importers being 1.26 times higher than KMMEF. This factor is used in the ESM to characterize non-KMMEF importers of methanol into China. Detailed assumptions and calculations are presented in Section 3.4.4.2, Section 3.6, and Appendix A.

The difference in life cycle GHG emissions is mostly due to upstream natural gas emission rates and the difference between KMMEF's ULE technology and the combined reforming technology used by some of the 29 existing facilities. To a lesser degree the emissions difference is

attributed to electricity and transportation emissions. The lifecycle GHG emissions of imported methanol may decrease over time as new facilities come on-line using ULE technology or even newer processes.

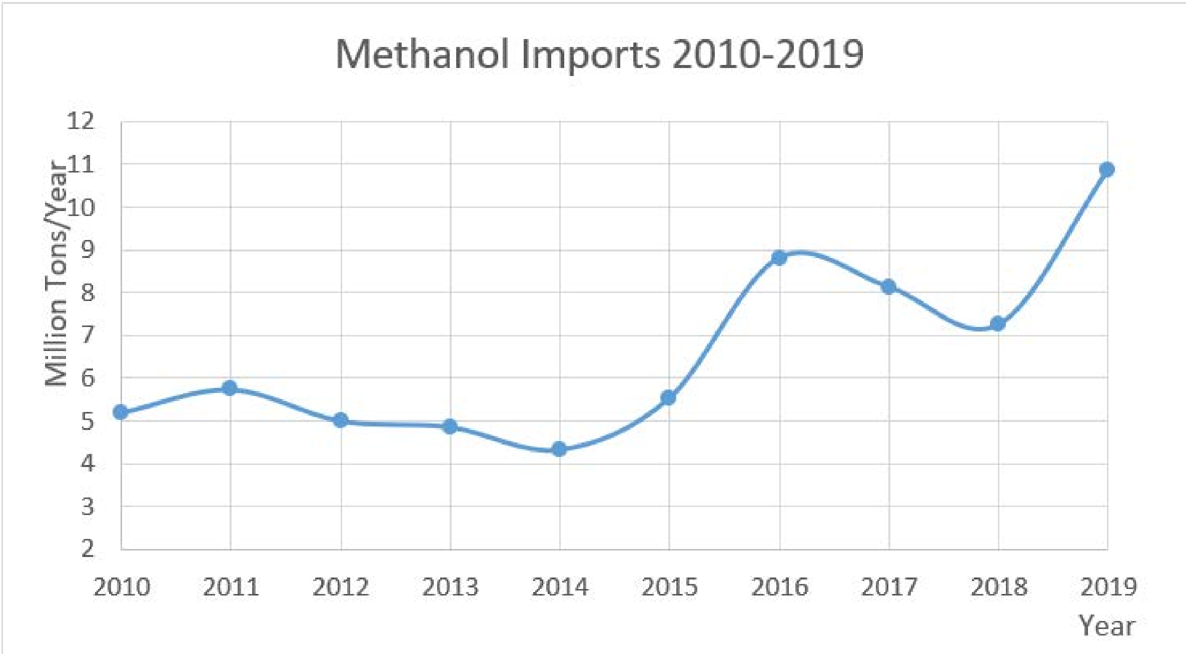

Figure 3.5-2. China Methanol Imports

A key distinction in how the ESM handles emissions from this pathway compared to China-based natural gas methanol, is that upstream emissions related to natural gas extraction and processing is set equal to that of KMMEF. This assumption was made based on the lack of emissions data from the methanol exporters evaluated in this study and the uncertainty around upstream methane emissions from natural gas extraction and processing (Gan et al. 2020).

3.5.1.4.4 Naphtha to Olefins

Naphtha and methanol are dominant feedstocks for olefin production in China. Naphtha is created as a byproduct of crude oil refining, and its supply is furnished through naphtha imports or from domestic production. The naphtha to olefin production pathway is included in this analysis as a substitute pathway because some portion of the olefins produced by this pathway have the potential to be substituted by olefins produced by KMMEF methanol.

Emissions from the naphtha to olefin pathway were summarized in Section 5.4 of the First SEIS and described in greater detail in Section 7 of the August 2019 Supplemental Technical Analysis for Response to DSEIS Comments. The emission rate for this pathway presented in the First SEIS is 2.3 MT CO_2e/MT Olefin. This is the value used by the ESM. An independent literature review resulted in a wide range of published values varying from 1.6 to 4.47 MT CO_2e/MT olefin (Ren et al. 2008; Neelis 2005; Xiang 2015; Chen et al. 2017; Yang 2017). The wide range of values in the literature can be attributed to several factors, primarily a lack of consistency among boundary conditions in the published data. The creation of naphtha from crude oil is not a standalone process. During oil refining, a number of valuable products are produced. Analyses that include all or most of the emissions generated from coproducts may be biased high, and those that include very few or none of the emissions generated from other coproducts may be biased low. Also, literature values are based on a wide range of olefin types. As indicated in the First SEIS, emissions depend on the final olefin being produced. Therefore, considering that the emissions reported in the First SEIS are within the range in published literature, the ESM utilizes the First SEIS emission rate of 2.3 MT CO_2e/MT Olefin for the crude oil to naphtha to olefin process.

3.5.1.5 Downstream methanol end use

Methanol has multiple uses in the Chinese economy. The ESM accounts for the emissions of various methanol end-use pathways, reflecting consumption in the Chinese market. In this analysis, two methanol end-use pathways are considered:

- Methanol feedstock for olefin production
- Methanol combustion as a fuel

Another group of end uses, broadly termed, “Chemical and Other” uses of methanol (see below, Section 3.5.2.1, “Global Methanol Demand and Use”), is dominated by formaldehyde, but also includes a wide variety of uses.

3.5.1.5.1 Methanol Feedstock for Olefin Production

The production of olefins, ethylene and propylene has in recent years been dominated by feedstocks derived from natural gas processing products and crude oil components, specifically naphtha. The ESM accounts for olefin production using either methanol or naphtha as a feedstock.

Table 3.5-6 shows the emissions related to upstream processing of the feedstock and the process of converting the feedstock to olefins.

Upstream emissions for KMMEF, imported methanol manufacturers, and Chinese coal-based feedstock are the same as presented earlier, accounting for product yield. The feedstock to olefin yields and upstream emissions of oil to naphtha are taken from the First SEIS. The First SEIS Appendix E, in addition to the 2019 Supplemental Technical Analysis for Response to DSEIS Comments, provide a very thorough explanation and literature review justifying the emission used in olefin production.

Table 3.5-6. Emissions from Olefin Production

Parameter	Naphtha to olefin	Methanol to Olefin KMMEF	Methanol to Olefin Imports	Methanol to Olefin Coal Based
Yield (MT feed/MT olefin)	1.7	3	3	3
Upstream Emissions[1]	1.2	1.9-2.2	2.4	8.9-12.3
Process Emissions[1]	1.1	0.3-0.5	0.3-0.5	0.3-0.5
Total Emissions[1]	2.3	2.2-2.7	2.7-3.3	10.5-11.9

1. MT of CO2e/MT olefin

The ESM assumes that the shares of naphtha-based, and methanol-based olefins remains constant, and therefore no naphtha-based olefin manufacturing in China will be affected one way or another by the existence of KMMEF methanol. However, since the supply of naphtha is tied to oil refining and influenced by the oil market, if oil prices increase or decrease, this affects the overall calculation of the Reference Case. If the price of oil decreases the demand for naphtha-based olefins will go up and the pace of increase in methanol demand is slowed down in the ESM. In this case, KMMEF is not likely to be replacing any naphtha. If the price of oil goes up, it will become more expensive to use naphtha as a feedstock for olefins and so in this case, naphtha is included in the alternate case because the methanol from KMMEF is now replacing methanol and a small share of naphtha. The interaction between KMMEF methanol-based olefin and naphtha-based olefins are explained more in detail below in Section 3.5.2.4, "Methanol Supply in China" and in Appendix B.

3.5.1.5.2 Methanol Combustion as a Fuel

China accounts for the largest vehicle fleet and transportation energy consumption in the world. Traditionally, methanol consumption as fuel has been in the form of methanol derivatives such as MTBE and as fuel blends ranging from M5 to M30 methanol-gasoline mixes (gasoline with between 5 percent and 30 percent methanol mixed in). Various regional policies in China mandate the use of methanol in these forms (Chen et al.). Beginning in 2012, however, a pilot program was launched to investigate M85 and M100 methanol vehicle reliability, safety, fuel economy, and other factors such as the feasibility of constructing methanol fueling and distribution networks across China (MIIT). This pilot program led to the Chinese government advocating the use of methanol as a transportation fuel. It is anticipated that in as few as five years' time up to 50,000 M100 methanol-fueled vehicles may be on Chinese streets, adding more than 500,000 tons to annual methanol fuel consumption (Zhao).

China has made significant research investments towards methanol use as fuel (CAERC). Figure 3.5-3 shows that China's consumption of methanol fuel has increased dramatically over the past two decades, reaching an estimated 500,000 barrels of methanol and methanol derivatives in 2016. More than 80 percent of methanol used for fuel is currently consumed for transportation. Regardless of how methanol fuel is combusted, whether by mobile or stationary sources, emissions are the same. Therefore, USEPA emission factors are suitable, and emission factors are taken from 40 CFR Part 98 Subpart MM, Table MM-1 for the combustion of methanol as a fuel source. The emission factor used in the ESM is 1.37 MT CO_2e/MT methanol combusted. It is assumed that during the combustion of methanol all CO_2e is emitted as CO_2 (CH_4 and N_2O emissions are assumed to be negligible).

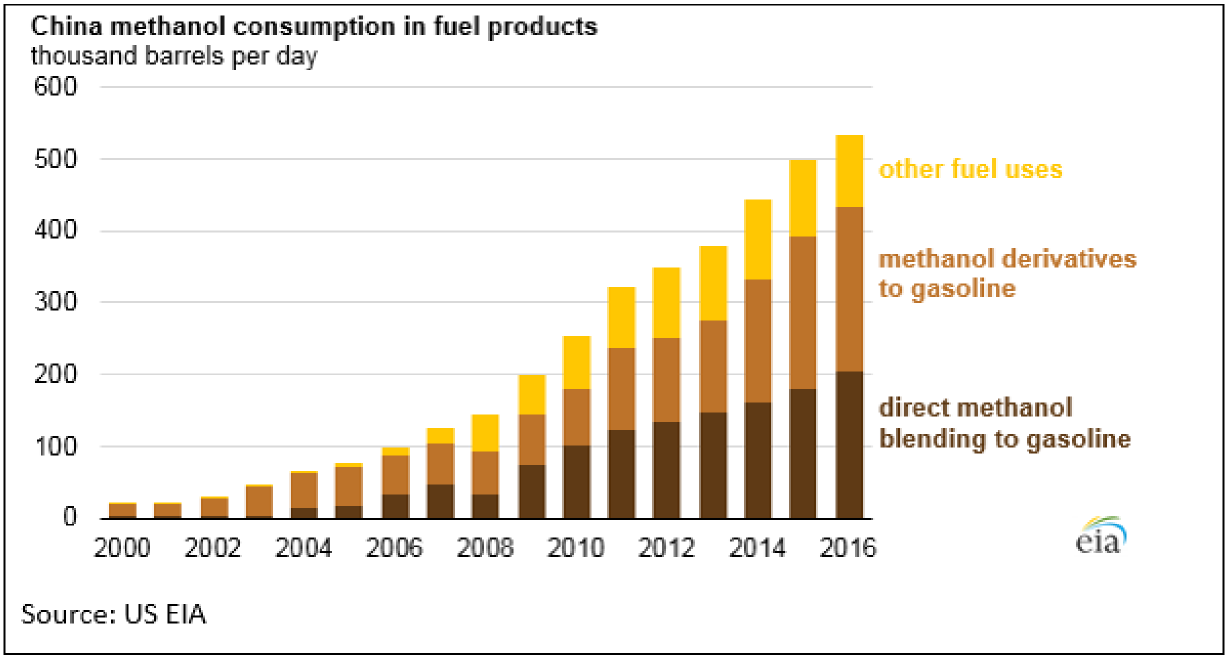

Figure 3.5-3. Chinese Methanol Fuel Consumption

3.5.2 Market demand, supply, and forecast

This section summarizes the global and Chinese methanol markets, focusing on demand, supply, and trade in recent years. Additional information on these subjects is available in Appendix B.

3.5.2.1 Global methanol demand and use

Methanol is used for a wide variety of products globally. In 2019, the two largest uses for methanol worldwide were in production of formaldehyde and olefins, both with 25 percent of global methanol use (see Table 3.5-7). Transportation fuels make up another significant use of methanol, with gasoline blending at 14 percent of all methanol, and methyl tert-butyl ether (MTBE) at 11 percent. Adding biodiesel and DME fuel uses brings the total fuel use for methanol to about 31 percent of the total. Grouping formaldehyde with other chemical uses comprises totals about 40 percent of all methanol use.

Additional data from Methanol Market Services Asia (MMSA) is compiled in Table 3.5-8, showing that overall methanol use in 2019 was over 98 MMT; expected use in 2020 is forecasted to be the same. This represents an increase of about 20 MMT, or 24 percent, in just five years between 2015 and 2020. Each of the three primary sectors of use (Fuels, MTO, and Chemical and Other) also grew during this period, although use for Fuels and Chemical and Other grew 15 and 17 percent respectively, while the MTO category grew 58 percent over this period. As is seen in Figure 3.5-4, while MTO still represents a smaller share of all use than do the Fuels or Chemicals and Other sectors, the MTO share grew from 20 percent of all use in 2015 to 25 percent of all use in in 2019.

Table 3.5-7. Global Methanol Use in 2019 in MMT and by Share of Total

Methanol End Products	2019	Share of Total
Formaldehyde	24,637	25%
Methanol-to-Olefins	24,571	25%
Gasoline Blending & Combustion	13,422	14%
Methyl tert-Butyl Ether (MTBE)	11,156	11%
Acetic Acid	7,554	8%
Others	3,717	4%
Biodiesel	3,291	3%
DME	3,052	3%
Methyl Chloride (Chloromethane)	2,437	2%
Methyl Methacrylate	1,755	2%
Methylamines	1,690	2%
Methanethiol (Methyl Mercaptan)	533	1%
Dimethyl terephthalate (DMT)	472	0.5%
Fuel Cells	12	0.0%
Total	98,300	100%

Source: MMSA World Supply and Demand Summary, downloaded on July 24, 2020.

Table 3.5-8. Methanol Demand by End Product (2015-2020) (in 1,000 MT/Year)

Methanol End Products	2015	2016	2017	2018	2019	2020*	Increase ('15–'20)	Annual Growth ('15-'20)
Fuels	**26,307**	**28,154**	**28,809**	**29,107**	**30,934**	**30,206**	**15%**	**2.8%**
Gasoline Blending	11,323	12,269	12,195	12,125	13,422	12,904	19%	2.6%
Biodiesel	1,383	1,831	2,844	3,005	3,291	3,474	138%	20.2%
DME	3,844	3,935	3,292	2,982	3,052	2,890	-21%	-5.5%
Fuel Cells	8	8	9	9	12	13	60%	11.4%
Methanol-to-Olefins	**16,200**	**19,218**	**20,353**	**20,886**	**24,571**	**25,651**	**58%**	**9.6%**
Chemical and Other	**36,714**	**37,653**	**39,665**	**41,720**	**42,795**	**43,043**	**17%**	**3.2%**
Formaldehyde	21,017	21,832	22,546	23,836	24,637	24,734	17%	3.3%
Acetic Acid	5,994	6,096	7,105	7,363	7,554	7,553	26%	4.7%
Methyl tert-Butyl Ether	9,748	10,111	10,469	10,985	11,156	10,925	14%	2.3%
Methyl Methacrylate	1,648	1,687	1,733	1,782	1,755	1,762	7%	1.4%

Methanol End Products	2015	2016	2017	2018	2019	2020*	Increase ('15–'20)	Annual Growth ('15-'20)
Dimethyl terephthalate	467	473	478	476	472	470	1%	0.1%
Methanethiol	503	513	528	545	533	544	6%	1.6%
Methylamines	1,522	1,558	1,600	1,649	1,690	1,718	11%	2.5%
Methyl Chloride	2,099	2,165	2,243	2,344	2,437	2,500	16%	3.6%
Others	3,465	3,330	3,430	3,726	3,717	3,762	7%	1.7%
Total	**79,221**	**85,025**	**88,828**	**91,713**	**98,300**	**98,900**	**24 %**	**4.5%**

*Expected
Source: MMSA World Supply and Demand Summary, downloaded on July 24, 2020.

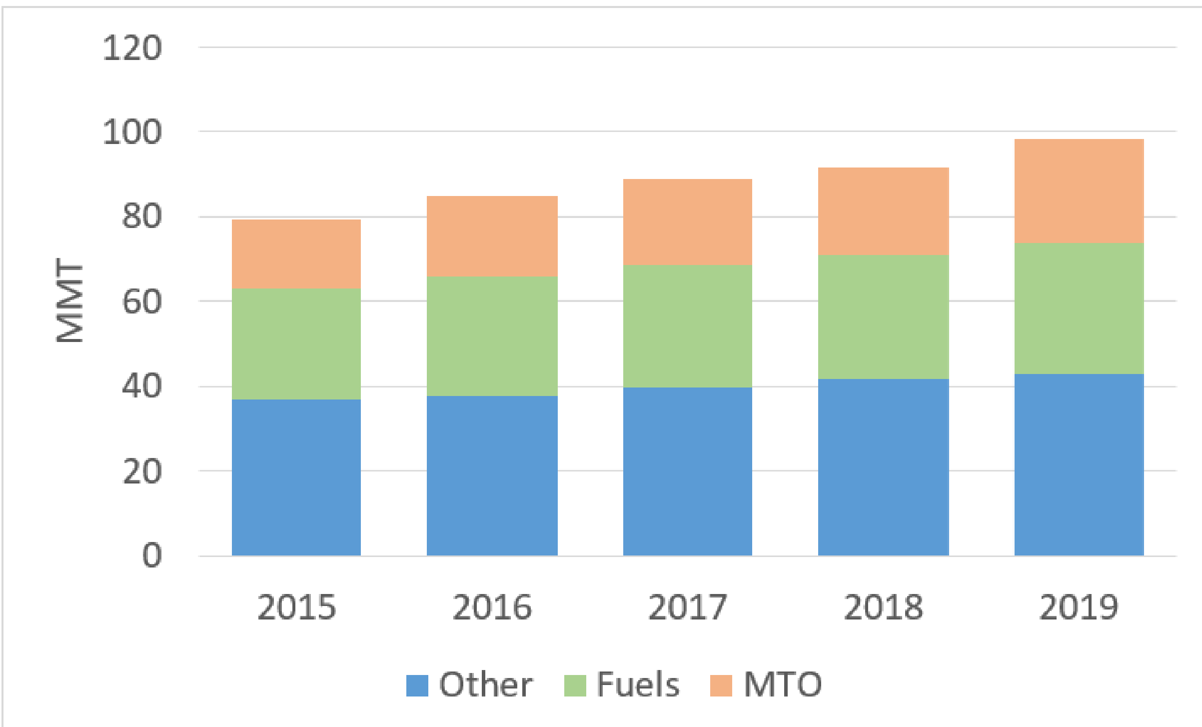

Figure 3.5-4. Methanol Demand 2015 – 2019 by End Product Group

Annual growth rates indicate which types of uses are growing faster, and which slower. As shown in Table 3.5-8, the annual growth for all methanol between 2015 and the expected use in 2020 was 4.5 percent, while the MTO sector grew at a rate of 9.6 percent per year in the same period.

It is important to note that global methanol production is a relatively nascent industry. Global production and demand was first led by technological innovation in the 1970s, after the Low Pressure Method of methanol processing was developed. Then in the 1980s, improved revenues in oil-producing nations (due to high oil prices) resulted in a second round of increased investment in petrochemical production in the Middle East and elsewhere. At the same time, many nations began searching for synthetic fuels to replace oil. The booming economy in China since the turn of the millennium led to a third increase in global methanol capacity, as China began to search for ways to reduce their dependence on imported oil and began expanding their coal-based methanol capacity (Sheldon, 2017).

3.5.2.2 Methanol demand and use in China

About 60 MMT of methanol were produced and used in China in 2018 and 2019, up from the approximately 10 MMT used in 2007 and the <5 MMT used in 2000. Imports persisted throughout this period, but only as a small fraction of domestic production. It is important to note that China represents about 60 percent of the global methanol market in terms of production and use of methanol, and the increasing use of MTO is driven primarily by olefin production in China. For greater detail on the Chinese methanol market, refer to Appendix A of the First SEIS "Supplemental GHG Analysis" and Appendix B of the First SEIS "Supplemental Technical Response to Draft SEIS Comments" for significant detail regarding market conditions. Additional information is also available in Appendix B.

3.5.2.3 Global methanol supply

Several factors are at work relative to global methanol supplies, complicating forecasts (IHS Markit 2019). As mentioned above, global production and demand have been increasing, and so has capacity. While 2019 global use was just under 100 MMT, worldwide capacity was significantly larger than demand, at approximately 157 MMT, up 8.5 percent over 2018 (CCF Group 2020). This excess of capacity over current demand reflects investment as methanol producers have been preparing for anticipated market increases and positioning themselves to respond quickly to changing market conditions by increasing or decreasing their operating rates. Hence, worldwide, 157 MMT of methanol could be produced without any additional infrastructure investment. But firms will only produce the amount that they believe they can sell, so they typically operate below capacity. Figure 3.5-5 below depicts how this capacity is distributed across the globe.

Because the market is in a transition phase – growing, with different producers vying for market share – there has been price volatility. Price volatility can place downward pressures on suppliers, causing some (usually the highest cost and least profitable) producers to shut down, or exit the market. However, in this case, the potential for long run profitability has led suppliers to be more willing to support short run losses in hopes of gaining long run market share. Other sources of uncertainty also complicate the forecasting calculus, including the complex MTO market, US-China trade policy, environmental policy in China and globally, and the gas-blending policy in China which might switch toward ethylene and away from methanol (IHS Markit 2020). Finally, the Covid-19 pandemic-induced recession affects entire economies and has slowed methanol demand for 2020. It is not clear when and how the recovery from this recession will occur, bringing one more element of uncertainty to the market.

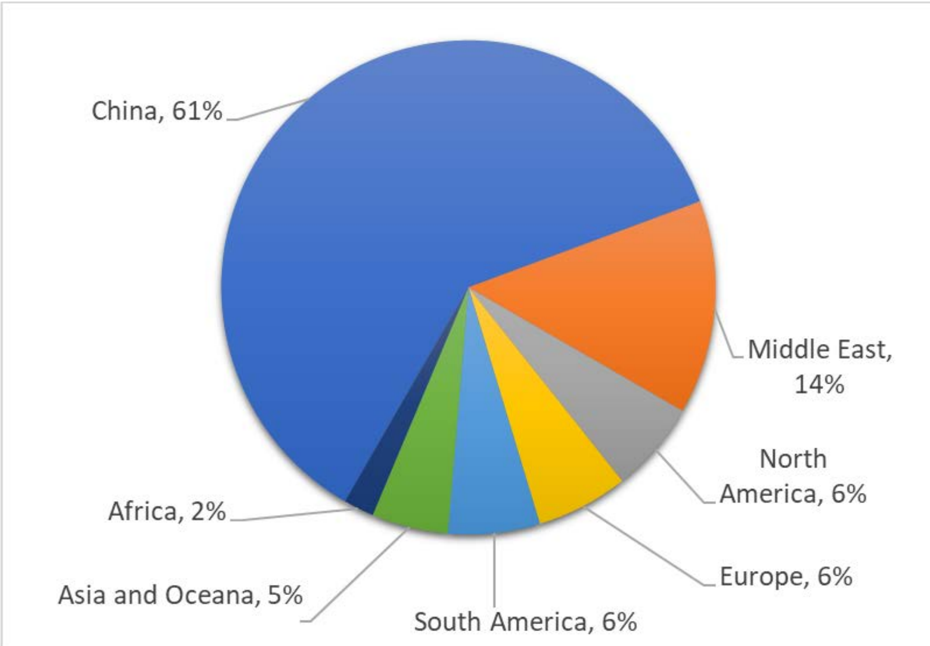

Figure 3.5-5. Global Methanol Capacity by Region
Source: CCFGroup, 2019 China Methanol Industry Annual Report, 2020.

3.5.2.4 Methanol supply in China

Much has been written about the supply of methanol in China. Fundamentally, methanol is produced from three different feedstocks in China: coal, natural gas, and coke oven gas. Data provided in the First SEIS Appendix A, Supplemental GHG Analysis, indicated that in 2018, 66 percent of Chinese methanol was made from coal, 12 percent from natural gas, and 22 percent from coke oven gas. Coke oven gas is a bi-product from steel mills and its supply is tied to steel production. Coke oven gas is not tied to methanol production and is not subject to the forces of the methanol market. Therefore, this feedstock and sector of the methanol market does not influence this analysis.

The Final EIS (2016) and First SEIS (2019) pointed out that much of the methanol use in China is concentrated in eastern coast regions, while most of the producers are located in western Inner Mongolia, Shaanxi and Ningxia provinces, which are nearer to Chinese coal resources. The distance between methanol use and production in China creates a transportation cost that allows the opportunity for new producers from other countries to compete with the Chinese domestic methanol industry (Shanghai ASIACHEM 2018). Shanxi, Shandong, Henan and Hebei Provinces also produce some methanol. For these eastern China methanol facilities, the challenge has been attaining raw materials (coal, and natural gas) for methanol production. The long-distance shipping of raw materials from outside of the region results in higher freight costs, leading to a higher general production cost, and ultimately a higher finished methanol product price (Shanghai ASIACHEM 2018).

Some of the challenges seen in Chinese methanol production resulted in a higher methanol price in 2018, and at that point, production of olefins from naphtha (by a non-catalytic process using steam-cracking) began to be considered as a more feasible way to produce olefins. Between 2020 and 2025, 19 new olefin-producing steam-crackers were slated to come online with a total nameplate capacity of 19.7 Mtpa. The potential favorability of naphtha-to-olefin investments over MTO in China is another source of uncertainty in the growing methanol market (Cui 2019). However, the profitability and economic feasibility of naphtha-to-olefins over MTO is highly dependent on oil prices since naphtha is derived from oil. This pathway is feasible at the moment because oil prices are relatively low.

3.5.2.5 Methanol prices

Given the recent history of methanol producers anxious to maintain their share of this growing market by increasing capacity, it is not surprising that in late 2018, prior to the COVID pandemic-induced recession, prices began to fall. A graph from MMSA shows global methanol prices starting to fall in early 2019 and staying about 25 percent lower than the January 2019 prices. This is a result of the increased supply capacity occurring in the past few years (see Figure 3.5-6).

In 2018, the many MTO plants in eastern China served unmet demand, driving prices to US$376/ton (Cui 2019). Subsequently, a responding surge in supply resulted in lower prices in 2019. Such price volatility may be expected in a growing market like methanol (see more on price volatility in Appendix B).

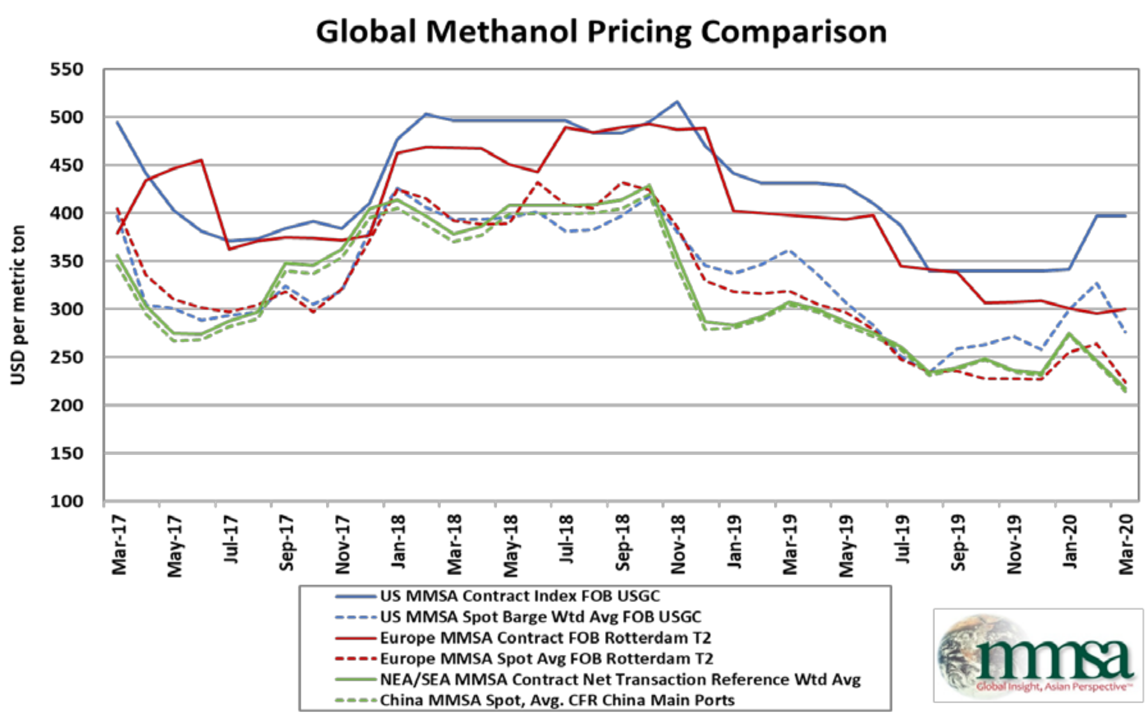

Figure 3.5-6. Global Methanol Price History from March 2017 to March 2020

Source: MMSA Global MeOH Price History, from Spreadsheet Workbook titled, "MMSA Price Forecast for Methanol Institute." Available at: https://www.methanol.org/methanol-price-supply-demand/.

The lower prices in 2019 followed by the COVID-19 recession in 2020 have resulted in many of the producers in China experiencing negative returns (see Figure 3.5-7). The recent profitability for methanol production in China using the three feedstocks (coal, natural gas, and coke oven gas) shows that coal-based methanol is the most profitable of the three, maintaining profitability until March 2020, and achieving the highest margins in October of 2019 at about 800 Chinese yuan (CN¥) or about $115 per ton. These margins are based on the difference between price for methanol and variable production costs. In comparison, profits for natural gas-based methanol and coke-oven gas methanol were much lower over the same period, with both processes producing negative returns starting in January 2020, and coke oven gas-based methanol and natural gas-based methanol only attaining a 306/MT CN¥ and 276/MT CN¥ respectively ($44/MT and $29/MT) at the highest point in the past year (CCF Group 2020).

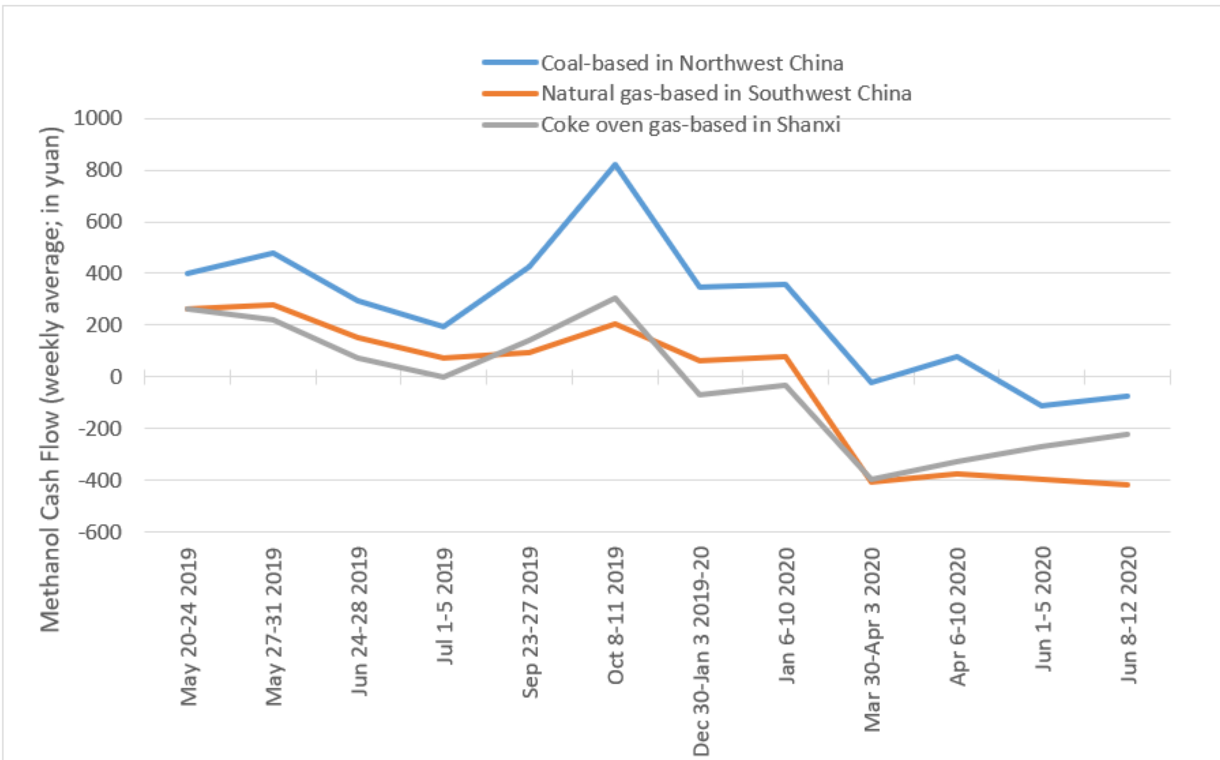

Figure 3.5-7. Methanol Profitability in China with Different Feedstocks (CCF Group 2019, CCF Group 2020b)

3.5.2.6 Methanol trade

China has been a net importer of methanol – presumably in cases where other nations can produce methanol at a lower cost than domestic producers in China. It is not clear why China has not exploited all of the methanol producing capacity in the country, but one reason may be, for example, that users in eastern China are located near ports that can access imports quickly and easily. In the past 10 years, methanol imports in China totaled between four and ten MMT annually. By June 2020, China had imported 1.27MMT from 20 different countries. The top ten exporting nations are shown in the table below (see Table 3.5-9).

Table 3.5-9. Major Methanol Imports to China by Origin in June 2020

Origin	Quantity (MT)
Iran	318,690
Oman	183,900
United Arab Emirates	173,880
New Zealand	139,580
Venezuela	122,300
Saudi Arabia	111,800
Trinidad and Tobago	69,380
Malaysia	68,000
Brunei	67,580
Indonesia	19,000
Total	1,274,000 MT

Source: CCFGroup, June Methanol Report, accessed July 8, 2020.

3.5.2.7 Methanol market structure

The structure of any market is key to understanding how shifts in supply and demand will play out in terms of prices and the quantities of products produced. Once a market has cleared, with a certain price and quantity, those become signals to buyers and sellers in the future, influencing future supply and demand, resulting in new prices and quantities produced. The outcomes in each case will differ depending upon the market structure. Examples of market structures include perfect competition, monopoly, monopolistic competition, oligopoly and many others, each having primarily to do with the numbers of buyers in the market (e.g. many or a few), the numbers of sellers, the nature of the products, the ease and speed with which new sellers can get into the market, the availability of information, and other factors.

The current global methanol market has a number of elements that are the hallmark of a perfectly competitive market. In reality, probably no market aligns completely with the theoretical framework of a perfectly competitive market, but competitive markets all tend to follow the laws of supply and demand and will adjust in the direction of the expected outcomes within a short period of time. Because the global methanol market meets the criteria for being a perfectly competitive market, the economic analysis in this report follows the assumptions of global competitiveness. Although the internal China methanol market is not a perfectly competitive market for methanol, evidence suggests that the global methanol market is currently very close to a perfectly competitive market.

The conditions for a perfectly competitive market, the degree to which China functions as a "nearly perfect" competitive market, and the parallels to the world methanol market are given below:

- Many buyers and sellers – the global methanol market has many buyers and many sellers as evidenced by the many countries that export to China and the many uses for methanol.

- Uniform product – unlike products that can be uniquely distinguished by their qualities, methanol is a uniform commodity.
- Perfect information about price – price information is widely and publicly available; in addition, the futures market helps stabilize the price of methanol in China.
- No transactions cost – transaction costs are low for methanol production (these are the costs of making an exchange).
- No barriers to entry and exit – upfront investment costs for methanol production are a barrier to entry and will slow down exit from this industry. However, at present there is sufficient excess capacity so that existing facilities may operate profitably at lower levels of output. Further, there is significant evidence of ongoing investment funds due to the anticipated growth in this market in the future.

Inside China, there are a number of forces at work. It is difficult to know how far the country has progressed toward a free market economy, and how much it retains the planned, or control economy where the government makes the decisions about what is produced where. China has been transitioning toward a mixed economy where market forces play a role in determining supplies. For example, a 2015 article on natural gas price reform alone identified four major efforts needed to ultimately help push that price toward a genuinely market-based price (Aolin and Qing 2015).

3.5.2.8 Summary and forecast

As a conclusion for this analysis of the methanol market, a three-tiered forecast for global methanol demand has been developed for the ESM. The results of the forecast are shown below, in Figure 3.5-8, which differentiate the slow, medium, and fast estimates representing the pace of recovery from the COVID-19 recession.

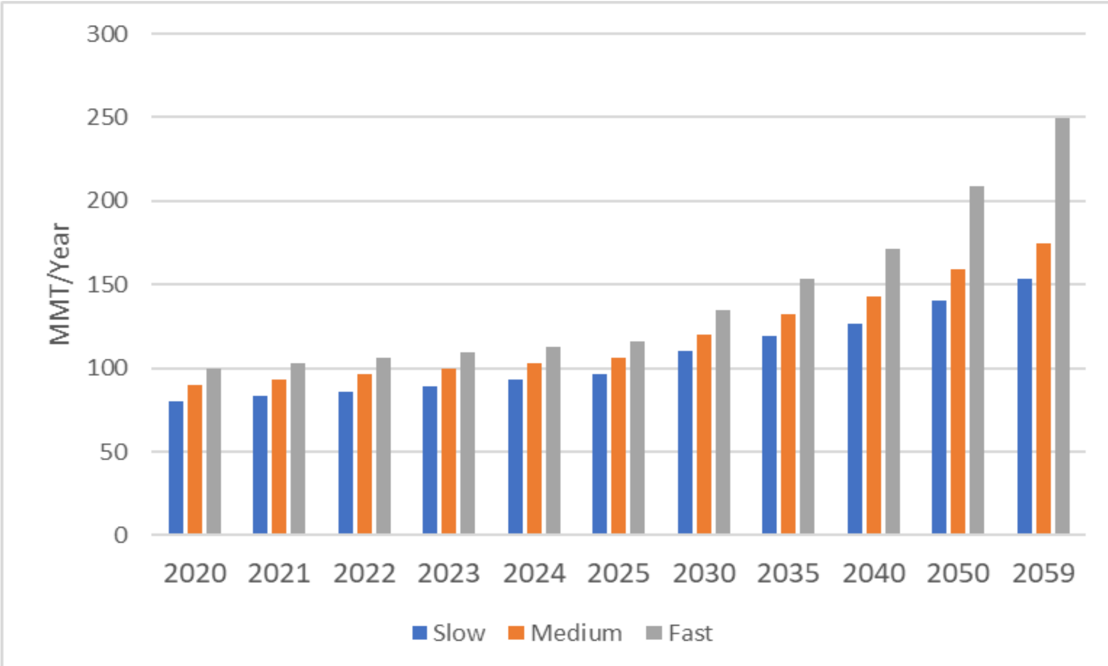

Figure 3.5-8. Global Methanol Demand Forecast from 2020 to 2059 in MMT Assuming a Slow, Medium, and Fast Pace for Recovery from the 2020 COVID-19 Recession

3.5.3 ESM output results

This section presents the modeling results that address the key questions noted above regarding lifecycle GHG emissions for the KMMEF project. These include questions about gross and net GHG emissions, the range of substitute emissions that would occur in the Reference Case (RC) absent KMMEF, the end-use emissions from KMMEF, and upstream methane emissions for KMMEF. Prior to addressing each of these questions we summarize the assumptions and ESM inputs used to generate the results presented in this section (Section 3.5.3.1). Next, a summary of emission results for each methanol production pathway is presented (Section 3.5.3.2). This summary establishes that it would be extremely difficult for global emissions to be higher as a result of the KMMEF relative to the RC. Section 3.5.3.3 presents results that demonstrate the expected gross emissions from the project and the three alternate cases (RC, lower coal-based production case (LCC), and a higher coal-based production case (HCC)). Section 3.5.3.4. shows how emissions change depending on the end use of the methanol. Section 3.5.3.5 presents emission results associated with recommended and alternative assumptions about upstream methane emission rates. Section 3.5.3.6 deals with the ranges of input emission rates used, comparing the low estimated emissions, medium, and high. Lastly, Section 3.5.3.7 compares the emission results with those developed in the previous SEIS and EIS.

3.5.3.1 ESM assumptions and inputs

Unless otherwise specified, the following assumptions and ESM input values were used to generate the results presented in Sections 3.5.3.2 through 3.5.3.4:

- The global market for methanol is competitive, and all Chinese methanol demand will be met with or without KMMEF.
- The market for methanol will continue to grow over the next 40 years.
- The Global Warming Potential (GWP) capacity of methane and nitrous oxide is converted to CO_2 equivalence by using conversion factors from the IPCC fourth climate assessment 100-year value.
- The RC assumption is that the equivalent 3.6 MMT of methanol per year would otherwise be provided by other methanol with 60 percent produced by a coal-based methanol production process, 10 percent by a Chinese natural gas-based process, and 30 percent from other importers.
- The LCC assumption is 20 percent coal-based methanol, 20 percent Chinese natural gas-based methanol, and 60 percent methanol imports.
- The HCC assumption is 80 percent coal-based methanol, 0 percent Chinese natural gas-based methanol, and 20 percent methanol imports.
- 60 percent of the methanol produced by KMMEF is assumed to be used for olefin production, and 40 percent is assumed to be used for fuel production. This estimated split in end use represents the two growing markets for methanol, with a slightly smaller share going to fuel since KMMEF has indicated that they are targeting the olefin market. The reason for the split is that market is very competitive, and all methanol demand will be met with or without KMMEF. If KMMEF sells to olefin producers and not fuel producers, other producers will sell methanol for fuel. And if KMMEF sells methanol to fuel producers (although this is not their stated intention), then other producers will sell methanol to the olefin producers.
- Low natural gas prices are presumed to persist in North America.
- Oil prices are assumed to remain stable at present levels – about $40/barrel. If oil prices increase or decrease, then it is expected that correspondingly less or more naphtha-based olefins would be produced, shifting the demand for methanol.
- The upstream methane emission rate is 0.97 percent for KMMEF.

The ESM also assumes that methanol production technologies are not materially improved in the future. In reality, methanol technology is likely to change and improve. If so, then the emission estimates for the alternate cases presented in this analysis are likely to be higher than future actual emissions with improved technology. However, lacking a strong basis for predicting future changes in methanol production technology, and without plausible reasons to allocate the use of improved technology among various producers, our results provide the best current estimate of future emissions.

The ESM recognizes that limitations likely will be placed on coal-based methanol expansion in China in the future. Over time, the ESM predicts an increase in natural gas-based imports to fulfill the methanol demand in China under the alternate cases. This is why the average annual emission values are lower than the initial year values (2020), because over time substitution for coal is slowly reduced, and RC emissions decline. Further, the ESM assumes full capacity methanol production at the KMMEF, starting in 2020 and lasting 40 years in order to simplify the analysis.

3.5.3.2 KMMEF and substitute pathway results

Lifecycle emissions for KMMEF methanol and methanol produced by substitute pathways are presented below in Table 3.5-10. The emissions are based on middle estimates for ESM inputs, and the values are shown in units of MT CO_2e per MT of methanol produced. For the naphtha pathway, emissions are shown in terms of the emissions associated with producing the quantity of olefin that is equivalent to the amount of olefin produced by one MT of methanol. Based on this analysis, methanol produced by KMMEF results in lower emissions than other methanol production pathways.

Table 3.5-10. Estimated Life Cycle GHG Emissions per Metric Ton of Methanol Produced For Substitute Pathways – Middle Estimate Used for ESM Inputs

Source	Emissions in (MT CO_2e/ MT Methanol or equivalent)
KMMEF	0.64
Coal based methanol	3.8
Natural gas-based methanol from China	1.2
Naphtha equivalent to substitute for methanol in olefin production	0.79
Imports from other countries	0.80

ESM output can be presented as either "gross" emissions or "net" emissions. Gross emissions (presented in Section 3.5.3.2 through 3.5.3.6) are simply the total GHG emissions associated with the process or scenario. For example, gross emissions for the KMMEF are the sum of upstream emissions, construction and process emissions, methanol transportation emissions, and emissions associated with the methanol's end use. Net emissions (presented in Section 3.5.5) are the difference between the gross emissions calculated for the KMMEF and a specified alternative case. In some instances, the discussion in Sections 3.5.3.2 through 3.5.3.6 includes mention of the net emissions, as this provides an indication of the resulting difference between KMMEF and the alternative cases.

3.5.3.3 Gross emissions – KMMEF and RC

Using the most plausible estimate of input values for emissions and assumptions under the RC (described in Section 3.5.3.1), the gross global emissions of the RC totals 10.6 MMTCO_2e annually for the 40 years of the proposed facility. With the KMMEF in place, the global gross emissions are estimated at 4.6 MMTCO_2e annually, which is approximately 55 percent less than the 10.6 MMTCO_2e annual gross emissions from the RC. These results are depicted in Figure 3.5-9 below, which presents the life-stage elements of associated with feedstock development;

upstream transportation emissions; direct emissions from processing feedstock to methanol; transportation emissions to ship methanol to its end use; and emissions associated with end use (fuel or olefins). Results are also shown for the LCC and the HCC.

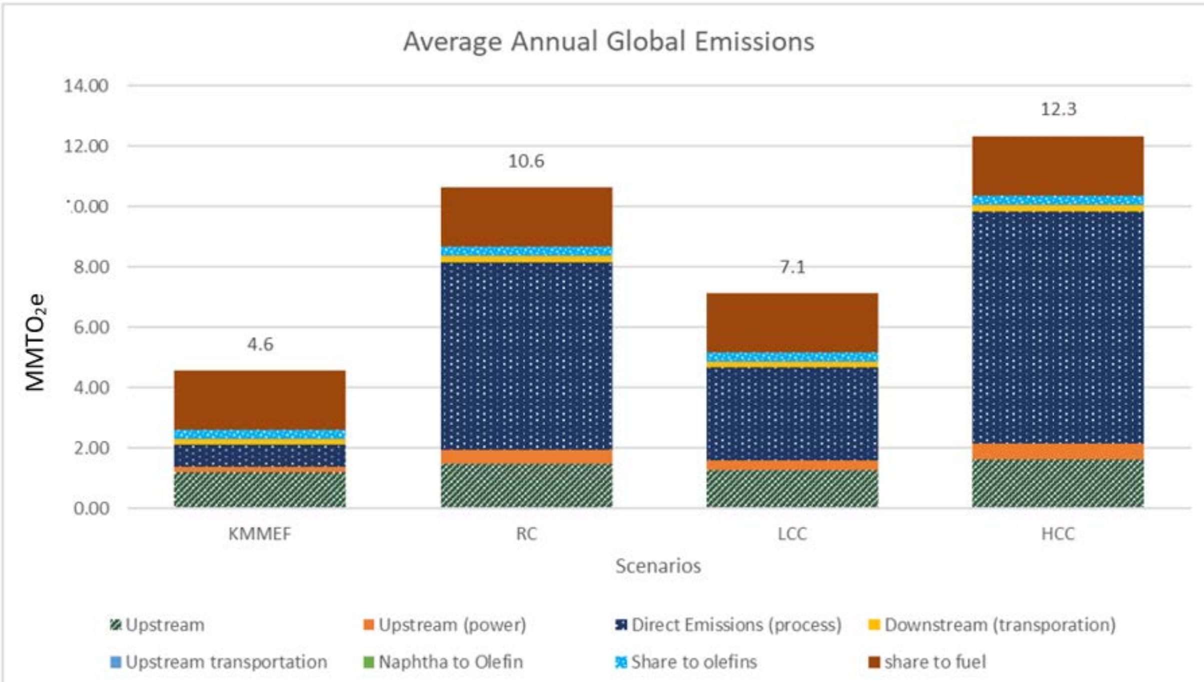

Figure 3.5-9. Average Annual Global Emission Estimates, 2020 – 2059 by Life Stage, KMMEF, RC, LCC, and the HCC

Under the LCC, absent KMMEF, most of the 3.6 MMT of methanol would come from other imported sources (60 percent), with 20 percent coming from coal-based methanol in China and 20 percent from natural-gas-derived methanol produced in China. This is a low estimate of the amount of coal-based methanol that would be produced in the absence of KMMEF. In this case, the total gross emissions is 7.1 MMT per year averaged over the 40-year project life, while KMMEF remains at 4.6 MMT per year. Under the HCC, 80 percent of the methanol produced absent KMMEF would come from coal-based methanol, and 20 percent would come from additional imports. This case represents the higher coal share of the alternative to KMMEF, and a scenario where natural gas-based methanol in China does not change production levels with, or without KMMEF. For this case, the results show that gross emissions would be 12.3 MMT in an average year over the 40-year life of the project, compared again with the 4.6 MMT with KMMEF.

Table 3.5.7 below shows initial emissions in year 2020, average annual emissions over the facility's 40-year lifespan, and total 40-year emissions for the KMMEF versus the RC.

Table 3.5-11. GHG Emission Results in $MMTCO_2e$ for KMMEF compared with the RC

Comparing Global Emissions* in $MMTCO_2e$	KMMEF	RC	KMMEF minus RC	Changes as % of RC
Initial Emission (2020)	4.6	11.7	-7.1	-61%
Average Annual Emission	4.6	10.6	-6.1	-55%
40-year Total Emissions	182	425	-243	-57

*Numbers in table may not total exactly due to rounding.

Under the RC, Figure 3.5.10 depicts annual emissions over time for both the KMMEF and the RC.

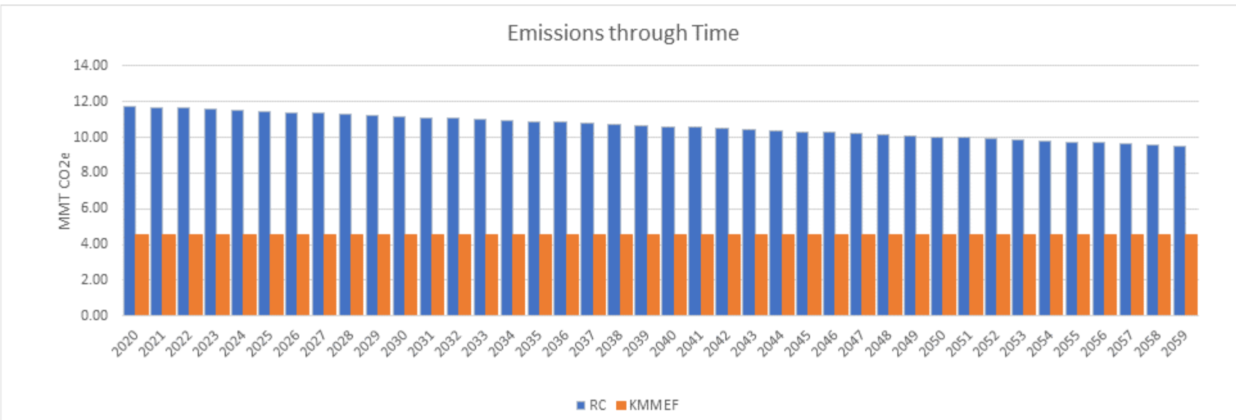

Figure 3.5-10. 20-Year Annual Expected Emissions, 2020 through 2059, RC and KMMEF

3.5.3.4 Results by end use

The emissions associated with KMMEF methanol include emissions attributable to the end use of the commodity. For purposes of this Second SEIS, the focus is on the potential use of KMMEF methanol for olefin production and for fuels. For reference, other end uses of methanol such as formaldehyde, which are not the subject of this analysis, are expected to generate emissions that are within the range of emissions generated by olefin production and fuel use. Formaldehyde and various other industrial uses of methanol are not included in this analysis because they make up a small percentage of the total methanol use in China, and these uses are not expected to grow as fast as the olefin or fuel sector (see Section 3.4.5.2).

With the ESM, total lifecycle emissions for KMMEF methanol may be compared depending on the allocation among end uses (e.g. olefin or fuel). For a given allocation, the model compares emissions between KMMEF and emissions from the RC assuming the same allocation of end use for 3.6 MMT per year. For example, allocating 100 percent of KMMEF methanol to olefin production results in global emissions that total 2.8 MMT CO_2e with KMMEF, and 8.8 MMT CO_2e under the RC. If instead 3.6 MMT of KMMEF methanol is allocated to the production of fuels, total global emissions with KMMEF would be 7.2 MMT CO_2e, and under the RC would total 13.3 MMT CO_2e (see Figure 3.5-11).

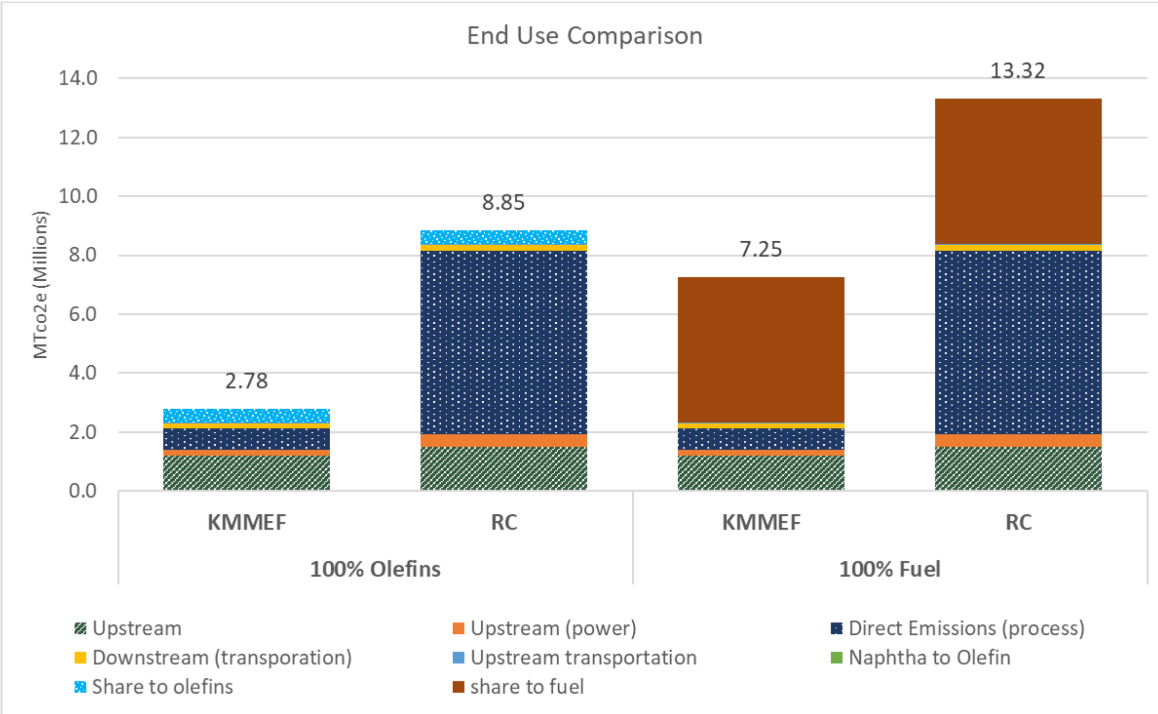

Figure 3.5-11. Total LCA GHG Emissions with KMMEF and Under the RC, Assuming 100 percent Use as Olefins (on the left) and 100 Percent Use as Fuel (on the right)

This analysis concludes that under either end use, net annual GHG emissions are the same, 6.07 $MMTCO_2e$. This result persists regardless of how KMMEF methanol is allocated between fuel use and the production of olefins. The reasoning is that if KMMEF sells to olefin producers and not fuel producers, other producers will sell methanol for fuel. And if KMMEF sells methanol to fuel producers (although this is not their stated intention), then other producers will sell methanol to the olefin producers. Because this market is very competitive, all methanol demand will be met with or without KMMEF. Consequently, KMMEF is not expected to affect net lifecycle GHG emissions based on its allocation among alternative end uses.

3.5.3.5 Upstream methane emissions

Results from the analysis of upstream methane emission rates indicate that the most plausible methane emission rate would be 0.97 percent of the natural gas used by the KMMEF. This value is used as the medium emissions estimate (see Section 3.4.1) and is derived from USEPA's GHG Emission Inventory. While the low estimate of 0.71 percent and a high estimate of 1.46 percent were also determined to be plausible, this analysis finds that the high estimate is likely more plausible than the low estimate. This conclusion is based on the research evaluated that supports the high estimate (Alvarez et al. 2018), which included thorough, ground-based facility scale measurements (bottom-up analysis) and broader atmospheric measurements from aircraft (top-down analysis). Studies that evaluate methane emissions cite significant variability in measured emissions both between facilities and at different times when measurements are made. Variability such as this leads to uncertainty in determining an accurate methane emissions rate. Due to this uncertainty an upstream methane emission rate of 3 percent was also included in the ESM to explore the impact of a higher methane emission rate on the overall GHG emissions from KMMEF. Average annual net emissions for KMMEF compared to the RC, with upstream methane emission rates of 0.71, 0.97, 1.46, and 3.0 percent, are shown below in Figure 3.5-12.

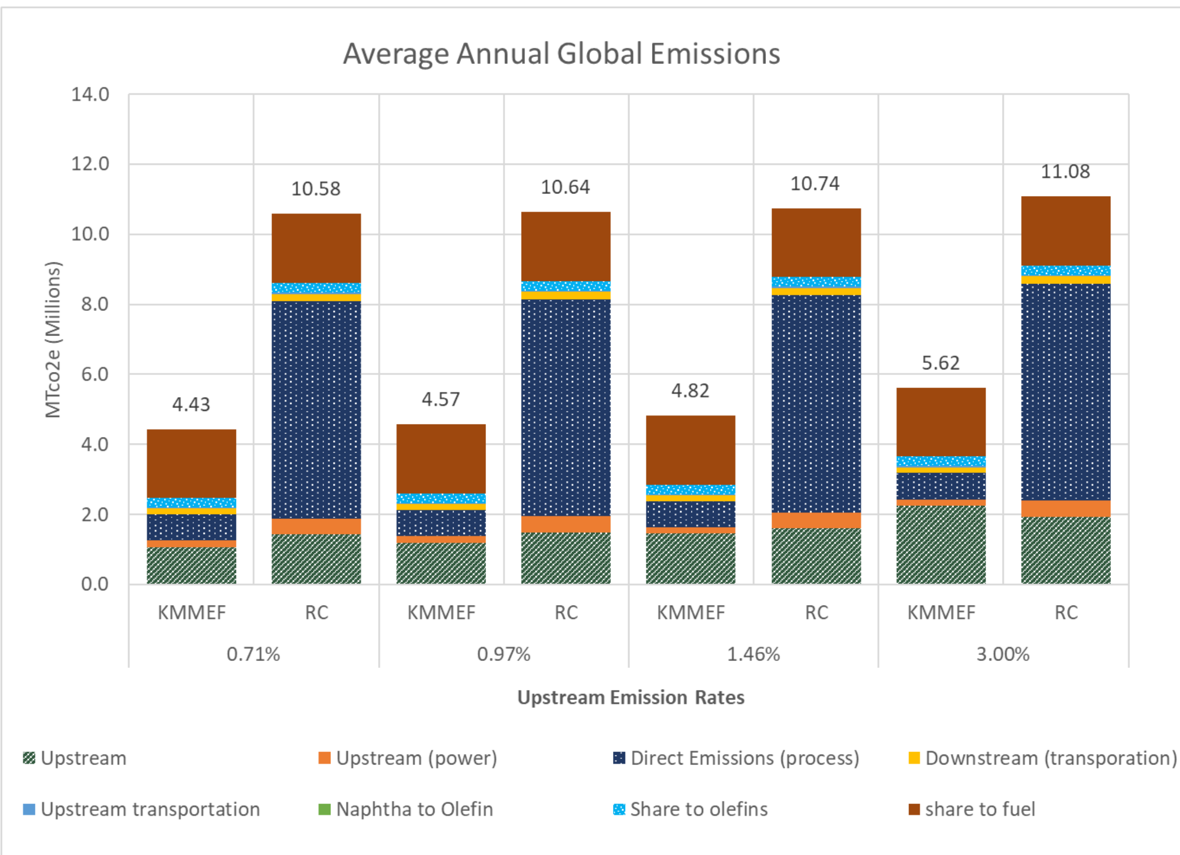

Figure 3.5-12. Average Annual LCA GHG Emission Estimates, with KMMEF the RC Using Upstream Emission Rate of 0.71, 0.97, 1.46, and 3.0

The results indicate that annual average emissions for KMMEF could vary from 4.43 MMTCO$_2$e to 5.52 MMTCO$_2$e depending on the upstream emission rate assumption. The estimated gross emissions for the RC vary from 10.58 to 11.08 for the same set of emission rate assumptions. The medium emission rate of 0.97 percent results in annual average emissions for KMMEF of 4.57, and 10.64 for the RC. The difference or net emission rate associated with KMMEF in this instance is -6.07 MMTCO$_2$e less than the RC.

3.5.3.6 Low, medium and high input rates

All estimates of emission rates for all three GHG gases (carbon dioxide, methane, and nitrous oxide) for each life cycle stage of methanol development are estimates developed using the best available scientific evidence for each stage and gas (see Chapter 3.4.1). However, there is variation in the available research for many of the stage/gas estimates and so low, medium, and high estimates for each were developed. Using all of the lowest estimates for emission rates, the result for KMMEF is 4.17 MMTCO$_2$e, and the RC produces 9.68 MMTCO$_2$e on average per year. The medium result is the same as that shown in the previous graphs, with KMMEF producing 4.57 MMTCO$_2$e and the RC producing 10.64. Using the higher range of input values for each life stage and gas, produces results of 5.41 for KMMEF and 11.60 for the RC, both again reported in terms of average annual MMTCO$_2$e. Figures 3.5-13 shows these results.

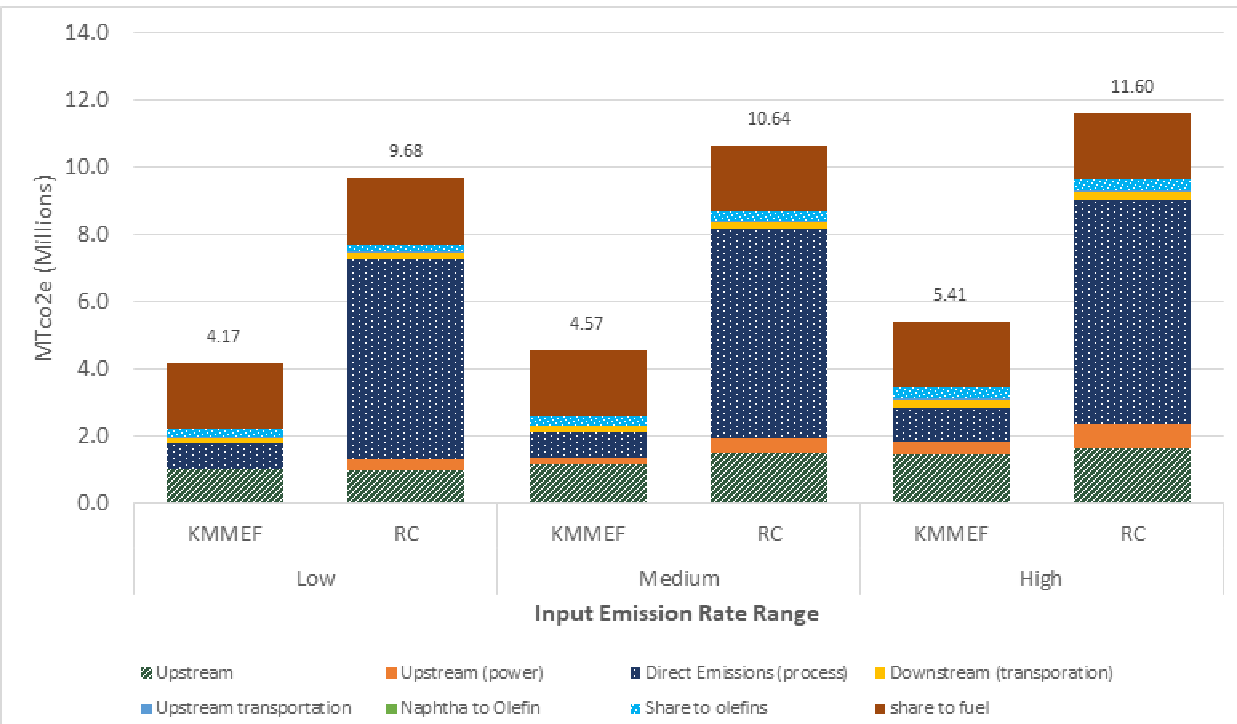

Figure 3.5-13. Average Annual LCA GHG Emission Estimates, KMMEF and RC, Using Low, Medium, and High Emission Input Estimates

3.5.3.7 Comparison with previous SEIS

Table 3.5-12 below presents GHG emission values for various ESM inputs included in this Second SEIS, along with corresponding GHG emission values from the First SEIS.

Table 3.5-12. Comparison of First and Second SEIS GHG Emission Values

Upstream Emissions from Natural Gas

Life Cycle Emissions	Units[1]	1st SEIS Low	1st SEIS Baseline	1st SEIS High	2nd SEIS Low	2nd SEIS Medium	2nd SEIS High
Total Emissions	MT CO_2e/ MT MeOH	0.285	0.289	0.392	0.288	0.333	0.403

KMMEF Construction, Decommissioning, Process, and Transport

Life Cycle Emissions	Units[1]	1st SEIS Low	1st SEIS Baseline	1st SEIS High	2nd SEIS Low	2nd SEIS Medium	2nd SEIS High
KMMEF Construction	MT CO2e/ MT Methanol	0.0041	0.0041	0.0041	0.0042	0.0042	0.0042
KMMEF Decommissioning	MT CO2e/ MT Methanol	NE			0.00003	0.00003	0.00003
Purchased Power	MT CO2e/ MT Methanol	0.0000	0.0515	0.0779	0.0001	0.0520	0.1035
ULE Methanol Production[2]	MT CO2e/ MT Methanol	0.2022	0.2022	0.2022	0.2022	0.2022	0.2708
Catalyst Replacement	MT CO2e/ MT Methanol	NE	NE	NE	0.00085	0.00085	0.00085
Employee Commuting	MT CO2e/ MT Methanol	NE	NE	NE	0.00025	0.00025	0.00025
Waste Disposal	MT CO2e/ MT Methanol	NE	NE	NE	0.00001	0.00001	0.00001
Methanol Transport[3]	MT CO2e/ MT Methanol	0.0548	0.0548	0.1021	0.0548	0.0548	0.0823
Total KMMEF Upstream and Onsite Emissions	MT CO2e/ MT Methanol	0.5462	0.6017	0.7780	0.5505	0.6473	0.8650

End Uses

Life Cycle Emissions	Units[1]	1st SEIS Low	1st SEIS Baseline	1st SEIS High	2nd SEIS Low	2nd SEIS Medium	2nd SEIS High
Methanol to Olefin	MT CO2e/ MT olefin	0.3 to 0.45	0.3 to 0.45	0.3 to 0.45	0.3	0.38	0.45
Methanol to Fuel	MT CO2e/ MT Methanol	1.37	1.37	1.37	1.37	1.37	1.37

Substitute Pathways: China Coal to Methanol

Life Cycle Emissions	Units[1]	1st SEIS Low	1st SEIS Baseline	1st SEIS High	2nd SEIS Low	2nd SEIS Medium	2nd SEIS High
Coal extraction to process of converting to MeOH	MT CO_2e/ MT Methanol	3.3	3.7	4	3.4	3.7	4
Transportation	MT CO_2e/ MT Methanol	0.1	0.1	0.1	0.1	0.1	0.1
Total:	MT CO_2e/ MT Methanol	3.4	3.8	4.1	3.4	3.8	4.1

Substitute Pathways: China Natural Gas to Methanol

Life Cycle Emissions	Units[1]	1st SEIS Low	1st SEIS Baseline	1st SEIS High	2nd SEIS Low	2nd SEIS Medium	2nd SEIS High
Total:	MT CO_2e/ MT Methanol	NE	NE	NE	1.2	1.2	1.2

Substitute Pathways: Non-KMMEF Methanol Imports

Life Cycle Emissions	Units[1]	1st SEIS Low	1st SEIS Baseline	1st SEIS High	2nd SEIS Low	2nd SEIS Medium	2nd SEIS High
Total:	MT CO2e/ MT Methanol	NE	NE	NE	0.77	0.8	0.88

Substitute Pathways: Oil-Naphtha-Olefin

Life Cycle Emissions	Units[1]	1st SEIS Low	1st SEIS Baseline	1st SEIS High	2nd SEIS Low	2nd SEIS Medium	2nd SEIS High
Upstream	MT CO_2e/ MT olefin	1.18 to 1.42	1.18 to 1.42	1.18 to 1.42	1.2	1.2	1.2
Process	MT CO_2e/ MT olefin	1.14	1.14	1.14	1.14	1.14	1.14
Total:	MT CO_2e/ MT olefin	2.3 to 2.5	2.3 to 2.5	2.3 to 2.5	2.34	2.34	2.34

1. Emissions presented as CO2e based on 100 yr AR4 GWPs.
2. Emissions for methanol production in First SEIS relate to the Continuous Operation Scenario for Low, Baseline, and High emission estimates. In the Second SEIS, the Continuous Operation Scenario is used for the Low and Medium estimates, and the Maximum Potential to Emit Scenario is used for the High estimate.
3. Emissions for the transport of methanol to China are based on Scenario 1 (100,000 MT vessels) for the Low and Baseline estimates in the First SEIS and the Low and Medium estimates in the Second SEIS. Scenario 2 (50,000 MT vessels) are used for the High estimates in both the First and Second SEIS.

NE = Not Evaluated

Table 3.5-13 below presents the total GHG emissions from KMMEF as presented in the First SEIS and the Second SEIS.

Table 3.5-13. Comparison of First and Second SEIS Total Annual GHG Emissions for KMMEF

KMMEF Life Cycle Emissions	Units[1]	1st SEIS Low	1st SEIS Baseline	1st SEIS High	2nd SEIS Low	2nd SEIS Medium	2nd SEIS High
Upstream, Construction, Decommissioning, Process, and Transport	MMT CO2e/ Year	1.97	2.17	2.80	1.98	2.33	3.11
End Use: Methanol to Olefins[2]	MMT CO2e/ Year	0.41	0.41	0.41	0.22	0.27	0.32
End Use: Methanol to Fuel[2]	MMT CO2e/ Year	0	0	0	1.97	1.97	1.97
Total KMMEF Emissions	MMT CO2e/ Year	2.37	2.58	3.21	4.17	4.58	5.41
Total Alternate Case Emissions[3]	MMT CO2e/ Year	12.68	14.10	15.02	9.68	10.64	11.60
NET EMISSIONS: KMMEF Minus Alternate Case Emissions	MMT CO2e/ Year	-10.31	-11.52	-11.81	-5.51	-6.06	-6.19

1. Emissions presented as CO2e based on 100 yr AR4 GWPs.
2. End use for the First SEIS is 100% olefins. End use for the Second SEIS is 60% olefins, and 40% fuel.
3. Alternate Case Emissions presented for the First SEIS correspond to values in Table 3-8 of the First SEIS. Alternate Case Emissions for the Second SEIS are the average annual emissions for the RC alternate case.

3.5.4 State emissions

Some GHG emissions associated with the KMMEF will occur within the boundaries of the State of Washington. In-state emissions arise from construction of the KMMEF, a portion of the total natural gas transmission to the KMMEF for use as feedstock, KMMEF operations, purchased electricity, the portion of the transportation of KMMEF methanol that occurs in-state, and decommissioning of the KMMEF. Table 3.5-14 below presents these emissions.

Table 3.5-14. KMMEF Emissions Occurring in Washington State.

Greenhouse Gas Emission Sources	Low Estimate ($MT\ CO_2e/yr^1$)	Medium Estimate ($MT\ CO_2e/yr^1$)	High Estimate ($MT\ CO_2e/yr^1$)
KMMEF Construction[2]	2,883	2,883	2,883
KMMEF Decomissioning[2]	81.7	81.7	81.7
Upstream Natural Gas Emissions[3]	47,024	53,101	60,048
Process Emissions: Purchased Power	526.7	187,112	372,752
Process Emissions: ULE Methanol Production[4]	728,009	728,009	975,051
Process Emissions: Catalyst Replacement	13.1	13.1	13.1
Process Emissions: Employee Commuting	903.9	903.9	903.9
Process Emissions: Waste Disposal	22.1	22.1	22.1
Transportation Emissions[5]	6,653	6,653	9,993
Total	**786,117**	**978,779**	**1,421,748**

1. CO_2e calculated using 100-year AR4 GWPs.
2. Emissions shown for one-time sources (Construction and Decommissioning) are annualized by dividing the total emissions by 40 years.
3. Upstream natural gas emissions in Washington State calculated by multiplying the transmission emissions from GHGenius or GREET (depending on scenario) by the fraction of the total pipeline miles from the natural gas source region that are within Washington State.
4. For emissions from ULE Methanol Production, the Continuous Operation Scenario is used for the Low and Medium estimates, and the Maximum Potential to Emit Scenario is used for the High estimate.
5. Low and Medium estimates assume transport by 100,000 MT vessels. The High estimate assumes transport by 50,000 MT vessels.

3.5.4.1 Construction and decommissioning

A portion of the emissions associated with the construction and decommissioning of the KMMEF will occur in the state of Washington. Emissions within Washington include direct and indirect emissions from construction equipment fuel use, production and transport of materials such as aggregate, concrete, and asphalt, and purchased electricity used during construction/decommissioning. Total construction and decommissioning emissions occurring within Washington are provided in Table 3.5-14.

3.5.4.2 Upstream

A portion of the upstream emissions associated with the facility's natural gas feedstock is expected to occur within the state of Washington. This portion of emissions is attributable to the natural gas transmission system within Washington only, as there is no in-state natural gas production or processing. The portion of transmission emissions expected to occur in Washington State was determined by applying the ratio of in-state to total transmission distance from natural gas sources to the KMMEF to the total emissions associated with transmission. Washington State emissions for the three upstream natural gas emission scenarios are provided in Table 3.5-14.

3.5.4.3 Process and transport

Emissions generated within Washington State associated with operations at the KMMEF and transport of KMMEF methanol to ports outside the State under both transportation scenarios are summarized in Table 3.5-14. All of the emissions associated with operations at KMMEF will occur in Washington State. In addition to direct transportation emissions for KMMEF methanol within Washington State, emissions are included from assist tugs and helicopters at the Port of Kalama and while crossing the Columbia River Bar. Additional details regarding each emission source are provided in Appendix C.

3.5.4.4 Summary of in-state emissions

In summary, in-state emissions associated with KMMEF include:

- Construction Emissions
- Decommissioning Emissions
- Onsite Direct Operations Emissions
- Transportation Emissions (in state)
- Upstream Natural Gas (in state)
- Purchased Power Supply (electricity used in state)

GHG emissions occurring within Washington State from the sources listed above are estimated to be between 786,117 and 1,421,748 MT CO_2e per year.

3.5.5 Net global emissions

The analysis suggests a high likelihood that bringing the KMMEF online would result in increasing global GHG emissions less than would occur absent the project. The ESM demonstrates that the potential for global GHG emissions from the project to exceed any other case is extremely limited. This is because the most likely RC production that would be replaced by KMMEF production is coal-based methanol in China, which has relatively high emissions associated with it. The degree to which KMMEF substitutes for each of the other sources of production in China, including natural gas-based methanol from China, naphtha-based olefin production in China, or other natural gas-based methanol imported to China, will cause the relative difference in emissions between KMMEF and the alternative to change. However, this analysis has concluded that emissions from KMMEF will always be lower than emissions from other substitute methanol pathways in the alternative scenarios when the medium (or best) estimate input values are used in the ESM. Using other assumptions in combination, such as low or high estimate values, or different GWP assumptions, there is very little potential for GHG emissions to increase, and these cases are evaluated in the Sensitivity Analysis presented in Section 3.6. But using the medium estimates for all emission sources, the lifecycle emissions from KMMEF methanol is lower than the alternative methanol sources.

The net global GHG emissions calculated by the ESM are presented in terms of the difference between emissions with KMMEF and emissions under one of the three alternative cases.

Figure 3.5-14 presents the net emissions using best estimate for ESM inputs (medium estimate), and all of the other recommended assumptions (AR4100 GWP; 0.97 percent upstream methane emission rate, and 60/40 use split between olefins and fuel). The results show a difference of -6.07 $MTCO_2e$ per year for the RC. A negative result for the net emissions indicates that KMMEF emissions are less than emissions expected to occur otherwise under the RC. The figure also shows the net annual GHG emission results under the LCC with a lower volume of coal-based methanol being replaced by KMMEF methanol to be -2.57, and a result of -7.77 for the high coal case, or the HCC.

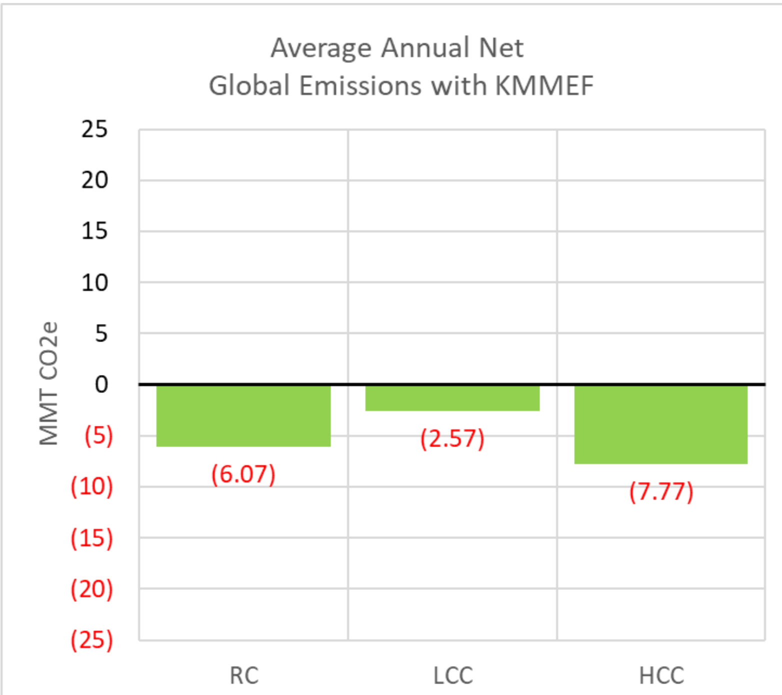

Figure 3.5-14. Average Annual Net Global Emissions with KMMEF Under the RC, LCC, and HCC Alternative Cases

3.6 Sensitivity analysis

In Section 3.5, results were presented for gross and net GHG emissions forecast through time with the KMMEF project and under alternative cases representing the best estimates of what would occur if the project were not to be developed. In that section, several assumptions were outlined, such as assumptions about market conditions including the end use of KMMEF methanol, and the sources of methanol that would supply market demand in the absence of KMMEF. Other assumptions were developed for the GHG emission calculations, such as GWP factors, low and high emission rate estimates, and upstream methane emission rates.

When a complex analysis such as this depends on a number of uncertain variables, a sensitivity analysis can build understanding about two fundamental questions. The first, is, “What happens to the results when the assumptions about one of the variables is modified?” And the second is, “What happens to the results when several assumptions are modified at the same time?” Some of the answers to the first question were explored in Section 3.5. Section 3.5

addressed the question of what happens when methanol based on different feedstocks and sources are assumed to supply the market absent the KMMEF project. That was covered through analyzing the RC, LCC, and HCC alternatives. Section 3.5 also addressed how results change when different end uses are considered (olefins vs. fuels); and when different assumptions about upstream methane emission rates were assumed. In addition, Section 3.5 reviewed how results changed when using low, medium, and high input emission rates.

There are thousands of possible combinations of these input variables, and each produce a slightly different result. Yet, it is not necessary to calculate all of the alternatives to conduct a sensitivity analysis to answer the key question: are there changes to the assumptions that will change the results in a way that could alter the decision that motivates the analysis? For example, a key question is whether it might be possible, with any combination of input assumptions, to have the KMMEF facility produce higher global emissions through time than with the alternative scenarios that are expected if the project is not built.

The sensitivity analysis in this section will build on some of the work in Section 3.5 that explored different results when one variable was modified. Those results were explored because they addressed some of the objectives of this Second SEIS, including:

- What happens when KMMEF methanol is used for different end uses?
- What happens when there are different assumptions about the source of methanol that will supply the market if KMMEF is not developed?
- How do assumptions about upstream emission rates change the results, and how do results change with different assumptions about the ranges of input variables?

The Second SEIS objectives also call for a sensitivity analysis, and a more complete sensitivity analysis is presented in this section.

The sensitivity in Section 3.5 addressed how changing one assumption could alter the results. In this section, results will be shown for altering different assumptions, for altering more than one assumption at a time, and finally exploring how simultaneously altering a broad collection of assumptions could produce outlier results. The outlier results would have a low probability of occurring but represent the net highest and the lowest feasible results that could be calculated using the ESM. The table below shows the different assumptions, or variables, that have been modified for this sensitivity analysis, whether each was explored in Section 3.5 or not, and if so, how this section expands the analysis. The table also shows which variables affect just the alternative cases, and which affect both KMMEF and the alternate cases (see Table 3.6-1). No assumptions affect just the KMMEF case. The table also shows which subsections address each question.

Table 3.6-1. Summary of Variables Used in Sensitivity Analysis

Assumption	Affects which case(s)	In 3.5?	How explored in 3.6	Subsection
Source Mix for Alternate Cases (RC, LCC, HCC)	Alternate Cases	3.5.3.3	Results for cases shown in combination with other assumption modifications	Various
End Use of Methanol (olefins, fuel)	Both KMMEF and Alternates	3.5.3.4	N/A	N/A
Upstream Methane Emission Rates	Both KMMEF and Alternates	3.5.3.5	Additional results for alternate cases	3.6.3
Other Input Emission Rates (Low, Med, High)	Both KMMEF and Alternates	3.5.3.6	Additional results for alternate cases, and expanded to show Low/High and High/Low variations	3.6.2
GWP Factors	Both KMMEF and Alternates	---	Results for four different factors and alternate cases	3.6.1
Pace of Recession Recovery	Alternate Cases	---	Results for three recovery paces and all alternate cases	3.6.4
Price of Oil in 2030	Alternate Cases	---	Results for three oil price actions and all alternate cases	3.6.5
Outlier Cases	Alternate Cases	---	Two new alternate cases producing outlier results	3.6.6

Sensitivity analysis results for GWP factors are presented in Section 3.6.1; results for the low, medium, and high input estimates are presented in Section 3.6.2; and results for upstream methane emission rates are presented in Section 3.6.3. For the RC, results using low, medium, and high emission input estimates are presented in Section 3.5.3.6; in 3.6.2, results are compared for all three alternate cases. Similarly, Section 3.6.3 builds upon varying upstream methane emission rates for the KMMEF presented in Section 3.5.3.5 by presenting additional comparisons for the LCC and HCC.

Market uncertainties related to the pace of recession recovery is covered in Section 3.6.4, and oil prices are addressed in Section 3.6.5. Each section below focuses on how gross, and sometimes net annual average GHG emissions change as input assumptions are varied. To the extent possible, results are also shown for emissions by life stage of the process. Subsequently, Section 3.6.6 addresses some limitations of the ESM. In Section 3.6.7, two scenarios are analyzed that represent two plausible outlier results of the sensitivity study. Finally, a summary of the sensitivity analysis results is presented in Section 3.6.8.

3.6.1 Sensitivity related to global warming potential

Global warming potentials (GWP) are factors that account for the varying amount of energy that is absorbed by GHGs during a set amount of time. GWPs are defined relative to CO_2, such that the GWP for CO_2 is set to unity (that is, equal to one). GWP values are periodically updated to reflect current science regarding the energy properties of GHGs and their lifetimes in the atmosphere. The most commonly used GWP values are the 100-year estimates from the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR 4) (shaded more darkly and on the left in Figure 3.6-1 below). The 100-year AR4 GWP values are currently set forth in 40 CFR Part 98 and Table A-1 of WAC 173-441-040. Other commonly cited GWP values are the 100-year estimates from the IPCC Fifth Assessment Report (AR 5), the 20-year estimates from AR 4, and the 20-year estimates from AR 5. The following table (Table 3.6-2) shows the various factors used to convert emissions from nitrous oxide and methane into carbon dioxide equivalents.

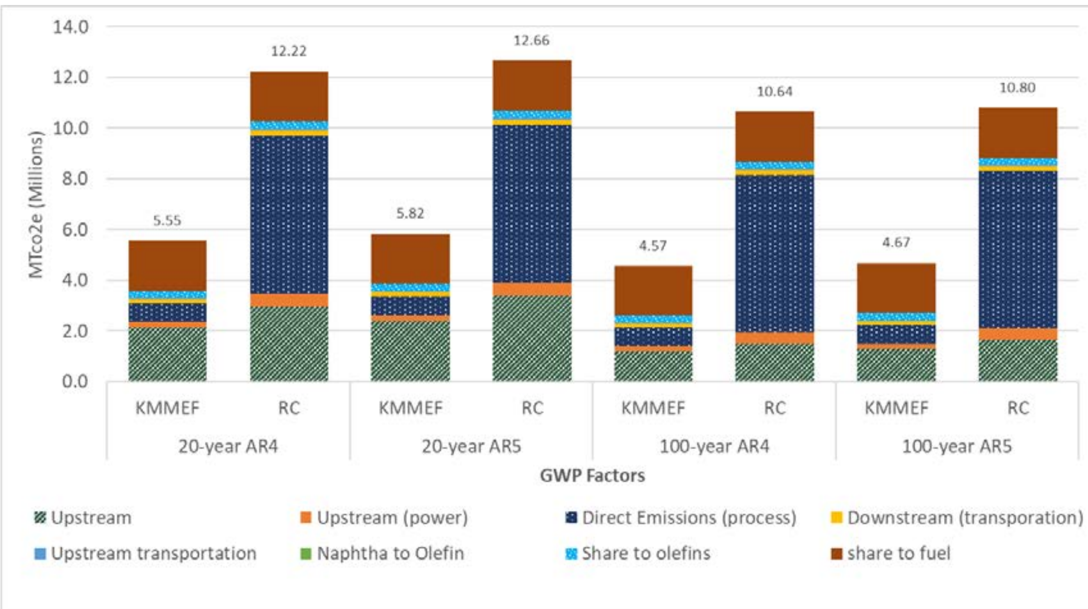

Figure 3.6-1. Average Annual Life Stage GHG Emissions for KMMEF and Three Alternate Case Using Four Different GWP Parameter Sets, 2020 - 2059

Table 3.6-2. Global Warming Potential Conversion Factors.

Source of GWP Carbon Equivalent Conversion Factor	CO_2	CH_4	N_2O
IPCC 4 100 year (100 AR4)[1]	1	25	298
IPCC 5 100 year (100 AR5)	1	28	265
IPCC 4 20 Year (20 AR4)	1	72	289
IPCC 5 20 Year (20 AR5)	1	84	264

1. IPCC 4 100-year GWP values (in bold) are the values used throughout this report to calculate CO_2e, unless otherwise specified.

Annual average GHG emissions for the KMMEF compared to the alternate cases (RC, LCC, and HCC), using the four sets of GWPs tabulated in Table 3.6-2 are presented in Figure 3.6-1. The figure depicts variation in estimated GHG emissions based on changing GWP parameters, as defined in the four sources listed in Table 3.6-1. Under all three alternate cases, the gross emissions increase sequentially moving from the AR4 100-year factors to the 100-year AR5 factors, the 20-year AR4 factors, and the 20-year AR5 factors. Moving from the 100-year AR4 result to the 20-year AR5 result, the difference in average annual emissions between KMMEF and the Alternate Cases increases by 15 percent for the RC, 13 percent for LCC, and 11 percent for HCC. This demonstrates that the AR4 100 GWP factors are the most conservative factors to use. Similar results may be seen in Table 3.6-3, which shows the numeric results by life stage for each of the alternate cases.

3.6.2 Sensitivity related to range of emission rate input values

The ESM models low, medium and high estimated emissions for all life stages of all emissions pathways. The medium scenario provides the best estimate of actual emissions. All emission estimates are developed in metric tons of GHG per metric ton of methanol. The ESM sums emission rates through each pathway and derives emission estimates by multiplying these rates by the total volume of methanol that is expected to be produced through that pathway. The low, medium and high estimates of emissions over the lifecycle (e.g. upstream emissions, upstream power, transportation, etc.) yield a range of results for comparison. For most of the results presented in Section 3.5, the medium emission rate input values were used. Figure 3.5-14 shows how altering the input estimates (low, medium, or high) for the RC and KMMEF affects the estimated net annual GHG emissions.

Figure 3.6-2 builds on Figure 3.5-14 to show how the net global GHG impact of KMMEF varies over the range of emission rates. The figure shows the emissions resulting from several combinations of emission rates, including “low/low”, “medium/medium”, “high/high”, “low/high”, and “high/low” combinations of KMMEF and alternate case inputs. In all combinations, the first adjective refers to KMMEF emission rates and the second to the alternate case emission rates. Thus, the “low/high” combination refers to the use of low emission rates for KMMEF and high emission rates for alternate case, and so forth. The purpose of these evaluations is to explore the boundaries of results that can be produced, even if under somewhat unrealistic combinations of input assumptions. It should be noted that the 2019 SEIS also reported combined emission estimates (e.g., for low/high and high/low combinations), providing a useful comparison.

The sensitivity analysis shows that, where emission rates are set lower than the mid-range (which reflect best estimates), then the net annual emission difference afforded by the KMMEF as compared to the RC is again smaller than under the medium/medium case. This result is a function of the comparison of cases, not an absolute reduction. In both the high/high case (in which both the KMMEF and the RC are characterized by the high range estimates) and the low/high case (in which the KMMEF is characterized by lower and the RC by higher estimates), difference in emissions between the KMMEF and the RC is increased as compared to the medium/medium case. Finally, if KMMEF emissions are set to the higher end while the RC is set to the lower end, the overall difference in average annual GHG emissions between KMMEF and the RC is smaller than when using the medium range. The latter situation does not represent a realistic situation, because there is no reason to believe that scientific results would err in one direction (e.g. high) on one side of the Pacific Ocean, and on the other direction (e.g. low) on the other side of the ocean.

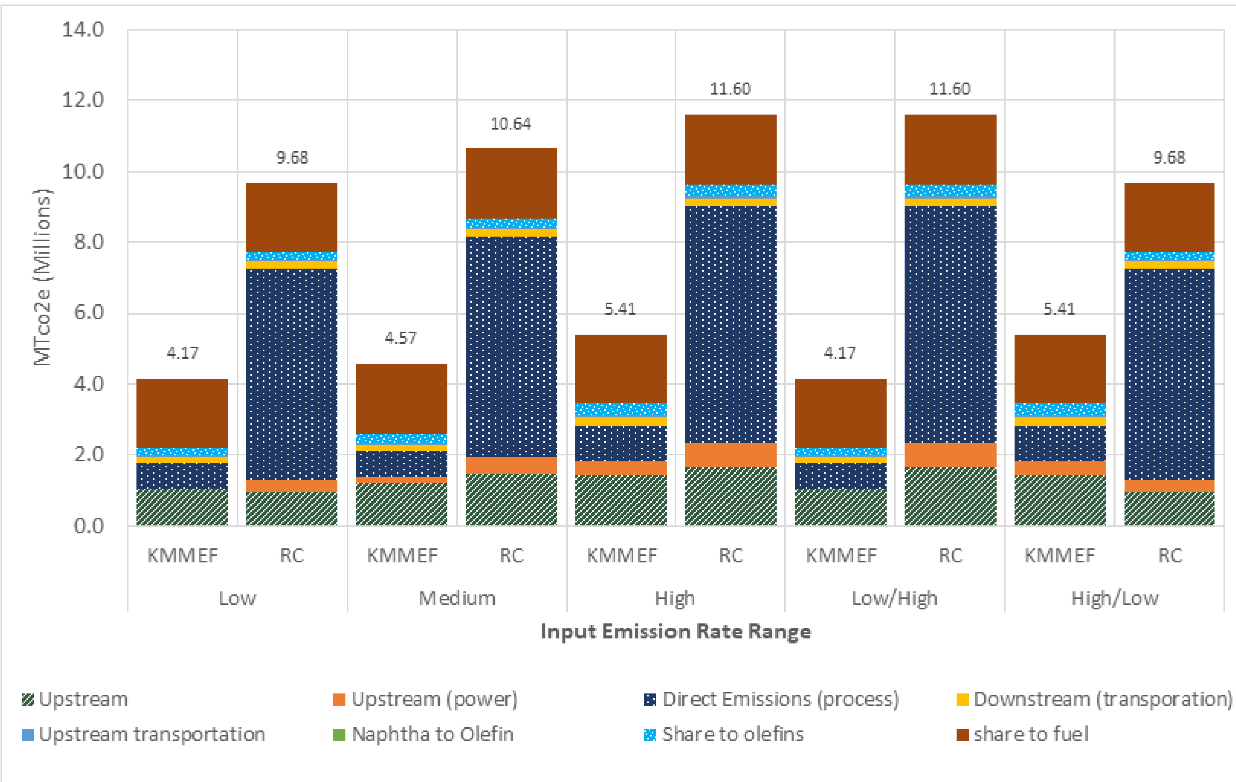

Figure 3.6-2. Average Annual Life Stage GHG Emissions for KMMEF and Three Alternate Case with Different Input Emission Rate Values

A complete analysis of all the input value ranges by life stage for each of the alternate cases (RC, LCC, and HCC) is provided in Table 3.6-3.

Table 3.6-3. Average Annual Life Stage GHG Emissions (MMT CO_2e/year) for KMMEF and Three Alternate Case Using Four Different GWP Parameter Sets

20-year	AR4 KMMEF	AR4 RC	AR4 LCC	AR4 HCC	AR5 KMMEF	AR5 RC	AR5 LCC	AR5 HCC
Upstream	2.14	2.97	2.43	3.23	2.40	3.37	2.75	3.68
Upstream Power	0.21	0.50	0.34	0.59	0.22	0.52	0.35	0.61
Direct Emissions	0.75	6.23	3.17	7.68	0.75	6.24	3.18	7.68
Downstream transp.	0.17	0.21	0.19	0.23	0.17	0.21	0.19	0.23
Upstream transp.	0.05	0.07	0.05	0.08	0.05	0.08	0.06	0.09
Naphtha to Olefin	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Share to olefins	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27
Share to fuel	1.97	1.97	1.97	1.97	1.97	1.97	1.97	1.97
Total	5.55	12.22	8.41	14.05	**5.82**	**12.66**	**8.77**	**14.53**

100-year	AR4 KMMEF	AR4 RC	AR4 LCC	AR4 HCC	AR5 KMMEF	AR5 RC	AR5 LCC	AR5 HCC
Upstream	1.20	1.49	1.27	1.61	1.29	1.64	1.39	1.78
Upstream Power	0.19	0.45	0.31	0.54	0.19	0.46	0.31	0.54
Direct Emissions	0.75	6.20	3.10	7.68	0.75	6.21	3.11	7.68
Downstream transp.	0.17	0.21	0.18	0.22	0.17	0.21	0.18	0.22
Upstream transp.	0.03	0.05	0.04	0.05	0.03	0.05	0.04	0.06
Naphtha to Olefin	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Share to olefins	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27
Share to fuel	1.97	1.97	1.97	1.97	1.97	1.97	1.97	1.97
Total	4.57	10.64	7.14	12.34	4.67	10.80	7.27	12.52

Table 3.6-4 Average Annual Life Stage GHG Emissions for KMMEF and Three Alternate Cases with Different Input Emission Rate Values

L/M/H Variance	Low KMMEF	Low RC	Low LCC	Low HCC	Medium KMMEF	Medium RC	Medium LCC	Medium HCC	High KMMEF	High RC	High LCC	High HCC
Upstream	1.04	0.97	1.01	0.95	1.20	1.49	1.27	1.61	1.45	1.64	1.46	1.76
Upstream (power)	0.00	0.33	0.11	0.44	0.19	0.45	0.31	0.54	0.37	0.72	0.55	0.82
Direct Emissions	0.75	5.94	3.02	7.33	0.75	6.20	3.10	7.68	0.99	6.64	3.46	8.17
Downstream transp.	0.17	0.21	0.18	0.22	0.17	0.21	0.18	0.22	0.25	0.25	0.25	0.26
Upstream transp.	0.03	0.05	0.04	0.05	0.03	0.05	0.04	0.05	0.05	0.05	0.05	0.06
Naphtha to Olefin	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Share to olefins	0.22	0.22	0.22	0.22	0.27	0.27	0.27	0.27	0.32	0.32	0.32	0.32
share to fuel	1.97	1.97	1.97	1.97	1.97	1.97	1.97	1.97	1.97	1.97	1.97	1.97
Total	**4.17**	**9.68**	**6.54**	**11.19**	**4.57**	**10.64**	**7.14**	**12.34**	**5.41**	**11.60**	**8.06**	**13.36**

L/M/H Variance	Low/High KMMEF	Low/High RC	Low/High LCC	Low/High HCC	High/Low KMMEF	High/Low RC	High/Low LCC	High/Low HCC
Upstream	1.04	1.64	1.46	1.76	1.45	0.97	1.01	0.95
Upstream (power)	0.00	0.72	0.55	0.82	0.37	0.33	0.11	0.44
Direct Emissions	0.75	6.64	3.46	8.17	0.99	5.94	3.02	7.33
Downstream transp.	0.17	0.25	0.25	0.26	0.25	0.21	0.18	0.22
Upstream transp.	0.03	0.05	0.05	0.06	0.05	0.05	0.04	0.05
Naphtha to Olefin	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Share to olefins	0.22	0.32	0.32	0.32	0.32	0.22	0.22	0.22
share to fuel	1.97	1.97	1.97	1.97	1.97	1.97	1.97	1.97
Total	4.17	11.60	8.06	13.36	5.41	9.68	6.54	11.19

3.6.3 Sensitivity related to upstream methane emission rates

Figure 3.6-3 is reproduced here as it shows how upstream methane emission rates affect gross average annual GHG emissions for KMMEF and the RC. In addition, Table 3.6-5 shows similar results for different emission rates and different alternate cases. The values for alternate emission rates reflect alternative upstream methane emissions expressed as a percentage of natural gas used by KMMEF (see Table 3.5-8 for a comparison of values used in the First and Second SEIS).

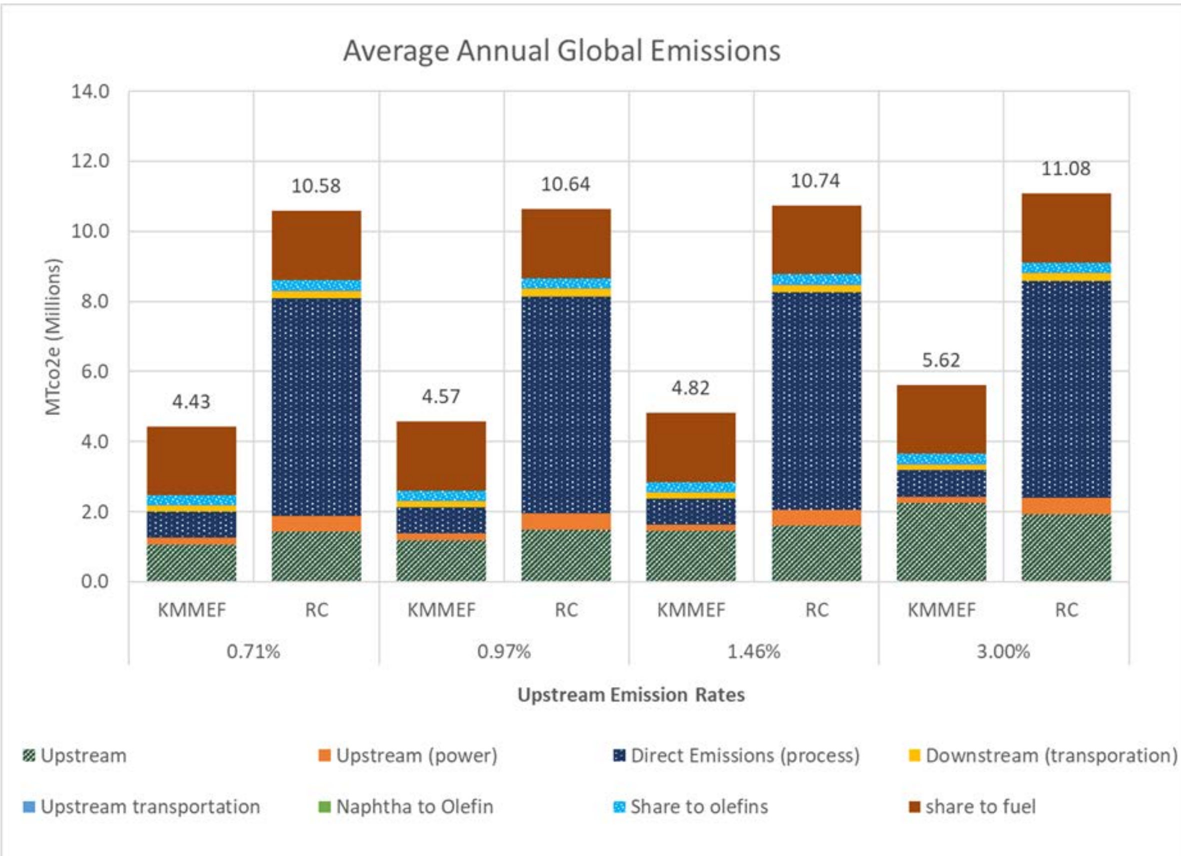

Figure 3.6-3. (Reproduced from Figure 3.5-13) Average Annual Emissions by Life Stage for KMMEF and RC with Different Assumptions about Upstream Emission Rates, 2020 – 2059

The medium estimate for upstream methane emissions for KMMEF is based on 0.97 percent of natural gas feedstock being emitted as methane. Assuming an emission of 0.71 percent, the RC and LCC do not demonstrate any significant difference from the results at 0.97 percent, and the HCC is just about one percent more than the results produced at 0.97 percent. At higher upstream methane emissions (1.46 percent and 3 percent), the difference between KMMEF and alternate case average annual net emissions becomes smaller (for all alternate cases) than at 0.97 percent. At three percent, the difference between the two decreases by 10 percent, 15 percent, and 9 percent for RC, LCC, and HCC, respectively, compared to the results using a rate of 0.97 percent. All of these changes in results demonstrate that the upstream emission rate does matter when totaling GHG emissions, but not by a significant amount. For example, the three percent emission rate is not supported with literature but was used to develop a point of comparison. Three percent is approximately a 200 percent increase over the estimate of 0.97, and yet the results only change by 9 to 15 percent. This builds reassurance to the analysis by showing that even in the event of inaccuracies in measured upstream methane emission rates, the results of this analysis would likely remain relatively stable.

Table 3.6-5. Average Annual LifeCycle GHG Emissions (MMT CO2e/year) for KMMEF and Three Alternate Cases with Different Assumptions about Upstream Emission Rates

Upstream Emission Rates	0.71% KMMEF	0.71% RC	0.71% LCC	0.71% HCC	0.97% KMMEF	0.97% RC	0.97% LCC	0.97% HCC
Upstream	1.06	1.43	1.17	1.56	1.20	1.49	1.27	1.61
Upstream (power)	0.19	0.45	0.31	0.54	0.19	0.45	0.31	0.54
Direct Emissions	0.75	6.20	3.10	7.68	0.75	6.20	3.10	7.68
Downstream transp.	0.17	0.21	0.18	0.22	0.17	0.21	0.18	0.22
Upstream transp.	0.03	0.05	0.04	0.05	0.03	0.05	0.04	0.05
Naphtha to Olefin	0.00	0.00	0.00	0.00		0.00	0.00	0.00
Share to olefins	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27
share to fuel	1.97	1.97	1.97	1.97	1.97	1.97	1.97	1.97
Total	**4.43**	**10.58**	**7.04**	**12.29**	**4.57**	**10.64**	**7.14**	**12.34**

Upstream Emission Rates	1.46% KMMEF	1.46% RC	1.46% LCC	1.46% HCC	3% KMMEF	3% RC	3% LCC	3% HCC
Upstream	1.45	1.60	1.44	1.69	2.25	1.94	1.98	1.96
Upstream (power)	0.19	0.45	0.31	0.54	0.19	0.45	0.31	0.54
Direct Emissions	0.75	6.20	3.10	7.68	0.75	6.20	3.10	7.68
Downstream transp.	0.17	0.21	0.18	0.22	0.17	0.21	0.18	0.22
Upstream transp.	0.03	0.05	0.04	0.05	0.03	0.05	0.04	0.05
Naphtha to Olefin	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Share to olefins	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27
share to fuel	1.97	1.97	1.97	1.97	1.97	1.97	1.97	1.97
Total	**4.82**	**10.74**	**7.31**	**12.42**	**5.62**	**11.08**	**7.85**	**12.69**

3.6.4 Sensitivity related to the pace of recession recovery

This sensitivity analysis also addresses the pace of the current COVID-19 recession recovery. If the recession recovers slowly, global demand for methanol will likely drop below 98 MMT for a few years, but then recover to grow after 2030. The medium recovery pace suggests that growth above the 2019 98 MMT would resume in 2023, while the fast pace projects growth beyond the 98 MMT level commencing in 2021. In the ESM, the recession recovery pace only affects the alternative cases, because it could influence the mix of methanol sources that would occur absent KMMEF.

The ESM KMMEF emissions on the other hand are not expected to be different depending on the recession recovery. But in response to the recession recovery, the alternate cases are expected to be slightly different. Specifically, the pace of global demand affects the pace of the market increase and therefore the pace with which the Chinese market is expected to increase production of coal-based methanol. In the early years, if the recovery is slower, then KMMEF is still expected to substitute for coal-based methanol and will do so for a longer period during lifetime of the project. If the recovery on the other hand is fast, KMMEF will be replacing coal-based methanol in the market for about 20 years, but then is more rapidly expected to be substituting for market share that would otherwise be supplied by other imported methanol, based primarily on natural gas as a feedstock, and therefore emitting fewer GHG emissions.

Figure 3.6-4 shows how the pace of the recession would affect results under the three-alternative case. For the RC, there is a greater net average annual GHG impact under a slow recovery scenario, leading to a greater difference between KMMEF and the RC. A faster recovery leads to smaller RC emissions and less difference between KMMEF and the RC. The average annual reduction in expected GHG attributable to the KMMEF project will be slightly smaller over the 40-year period because coal-based methanol from China phases out sooner in a faster recovery. Thus, KMMEF will be replacing less coal in the market in a fast COVID recovery scenario than in a slow recovery.

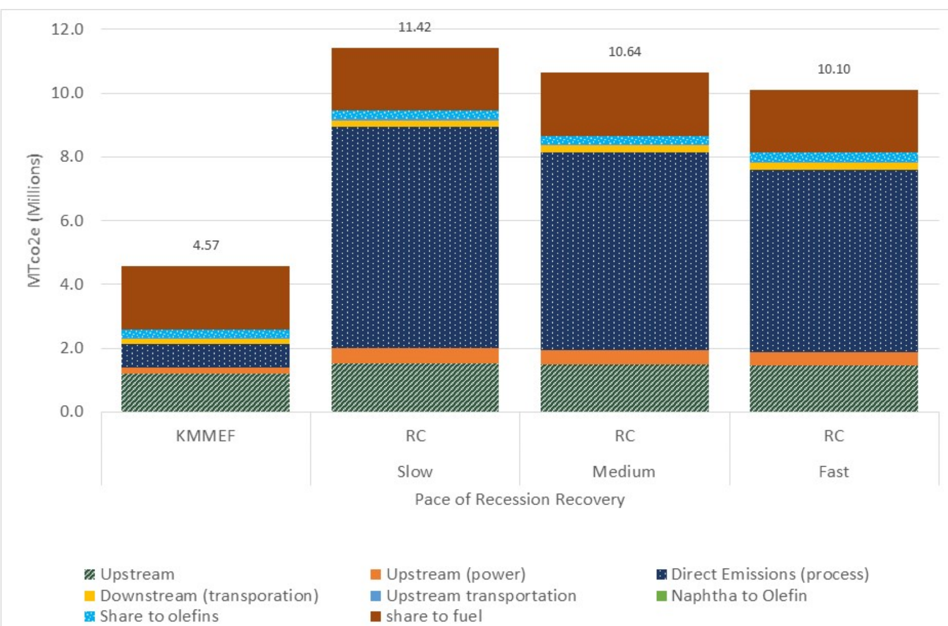

Figure 3.6-4. Average Annual Lifecycle GHG Emissions for KMMEF and the RC Under Varying Paces of Recovery from COVID -19 Recession, 2020 – 2059

Additional combinations of the uncertain recession recovery and the alternate cases (including now the LCC and the HCC) are shown in Table 3.6-6. Similar patterns emerge, showing that in general, a slower recovery implies a greater share of coal-based methanol produced in the alternate cases, and therefore higher emissions compared with the emissions from a faster recovery.

Table 3.6-6. Average Annual Lifecycle GHG Emissions (MMT CO_2e/year) for KMMEF and the Alternate Cases Under Varying Paces of Recovery from COVID -19 Recession, 2020 – 2059

Recession Recovery Rate	KMMEF	Slow RC	Slow RC LCC	Slow RC HCC	Medium RC	Medium LCC	Medium HCC	Fast RC	Fast LCC	Fast HCC
Upstream	**1.20**	1.53	1.27	1.67	1.49	1.27	1.61	1.46	1.26	1.57
Upstream Power	**0.19**	0.47	0.30	0.57	0.45	0.31	0.54	0.43	0.30	0.51
Direct Emissions	**0.75**	6.93	3.43	8.59	6.20	3.10	7.68	5.72	2.94	7.03
Downstream transp.	**0.17**	0.21	0.18	0.23	0.21	0.18	0.22	0.21	0.18	0.22
Upstream transp.	**0.03**	0.05	0.03	0.05	0.05	0.04	0.05	0.04	0.04	0.05
Naphtha to Olefin		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Share to olefins	**0.27**	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27
share to fuel	**1.97**	1.97	1.97	1.97	1.97	1.97	1.97	1.97	1.97	1.97
Total	**4.57**	**11.42**	**7.45**	**13.35**	**10.64**	**7.14**	**12.34**	**10.10**	**6.95**	**11.62**

3.6.5 Sensitivity related to oil prices

This sensitivity analysis also considers the potential effects of changes in oil prices between 2020 and 2030. The potential for oil prices to increase, decrease, or stay the same is modeled in the ESM as affecting just the alternate cases, and not KMMEF. This follows the same reasoning behind the recession recovery affect – that changes in the global market will have an impact on the emissions expected to occur in the alternate cases absent KMMEF – while KMMEF emissions are not expected to change as a result of a changed oil price. With increasing oil prices, the demand for methanol increases sooner, as naphtha-to-olefins conversion becomes more expensive. In this instance, a small amount of naphtha is replaced by KMMEF, because the increased demand for methanol stems from foregone naphtha-based olefin production that derived from the increase in oil price. Because emissions for naphtha are at the lower end of the alternate emission pathways (see Table 3.5-10), RC emissions are now slightly lower than if there is no oil price change.

Conversely, if oil prices go down, demand for methanol would decline, as MTO producers turn toward naphtha to produce olefins. However, in this case also, emissions from the RC increase because the conversion away from coal-based methanol happens later in the project life than it would otherwise. The results of an increase or decrease in oil price is shown in Figure 3.6-5. Additional results for the LCC and HCC are shown in Table 3.6-7 and show a similar pattern as the RC.

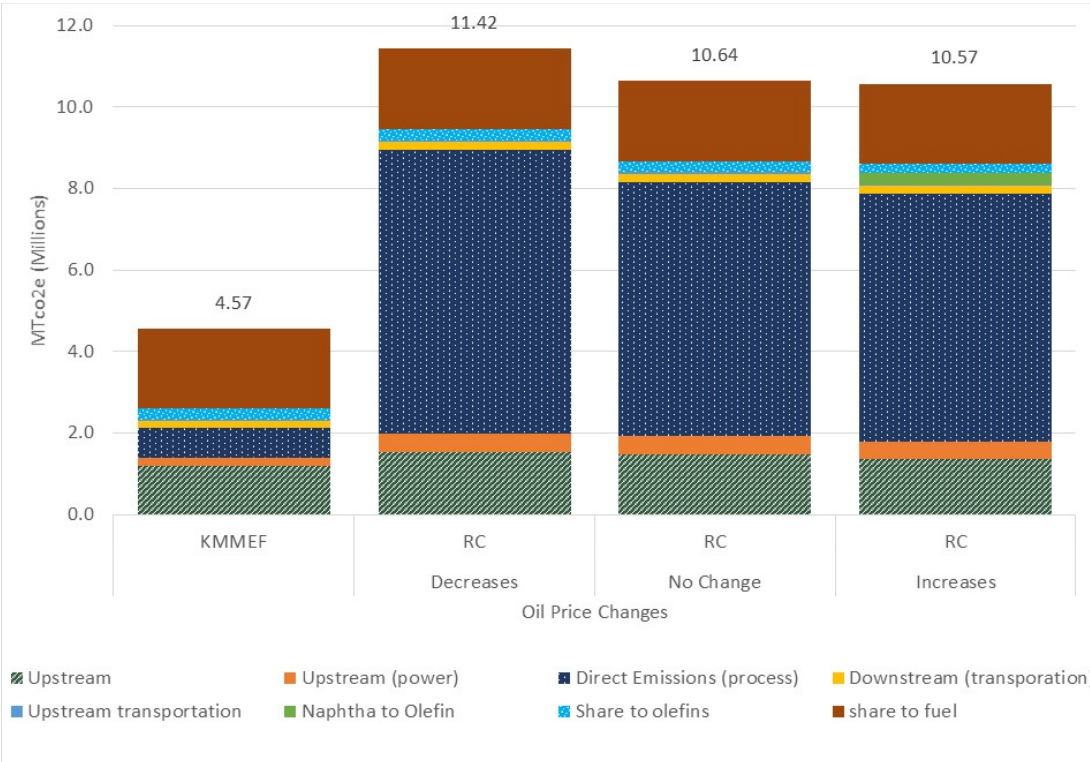

Figure 3.6-5. Average Annual LCA GHG Emissions for Three RC Scenarios Under Different Assumptions about the Price of Oil in 2030, 2020 – 2059

Table 3.6-7. Average Annual Lifecycle GHG Emissions for KMMEF and the Alternate Cases Under with Assumed Decrease, No Change, and Increase in 2030 Oil Price

Oil Prices	KMMEF	↓ RC	↓ LCC	↓ HCC	— RC	— LCC	— HCC	↑ RC	↑ LCC	↑ HCC
Upstream	1.20	1.53	1.27	1.67	1.49	1.27	1.61	1.37	1.15	1.49
Upstream power	0.19	0.47	0.30	0.57	0.45	0.31	0.54	0.42	0.28	0.51
Direct Emissions	0.75	6.93	3.43	8.59	6.20	3.10	7.68	6.09	2.99	7.56
Downstream transp.	0.17	0.21	0.18	0.23	0.21	0.18	0.22	0.19	0.16	0.20
Upstream transp.	0.03	0.05	0.03	0.05	0.05	0.04	0.05	0.04	0.03	0.05
Naphtha to Olefin		0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.27	0.27
Share to olefins	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.23	0.23	0.23
share to fuel	1.97	1.97	1.97	1.97	1.97	1.97	1.97	1.97	1.97	1.97
Total	**4.57**	**11.42**	**7.45**	**13.35**	**10.64**	**7.14**	**12.34**	**10.57**	**7.07**	**12.28**

↓ = Decreases
— = No Change
↑ = Increases

3.6.6 ESM limitations

The ESM was developed to afford a full range of input options to maximize its flexibility for sensitivity analysis. However, some input value options are determined to be implausible. For example, although the ESM allows each of the alternative pathways for methanol production to be varied from 0 percent to 100 percent, this range is far larger than is plausible for most pathways. Additionally, available emissions information is limited for some pathways, limiting the comparisons that can be drawn between the KMMEF and alternate case scenarios.

ESM limitations and input options that are considered implausible include:

- While all pathways for methanol production can be varied between 0 percent and 100 percent in the ESM, it is highly unlikely that there would be little to no coal production substitution in any alternate cases (see Section 3.5.2).
- The portion of any alternate case that could be provided by Chinese natural gas-based methanol is limited. It would not be economic to meet expanding methanol demand in China with increased natural gas-based methanol in China because this is the highest cost methanol to produce.
- The portion of the alternate case that could be provided by Chinese natural gas-based methanol is also limited by government policy. In 2012, the Chinese government prohibited any expansion of natural gas-based methanol production (see Section 3.5.1.4).

- Emissions from the methanol import pathway are heavily influenced by the technologies currently used by these importers to produce methanol. The bulk of the emissions arising from imports derives from the direct emissions during methanol production. Since the majority of the 29 methanol-producing facilities evaluated in this study use combined reforming to produce methanol, the direct emissions from these facilities are assumed to be equivalent (per MT of methanol produced) to the emissions from the combined reforming alternative presented in the First SEIS (see Section 3.4.4.2).
- When a high upstream methane emission rate (3 percent) is paired with the 20-year GWP parameters, a large impact on emissions can result for the natural gas substitution pathway in China. This appears to be an artifact of limited information on upstream emissions attributable to the China natural gas pathway.

While there have been a significant number of studies evaluating methane emissions from natural gas production in North America, there are fewer reliable estimates of the emissions that result from natural gas production in China or other parts of the world. It is generally believed that upstream methane emissions vary as a function of several factors, including the method used for natural gas extraction; the design and condition of the equipment used to extract, process, and transport natural gas; and the diligence with which natural gas producers control leaks or upset conditions that may occur. However, this understanding of the general conditions that influence upstream methane emissions does not necessarily translate into reliable emission estimates. In the absence of a clear indication as to whether emissions from natural gas production in North America are greater than or less than emissions that occur in another part of the world, this study assumes that greenhouse gas emissions from other natural gas producing, exporting nations are equivalent to the greenhouse gas emissions selected for the KMMEF; therefore, increasing the methane emission rate for KMMEF also is reflected in the methanol import pathway within alternate cases.

Nevertheless, GHG emissions estimated in this study for the China natural gas pathway are not tied to the upstream methane rate selected for the KMMEF. Data from the literature indicates a narrow range of life cycle emission for the China natural gas-based methanol production pathway (Table 3.5-6). Although being in a narrow range, the literature review from the three studies did not provide clear information on upstream leakage data. Because information available for the China natural gas pathway is not detailed enough to calculate the upstream methane emission rate or the upstream portion of the emissions to be varied as part of the sensitivity study, this study concluded that the upstream portion of the emissions of China natural gas-based methanol production should not rely on the upstream emissions of KMMEF. Therefore, when upstream methane emissions are adjusted in the ESM, upstream emissions are applied to international exporters at the same level, but not to the China natural gas pathway. As a result, methane emissions for the China natural gas pathway may be underestimated in comparison to KMMEF, especially at high upstream methane rates. When higher methane emission rates are coupled with the 20-year GWP values for methane (72 for AR4 and 84 for AR5) rather than the 100-year GWP values (25 for AR4 and 28 for AR5), the difference in methane emissions becomes magnified (calculated as CO_2e). Thus, there is limited flexibility in the ESM to conduct a sensitivity analysis of China natural gas-based methanol because upstream methane emissions for this pathway is fixed and does not depend on the leakage rate assigned to KMMEF.

3.6.7 Outlier sensitivity cases

Two scenarios, each with a unique new alternate case to describe the expected methanol production absent KMMEF and differing ESM inputs, were developed to illustrate potential outliers in terms of emission values that would be unlikely but plausible. These two scenarios do not represent the extremes of what the ESM is able to predict. Rather, although some inputs for these two scenarios may be unlikely, they represent the range of what this analysis concludes is plausible.

3.6.7.1 Outlier Sensitivity Case 1 (OS1)

In this case, 100 percent of methanol would be supplied by imports absent KMMEF. As noted in Section 3.5.3, our analysis concludes that this amount of substitution from imports is unlikely. However, imports provide a sufficiently large source of methanol that could plausibly meet future methanol demand in China. This scenario also compares KMMEF to its most similar competitors. The remaining ESM inputs under Outlier Sensitivity Case 1 include:

- Recession Recovery is set to “slow”
- Price of oil is expected to increase by 2030
- Upstream methane emissions are set to 3 percent of natural gas supplied
- AR5 20-year values are used for GWP values
- The end use distribution for methanol is 60 percent for olefins and 40 percent for fuel

The ESM results for this scenario are provided below in Figure 3.6-6 and in Table 3.6-8.

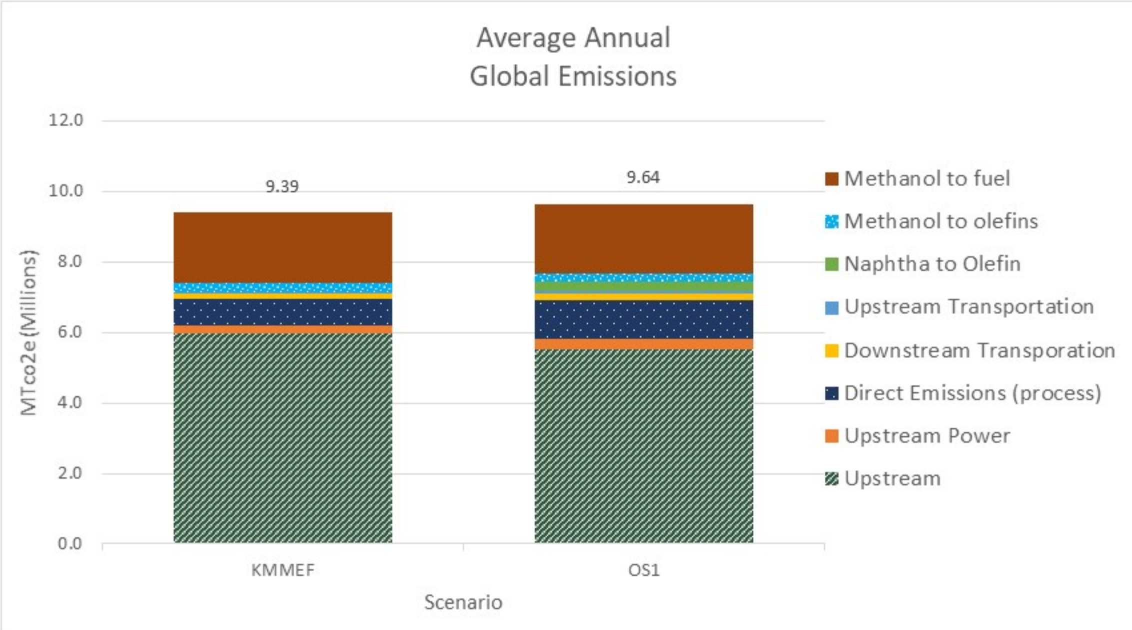

Figure 3.6-6. Average Annual Emissions from KMMEF and OS1, with Imports Supplying 100% of Chinese Methanol Absent KMMEF

Table 3.6-8. Emission Values from KMMEF and OS1, with Imports Supplying 100% of Chinese Methanol Absent KMMEF

Comparing Global Emissions	KMMEF	OS1	DMMEF minus OS1	Change as % of OS1
Initial Emission	9.39	9.98	-0.6	-6%
Average Annual Emission	9.39	9.64	-0.2	-3%
40-year Emission	376	386	-10	-3%

As shown in Figure 3.6-6 and Table 3.6-2, average annual emissions for the KMMEF are 9.4 $MMTCO_2e$, with the bulk derived from upstream methane emissions. For OS1, average annual emissions are 9.6 $MMTCO_2e$, a value only slightly higher than for the KMMEF. The higher direct emissions under OS1 are due to the import pathway, which is based on the combined reforming (the most common technology currently used for producing methanol globally). As noted above, combined reforming has higher GHG emissions than the KMMEF technology (ULE). Upstream methane emissions under OS1 are also lower than under the KMMEF. This result is driven by the assumption that the price of oil increases over time. The increasing price of oil shifts a portion of the olefins produced in OS1 to naphtha feedstock rather than a methanol source. This means that, over time, imports begin to supply less methanol than the KMMEF, to which it is compared, artificially reducing the comparative emissions of the imports.

3.6.7.2 Outlier Scenario 2 (OS2)

In this scenario, 100 percent of the alternative case methanol is initially provided by the coal pathway. This assumption is similar to the First SEIS. The remaining ESM inputs that are part of OS2 include:

- Recession Recovery is set to "medium"
- Price of oil is expected to increase by 2030
- Upstream methane emissions are set to 0.97 percent of natural gas supplied
- The AR4 100-year values are used for GWP
- The distribution of end use for methanol is 100 percent for olefins and 0 percent for fuel

The ESM results for this scenario are provided below in Figure 3.6-7 and in Table 3.6-9.

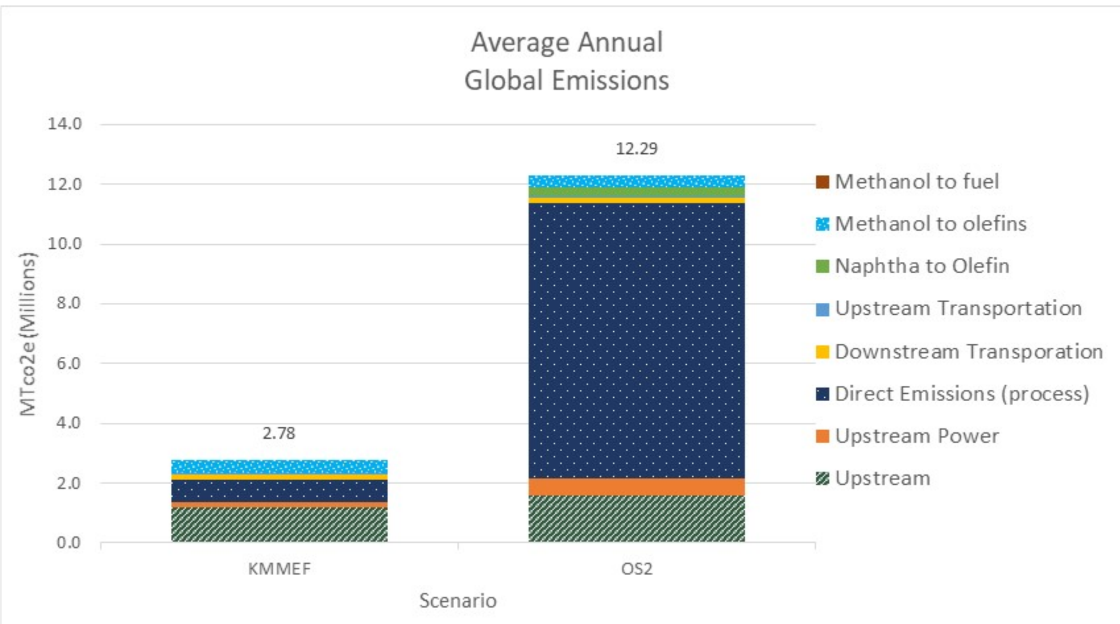

Figure 3.6-7. Average Annual Emissions from KMMEF and OS2, with the Coal-based Pathway Supplying 100% of the Market

Table 3.6-9. Emission Values Corresponding to Results Presented in Figure 3.6-6

Comparing Global Emissions	KMMEF	OS2	KMMEF minus OS2	Change as % of OS2
Initial Emission	2.78	14.15	-11.4	-80%
Average Annual Emission	2.78	12.29	-9.5	-77%
40-year Emission	111	492	-380	-77%

As shown in Figure 3.6-7 and Table 3.6-9, average annual emissions for the KMMEF are 2.8 $MMTCO_2e$, as compared to 12.3 $MMTCO_2e$ for the OS2 (in which the bulk of the emissions result from the direct production of methanol from coal). This reflects the significantly higher emissions associated with the coal-based methanol pathway. The difference in emissions between the KMMEF and the OS2 based on coal-based methanol production yields a result similar to that presented in the First SEIS.

3.6.8 Summary of sensitivity study results

All ESM results using plausible input values demonstrate that the KMMEF is expected to result in less GHG emissions increases than the alternate cases. Gross annual average emissions from KMMEF vary from 2.8 to 9.4 MMTCO_2e in the sensitivity scenarios that have been evaluated, compared to gross annual average emissions from the alternate cases that vary from 9.6 to 12.3 MMTCO_2e. Most of the sensitivity analyses show that the KMMEF results in less annual average emissions of between 2 and 9 MMTCO_2e as compared to the alternate cases.

These results indicate that the KMMEF would slow the global increase in emissions arising from methanol production and use. This report analyzes the GHG impacts of KMMEF in the context of a growing methanol market.

This does not address the question of whether a growing methanol market results in an overall increase or decrease in global GHG emissions when other sectors of the global economy are considered. It is plausible that a global increase in methanol use could have an impact on other sectors of the global economy, such as the plastics market or the fuels market, and thus result in either a relative increase or decrease in emissions. One analysis of the petrochemicals industry future conducted by the International Energy Agency argues that the increasing use of methanol reduces GHG as compared to a reference scenario in which substitute inputs are used for making plastics (IEA 2018). A broader evaluation of the growing methanol market within the context of the entire global economy was not evaluated as part of our study and is beyond the scope of the analysis in this SEIS. Neither does this analysis consider the possibility of new policies or market shifts to occur in the markets for fossil fuels or plastics. For example, a ban or phase-out of those products could have results that would alter the assessed impacts of the KMMEF.

3.7 Significant impacts and mitigation

Ecology has determined that the total in state greenhouse gas (GHG) emissions that are directly or indirectly attributable to the Northwest Innovation Works (NWIW) Kalama methanol facility are significant and capable of being mitigated. In state emissions include:

- Construction Emissions
- Decommissioning Emissions
- Onsite Direct Operations Emissions
- Transportation Emissions (in state)
- Upstream Natural Gas (in state)
- Purchased Power Supply (electricity used in state)

GHG emissions occurring within Washington State from the sources listed above are estimated to be between 786,117 and 1,421,748 MT CO_2e per year. Additional details regarding in-state emissions are presented in Section 3.5.4. The project owner, NWIW, has proposed a framework Appendix D to account for and mitigate 100 percent of these direct and indirect greenhouse gas emissions on an annual basis for the life of the project, which is expected to be 40 years. The full mitigation framework can be found as Appendix D of this Second SEIS document.

The emission reduction obligation proposed under the framework would be established by methods used, or consistent with, the existing Washington greenhouse gas reporting program (WAC 173-441). Where appropriate, alternative methods may be used for emissions not originally covered in the reporting program, subject to Ecology's approval. This ensures all emissions subject to mitigation are reported and verified to Ecology's standards.

In summary, the mitigation framework would establish an annual greenhouse gas emission reduction obligation equal to emissions as determined by Ecology's GHG reporting rule, to the extent possible. An implementation board consisting of community, tribal, environmental and government members would solicit and recommend a set of projects to meet the annual emission reduction obligations. A budget to fund the mitigation projects would be created by multiplying the total required emissions reductions by the average price of allowances in US carbon markets in a given year.

Priority would be given to local projects, expanding out statewide or regionally if needed. The mitigation portfolio or projects would attempt to maximize these local and regional projects. If the emission reduction obligation cannot be met with local and regional projects within the budget, the board will look to purchasing credits through established national or international carbon markets as a last resort to fill out the remainder of the project portfolio. Priority would also be given to projects in economically distressed areas and communities disproportionately affected by climate change.

Emissions reductions attributable to projects would have to be real, permanent, verifiable and additional as those criterial are commonly used and defined in established carbon markets.

The requirement to meet this mitigation plan would remain in effect through the life of the project, unless a state or federal program becomes active that would also require coverage of some or all of the affected emissions. In this case the mitigation obligation would be reduced in proportion to the emissions reduction requirement of the new government greenhouse gas program.

Ecology and Cowlitz County would sign off on and have oversight of the mitigation plan and projects.

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Appendix A:
Upstream and Substitute Emissions

Introduction

This appendix provides detailed calculations for emission sources that were evaluated as part the GHG Emissions Analysis. Emissions detailed in this appendix include:

- Upstream emissions associated with natural gas to be used by the KMMEF
- Emissions from the following alternate methods of methanol production:
- China coal-based methanol
    - China natural gas-based methanol
    - Imports of methanol to China
- Life cycle emissions of oil to naphtha to olefin production
- Emissions from the following potential end uses of KMMEF methanol:
    - Olefins
    - Fuel

Upstream emissions

Detailed calculations for the low, mid, and high scenarios for calculating upstream emissions associated with natural gas supplied to the KMMEF are provided in the tables below.

Table A-1. Constants Used for Upstream Emissions

Constants	Unit	Source
Gas usage rate (mmBTU/MT MeOH)	29.6	Table 3.12, Appendix A, First SEIS
Methanol production (MMT/year)	3.6	Executive Summary, Appendix A, First SEIS
Gas heat content (BTU/lb)	23,180	Table 3.7, Appendix A, First SEIS

Table A-2. Low Emissions Scenario

Baseline Scenario from First SEIS

Natural Gas source is 99.4% British Columbia and 0.6% Rocky Mountain

BC Natural Gas (g/mmBtu) HHV Processing Step	CO_2 Emissions	CH_4 Emissions	N_2O Emissions	CO_2e[2] Emissions
Natural Gas Extraction	2,080	23	0.1	2,685
Fugitive Emissions	997	104	0	3,597
Natural Gas Processing	2,100	9	0.04	2,337
Transmission	1,077	2	0.009	1,130

North American Natural Gas (g/mmBtu) HHV Processing Step	CO_2 Emissions	CH_4 Emissions	N_2O Emissions	CO_2e[2] Emissions
Natural Gas Extraction	2,127	142	0.019	5,683
Natural Gas Processing	2,368	6	0.013	2,522
Transmission & Storage	1,651	42.3	1.3	3,096

TOTALS	CO_2 Emissions	CH_4 Emissions	N_2O Emissions	CO_2e[2] Emissions
Total (g/mmBtu)	6,253	138	0.14	9,745
Total (kg/MT NG)	320	7.1	0.007	500
Total (kg GHG/MT MeOH)[1]	185	4.1	0.004	289
Total (MT GHG/MT MeOH)	0.1851	0.0041	0.000004	0.289
Total (MMT GHG/year)	0.67	0.01	0.000014	1.04
MT CH_4/MT natural gas (%)	-	0.71	-	-

1. Emission factors from Table 3.9, Appendix A, First SEIS, from GHGenius
2. CO_2e calculated using 100-year AR4 GWP values.

Table A-3. Medium Emissions Scenario

North American Source for Natural Gas

Processing Step	CO_2 Emissions	CH_4[2] Emissions	N_2O Emissions	CO_2e Emissions
Natural Gas Extraction (g/mmBtu) HHV[1]	2,127	142	0.019	5,683
Natural Gas Processing (g/mmBtu) HHV[1]	2,368	6	0.013	2,522
Transmission & Storage (g/mmBtu) HHV[1]	1,651	42.3	1.3	3,096
Total (g/mmBtu)	6,146	190	1	11,300
Total (kg/tonne NG)	314	10	0.07	578
Total (MT GHG/MT MeOH)	0.1815	0.0056	0.0000	0.334
Total (MMT GHG/year)	0.65	0.02	0.000	1.20
MT CH_4/MT natural gas (%)	-	0.97	-	-

1. "EPA Shale GREET1_2019" emission factor for CH_4 (Burnham 2019). Other emission factors from Table 3.8, Appendix A, First SEIS, from GREET
2. Emission factor for extraction and processing steps includes fugitive emissions.

Table A-4. High Emissions Scenario

North American Source for Natural Gas

Processing Step	CO_2 Emissions	CH_4[2] Emissions	N_2O Emissions	CO_2e Emissions
Natural Gas Extraction (g/mmBtu) HHV[1]	2,127	215.7	0.019	7,525
Natural Gas Processing (g/mmBtu) HHV[1]	2,368	9.6	0.013	2,612
Transmission & Storage (g/mmBtu) HHV[1]	1,651	58.5	1.3	3,501
Total (g/mmBtu)	6,146	284	1	13,638
Total (kg/tonne NG)	314	15	0.07	697
Total (MT GHG/MT MeOH)	0.1815	0.0084	0.0000	0.403
Total (MMT GHG/year)	0.65	0.03	0.000	1.45
MT CH_4/MT natural gas (%)	-	1.46	-	-

1. "EDF Shale GREET1_2019" emission factor for CH4 (Burnham 2019). Other emission factors from Table 3.8, Appendix A, First SEIS, from GREET
2. Emission factor for extraction and processing steps includes fugitive emissions.

China coal-based methanol emissions

The First SEIS calculated GHG emissions for methanol production using China-based coal as a feedstock. The literature review for this Second SEIS yielded values consistent with the emissions presented in the First SEIS, and as a result the production related GHG emission values presented in the First SEIS were adopted for use in the in the current analysis (ESM). The emission values associated with this life cycle step are presented below for the low, preferred, and high ranges. Details on the calculations are presented in Chapter 5 and Appendix B in the First SEIS.

Table A-5. China Coal to MeOH Emissions Summary

Emissions	CO_2 Low	CO_2 Med	CO_2 High	CH_4 Low	CH_4 Med	CH_4 High	N_2O Low	N_2O Med	N_2O High	CO_2e Low	CO_2e Med	CO_2e High
Upstream Processing (MT GHG/MT MeOH)	0.080	0.213	0.224	0.007	0.012	0.012	0.000	0.000	0.000	0.253	0.504	0.530
Upstream Power (MT GHG/MT MeOH)	0.173	0.173	0.236	0.000	0.000	0.000	0.000	0.000	0.000	0.184	0.184	0.184
Process to MeOH (MT GHG/MT MeOH)	2.885	3.029	3.181	0.000	0.000	0.000	0.000	0.000	0.000	2.891	3.035	3.187
Transportation (MT GHG/MT MeOH)	0.076	0.076	0.076	0.000	0.000	0.000	0.000	0.000	0.000	0.082	0.082	0.082
Total (MT GHG/MT MeOH)	3.214	3.491	3.717	0.008	0.012	0.013	0.000	0.000	0.000	3.410	3.805	4.061

China natural gas-based methanol emissions

The FSEIS did not calculate emissions for this substitute methanol production pathway. A literature review was conducted for the Second SEIS, specifically addressing emissions from methanol produced from Chinese natural gas. A single value for these emissions was assigned based on the research by Chen et al. (2019) and used in the ESM. The values presented by Chen et al. (2019) provide a breakdown of emissions by CO_2e, CO_2, CH_4, and N_2O.

Table A-6. China Natural Gas to MeOH Emissions Summary

Emissions	CO_2	CH_4	N_2O	CO_2e
Upstream (MT GHG/MT MeOH)	0.08	0.007	0.0	0.27
Process to MeOH (MT GHG/MT MeOH)	0.82	0.002	0.000007	0.88
Total (MT GHG/MT MeOH)	0.90	0.01	0.000007	1.2

Imports of methanol into China

The FSEIS did not calculate emissions for this substitute methanol production pathway. Analysis considered 29 methanol producers from various parts of the Middle East, North America, Southeast Asia, Africa, and South America. The KMMEF ULE technology is not currently implemented by any other methanol manufacturer and is the driver behind the lower GHG footprint for methanol production by KMMEF, as compared to other producers. Existing methanol importers to China use either CR or steam methane reforming (SMR) to produce methanol from natural gas (see Table A-7 below). SMR is associated with higher GHG emissions than CR. While it is likely that in the future, methanol production globally will move towards lower GHG emitting technologies (CR or ULE), it is not possible at this point to forecast the extent to which this occurs. Therefore, the direct emissions for methanol importers to China conservatively assume that the importer uses CR technology to manufacture methanol rather than either the higher emitting SMR or the lower emitting ULE. The following additional assumptions were used to calculate life cycle GHG emissions from the 29 methanol producers investigated.

- Upstream natural gas: KMMEF's emission rate is applied to other methanol importers. Location-specific data on upstream GHG emissions, including methane emission rates, for methanol importers to China is limited. Literature has shown that there is high degree of uncertainty in the estimates of upstream methane emissions associated with natural gas extraction and processing, especially for foreign manufacturers (Gan et al. 2020). Due to the high uncertainty, the evaluation of upstream GHG emissions for non-KMMEF importers of methanol assumes that their upstream emission is equivalent to the upstream KMMEF emissions on a per MT of methanol produced basis.

- Upstream power: Emissions from power generation were scaled by the ratio of KMMEF electricity emission factors to those of other importers. Emission factors were obtained from the International Energy Agency (IEA) and the U.S. Environmental Protection Agency (USEPA).
- Direct emissions from the conversion of natural gas to methanol: KMMEF utilizes ULE, a technology which has been shown to reduce GHG emissions by as much as 80 percent (Ingram 2017) as compared to combined reforming, and by even more as compared to steam methane reforming. None of the 29 importers considered utilize ULE but rather either combined reforming or steam methane reforming technologies. Calculations from the First SEIS presented ULE as providing a 38 percent reduction in GHG emissions as compared to combined reforming, and that difference in emissions between KMMEF and other importers is adopted in this analysis.
- Transportation: It is assumed that transportation emissions are proportional to travel distances between manufacturers and China. The ratio of transportation distance between an importer and the KMMEF is applied to the transportation emissions of KMMEF.

Table A-7 shows the detailed calculation of emissions for methanol producers. This shows that methanol importers are 1.27 times higher in life cycle emissions than KMMEF (bottom right cell in spreadsheet) and this ratio is integrated into the ESM.

Table A-7. Emissions Summary Per Methanol Producer

Technology	Plant	Region	Estimated Transport Distance to China (kn mi)	Transport Distance Ratio to KMMEF	GHG Electricity EF (kgCO2/KWh)*	GHG Electricity EF Ratio to KMMEF	Capacity (Tonne/Year)	GHG Emission from Upstream NG (kg CO2e/T Methanol)	GHG Emission from Upsteam Power (kg CO2e/T Methanol)	Direct GHG Emission (kg CO2e/T Methanol)	GHG Emission from Downstream (kg CO2e/T Methanol)	Total GHG Emission (kg CO2e/T Methanol)	Upstream NG GHG Emission Weighted based on Capacity (kg CO2e/T Methanol)	Upstream Power GHG Emission Weighted based on Capacity (kg CO2e/T Methanol)	Direct GHG Emission Weighted based on Capacity (kg CO2e/T Methanol)	Downstream Emission and GHG Emission from Downstream Weighted based on Capacity (kg CO2e/T Methanol)	Total GHG Emission Weighted based on Capacity (kg CO2e/T Methanol)
ULE	**KMMEF**	**NA**	**5341**	**1.00**	**0.2166**	**1.00**	**3600000**	**289.00**	**51.50**	**207.60**	**55.00**	**603.10**	-	-	-	-	-
CR	Iran	ME	5910	1.11	0.640	2.95	5000000	289.00	152.17	284.41	60.86	786.44	32.53	17.13	32.02	6.85	88.53
CR	US Gulf Coast	NA	5341	1.00	0.437	2.02	3600000	289.00	103.81	284.41	55.00	732.22	23.42	8.41	23.05	4.46	59.35
CR	Australia	SEA	2838	0.53	0.651	3.01	1800000	289.00	154.79	284.41	29.22	757.42	11.71	6.27	11.53	1.18	30.69
CR	SE Asia-Petronas	SEA	1419	0.27	0.610	2.82	2516000	289.00	145.04	284.41	14.61	733.06	16.37	8.22	16.11	0.83	41.52
CR	Mid East-Zagros PC	ME	5910	1.11	0.640	2.95	3240000	289.00	152.17	284.41	60.86	786.44	21.08	11.10	20.75	4.44	57.37
	Africa-Balance	AF	5676	1.06	0.568	2.62	1100000	289.00	135.05	284.41	58.45	766.91	7.16	3.34	7.04	1.45	18.99
	Atlantic Methanol Equatorial New Guinea	AF	7379	1.38	0.568	2.62	900000	289.00	135.05	284.41	75.98	784.45	5.86	2.74	5.76	1.54	15.89
	Methanex Egypt	AF	8405	1.57	0.460	2.12	1300000	289.00	109.32	284.41	86.55	769.27	8.46	3.20	8.32	2.53	22.51
SMR	SE Asia-Brunei Metanol Co	SEA	1419	0.27	0.755	3.48	884000	289.00	179.39	284.41	14.61	767.42	5.75	3.57	5.66	0.29	15.27
SMR - C	So Am-MHTL-M4	SA	9951	1.86	0.687	3.17	600000	289.00	163.28	284.41	102.47	839.17	3.90	2.21	3.84	1.38	11.34
	Mid East-Salalah Methanol	ME	5910	1.11	0.858	3.96	1296000	289.00	203.93	284.41	60.86	838.20	8.43	5.95	8.30	1.78	24.46
SMR - C	Mid East-Ibn Sina	ME	6465	1.21	0.640	2.95	972000	289.00	152.17	284.41	66.57	792.16	6.32	3.33	6.22	1.46	17.33
	Mid East-Oman Methanol	ME	5910	1.11	0.858	3.96	1134000	289.00	203.93	284.41	60.86	838.20	7.38	5.21	7.26	1.55	21.40
SMR - C	Mid East-Ar Razi	ME	6465	1.21	0.640	2.95	4860000	289.00	152.17	284.41	66.57	792.16	31.62	16.65	31.12	7.28	86.67
	SE Asia-Methanex New Zealand Taranki, Methanex Web site, 2.4 million tonnes	SEA	5676	1.06	0.214	0.99	818000	289.00	50.77	284.41	58.45	682.63	5.32	0.93	5.24	1.08	12.57
	SE Asia Methanex Taranki 2 NZ	SEA	5676	1.06	0.214	0.99	815000	289.00	50.77	284.41	58.45	682.63	5.30	0.93	5.22	1.07	12.53
	SE Asia Methanex Waitara NZ	SEA	5676	1.06	0.214	0.99	815000	289.00	50.77	284.41	58.45	682.63	5.30	0.93	5.22	1.07	12.53
	So Am-Methanex	SA	5301	0.99	0.181	0.83	800000	289.00	42.94	284.41	54.59	670.94	5.21	0.77	5.12	0.98	12.08
SMR - HC	So Am-Supermetanol	SA	9783	1.83	0.203	0.94	900000	289.00	48.16	284.41	100.74	722.31	5.86	0.98	5.76	2.04	14.64
CR	So Am-Methanex-Titan	SA	9951	1.86	0.687	3.17	850000	289.00	163.28	284.41	102.47	839.17	5.53	3.12	5.44	1.96	16.06
SMR - HC	So Am-Metor	SA	9783	1.83	0.203	0.94	1700000	289.00	48.16	284.41	100.74	722.31	11.06	1.84	10.89	3.86	27.64
CR	So Am-Methanex-Atlas	SA	9951	1.86	0.687	3.17	1700000	289.00	163.28	284.41	102.47	839.17	11.06	6.25	10.89	3.92	32.12
SMR - C	So Am-MHTL-M5	SA	9951	1.86	0.687	3.17	1900000	289.00	163.28	284.41	102.47	839.17	12.36	6.98	12.17	4.38	35.90
	No Am-La Porte Methanol	NA	10291	1.93	0.353	1.63	680000	289.00	83.93	284.41	105.97	763.32	4.42	1.28	4.35	1.62	11.69
	No Am-Methanex	NA	5301	0.99	0.181	0.83	2188000	289.00	42.94	284.41	54.59	670.94	14.24	2.11	14.01	2.69	33.05
	No Am Methanex Medicine Hat	NA	5301	0.99	0.181	0.83	600000	289.00	42.94	284.41	54.59	670.94	3.90	0.58	3.84	0.74	9.06
	So Am-MHTL-M3	SA	9951	1.86	0.687	3.17	600000	289.00	163.28	284.41	102.47	839.17	3.90	2.21	3.84	1.38	11.34
	So Am-MHTL-M2	SA	9951	1.86	0.687	3.17	550000	289.00	163.28	284.41	102.47	839.17	3.58	2.02	3.52	1.27	10.39
	So Am-MHTL-M1	SA	9951	1.86	0.687	3.17	300000	289.00	163.28	284.41	102.47	839.17	1.95	1.10	1.92	0.69	5.67
												sum	289.00	129.38	284.41	65.79	768.58
												Ratio to KMMEF	1.00	2.51	1.37	1.20	1.27

Note:
*Obtained from IEA
- = Not Applicable

Methanol feedstock for olefin production

The First SEIS presented GHG emissions for olefin production using both oil-based naphtha and methanol as a feedstock. Upstream and process emission rates used in this analysis, with the exception of the upstream emissions rate of KMMEF methanol, are taken from the First SEIS (based on confirmation of the supporting data). Details of the calculations are presented in Chapter 5 and Appendix E of the First SEIS. Upstream emissions from KMMEF methanol are presented in Chapter 3 of this study. Life cycle emissions for this step are presented in the tables below for CO_2e, CO_2, CH_4, and N_2O, showing the low, preferred, and high ranges. This series of tables includes:

- Table A-8. KMMEF Methanol-Based Olefin Emissions Summary. These are the upstream and process emissions related to the production of KMMEF methanol and subsequent conversion to olefins.
- Table A-9. China Coal to Methanol Based Olefin Emissions Summary. These are the upstream and process emissions related to the production of China Coal-Based Methanol and subsequent conversion to olefins.
- Table A-10. China Natural Gas Methanol Based Olefin Emissions Summary. These are the upstream and process emissions related to the production of China natural gas-Based Methanol and the subsequent conversion to olefins.
- TableA-11. Imported Natural Gas Methanol Based Olefin Emissions Summary. These are the upstream and process emissions related to the import of natural gas-Based Methanol into China and the subsequent conversion to olefins.
- Table A-12. Oil to Naphtha Based Olefin Emissions Summary. These are the upstream and process emissions related to the production of naphtha from crude oil and the subsequent conversion to olefins.

Table A-8. KMMEF Methanol Based Olefin Emissions Summary

Emissions	CO_2 Low	CO_2 Medium	CO_2 High	CH_4 Low	CH_4 Medium	CH_4 High	N_2O Low	N_2O Medium	N_2O High	CO_2e Low	CO_2e Medium	CO_2e High
Upstream (MT GHG/MT Olefin)	1.5	1.5	1.8	0.017	0.017	0.017	0.00002	0.00013	0.00013	1.9	1.9	2.2
Process (MT GHG/MT Olefin)	0.3	0.4	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.4	0.5

Table A-9. China Coal to Methanol Based Olefin Emissions Summary

Emissions	CO_2 Low	CO_2 Medium	CO_2 High	CH_4 Low	CH_4 Medium	CH_4 High	N_2O Low	N_2O Medium	N_2O High	CO_2e Low	CO_2e Medium	CO_2e High
Upstream (MT GHG/MT Olefin)	8.9	9.8	11.1	0.020	0.035	0.038	0.000064	0.000075	0.00025	8.9	10.7	12.2
Process (MT GHG/MT Olefin)	0.3	0.4	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.4	0.5

Table A-10. China Natural Gas Based Methanol Based Olefin Emissions Summary

Emissions	CO_2 Low	CO_2 Medium	CO_2 High	CH_4 Low	CH_4 Medium	CH_4 High	N_2O Low	N_2O Medium	N_2O High	CO_2e Low	CO_2e Medium	CO_2e High
Upstream (MT GHG/MT Olefin)	2.8	2.8	2.8	0.03	0.03	0.03	0.0	0.0	0.0	3.5	3.5	3.5
Process (MT GHG/MT Olefin)	0.3	0.4	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.4	0.5

Table A-11. Imported Natural Gas to Methanol Based Olefin Emissions Summary

Emissions	CO_2 Low	CO_2 Medium	CO_2 High	CH_4 Low	CH_4 Medium	CH_4 High	N_2O Low	N_2O Medium	N_2O High	CO_2e Low	CO_2e Medium	CO_2e High
Upstream (MT GHG/MT Olefin)	2.0	2.0	2.3	0.02	0.02	0.02	0.00003	0.0001	0.0001	2.4	2.4	2.8
Process (MT GHG/MT Olefin)	0.3	0.4	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.4	0.5

Table A-12. Oil to Naphtha Based Olefin Emissions Summary

Emissions	CO_2 Low	CO_2 Medium	CO_2 High	CH_4 Low	CH_4 Medium	CH_4 High	N_2O Low	N_2O Medium	N_2O High	CO_2e Low	CO_2e Medium	CO_2e High
Upstream (MT GHG/MT Olefin)	0.87	0.87	0.87	0.012	0.012	0.012	0.000016	0.000016	0.000016	1.18	1.18	1.18
Process (MT GHG/MT Olefin)	1.14	1.14	1.14	0.0	0.0	0.0	0.0	0.0	0.0	1.14	1.14	1.14

Methanol combustion as a fuel

Regardless of how the methanol fuel is combusted, whether by mobile or stationary sources, emissions are the same. For this study, emissions from methanol combustion primarily consist of CO_2 and the emissions from CH_4 and N_2O are negligible. Therefore, for this study, emission factors from US EPA guidance are suitable, and fuel combustion emission factors are taken from 40 CFR Part 98 Subpart MM, Table MM-1 for the combustion of methanol as a fuel source. The emission factor used in the ESM is 1.37 MT CO_2e/MT methanol combusted.

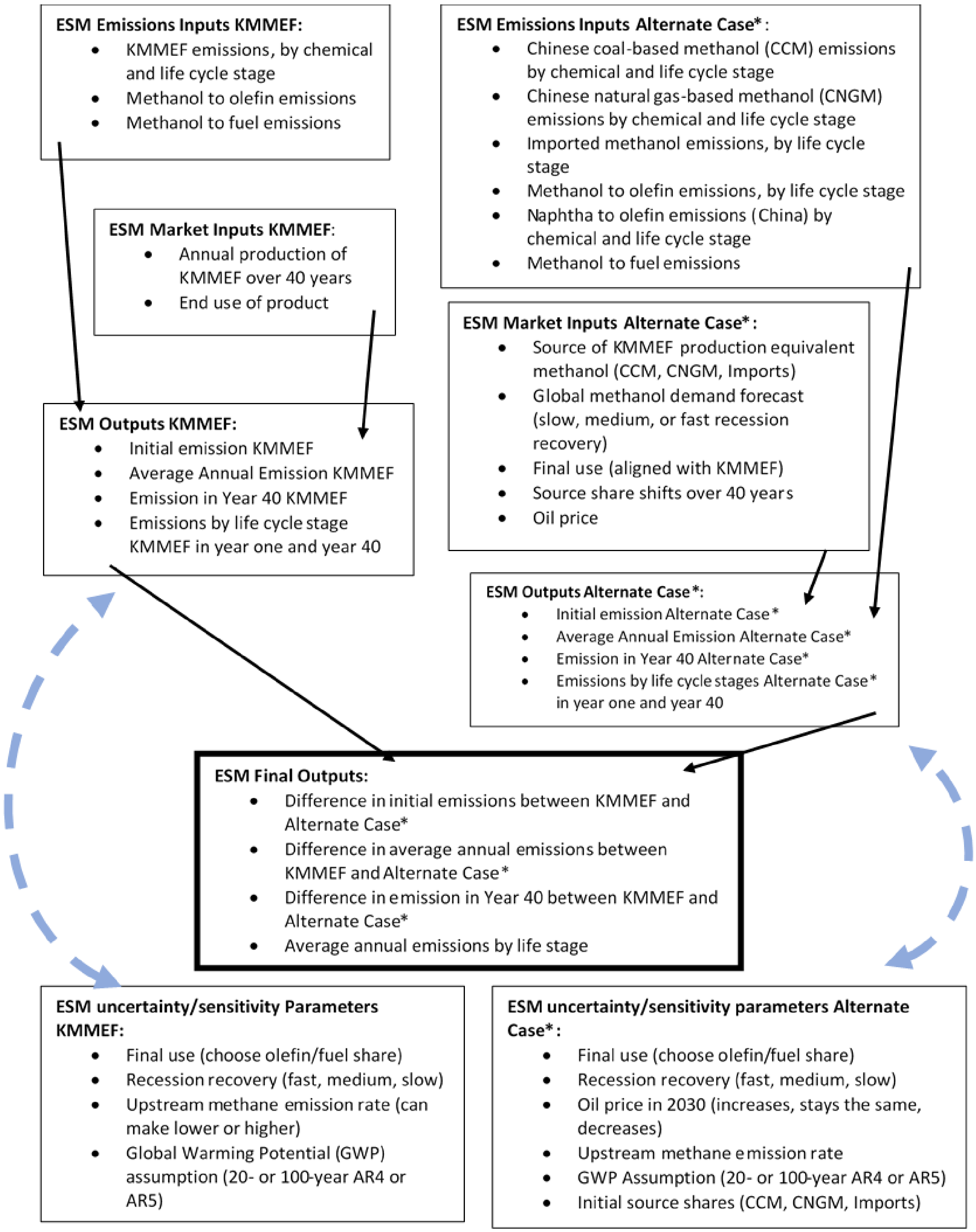
Pt. 98, Subpt. MM, Table MM–2 **40 CFR Ch. I (7–1–13 Edition)**

Products	Column A: density (metric tons/ bbl)	Column B: carbon share (% of mass)	Column C: emission factor (metric tons CO_2/bbl)
Oxygenates			
Methanol	0.1268	37.48	0.1743

Emission sensitivity model (ESM)

The ESM sums emissions for KMMEF and for alternate cases, using emissions from all methanol production pathways and methanol end uses evaluated in this study as inputs. All ESM inputs are normalized units of per metric ton of methanol produced. In cases where olefin production is the end use, olefin to feedstock yields are applied to convert the emissions to units of per metric ton of methanol.

Figure A-1 below illustrates the inputs and outputs used in the ESM. At the top on the left side, there are two boxes showing the emissions input assumptions and the economic input assumptions surrounding KMMEF production. On the right side at the top are emissions and economic inputs to the ESM calibrated for the alternative cases. Each of these feed into estimates of emissions outputs for KMMEF on the left and for the alternative cases shown on the right. In the middle of the page is a box that shows the actual ESM results which compare KMMEF emissions with alternative case emissions to produce a net emission estimate. At the bottom of the figure, options for exploring the sensitivity of the results to alternative input assumptions are shown. On the left are options for changing KMMEF input assumptions and on the right are options for changing alternative case assumptions.



*The Alternate Case includes 3 sets of alternate parameters in the absence of KMMEF. Reference Case (RC) includes our best estimate of parameters; Low Coal Case (LCC) includes a lower mix of coal in the production of olefins; and High Coal Case (HCC) includes a higher mix of coal in the production of olefins.

Figure A-1. Illustrative Depiction of ESM Inputs, Outputs, and Variables

Equations of the methanol pathways and end uses within the ESM are as follows:

Emissions related to methanol supply (including China based coal to methanol, China based natural gas to methanol, and non KMMEF imports of methanol into China).

China Methanol Production/Import (CCM) – Emissions related to methanol supply into China relative to 3.6 MMT (throughput of KMMEF methanol). This represents the emissions of China supply of methanol that could potentially be substituted for KMMEF methanol. The percentage of methanol from China based coal, China based natural gas, and imports of non KMMEF methanol into China vary and represent different alternative case scenarios. Specific alternative cases are addressed in Section 3.4.7.2.

Equation A

$$\left[(\%\ China_{Coal})\left(LCA_{Coal}, \frac{MTCO_2e}{MTMeOH}\right) + (\%\ China_{NG})\left(LCA_{NG}, \frac{MTCO_2e}{MTMeOH}\right) + (\%\ non\ KMMEF_{import})\left(LCA_{import}, \frac{MTCO_2e}{MTMeOH}\right)\right] \times 3{,}600{,}000\ MTMeOH\ from\ KMMEF$$

$\%\ China_{Coal}$ – Percent of methanol from China based coal

LCA_{Coal} – Life cycle GHG emissions from coal to methanol (MT CO_2e per MT MeOH)

$\%\ China_{NG}$ – Percent of methanol from China based natural gas

LCA_{NG} – Life cycle GHG emissions from natural gas to methanol (MT CO_2e per MT MeOH)

$\%\ non\ KMMEF_{import}$ – Percent of methanol from non-KMMEF imports

LCA_{import} – Life cycle GHG emissions from non-KMMEF imports (MT CO_2e per MT MeOH)

3,600,000 – Represents the emissions impact of introducing 3,600,000 MT of KMMEF based methanol into the Chinese methanol market (MT MeOH)

Emissions related to methanol to olefins.

Emissions of methanol to olefins – Emissions related to the use of KMMEF methanol as a feedstock for olefins.

Equation B

$$\left[(\%\ to\ Olefins)\left(Process\ of\ MeOH\ to\ Olefin, \frac{MTCO_2e}{MT_{Olefin}}\right)\left(\frac{1\ MT_{Olefin}}{3\ MTMeOH}\right)(3{,}600{,}000\ MTMeOH\ from\ KMMEF)\right]$$

$\%\ to\ Olefins$ – Percent of methanol derived from KMMEF used as feedstock for olefin production

$Process\ of\ MeOH\ to\ Olefin$ – GHG emissions from converting methanol to olefin (MT CO_2e per MT olefin)

$\frac{1\ MT_{Olefin}}{3\ MTMeOH}$ – Yield converting methanol to olefin

3,600,000 – Represents the emissions impact of introducing 3,600,000 MT of KMMEF based methanol into the Chinese methanol market (MT MeOH)

Emissions related to methanol as fuel.

Emissions of methanol as a fuel – Emissions related to the combustion of KMMEF methanol as a fuel.

Equation C

$$\left[(\%\ to\ Fuel)\left(Combustion\ of\ MeOH\ as\ Fuel, \frac{MTCO_2e}{MTMeOH}\right)(3{,}600{,}000\ MTMeOH\ from\ KMMEF)\right]$$

$\%\ to\ Fuel$ – Percent of methanol derived from KMMEF used as fuel

$Combustion\ of\ MeOH\ as\ Fuel$ – GHG emissions from using methanol derived from KMMEF as fuel (MT CO_2e per MT MeOH)

$3{,}600{,}000$ – Represents the emissions impact of introducing 3,600,000 MT of KMMEF based methanol into the Chinese methanol market (MT MeOH)

Emissions related to naphtha-based olefin production.

Emissions from naphtha-based olefin that could potentially replace KMMEF methanol-based olefins.

Equation D

$$\left(LCA, oil\ to\ naphtha, \frac{MTCO_2e}{MT_{Olefin}}\right) \times (\%\ of\ naphtha\ based\ olefin\ replacing\ KMMEF\ MeOH\ based\ olefin) \times \left(\frac{1\ MT_{Olefin}}{3\ MTMeOH}\right) \times (3{,}600{,}000\ MTMeOH\ from\ KMMEF)$$

$LCA, oil\ to\ naphtha$ – Life cycle GHG emissions from oil to naphtha (MT CO_2e per MT olefin)

$\frac{1\ MT_{Olefin}}{3\ MTMeOH}$ – Yield converting methanol to olefin

$3{,}600{,}000$ – Represents the emissions impact of introducing 3,600,000 MT of KMMEF based methanol into the Chinese methanol market (MT MeOH)

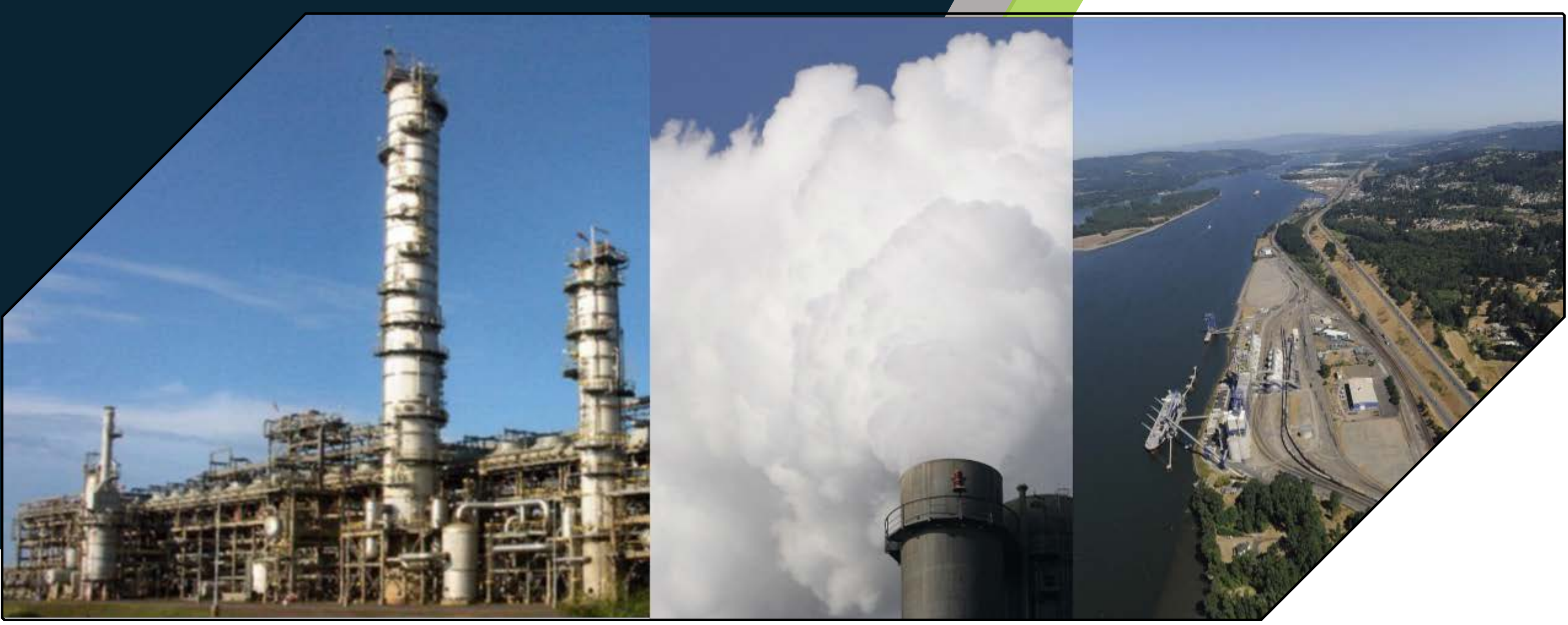
Appendix B:
Analysis of Methanol Markets for Kalama Manufacturing and Marine Export Facility Greenhouse Gas Impact Analysis

Greene Economics LLC

Email: ggreene@greeneeconomics.com

Website: www.greeneeconomics.com

Analysis of Analysis of Methanol Markets for Kalama Manufacturing and Marine Export Facility Greenhouse Gas Impact Analysis
(*Preliminary Draft*)



Prepared for: Department of Ecology

GREENE ECONOMICS

Analysis of Methanol Markets for Kalama Manufacturing and Marine Export Facility Greenhouse Gas Impact Analysis
(*Preliminary Draft*)

Prepared for

Department of Ecology
Air Quality Program
P.O. Box 47600
Olympia, WA 98504-7600

Prepared by

Greene Economics LLC
3316 NW 289th Street
Ridgefield, WA 98642

August 27, 2020

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Executive Summary

This analysis provides the economic reasoning behind the methanol market emissions analysis conducted as part of the second supplemental environmental impact statement (SEIS) for the Kalama Manufacturing and Marine Export Facility (KMMEF). The conclusions of this analysis cover three distinct topics. The first is a review of the previous research. The second is a general overview of global methanol markets and trends in those markets. The third topic relates to what would happen in the global, and Chinese methanol markets if the facility at Kalama does not go into methanol production as proposed.

PREVIOUS RESEARCH

- The first SEIS produced a supply curve for methanol production in China by estimating the marginal costs of methanol producers using different feedstocks throughout China. The supply curve shows that coal-based producers are found along the supply curve, from low-cost producers to higher cost producers.
- The first SEIS static analysis of methanol markets correctly forecasts that high-cost producers in China would likely decrease production with the introduction of the Kalama facility. However, a dynamic analysis of a growing market would suggest that low-cost methanol from Kalama would replace other low-cost Chinese suppliers – those that would be more likely to expand with the growing market.

MARKETS AND TRENDS

- Global methanol use (consumption) stands at 98 million metric tons per year, split approximately into three groups: olefin production, fuel production, and formaldehyde and other chemicals.
- Global methanol demand is increasing rapidly – at over four percent per year, even after adjusting for the 2020 COVID-19 recession. The methanol to olefin (MTO) share of the market is growing the fastest.
- In China, 50 percent of methanol use is for olefin production.
- Global capacity has also grown (especially over the last decade) and exceeds production by more than 50 percent. This means that global supplies are expected to be able to increase to meet the growing demand without constraint.
- The global methanol market has the characteristics of a competitive market. The importance of this conclusion is that it suggests that all future methanol demand will be met by methanol producers at the market clearing price.

CHINESE MARKET WITHOUT KALAMA PRODUCTION

- Chinese methanol supplies are available from coal-based feedstocks, from natural gas-based feedstocks, and from imports.
- Coal-based methanol production in China has been increasing in the last couple of years and is generally more profitable than natural gas-based methanol.
- The rapid increases in demand have resulted in significant price volatility over the past five years as suppliers over- and underestimate anticipated demand increases.

1. Introduction and Background

This report provides supporting information on methanol markets as they pertain to the methodology used in the Second Supplemental Environmental Impact statement (Second SEIS) addressing greenhouse gas emissions from the proposed Kalama Manufacturing and Marine Exporting Facility (KMMEF). This report presents additional information used in developing the Emissions Sensitivity Model (ESM), that calculates how emissions outcomes associated with KMMEF could change under varying assumptions about the economy going forward, methanol market drivers, and using alternative approaches to measuring greenhouse gas (GHG) emissions.

The proposed facility has been under review since 2015, and previous environmental documents have addressed the project and potential impacts. This report provides additional analysis utilizing data from previous analyses as well as additional data from other sources. Section 2 covers the economic information found in earlier State Environmental Policy Act (SEPA) documents related to this project. Section 3 addresses the status of global, and Chinese methanol markets, while Section 4 drills down into the Chinese methanol supply, and how the economic information is used to establish an appropriate methodology for evaluating life cycle GHG emissions for the KMMEF. A brief summary concludes the Appendix.

A lifecycle analysis of GHG emissions assesses the production of methanol feedstock materials, the transportation of feedstock materials to the production facility, the manufacturing process used to produce methanol, the transportation of the methanol to market, and the end use of the methanol.

Economic elements influence how sources of methanol will shift in the global market, and how methanol production (and therefore emissions) is likely to proceed if the KMMEF plant were not to produce methanol in the future. For example, would other producers expand production? Would methanol consumers (e.g., manufacturers of olefins, and fuel products that use methanol as an input) use alternatives to methanol to produce their products? Would other methanol producers fulfill the methanol needs of potential KMMEF methanol consumers? The answers to these questions are generally driven by economics. In many cases, producers and consumers will consider their available options and choose the alternative with the lowest cost. Importantly, the lowest cost option might not be the lowest GHG emitting option. Market conditions play a role, and expectations for the future play a role in the decisions of methanol consumers and producers, as well as trade policies, taxes, and other factors.

This report reviews these topics to reinforce estimates of potential KMMEF GHG emission impacts using the most recent and relevant available economic information. Key questions explored in this economic analysis include:

- What is the general range of expected end uses of methanol produced at KMMEF?
- What would happen in the methanol markets going forward if KMMEF were not built?
- If there is uncertainty in the future for methanol markets, can a range of reasonable alternatives be developed so that different GHG emission results may be evaluated?

2. Previous Research

Several types of economic analyses have been completed as part of the permitting process for the proposed KMMEF. Each was developed with slightly different regulatory goals in mind. The analysis developed in this report for the Second SEIS will borrow from and build upon some of the previous work and will also bring a new lens to the GHG emissions analysis. The economic analyses associated with the 2016 Final Economic Impact Statement (FEIS) and the First Supplemental Environmental Impact Statement (First SEIS) are reviewed below. Some statements from the Department of Ecology about the need for a Second SEIS are included for context.

2.1. Final Environmental Impact Statement (FEIS) - 2016

Appendix M of the 2016 FEIS looks at the economic impacts of the Proposed KMMEF. The analysis was conducted by ECONorthwest, dated December 18, 2015, and is titled, "Final Economic Impact Analysis of the Proposed Kalama Manufacturing & Marine Export Facility." An economic impact model was created for the twelve-county region using the 2013 IMPLAN data. Appropriate adjustments were made for inflation and impacts were reported in 2018 dollars. The analysis was divided into two parts – impacts during the plant construction and impacts of an average year of plant operations. The results are reported below, with details shown in Tables 2-1 and 2-2.

Economic Impact Analysis of Construction:

- Assumption - Construction to span three years, beginning September 2016 and concluding October 2018.
- Capital investment required - $1.8 billion
- Total Impacts - over $1 billion (in the twelve-county region).
- Direct Impacts - $625.9 million expected to be spent in the local region on labor, goods, fees, and services, and additional substantial indirect spending by other businesses and government.
- Indirect and Induced Impacts - $391.5 million
- Labor Income - $289.5 million in wages, salaries, and benefits ($158.9 in labor income at the KMMEF jobsite earned over the 26-month construction period).
- Combined sales, use, and business and occupation (B&O) taxes - $57.7 million (benefits going to the state, Cowlitz County, and taxing jurisdictions within the County).

Table 2-1 Local Economic Impacts of KMMEF Plant Construction

Impacts	Total Project Costs and Employment	Local Direct Impacts	Local Indirect Impacts	Local Induced Impacts	Total Local Impacts
Output (Mn. 2018 $)	$1,800.0	$625.9	$203.4	$188.1	$1,017.3
Labor Income (Mn. 2018 $)	177.7	158.9	65.6	65.0	289.5
Employment (Jobs-Years)	1,122	1,001	1,129	1,389	3,519

Note: Direct local employment excludes jobs held by non-residents.

Results of Economic Impact Analysis of Operations

Assumptions - Operations commence late in 2018; the plant could produce 3.65 million metric tonnes in a year at full capacity; in practice the plant should average 92 percent of capacity over a full year.

Direct output is large ($1.286 billion) because of the high value of exports. Indirect output, at $42.6 million, is comparatively small since most of the inputs used for making methanol originate outside of the regional economy and the impact analysis only measures spending effects within the twelve counties. In total, 668 jobs a year are linked to the KMMEF operations.

The project would provide economic benefits to the region by creating jobs and tax revenues during construction and operation and improving access to recreational resources at the Port. The project meets the Port's mission to "induce capital investment in an environmentally responsible manner to create jobs and to enhance public recreational opportunities."

- Annual direct economic output - $1.286 billion.
- Direct Employment - 192 full-time workers; $21 million per year in payroll.
- Total impact to local economy - approximately $1.4 billion annually.
- Combined sales, use, property, leasehold, hazardous substances, and B&O taxes – average approximately $36 million per year (would vary based on levy rates and other factors).

Table 2-2 Annual Local Economic Impacts of KMMEF Operations

Impacts	Direct	Indirect	Induced	Total
Output (Mn. 2018 $)	$1,286.3	$42.6	$30.3	$1,359.2
Labor Income (Mn. 2018 $)	21.0	16.1	10.7	47.8
Employments (Job-Years	192	258	218	668

2.2. First Supplemental Environmental Impact Statement (First SEIS) – 2018/2019

Chapter 4 of the 2018 Draft First SEIS presents a methanol market and economic analyses. It was prepared by Life Cycle Associates and is titled, "Market Analysis and Economics." The economic analysis of the supply and demand for methanol in China provides the basis for determining the methanol that is anticipated to be "displaced" by the production at KMMEF. The analysis specifically covers: displacement effects, methanol supply, methanol and end product demand, methanol production cost, and marginal impact of KMMEF methanol. Key sources of information include the Methanol Institute, Methanex, IHS Markit, the DOE Energy Information Agency (EIA), Wood McKenzie, and ASIACHEM. Other data sources used in this effort include:

- analyses from the U.S. Energy Information Administration detailing China's energy usage, imports, supply, capacity, use of methanol in liquid fuels, and its most-recent outlook forecast,
- background information from EIA, Methanol Institute, Argus Methanol report,
- a report on development of China's methanol market and global supply from Argus DeWitt,
- data from the CCFGroup on China's domestic methanol production and regional flows,

- background news reports from ICIS on supply and demand of methanol in China, and
- miscellaneous news reports identified by online keyword searches found online.

The report concluded that the proposed project would provide economic benefit to the region, create jobs, and improve access to recreational resources. The analysts focused on the demand for methanol on the east coast of China.

In addition, the report concludes that production costs for the KMMEF facility are significantly lower compared to the alternative of coal-to-methanol production costs in China (including transport of the methanol to the olefin facilities in China). This cost difference will result in "displacing" methanol from coal-based production facilities in China with that of methanol produced using natural gas at the KMMEF.

The First SEIS provides an additional technical GHG life cycle analysis, responds to comments received on the Draft First SEIS, issued on November 13, 2018 and provides updated information, corrections and clarifications to the GHG analysis in the Draft Supplemental EIS.

Appendix B of the First SEIS presents a methanol market and economic analyses, entitled, "Supplemental Technical Analysis for Response to DSEIS Comments" (prepared by Stephan Unnasch, Life Cycle Associates and Mike Lawrence, Jack Faucett Associates in August of 2019). Information provided in Sections 5 and 7 is especially pertinent to the current economic analysis.

It is notable that, in the First SEIS Appendices A and B, emphasis is placed on developing a supply curve for the methanol market in China (see, e.g., figure 4.17 from Appendix A, reproduced as Figure 4-4 in Appendix B). The authors create a detailed analysis of capacity and cost for methanol producers with access to the Chinese MTO markets. However, these approaches to analyzing which producers would be operating absent KMMEF are conducted in a static sense. That is, the reports conclude that, given a specific quantity demanded in China, higher-cost producers would successfully sell methanol in the absence of KMMEF. However, if KMMEF entered the market at a lower price, those higher cost producers would be replaced by KMMEF. This makes sense if we consider that KMMEF will essentially shift the supply curve to the right. Also, because some high-cost producers use coal as a feedstock, these coal-based methanol facilities would reduce production in response to KMMEF entry in the China market. Such an analysis is legitimate for a single year – a static analysis. But since methanol markets are growing rapidly, these analyses neglect to address these key points:

1. Since both supply and demand are increasing through time, a static analysis is of limited applicability, and
2. The supply curve developed in the First SEIS shows that coal-based methanol is produced at a range of costs, including low- and medium-cost suppliers as well as a few higher-cost producers. Also, coal-based methanol is generally considered to be the lower-cost alternative to producing methanol from natural gas in China.

As is shown below, the analysis presented in the second SEIS will address those two points (see Sections 3.6 and 3.7, this Appendix).

2.3. Need for Second Supplemental EIS

The Department of Ecology determined a need for a Second Supplemental EIS (November 22, 2019), noting:

- Second SEIS is required to adequately identify and analyze the greenhouse gas emissions and impacts for the shoreline conditional use permit to construct and operate a marine facility to manufacture and export methanol at the Port of Kalama.
- The Second SEIS will supplement the information included in the August 30, 2019, Final SEIS prepared by Cowlitz County and the Port.

- The lead agency has identified the following areas for discussion in the EIS:
  - The Second SEIS will supplement Chapter 3, Appendix A, and Appendix C of the-2019 Supplemental EIS.
  - The Second SEIS will complete the analysis of the Project's life cycle greenhouse gas emissions, the Project's environmental impacts, and the potential mitigation of those impacts.

Ecology has directed that the intent of the second SEIS is to, "*quantify the Project's global lifecycle greenhouse gas (GHG) emissions and supplement Chapter 3 and Appendix A of the 2019 Supplemental EIS with a focus on upstream emissions from the extraction and distribution of natural gas to the project and how the methanol produced would affect other sources of methanol production.*"

3. Overview of Methanol Markets

The emissions impact of the KMMEF hinges on questions related to global methanol markets. The goal of this chapter is to review recent market trends and offer an economic understanding of how the global and Chinese markets would operate with and without the KMMEF facility.

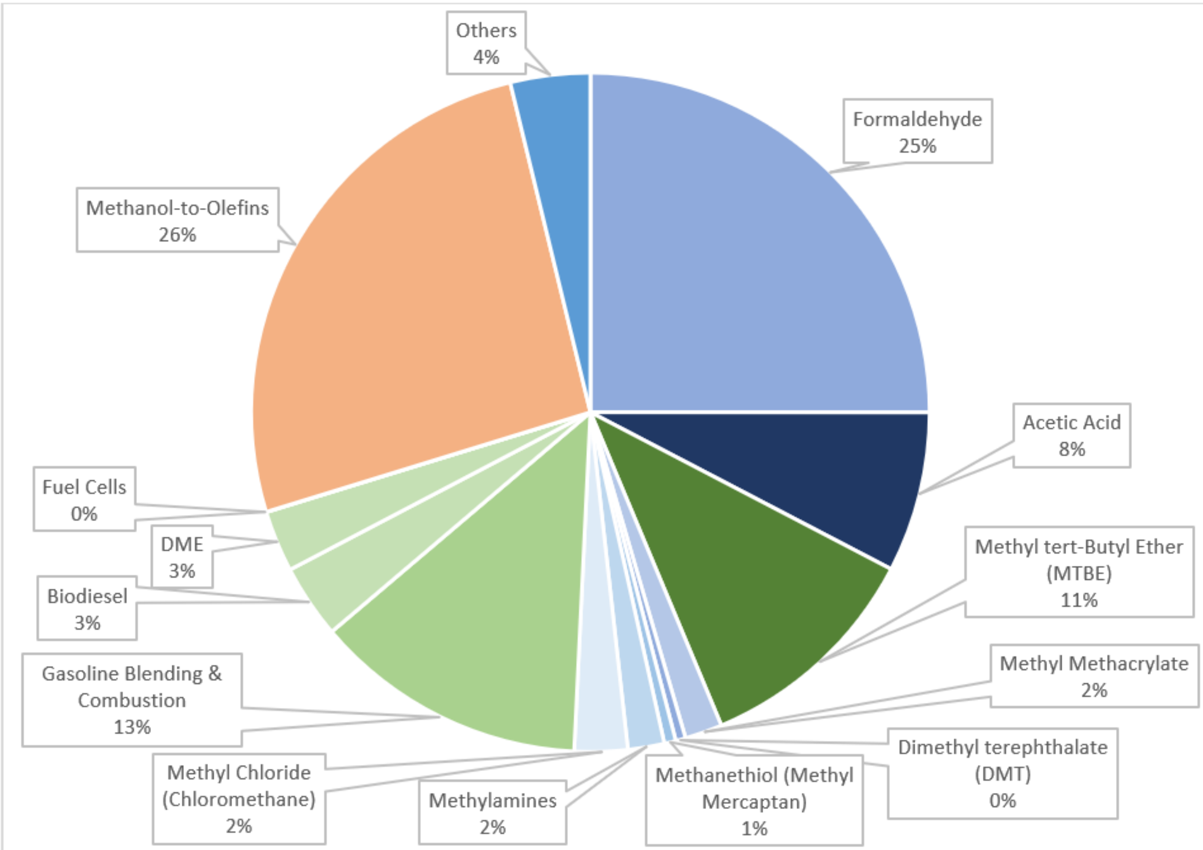
- Section 3.1 addresses global demand for methanol, and the trends in global demand driven by the growing market inside China.
- Section 3.2 briefly discusses Chinese demand.
- Section 3.3 addresses the global supply of methanol and how the methanol supply will respond to the growing need.

3.1. Global Methanol Demand

With a price of approximately $300/metric ton (MT) and the 98 million metric ton (MMT) produced in 2019, the global methanol market is worth about $30 billion per year. As a point of comparison, global sugar production is about 80 percent larger in terms of tons produced (180 MMT in recent years), with a slightly lower price ($265/ton) and so is worth about $48 billion per year. Also similar to sugar, methanol is a commodity, in that the quality doesn't vary noticeably from one producer to the next, it is produced in many countries, and it is used in nearly all.

There are wide variations in methanol end uses globally. However, the dominant end use has been for the production of olefins and formaldehyde in 2020, at 26 percent and 25 percent, respectively (see Figure 3-1). Another large end use is for various transportation fuels (shaded in green in Figure 3-1), including gasoline blending at 13 percent of all methanol, and Methyl tert-Butyl Ether (MTBE) at 11 percent. Biodiesel and dimethyl ether (DME) are two additional fuel uses that together bring total fuel uses for methanol to about 30 percent. Grouping formaldehyde with other chemical uses makes up about 44 percent of all methanol use (shaded in blue colors in Figure 3-1).

Figure 3-1: Global Methanol Use in 2019



Source: Methanol Market Services Asia (MMSA). 2020. MMSA World Supply and Demand Summary. Accessed on July 24, 2020.

In terms of growth, data shows that the overall methanol use in 2019 and expected use in 2020 were over 98 MMT per year for each of these years.[1] This represents an increase of about 20 MMT, or 24 percent since 2015, or 4.1 percent in average annual growth.[2] Annual growth rates for each type of use indicates which types of uses are growing faster, and which slower. Each of the three primary sectors of use (Fuels, MTO, and Chemical/Other) grew during this period, although the Fuel category and the Chemical/Other category grew 18 and 17 percent respectively while the MTO category grew 52 percent over this period. MTO still represents a smaller share of all use than fuels or Chemicals/Other, but the MTO share grew from 20 percent in 2015 to 25 percent in 2019. The annual growth between 2015 and 2019 for MTO sector grew at a rate of 9.6 percent per year[3]

[1] Methanol Market Services Asia (MMSA). 2020. MMSA World Supply and Demand Summary. Accessed on July 24, 2020.

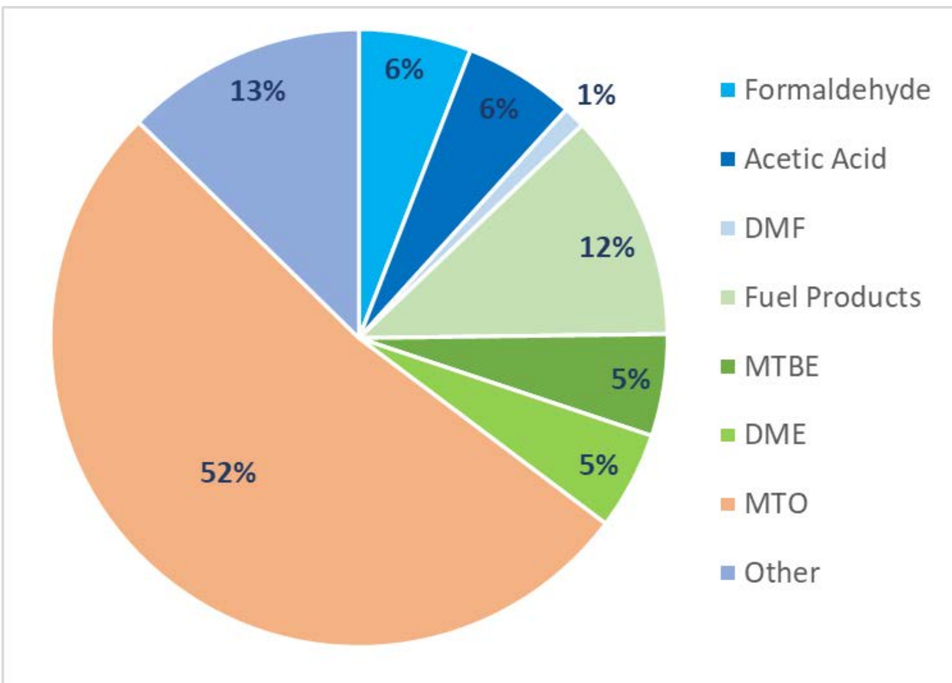
[2] Ibid.

[3] Ibid.

3.2. Chinese Methanol Demand

China is the largest consumer of methanol in the world, followed by Western Europe and the United States.[4] China's methanol supply totaled 73.44 MMT in 2019, up 8.65 MMT or 13.35 percent from 2018. The largest portion of this, over 52 percent (38.22 MMT), was consumed by MTOs/MTPs. Another 11.9 percent (8.75 MMT) went into the fuel products sector. Other sectors using this methanol included formaldehyde (4.32 MMT; 5.9 percent), DME (3.77 MMT; 5.1 percent), acetic acid (4.29 MMT; 5.8 percent), Methyl Tertiary Butyl Ether (MTBE) (3.91 MMT; 5.3 percent), Dimethylformamide (DMF) (0.84 MMT; 1.2 percent), and other sectors (9.30 MMT; 12.7 percent).[5] The chart below (Figure 3-2) shows this breakdown of methanol use in China, and may be compared with global use, shown in Figure 3-1. With MTO representing over half of the methanol use in China, it is clear that MTO plays a much larger role in the Chinese methanol market than the global market, while formaldehyde, at six percent plays a much smaller role in China compared with the world.

Figure 3-2: Methanol Use in China, 2019



Demand for methanol in the various sectors has persistently grown in China in recent years, and the industry structure has evolved. The traditional downstream sectors are seeing a slowdown in methanol demand. For example, formaldehyde and DME capacity barely expanded in 2019 primarily due to environmental protection policies and weak prices. Several plants were idled. Acetic acid capacity increased only in limited plants, while demand for methanol for MTBE stayed about the same. Demand from new sectors continued increasing in 2019, as new MTO plants came online and MTO operating rates were higher due to positive returns.[6]

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[4] IHS Markit. 2019. Chemical Economics Handbook – Methanol. Available at (https://ihsmarkit.com/products/methanol-chemical-economics-handbook.html), accessed July 27, 2020.

[5] CCFGroup. 2020. 2019 China Methanol Industry Annual Report.

[6] Ibid.

Methanol demand in China is concentrated in eastern coast regions, while many of the producers are located in western Inner Mongolia, Shaanxi and Ningxia.[7] Most of the MTO projects that use outsourced methanol supply occur within coastal regions.[8] The north and northwest China, including Inner Mongolia and Shaanxi provinces, have an abundance of coal reserves (see Figure 3-3 below).[9] China's largest open-pit coal mine is located in Haerwusu in the Inner Mongolia Autonomous Region, and mines in this area have continued to expand production.[10] The transportation of coal from these regions has resulted in logistical issues, such as using up nearly half the country's rail capacity[11] and overloading highways.[12]

Figure 3-3: Chinese Coal Production, 2020tax

Source: Stratfor - Worldview. 2015. China's New Coal Tax Will Affect Regions Differently. January 15. Available at (https://worldview.stratfor.com/article/chinas-new-coal-tax-will-affect-regions-differently). Accessed on August 22, 2020.

7 Shanghai ASIACHEM Consulting Co. Ltd. 2018. Chinese Coal Methanol Industry – Emissions and Economic Analysis. June.

8 Ibid.

9 World Nuclear Association. 2020. Nuclear Power in China. August. Available at (https://www.world-nuclear.org/information-library/country-profiles/countries-a-f/china-nuclear-power.aspx). Accessed om August 22, 2020.

10 The New York Times. 2010. China's Growth Leads to Problems Down the Road. August 28. Available at (https://www.nytimes.com/2010/08/28/world/asia/28china.html). Accessed on August 22, 2020.

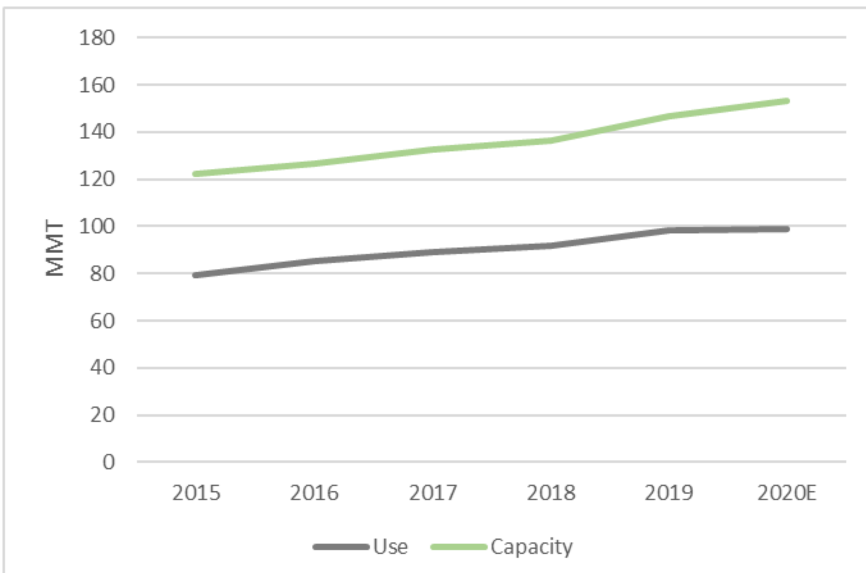
11 World Nuclear Association. 2020. Nuclear Power in China. August. Available at (https://www.world-nuclear.org/information-library/country-profiles/countries-a-f/china-nuclear-power.aspx). Accessed om August 22, 2020.

12 The New York Times. 2010. China's Growth Leads to Problems Down the Road. August 28. Available at (https://www.nytimes.com/2010/08/28/world/asia/28china.html). Accessed on August 22, 2020.

3.3. Global Methanol Supply

Globally, methanol capacity totaled 157.61 MMT/Year 2019, up 8.54 percent from 2018. Capacity is an important feature of this market because the market is growing. When demand continues to grow, supplies will also tend to increase to meet that demand. The total manufacturing capacity helps in understanding how quickly supplies can be expected to respond to increases in demand. If the manufacturing infrastructure is fully utilized, then additional costly infrastructure will be needed to meet the growing demand. This can take time and in the interim prices may be expected to rise. But if capacity is available, then suppliers can respond quickly by adjusting the quantities of methanol produced with the existing capacity. While most of recent capacity expansion occurred in China, new plants also went online in the US and Iran.[13] China, with its abundant resources of coal, is by far the largest producer of methanol in the world, with 61 percent of global capacity in 2019. The Middle East and South America, where there are rich reserves of natural gas, are also large methanol producers making up 14 percent and 6 percent of global capacity, respectively. Other larger methanol producing areas include North America (6 percent), Europe (6 percent), Southeast Asia and Oceania (5 percent), and Africa (2 percent).[14] Figure 3-4 highlights how capacity has kept pace with methanol consumption, or use.

Figure 3-4: Global Methanol Use and Capacity



Feedstocks used globally for methanol production include coal and natural gas. Decisions regarding which feedstock to use are primarily based on cost of production, feedstock availability, regional regulations, and local costs of labor.[15] Most commercial scale methanol plants either use coal (as in China) or natural gas as feedstock.[16] Coal-

[13] CCFGroup. 2020. 2019 China Methanol Industry Annual Report.

[14] Ibid.

[15] IEA. 2018. The Future of Petrochemicals, Towards more sustainable plastics and fertilisers. Available at (www.iea.org), accessed June 2, 2020, page 31.

[16] Nexant. 2020. A Global Methanol Market Snapshot – The Coronavirus influence! June 16. Available at (https://nexanttraining.com/blog/global-methanol-market-snapshot-the-coronavirus-influence/), accessed June 17, 2020.

based methanol production is primarily concentrated in China, while natural gas is the global feedstock choice for producing methanol in most other methanol producing areas, such as the Middle East and South America.[17]

The global methanol industry expanded between 2017 and 2020, and incremental capacity increases continued to exceed incremental demand increases. The United States, Iran, the Caribbean, China and Russia are adding capacity, thus increasing worldwide availability of methanol.[18]

[17] CCFGroup. 2020. 2019 China Methanol Industry Annual Report.

[18] Nexant. 2019. Global Methanol - Market Snapshot. May 01. Available at (https://www.nexantsubscriptions.com/blog/201905/global-methanol-market-snapshot), accessed June 17, 2020.

4. Chinese Methanol Supply

The Chinese supply of methanol is challenging to predict, but critical to understanding what would occur absent production from KMMEF. The emission model developed for the Second SEIS is flexible so that many versions of alternate cases may be analyzed for different potential emission results. Three alternate cases are developed for use in the second SEIS, representing three of the most likely cases for future increased methanol production in China absent the KMMEF facility. This section first summarizes the numbers of facilities, capacity, and feedstocks used in China to produce methanol, then analyzes the costs of production, and finally a few highlights of other factors that influence the market and the economic analysis.

- Section 4.1 describes the Chinese methanol supply.
- Section 4.2 summarizes trade in methanol, with emphasis on China.
- Section 4.3 provides a price analysis.
- Section 4.4 clarifies how outcomes differ when using a static versus a dynamic analysis.

4.1. Facilities, Output, Capacities, and Feedstock

China had 183 methanol plants in 2018 with a total capacity of about 60.1 MMT/Year. Forty-two (42) of these have capacities of 500,000 MMT/Year or more. Of the total, 64 (35 percent) use coke oven gas as feedstock and have a combined capacity of about 12 MMT/Year (19 percent). Another 55 plants (30 percent) use coal/ammonia with a combined capacity of over 20 MMT/Year (34 percent). Similarly, the 46 (25 percent) coal-based plants add over 20 MMT/Year (34 percent) of capacity. The remaining capacity is shared between natural gas (15 plants; over 6 MMT/Year), natural gas/coal (2 plants; over 1 MMT/Year), and natural gas/coke oven (1 plant; over 0.5 MMT/Year).[19]

Most of the coal, coal/ammonia, and coke oven gas-based plants are located in the East (Anhui, Jiangsu, Shandong, Zhejiang), North (Hebei, Shanxi, Tianjin), and Northwest (Inner Mongolia, Gansu, Ningxia, Qinghai, Shaanxi, Xinjiang) regions. The natural gas-based production is concentrated in the Northwest, Southwest, and Northeast regions.[20]

China experienced an oversupply of methanol in 2017 and the price dropped. In 2018, demand came back faster than supplies, and methanol prices rose. This volatility led to the postponement of several new methanol plants both domestic and abroad.[21] Newer methanol projects in China came online combined with MTO facilities.[22]

4.2. Costs of Production

The cost of methanol production is based on many factors, such as feedstock choice, equipment costs, and process yields. Other factors can also affect the costs, such as feedstock availability, regional regulations, and local costs of

[19] LifeCycle Associates. 2020. Supply Curve for Methanol Plants with Access to East China (Spreadsheet). August.
[20] Ibid.
[21] CCFGroup. 2018. Methanol-to-Olefins Producers Feel the Pain. June 13. Available at (https://www.ccfgroup.com/newscenter/newsview.php?Class_ID=D00000&Info_ID=20180613038), accessed June 16, 2020.
[22] Ibid.

labor.[23] Equipment costs to produce chemicals from coal are more capital intensive than from natural gas. For example, equipment costs per unit of ammonia production are more than double for coal compared to natural gas.[24] Producing methanol from coke oven gas, a by-product of coke refining, is a cost-effective method.[25]

Within China, there is often a shortage of raw material supply for methanol production in the East China region, resulting in higher price. The long-distance shipping from outside of the region results in higher freight, leading to higher general production cost and higher finished methanol product price.[26] During 2019, methanol production in China using the three feedstocks, coal, natural gas, and coke oven gas, mostly remained profitable. Production using all three feedstocks did experience losses though only for a short period.[27] The chart below shows recent trends in methanol cash flows in China using different feedstocks during selected weeks in 2019 and 2020 (see Figure 4-1).

[23] IEA. 2018. The Future of Petrochemicals, Towards more sustainable plastics and fertilisers. Available at (www.iea.org), accessed June 2, 2020, page 31.

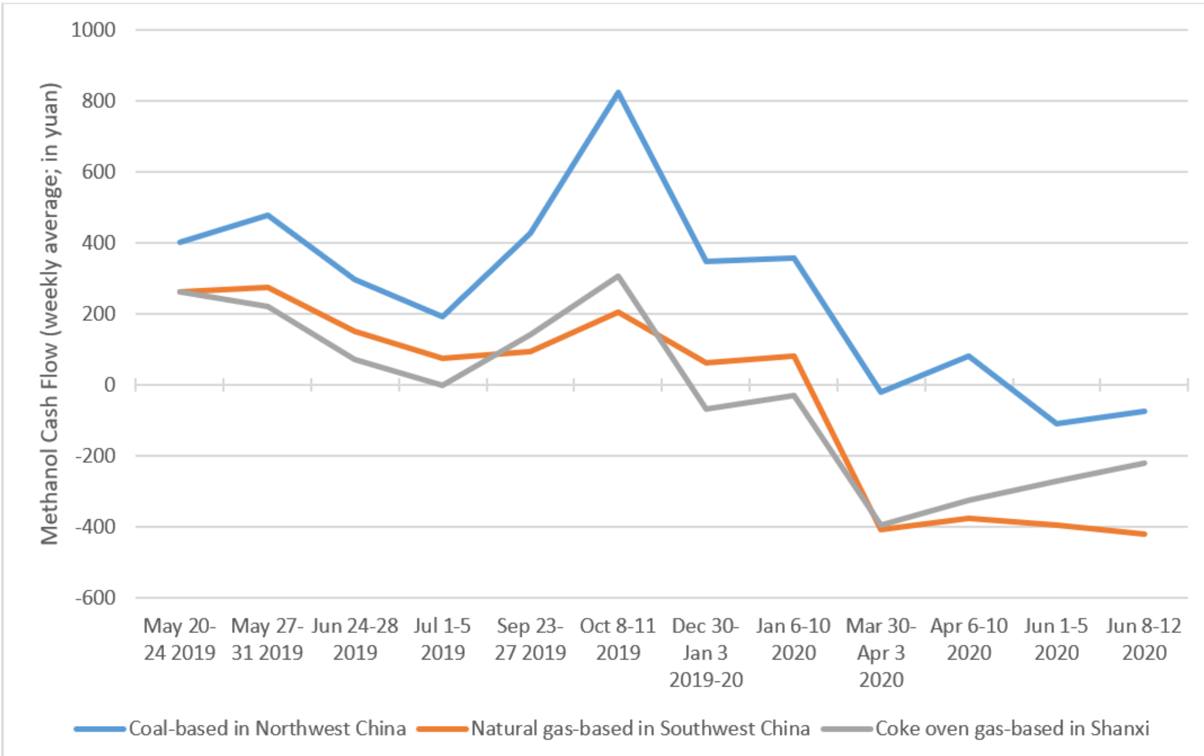
[24] IEA. 2018. The Future of Petrochemicals, Towards more sustainable plastics and fertilisers. Available at (www.iea.org), accessed June 2, 2020, page 31.

[25] CCFGroup. 2020. 2019 China Methanol Industry Annual Report.

[26] Shanghai ASIACHEM Consulting Co. Ltd. 2018. Chinese Coal Methanol Industry – Emissions and Economic Analysis. June.

[27] CCFGroup. 2020. 2019 China Methanol Industry Annual Report.

Figure 4-1: Methanol Cash Flows in China with Different Feedstocks[28]



4.3. Other Factors Affecting Supply

In addition to the effect of methanol prices on the production of methanol, MTO and coal-to-olefin (CTO) development in China are potentially affected by environmental regulations and competition from naphtha to supply the olefin market. Between 2020 and 2025, 19 new steam crackers were slated to come online with a total nameplate capacity of 19.7 MMT/Year. Investors were then hesitant to invest in MTOs because of price volatility and steam cracker investments.[29]

In addition to threats of competition from naphtha, environmental concerns related to the use of coal for methanol production pose a potential concern for long term production. The CTOs use a substantial amount of water and contribute greatly to CO_2 emissions. Estimations on water usage vary. A reasonable estimate is that one ton of CTO-derived olefins use about 30 metric ton (MT) of water per ton of chemicals which is 250 percent more than a traditional naphtha cracker.[30] About 29 to 40 tons of water is required in CTO plants per ton of olefins production,

[28] CCFGroup. 2018-2020. Methanol Market Weekly (reports for various weeks). Available at (www.ccfgroup.com), accessed June 15, 2020.

[29] Cui, Kelly. 2019. Can China's CTO and MTO Industries Survive the Threat of Massive Steam Cracker Investment? For Wood Mckenzie. September 09. Available at (https://www.woodmac.com/news/can-chinas-cto-and-mto-industries-survive-the-threat-of-massive-steam-cracker-investment/), accessed June 15, 2020.

[30] S&P Global Platts - Insights. 2015. China's Olefins Future Shaped by Economics and Environmental Concerns. February 11. Available at (https://blogs.platts.com/2015/02/11/china-coal-methanol-olefins/), accessed June 15, 2020.

which is a substantial amount.[31] Further the CTO process produces about 11 tons of CO_2 per ton of olefins, which is over three times the emissions of naphtha crackers. [32]Therefore, the CTO process has a large carbon footprint.[33]

Another policy factor involves the limitations on use of new natural gas being used for methanol following the 2012 National Development and Reform Commission policy for natural gas use. The policy prohibits new gas being used for methanol production and explicitly prohibits gas used to replace coal in methanol production. But if China does not produce methanol domestically, it will import from elsewhere in the world, and if so these transactions will be subject to ongoing trade relationships with many different countries.

4.4. Trade in Methanol

The largest exporters of methanol to China include Iran, Oman, United Arab Emirates, New Zealand, Venezuela, Saudi Arabia, Trinidad and Tobago, Malaysia, Brunei, and Indonesia. The United States also exports methanol to China, but it is lower down on the list.[34] In May of 2020, of the total about 1.3 MMT of methanol imported by China, about 0.32 MMT of methanol was imported from Iran; 0.18 MMT from Oman; 0.17 MMT from United Arab Emirates; and 0.14 from New Zealand.[35] During this period, the United States exported 0.695 MT to China.[36]

It is anticipated that the natural gas-based capacity developments in other regions will change the dynamics of trade. The United States is expanding capacity and may become a net exporter of methanol. The Middle East, led by Iran, will export to China and India. Many factors could affect this changing dynamic, including the COVID-19 pandemic, and investment into Iran following economic sanctions.[37]

4.5. Price Analysis

The price of methanol globally and in China has demonstrated significant volatility in the past few years, as might be expected in a growing market. For example, using a weighted average contract price from the MMSA, the price dropped 31 percent between March 2017 and June 2017, from \$356/MT to \$274/MT. Then, the price increased to \$414/MT by June of 2018, an increase of 51 percent. By October 2018, the price had climbed back to \$429/MT, and then fell again another 45 percent by August 2019 – before significant COVID-19 impacts had hit any markets – to \$234/MT. Since then, the price has remained lower, dropping to \$217/MT in March of 2020.

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[31] Cui, Kelly. 2017. The opportunities and challenges of CTO/MTO development. For Wood Mckenzie. November 07. Available at (https://www.woodmac.com/news/editorial/the-opportunities-and-challenges-of-cto-mto-development/), accessed June 15, 2020.

[32] Ishwaran, Mallika, et al. 2017. Shell International and The Development Research Center (Eds.), China's Gas Development Strategies, Advances in Oil and Gas Exploration & Production. Available at: (https://cdf-en.cdrf.org.cn/jjh/pdf/en17.pdf)

[33] Cui, Kelly. 2017. The opportunities and challenges of CTO/MTO development. For Wood Mckenzie. November 07. Available at (https://www.woodmac.com/news/editorial/the-opportunities-and-challenges-of-cto-mto-development/), accessed June 15, 2020.

[34] CCFGroup. 2020. June Methanol Market Report. June. Available at (www.ccfgroup.com), accessed July 8, 2020.

[35] CCFGroup. 2020. May Methanol Market Report. May. Available at (www.ccfgroup.com), accessed June 15, 2020.

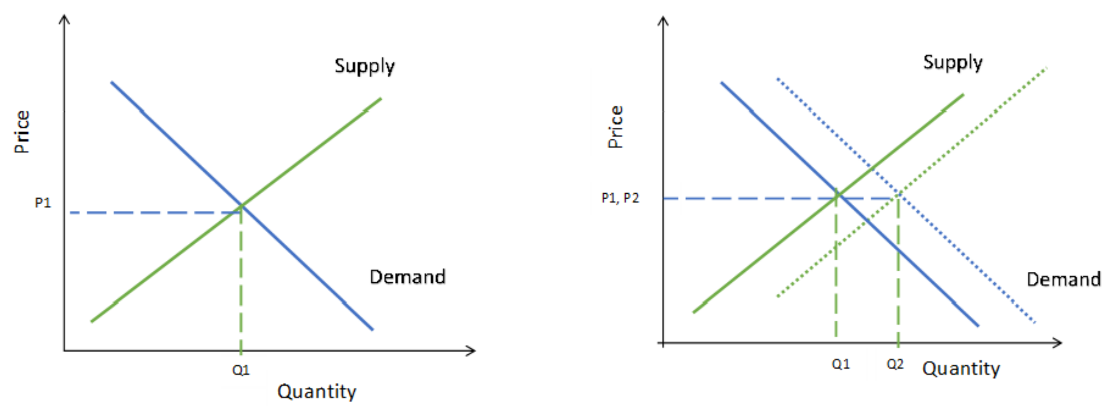
[36] Ibid.

[37] Nexant. 2020. A Global Methanol Market Snapshot – The Coronavirus influence! June 16. Available at (https://nexanttraining.com/blog/global-methanol-market-snapshot-the-coronavirus-influence/), accessed June 17, 2020.

This volatility supports the notion of a competitive market that is adjusting to global prices, even though China does not currently operate a completely free market. China has been moving rapidly towards a free market, with efforts to correct prices for all commodities, but this is an enormous transition and will take a long time to accomplish.

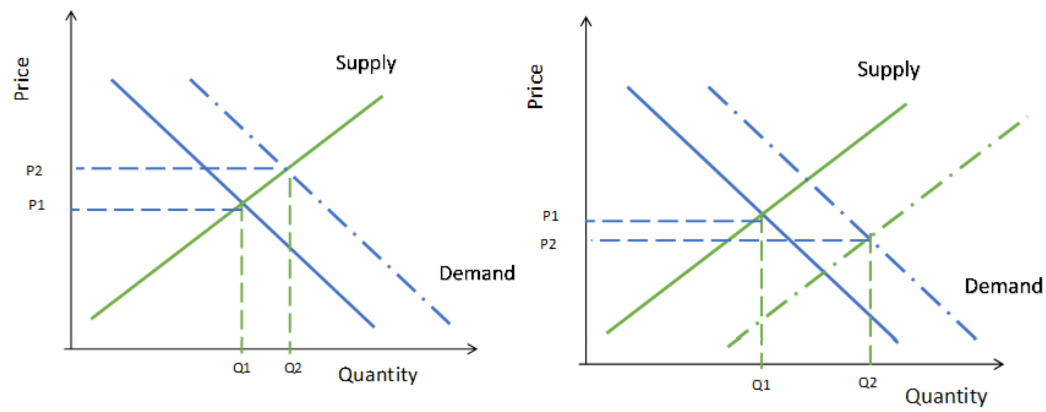
The explanation for why price volatility typifies a growing market is demonstrated in the graphics presented below (Figure 4-2). The first panel shows how the supply and demand in a competitive market achieves an equilibrium price and quantity. The second panel shows what happens when demand increases. Demand increases for a variety of reasons such as a change in technology (e.g., the evolution of methanol use in new fuels), a change in the number of consumers (e.g., more buyers associated with more uses for methanol as fuels), changes in income (e.g., global recession), the price of substitutes and complements (e.g., the price of naphtha as a substitute for methanol in production of olefins), and expectations about the future price and market (e.g., if olefin producers expect olefin demand to decrease with the recession, then they might expect the price of methanol will also decrease in the future and hold off purchasing until a lower price may develop). Demand for methanol has been increasing through time as more and more uses for it are found. If supply also increases as demand increases, the price may reach a new equilibrium. In the second figure, the dotted line represents what can happen when demand shifts to the right, and the supply responds quickly with a parallel shift to the right. The result is that a greater quantity of methanol is used and the price could be the same as it was before the shifts. This is what is expected in a competitive market.

Figure 4-2: Methanol Supply and Demand with Increasing Demand in a Competitive Market



However, if demand for methanol increases but producers are not able to quickly respond with increased supply, the price will increase, at least for a short period, until the suppliers are able to respond. This is shown in the left panel of Figure 4-3. Conversely, suppliers might anticipate an increase in demand, but then overproduce, resulting in a drop in price, as shown in the right panel of Figure 4-3.

Figure 4-3: Methanol Supply and Demand Showing Potential Price Volatility



The price volatility shown in Figure 4-3 is also part of the dynamic reality of the methanol market today. The adjustments are normal and temporary, with the ultimate result expected to resemble the right-hand side of Figure 4-2, with both demand and supply advancing through time. The expected result will be a similar price, and larger capacity, or a larger volume of trade.

4.6. Static and Dynamic Analyses

The economic arguments presented in the First SEIS show a supply curve for methanol in China with emphasis on those producers that could supply the growing MTO market. As identified above, the analysis suggested that coal producers at the high end of the cost curve[38] would reduce production as a result of the additional product from KMMEF. The figure is reproduced below (Figure 4-4). However, this static analysis does not adequately capture the dynamics of a growing market for methanol. In a growing market, year to year dynamics will look more like the shifts in Figures 4-2 and 4-3. In these cases, we see demand increasing as supply is also increasing, with price volatility expected inasmuch as these increases are never perfectly synchronized through time.

It is the conclusion of this report that this *additional supply will come not from expansion of high-cost producers, but instead from low-cost producers*. Importantly, the majority of coal-based methanol producers are in fact lower on the cost curve, and they make up the largest volume of low-cost producers in China. Further, there are policy constraints on the expanded use of natural gas for methanol production.

Therefore, using a dynamic analysis of the market, , *more coal-based methanol would be produced in China absent KMMEF*. This conclusion is consistent with the conclusions in the First SEIS, but it is based on entirely different reasoning than was used in the First SEIS. This conclusion stems from the fact that coal-based methanol is a low-cost producer and not because <u>some</u> coal-based methanol producers operate at high cost. High-cost producers may or may not decrease production – and this will depend on the pace of increased demand, and a host of facility-specific factors including the existing relationships with customers, and possibly government policies related to local employment. The forecast that low-cost coal-based methanol will expand production in China as demand for

[38] A supply curve in a competitive market shows the marginal cost of production for all producers within an industry, by ordering them from low to high, and summing the available product at each price. The result is an upward sloping curve made up of combinations of points depicting the total product that is available at each price. At higher prices, more product will be available in the market.

methanol increases is supported with additional research on the methanol markets in China, such as the cash-flow analysis shown in Figure 4-1, and the fact that in 2019, 4.6 MMT of the 5.1MMT expanded methanol production capacity was coal-fed.[39] Imported methanol is also shown to be lower cost (as shown in Figure 4-4), and this portion of Chinese methanol supply is also expected to expand in the future. However, within China there is likely a preference for expanding domestic production where feasible, and so expanded low-cost coal-based methanol is expected to make up the largest share of the increased methanol supplies in the coming years.

Figure 4-4: Methanol Supply Available to MTO Markets as Portrayed in First SEIS

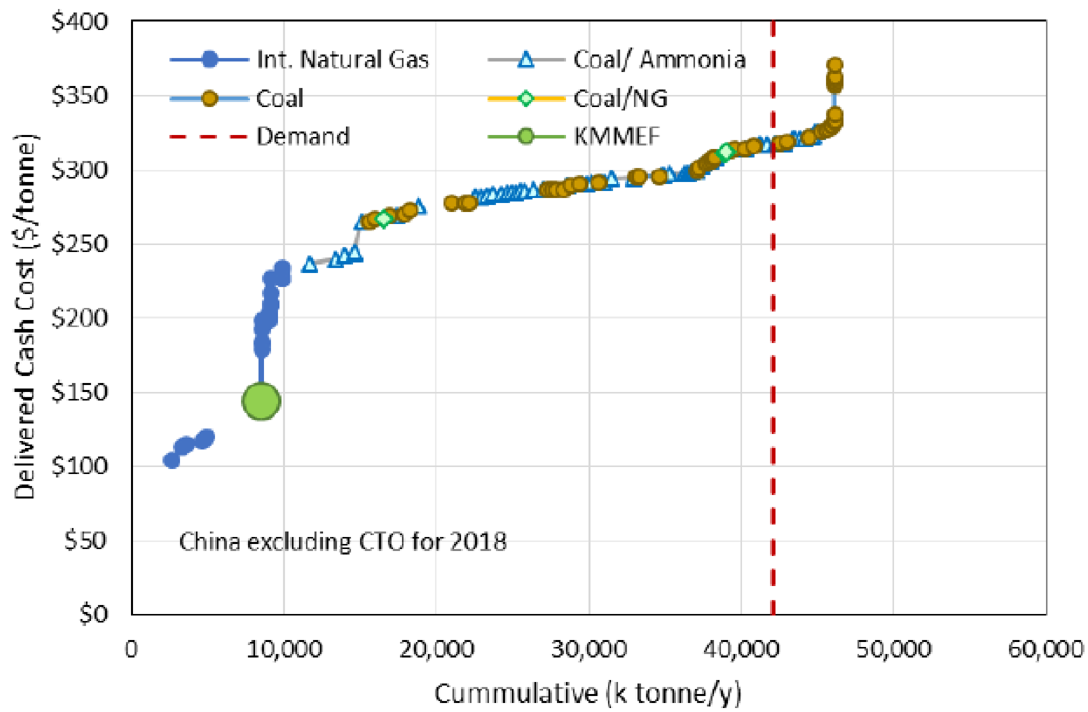


Figure 4.17. Supply curve of methanol producers that can access China MTO markets with KMMEF methanol.

[39] CCFGroup. 2020. 2019 China Methanol Industry Annual Report.

5. Summary

This report provides supporting information for the estimation of potential KMMEF GHG emission impacts using the ESM. The motivating questions explored in this economic appendix are:

- What is the general range of expected end uses of methanol produced at KMMEF?
- What would happen in the methanol markets going forward if KMMEF were not built?
- If there is uncertainty in the future for methanol markets, can a range of reasonable alternatives be developed so that different GHG emission results may be evaluated?

Each question is addressed below, with a summary of how the additional information in this appendix supports the assumptions and/or framework described in the EIS sections 3.4 Methods and Approach, and 3.5 Results.

5.1. Range of Expected Uses of KMMEF Methanol

Supporting information on methanol demand trends in China confirms that MTO and fuel are both growing sectors of methanol demand in China. These are both growing markets, and methanol production in the coming years and decades will expand to meet these needs.

5.2. What Would Happen in the Markets if KMMEF were not to go into Operation?

The analysis of methanol supply in China shows that there is existing capacity in China to increase methanol production and meet growing demand. This is expected to be supplied from coal-based methanol, as coal-based methanol is the lowest-cost producer in China. Additional demand will be met with natural gas-based imports, which are also low-cost. KMMEF is expected to be one of the lowest-cost of these exporting producers, but absent KMMEF, other lower-cost natural gas-based exporters would also supply the growing market in China.

5.3. Uncertainty in Future Markets

There is always uncertainty in future markets with respect to prices, policies, the global pandemic recession, and relationships between input suppliers and producers. For this reason, the ESM is designed to explore outcomes based on different input assumptions. The key to answering questions about global emissions is to recognize that there is uncertainty in the markets, bracket that uncertainty with economic reasoning, and ultimately analyze the range of possible outcomes.

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Accessed om August 22, 2020.

Appendix C: Onsite Emissions

This Appendix details the methodologies and assumptions used to develop the emission calculations for the construction, direct operation and transport of finished product for the Kalama Manufacturing and Marine Export Facility (KMMEF or the proposed project). The majority of the emissions reported are detailed in Appendix A and Appendix B to the Final Supplemental Environmental Impact Statement (FSEIS) published by the Port and County on August 30, 2019. The emissions reported herein represent only a portion of the life cycle emissions associated with the KMMEF. Upstream natural gas and emissions associated with market displacement of methanol are presented elsewhere.

Methodology

General approach

Emission values

Emissions are reported by individual gas in this report based on the life cycle GHG model provided to Ecology. Values are reported in metric tonnes (MT) on an annualized basis. This report provides additional detail on the GHG emissions from the KMMEF including direct project emission, upstream energy inputs from construction activities and purchased power, and downstream fuel delivery emissions.

Alternatives, scenarios and range of emissions

Methanol production alternatives

Emissions from production of methanol at the proposed project site are calculated based on the amount of methanol produced in one year of continuous operation with a production capacity of 10,000 MT per day for 360 days per year. This results in total production of 3.6 million metric MT per year. Emissions from two alternatives and two scenarios were calculated.

Producing methanol from natural gas is an established technology. Natural gas is combined with steam and heat to produce a “synthesis gas” of carbon monoxide, carbon dioxide, and hydrogen. A catalyst is then used to create a chemical reaction and the resulting liquid is distilled to yield 99.9 percent pure methanol and 0.1 percent water.

The process for producing methanol from natural gas has three key steps:

1. Natural gas reforming – the process of converting natural gas to synthesis gas (a mixture of hydrogen and carbon oxides; also referred to as syngas);
2. Methanol synthesis – the process of converting syngas to methanol; and
3. Methanol distillation – the process of purifying the methanol product to the required purity.

Emissions from two different alternatives for completing the initial step are included. Steps 2 and 3 are the same for both alternatives. In the reforming process, natural gas is compressed, then saturated with process water, and mixed with steam to increase water content. The treated water-rich natural gas is converted in the reformers into a mixture of carbon oxides and hydrogen, which is referred to as “synthesis gas” or “syngas” and contains the reactants for the formation of methanol. The process involves a partial natural gas reforming with steam as a primary step, and a complete reforming with oxygen in an autothermal reformer (ATR) as a secondary step. Combining the two reforming processes creates the optimum synthesis gas composition for methanol synthesis. The synthesis gas is cooled in a series of heat exchangers that recover waste heat that is returned to the system to provide energy to feed the gas and methanol distillation process.

Emission calculations also include fugitive emissions from components and during the loading process. Fugitive emissions from methanol production facilities include methanol vapors and other light hydrocarbons that escape from storage tank vents as well as methanol vapors that are lost during the transfer of methanol from storage tanks to transport vessels. Note that fugitive methanol emissions are treated as fully oxidized CO_2 as these pollutants oxidize to form CO_2 rapidly in the atmosphere.

ULE alternative

The Ultra Low Emissions (ULE) process is designed to use process heat directly to provide energy for the reforming reaction. With ULE, hot synthesis gas from the secondary reformer (referred to as the autothermal reformer) flows through the shell side of the primary reformer (referred to as the GHR) and rotating process equipment are driven by electricity instead of steam turbines.

CR alternative

The Combined reforming (CR) process, which represents an efficiency improvement over older steam reforming plants, is widely used in the methanol industry to perform the primary reforming of natural gas with steam. The energy required by the reforming reaction is provided mainly by burning natural gas. Natural gas as fuel combusts through the firing burners, provides heat to allow natural gas steam reforming in the tubes of the SMR, and the flue gas is emitted to the atmosphere. The waste heat carried by hot flue gas is recovered through a series of heat exchangers to generate steam, and the steam is sent to turbines to drive rotating process equipment (such as pumps and compressors).

Methanol production operational scenarios

Operation emissions from two different operation scenarios were developed and assessed.

Scenario 1 - Continuous Operation

Energy inputs and emissions from continuous operation are based on the process design and correspond to a mass and energy balance between the natural gas feed, methanol produced, and emissions. No reduction in emissions are assumed based on reduced production values during initial operations (assumed to not start on calendar year), startups or shutdowns (planned or unplanned), reduced operating scenarios or planned maintenance activities. Start of run conditions are assumed where the plant is least efficient, and emissions are highest.

Continuous operation is used as both the low and medium emission scenarios in the Emission Sensitivity Model (ESM).

Scenario 2 – Maximum Potential to Emit

Emissions are based on the maximum emission rates for each operating unit (including flare and firebox emissions which do not operate during normal operations). These emissions are consistent with the emissions evaluated by the Southwest Clean Air Agency (SWCAA) as part of the permit approval process for the Air Discharge Permit for the ULE Alternative. (SWCAA 2017a). Details of the operations and analysis are contained in the Appendix D to the FEIS, the SWCAA Permit Application (Ramboll Environ 2016b) and the Technical Support Document (SWCAA 2017b). The maximum potential to emit serves as the high emission scenario in the ESM.

Electrical power demand

Electrical power will be required for KMMEF operations. A portion of the power required will be generated from onsite combustion turbines, and the rest, estimated to be 100 MW by NWIW, will be purchased from the power market. Emissions from electrical generation by the onsite combustion turbines are included in the emission calculations for methanol production for the ULE alternative. Emissions for the 100 MW of purchased power are based on three generation scenarios:

- Low Scenario. All purchased power is generated from renewable sources. The current renewable mix from Cowlitz PUD is 86% hydroelectric, 8% nuclear, and 6% wind.
- Mid Scenario. Purchased power is from a mix of generation sources, which changes over time in line with the expected, future energy mix in accordance with the Washington State Clean Energy Transformation Act (CETA) signed into law on May 7, 2019. In the mid scenario, generation from 2020 to 2030 is from the current marginal power source (defined as the source of electricity that is first or cheapest available to meet an increased power demand), generation from 2030 to 2045 is from a mix of 20% marginal power and 80% renewable power, and generation from 2045 and beyond is all from renewable sources.
- High Scenario. Purchased power is all from the current marginal power source.

A NW Power and Conservation Council study of CO_2 emissions in the NW power system published in 2018 concluded that the expected emissions over the time frame of the project from marginal power sources were in a range that correlates well with the emissions from a combined cycle natural gas-fired powerplant. Therefore, for the purposes of this study, a combined cycle natural gas-fired powerplant was assumed as the current marginal power source.

Emission factors for combined cycle natural gas-fired powerplants, hydroelectric generation stations, nuclear powerplants, and wind turbines were derived from GREET and are shown below in Table C-1.

Table C-1. Emission Factors for Purchased Power.

Purchased Power GHG Emission Factors (g/kwh)	Low (100% Renewable)	Mid[1] (CETA Resource Mix)	High (Marginal Power)
CO_2	0.57	200.80	400
CH_4	1.45E-03	0.60	1.19
N_2O	9.43E-06	2.83E-03	5.63E-03
CO_2e	**0.61**	**216.57**	**431.43**

1. Emission factor for Mid case is a weighted average based on the generation mix evolving between 2020 and 2060.

Construction

Construction is planned for 26 months. Construction emissions include fuel combustion that occurs during construction as well as potential organic carbon releases from dredging. Upstream life cycle emissions consist of electric power for construction as well as the upstream life cycle emissions for fuels. Construction emissions are assumed to be same for all alternatives and scenarios. GHG emissions were calculated in Section 3.1 of Appendix A to the FSEIS for the following:

- Construction equipment operating;
- Construction equipment power;
- Construction worker (employee) commuting;
- Construction worker shuttle bus (added to the analysis)
- Material delivery;
- Dredging fuel use;
- Organic material decomposition from dredging operations; and
- Material manufacturing.

Minor changes have been made to the emissions calculated in the FSEIS based on changes to the assumptions detailed herein.

Transport

Transport of methanol from the KMMEF would include marine vessels (tanker) with a tonnage in the range of 60,000 to 120,000 dead weight MT (actual carrying capacity would be 50,000 to 100,000 MT). Tanker traffic is proportional to the amount of methanol shipped. At full methanol production capacity, this would result in 36 to 72 shipments to China per year. These two scenarios are presented. The 50,000 MT scenario results in twice the number of shipments per year.

As described in Section 3.4 of the LCA report, emissions are based on transport from the project site in Kalama, Washington to a representative port in China as there are no formal contracts for off-take of the project production. Bohai Tianjin, China was selected as a representative port as there are facilities in operation for the production of olefins from methanol and the port is also approximately an equal distance to other major productions centers in Eastern China. The transport includes fuel use for transporting the bar pilot by helicopter, tugboat operation in the Columbia River, and transport in a marine vessel.

Fuel production

The production, construction and transportation elements of the project all utilize petroleum fuels. To account for the full emissions associated with these elements, upstream emissions for petroleum fuel production have been included. Appendix A to the FSEIS includes an analysis of the upstream emissions for crude oil production and refining. Crude oil production emissions were based on the Oil Production Greenhouse gas Emissions Estimator (OPGEE) model and the mix of production emissions is documented in a separate appendix. The GREET model estimates the emissions for refining petroleum fuels based on the complexity of the oil refineries in different regions of the U.S. Among other parameters the GHG emissions from a refinery are directly related to the density of crude oils measured in API gravity. Crude oils that are light (higher degrees of API gravity or lower density) tend to require less intensive processing which results in lower GHG emissions. The GREET model also provides estimates of the detailed CO_2, CH_4 and N_2O emissions for petroleum fuel production. Different upstream emissions were estimated for bunker fuel, diesel, gasoline and naphtha as mentioned in Appendix B to the FSEIS and documented in Petroleum Appendix.

In-state / out of state emission values

Emissions are reported for those that occur inside Washington State and those that are outside of Washington State. The Table C-2 lists the approach applied to determining in-State emissions applied in the analysis. Some values were refined in the supplemental analysis.

Table C-2 Emission Location Assumptions by Source.

Source	Assumption
Methanol Production	100% in state
Purchased Power[1]	Natural gas power generation 100% in-state Upstream emissions about 5% in-state
Construction	Direct -100% in state Indirect (fuel) – see petroleum fuels below Cement production– 36% in state[2] Structural steel, copper and stainless steel – 100% out of state Rebar – 100% in state Asphalt production – 27% (Oil refining 100% in state, Crude oil production 0% in state) Aggregate production – 100% in state Dredging Organic C – 100% in state Employee commute – 100% in state
Transport of methanol	Tug assist and Helicopter transport (pilots) in Kalama – 100% in state Tanker Transport – 75 miles considered in state (Project site to 3 nm limit) All remaining are out of state
Diesel and Gasoline Production for trucks and helicopters	Oil refining 100% in state Crude oil production 0% in state
Bunker fuel production for construction material, catalyst, and methanol transport	Oil refining 50% in state Crude oil refining 0% in WA
Other sources: • Waste disposal • Employee commute • Catalyst Replacement • Decommissioning	100% in state 100% in state Truck transport 100% in-state, production and vessel transport 100% out of state[3] 100% in state

1. At the request of Ecology only power demand has been provided. Ecology will be analyzing power based on a natural gas-based marginal mix. Direct emissions will occur primarily in Washington and natural gas production outside of the state with a fraction of pipeline leakage occurring in Washington.
2. Based on in-state production capacity as a percentage of overall demand. From: https://www.cement.org/docs/default-source/market-economics-pdfs/2019-state-pdfs/wa-statefacsht-19.pdf?sfvrsn=877ae3bf_2
3. Transportation of catalyst will include a small component within state which are estimated to correspond to a 200-mi round trip. Per 1% cut of criteria we have not calculated the emissions associated with the minor distance of container vessel transport in the State of Washington.

Cut-off criteria

Minor inputs and emissions that have a small effect on life cycle GHG emissions were excluded from emission calculations. A cut off level of relevance of 1% of the total project emissions was selected. This level is less than the variability in most LCA studies on similar products. These emissions include domestic wastewater treatment, potable water supplied by the City of Kalama, office supplies, heating and other general building requirements such as general solid waste disposal, disposal of sulfur co-product and air travel associated with operations. The exclusion of these activities is consistent with the ISO 14040 standards.

Some specific emission categories that could be calculated without significant assumptions are included in this technical report even though they would account for less than 1% of the emissions. These include decommissioning of the plant, local employee commuting during operations, process water supplied by the Port, catalyst replacement and disposal of waste product form process water treatment.

Direct emissions

Methanol production

Direct operating emissions from the ULE Alternative include the sources shown in Figure C-1. Natural gas is converted to methanol with some unconverted byproduct gas burned in a boiler along with natural gas. Natural gas also provides fuel for a natural gas combined cycle power plant. A small quantity of natural gas is also combusted in a flare pilot. Fugitive emissions also occur from the methanol system and storage tank. Net CO_2 emissions for the KMMEF (CK) are verified by carbon balance such that the carbon in each of the components balance.

Net carbon emissions (C_K) are calculated such that:

$$C_K = C_{NGT} - C_{MeOH}$$

Where:

C_K = Carbon emissions from methanol production

C_{NGT} = carbon in natural gas feed

C_{MeOH} = Carbon in methanol

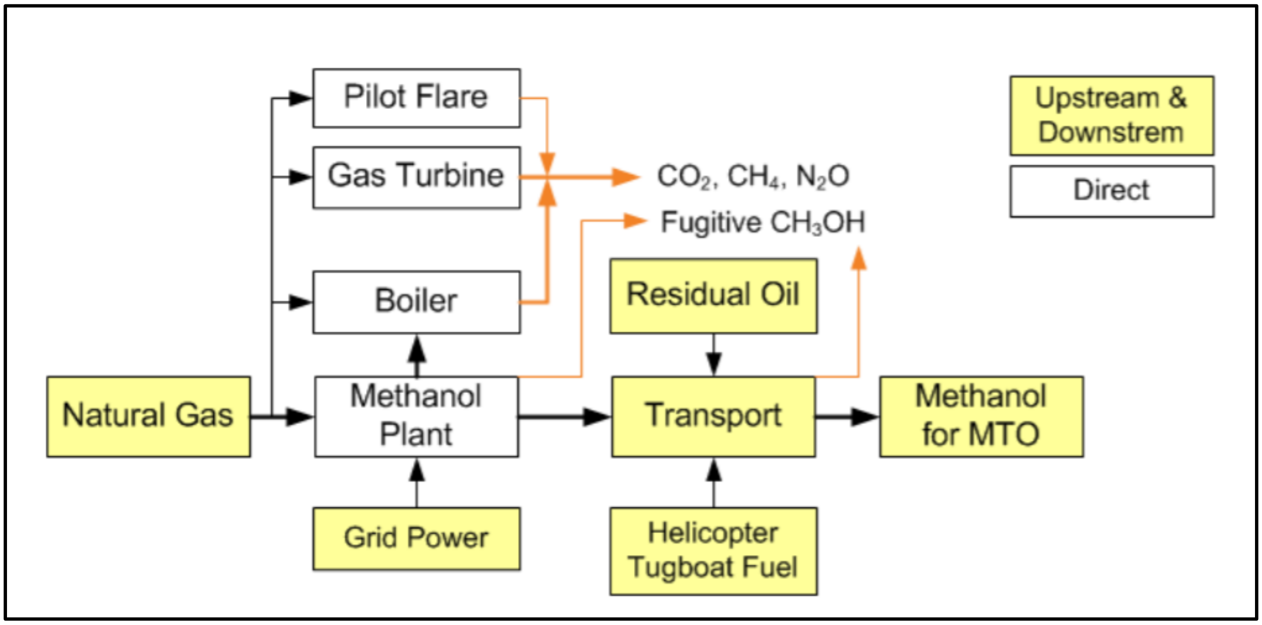

Figure C-1. ULE Emission Sources

The CR alternative differs in that the Gas Turbine is not needed due to lower electricity demand and the addition of the reformer which uses natural gas as the feedstock for power.

Direct emissions from the project correspond primarily to the combustion of natural gas for on-site power and the unconverted CO_2 from the methanol production process. Natural gas for process boilers, flares and backup diesel equipment also contribute to direct GHG emissions. Energy inputs and emissions from continuous operation are based on the process design and correspond to a mass and energy balance between the natural gas feed, methanol produced, and emissions. A carbon balance provides the basis for the net emissions followed by a summary of the total KMMEF emissions. Carbon Balance GHG emissions from the methanol production process consist of fired natural gas and fuel gas. CO_2 emissions are represented by the carbon balance shown in Figure C-2. Natural gas is combusted in a combined cycle power plant as well as boilers. In addition, fuel gas from the methanol plant is burned in the boilers. The carbon balance shows the mass, energy content and carbon in the natural gas to the facility. The distribution of the natural gas streams is also shown. The net CO_2 emissions from the methanol plant are consistent with a carbon balance as per the following equation such that:

$$C_K = C_{NGF} - C_{MeOH} + C_{NGP}$$

Where:

C_K = Carbon emissions

C_{NGF} = Carbon in natural gas feedstock

C_{NGP} = Carbon in power plant fuel

C_{MeOH} = Carbon in methanol

Thus, the carbon in the fuel gas is determined by difference and is also consistent with the process design. The natural gas inputs correspond to feed for the methanol production system. A small portion of the feed natural gas also provides boiler fuel as shown in Figure C-2.

Natural gas is also the source of electric power for on-site power production. On site power production with a combined cycle power plant provides 110 MW or 264 kWh of power per tonne of methanol. A heat rate of 7500 Btu/kWh of natural gas for power generation requires 19,800 mmBtu/d, HHV basis. The energy consumption corresponds to a lower heating value efficiency of 50.4%.

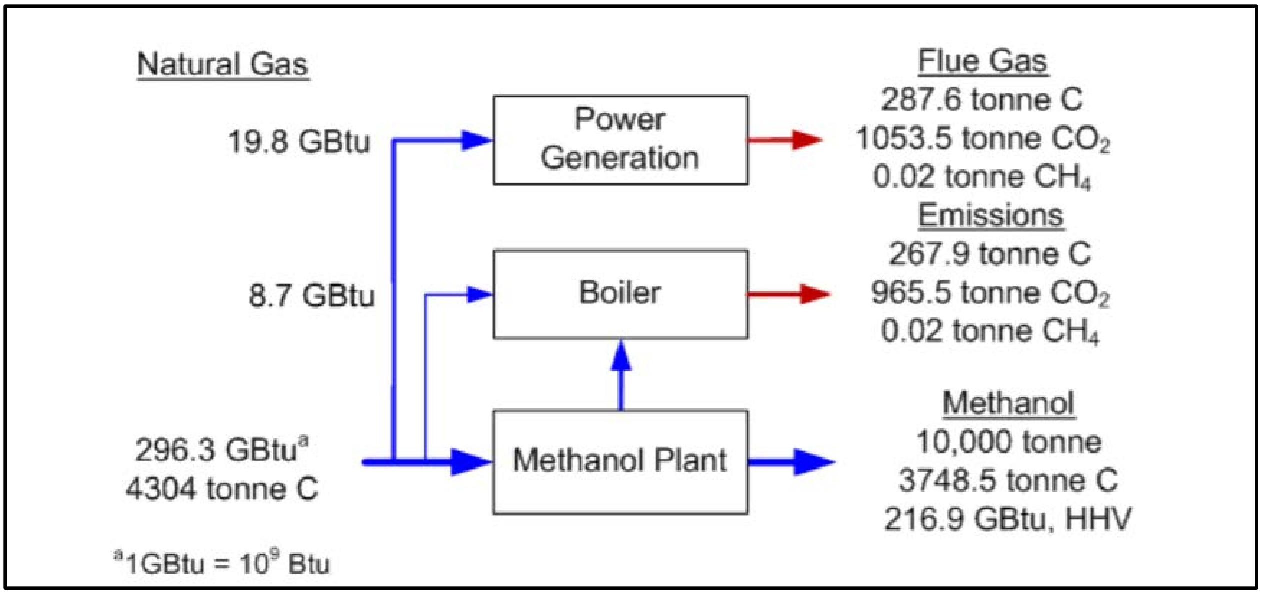

Figure C-2. Carbon Balance for ULE Daily Operation (SOR)

Table C-3 shows the total natural gas inputs during continuous operation based on the facility design. These maximum natural gas inputs occur at the start of operation where natural gas to the boiler is slightly higher than at the end of run. Total natural gas inputs are slightly lower at the end of run.

Table C-3. Natural Gas Inputs for Methanol Production – ULE Alternative

Natural Gas Input	Methanol Plant	On Site Power Generation	Total Natural Gas Feed
tonne/h	225.4	16.1	241.5
Tonne C/h	167.3	12.0	179.3
C wt %	74.25%	74.25%	74.25%
mmBtu/tonne, HHV	27.65	19.8	29.63
mmBtu/d, HHV	276,512[1]	19,800	296,312

Source: NWIW process design, start of run

1. Natural gas to boiler is 8,661 mmBtu/d during SOR and drops to 7,777 mmBtu/d at EOR condition

The carbon balance in Figure C-2 provides the basis for determining CO_2 emissions and the energy inputs to the power plant/boiler provide the basis for determining CH_4 and N_2O emissions, which corresponds to a small fraction of the overall GHG emission.

Fugitive emissions

Fugitive emissions from production are consistent between the two alternatives and two scenarios as it is based total methanol production. Fugitive emission rates and calculations are specified in Appendix D to the FEIS (Ramboll Environ 2016a). CO_2 emissions correspond to fully oxidized methanol.

Direct combustion emissions

Direct combustion emissions occur from a variety of sources in the life cycle. These emissions include CO_2, CH_4 and N_2O which depend on the carbon content and heating value of the fuel and the combustion characteristics of the boiler, engine, or other applications. CO_2 emissions for fuel combustion depend upon the carbon content, density, and heating value of fuels such that all of these properties are consistent. Emission factors are identified in the units based on the original data source including the higher heating value (HHV) or lower heating value (LHV) basis. Table C-4 shows the calculation of the carbon factor (g CO_2/mmBtu) for the primary fuels used. The carbon factor is calculated such that the carbon per Btu is multiplied by the molecular weight ratio of CO_2 to carbon such that:

$$\text{Carbon factor} = \text{wt\%C/HHV (Btu/lb)} \times 453.59\ \text{g/lb} \times 44/12.01 \times 10^6$$

Table C-4. Calculation of CO_2 Emission Factors from Fuel Properties

Fuel	Natural Gas	Residual Oil	Diesel
Carbon (wt%)	74.2%	86.8%	86.5%
Higher Heating Value (Btu\lb)	23,180	18,148	19,676
Higher Heating Value (But\unit)	1,049	150,110	137,380
Unit	scf	Gal	Gal
Carbon Factor (g CO_2/mmBtu)	53,223	79,478	73,049
Carbon Factor (kg CO_2/kg)	2.72	3.18	3,17

Other emissions during operations

During operations other emissions result from the operation of the facility that are not direct emissions from methanol production. These emissions are less than 1% of the direct project emissions and would fall under the cut-off criteria. However, because assumptions could be developed to estimate emissions, they have been included based on the assumptions identified in this section.

Employee commuting

The proposed project is estimated to employ approximately 192 full time employees that will need to commute from their place of residence to the project site at the Port of Kalama. Table C-5 identifies the assumptions used to calculate the emissions.

Table C-5. Employee Commuting Assumptions.

Input	Assumption	Source (if applicable)
Commute Days	Standard 5-day work week. No reduction for time off or other circumstances such as work from home.	NWIW
Mode Split	80% single occupancy vehicle 20% carpool/vanpool (2 persons per vehicle)	US Census data for Cowlitz County[1]
Distance	Less than 10 miles – 39% = 67 trips 10 to 24 miles – 14.1% = 24 trip 25 to 50 miles – 18.7% = 32 trips Greater than 50 miles– 28.2% = 49 trips Note: for the purposes of determining miles a midpoint in the range was used of 50 miles for those trips of more than 50 miles. Each trip is doubled to account for round trip distances	2017 US Census Data
Location	All trips assumed to occur fully in Washington State[2]	
Emission calculation method	See Appendix A Section 3.1 (fuel use X direct and upstream emissions factors)	GREET transport and backhaul fuel use factors.

1. No transit serves the site, the percentage reported by the US Census for this mode was moved the single occupancy vehicle category.
2. The economic analysis indicates that labor would come from a wider area including Oregon. Due to the lack of assumptions on which to base a split in location and miles traveled, and to overestimate emissions no accounting for out of state emissions was made.

Catalyst replacement

A mixed-metal catalyst is used as part of the methanol production process. Over time the catalyst loses effectiveness due to loss of metals and must be replaced. NWIW has indicated that catalysts will be replaced every four years. Emissions result from manufacturing of the catalyst, shipping from the manufacturer and shipping of the spent catalyst for recycling. Table C-6 identifies the assumptions used in calculating the emissions.

Table C-6. Catalyst Replacement Assumptions

Source	Assumption	Source (if applicable)
Catalyst Manufacturing	United Kingdom	NWIW
Material volume	480 MT per year	NWIW
Transport	Southampton, UK to Seattle WA via container vessel, 8,618 kn (one way) Seattle to Kalama via truck, 143 miles (one way)	Seadistance.org, Google maps

Waste disposal

Waste is generated from the treatment of raw water through the RO-EDI process and by the process wastewater treatment system (ZLD). Emissions result from transport of the waste product from the project site to a landfill. Both waste streams can be deposited in municipal solid waste landfills and do not require special consideration. In addition, neither waste stream includes significant volumes of organic materials that could result in emissions from decomposition, and no emissions are calculated from this.

Table C-7. Waste Disposal Assumptions

Source	Assumption	Source (if applicable)
RO-EDI	1,200 lbs to 2,100 lbs per hour	NWIW, equipment supplier
Process Wastewater	600 lbs per hour	NWIW, equipment supplier
Transport to landfill	25 tonne capacity, ,286 trips per year 42-mile round trip to Cowlitz County landfill	NGREET transport and backhaul fuel use factors.

Decommissioning

Decommissioning emissions result from direct and indirect emissions from petroleum powered equipment that will be used to remove the equipment and structures. The dock below ground features and administrative buildings will be left in place. Emissions are calculated based on the same methodology as construction emissions (see Section 2.7 below and Appendix A to the FSEIS) except that there are no emissions from material manufacturing and dredging. The number of required workers is 25% of that used for construction and fuel use is 23% of that used for construction. No credit is provided for material recycling.

Transport

Methanol from the proposed project will be transported to a representative port in China (Bohai Tianjin, China) in tankers with a tonnage in the range of 60,000 to 120,000 dead weight MT (actual carrying capacity would be between 50,000 and 100,000 MT). Methanol will be loaded onto the tanker which transits down the Columbia River to the Pacific Ocean. The tanker will make a 5,310-nautical mile trip to Bohai Tianjin, China. The tanker will return with an empty backhaul.

The transport of methanol from Kalama to China includes a number of support efforts and resulting GHG emissions. During docking and undocking two assist tugs will guide the ship to and from the dock. Vessel pilots will be transported to and from the ship by helicopter and/or motor vessel. The energy inputs, emission factors and transport distances for each transport segment are shown in Table C-8 for 100,000 MT vessels and Table C-9 for 50,000 MT vessels.

Table C-8. Transport Emission Factors 100,000 MT Vessels.

Transport Leg	Nautical Miles	Btu/ton mi. HHV
Piloting (Kalama)	N/A	0.0000004
Kalama to China	5,310	46.3
Piloting (China)	N/A	0.0000002
Bohai to Kalama	5,310	39.0

Source: Energy intensity for marine transport based on GREET model T&D Sheet. 1 hour of tugboat operation for docking and departure, 43.5 gal/h (ARB 1999) Helicopter fuel use from aircraft calculator.com, 57.6 gal/h, 15-minute one-way trip from Astoria to vessel.

Table C-9. Transport Emission Factors 50,000 MT Vessels

Transport Leg	Nautical Miles	Btu/ton mi. HHV
Piloting (Kalama)	N/A	0.0000008
Kalama to China	5,310	85.2
Piloting (China)	N/A	0.0000005
Bohai to Kalama	5,310	71.9

Source: Energy intensity for marine transport based on GREET model T&D Sheet. 1 hour of tugboat operation for docking and departure, 43.5 gal/h (ARB 1999) 200 Helicopter fuel use from aircraft calculator.com, 57.6 gal/h, 15-minute one-way trip from Astoria to vessel.

Indirect (upstream) emissions

Petroleum products are used for construction equipment, construction material transport, employee commuting, methanol transport, small quantities of on-site diesel, and disposal of waste materials. The upstream life cycle emissions associated with this petroleum product use include crude oil extraction, transport, oil refining, and delivery of the petroleum product. Petroleum fuels are used in the transport of methanol to the representative port and fuel for equipment during construction.

Crude oil is produced and transported from a variety of resources and regions in the world. In some cases, crude oil production results in the production of associated gas and the cogeneration of electric power. Crude oil is transported to oil refineries and refined into a range of products. GHG emissions from petroleum production depend on the crude oil type and the extraction method as well as oil refinery configuration with about a 10% range in life cycle emissions from different crude oil types (Gordon et al. 2015; Keesom et al. 2012). The life cycle analysis of petroleum production in the GREET model takes into account the upstream emissions for crude oil production as well as the energy intensity to refine different products. The GREET inputs for petroleum product refining are based on a linear programming analysis of U.S. refineries (Elgowainy et al. 2014). The energy inputs and emissions within oil refineries are allocated with this approach between diesel, gasoline, residual oil, LPG, naphtha, and coke. The GREET modeling approach assigns greater energy inputs to gasoline and diesel fuels and less to residual oil and naphtha since refinery units are designed to produce diesel and gasoline.

The GREET model estimates the emissions from crude oil to petroleum fuels based on the complexity of the oil refineries in different regions of the U.S. Among other parameters the GHG emissions from a refinery are directly related to the density of crude oils measured in API gravity. Crude oils that are light (higher degrees of API gravity or lower density) tend to require less intensive processing which results in lower GHG emissions. Details of upstream emission for petroleum fuels are provided in an Appendix.

Construction emissions

Direct

Direct emissions from construction correspond to the fuel for construction equipment, dredging, shuttle bus (to and from offsite parking areas) and employee commute traffic shown in Table C-10. NWIW estimated the fuel used for cranes, dozers, compressors, and other construction equipment. The basis for estimating fuel use for other construction activities is described in the table. Material hauling is based on the amount of material, distance to distribution center, and cargo hauling efficiency. Half of the construction materials are assumed to be delivered by marine vessel from Asia.

Table C-10. Energy Inputs for Direct Construction Emissions

Construction Fuel	Gallons[1]	Lb	mmBtu, HHV	Source
Construction diesel	423,505	2,933,435	56,358	NWIW
LPG	154,135	653,48	14,090	NWIW
Soil hauling diesel	37,128	257,172	4,941	227,370 CY, 10 mi[2]
Concrete hauling diesel	13,332	92,346	1,774	55,110 CY, 10 mi[2]
Material hauling diesel	19,796	137,120	2,634	148,472 MT, 10 mi[2]
Material hauling marine	515,644	4,265,231	1 77,403	148,472 MT, 5,310 kn[2]
Dredging marine diesel	40,373	333,955	6,060	126,000 cy, 2.5 kg /CO_2/m^3 [4]
Commute gasoline	283,961	1,771,375	34,600	560 employee, 26 mo, 30 mi [5]
Shuttle diesel	4,462	30,909	594	70% of employees

1. Fuel properties from GREET are in Appendix A to the FSEIS (see FSEIS Appendix C to Appendix A).
2. Truck fuel economy 6 mpg for local delivery including empty backhaul. Transportation is included in upstream data.
3. Transport of half of equipment from Asia in 100,000 MT capacity vessel, 85.3 Btu/ton-mi, with empty backhaul.
4. Fuel use for dredging is calculated from emission rate 2.5 kg CO_2/m3 of dredged material (EuDA 2016) combined with marine diesel fuel carbon content.
5. Average employee count from EIS Appendix K, page 83. Fuel consumption of 24.1 mpg based on VISION model (ANL 2014) with 50% passenger cars and 50% light trucks. Assume 25% carpooling, 20 working days per month.

The direct combustion emissions depend on the amount of fuel consumed and the carbon content of the fuel. In addition, CH_4 and N_2O emission vary by combustion technology (e.g. boilers or engines). Emission factors for the fuels used during construction shown in Table C-11 are combined with the energy inputs to calculate emissions. Energy use is shown on an HHV basis.

Table C-11. Direct Emission Factors for Fuel Combustion

Emission Factor (g/mmBtu), HHV[1]	CO_2	CH_4	N_2O
Diesel[2]	74,889	4.4	0.2
LPG	63,252	3.3	1.0
Gasoline	71,629	2.8	0.6
Marine Fuel	79,540	4.3	1.9

1. Direct emission factors described in Appendix C (in Appendix A to FSEIS)
2. Emission factor based on 80% trucks and 20% off-road engines with minor effect on CH4 emissions.

Indirect

Upstream emissions for construction activity include the production of fuel for construction equipment, generation of power for construction equipment, and manufacturing of materials. The potential release of CO_2 from organic material decomposition from dredged material is also included.

Upstream emissions for construction energy inputs correspond to the total energy inputs multiplied by the upstream emission rate from GREET configured with Washington-specific parameters for crude oil production and power generation. The construction phase occurs before KMMEF's power purchase agreements are implemented; therefore, GHG emissions are based on the current electricity mix for Cowlitz County. Upstream emission rates associated with energy inputs for construction are shown in Table-12 and are described in Appendix A to the FSEIS (see Appendix B to Appendix A). Upstream emissions associated with diesel, marine diesel and production are based on the mix of crude oil resources that supply Washington refineries plus imports of refined diesel from Montana. Potential carbon releases from dredging is also included.

Table C-12. Upstream Emission Rates for Construction Materials.

Life Cycle Emission Rate	CO_2	CH_4	N_2O	Source
Structural Steel	2,687	4.3	0.022	GREET2_2017
Rebar	2,020	3.5	0.023	GREET2_2017
Stainless Steel[2]	5,204	11.3	0.090	GREET2_2017
Copper[2]	3,083	6.3	0.0555	GREET2_2027
Asphalt[3]	639	0.4	0.003	GREET1_2027
Aggregate[4]	300	0.2	0.000	US LCI
Cement[4]	2,900	0.7	0.002	GREET1_2017

1. Includes additional assumed 800 miles transport, 50% truck, 50% rail to manufacturing facility. Delivery to Kalama is counted additionally. GHG emissions are based on material use in Appendix A, Table 3.5 combined with upstream life cycle emission rates in this table.
2. Stainless steel composition, 56% steel, 20% Ni, 20% Cr, 2% Mn, 2% Ci, Compare to 6,800 kg CO_2e/kg stainless steel, 3,300 kg CO_2e/kg copper (IMA 2018)
3. Emissions for asphalt based on 90% aggregate and 10% residual oil.
4. Emissions from cement production include limestone production and cement manufacture. Life cycle emissions based on CaO production from GREET1.

Dredging of the new Port of Kalama Berth Basin will redistribute sand which contains organic material that could potentially decompose when disturbed. Organic carbon releases from dredged material are estimated to correspond to 50% of the carbon content (1.67 wt%) of the dredged material. The samples ranged from 0.9 to 1.67% carbon. This level of carbon release is conservative since the dredged material is redeposited or redistributed and not subject to future disturbance.

Materials of construction for the KMMEF include steel and other metals, asphalt, and concrete. NWIW estimated the weight of materials based on the facility design as shown in Table C-13.

Concrete is divided between the aggregate and Portland cement components. The GREET2 model provides the estimates for upstream life cycle emissions from metal production. These life cycle results are consistent with other LCA models such as Ecoinvent and the USLCI database. These upstream calculations in GREET2 incorporate the upstream life cycle results for fossil fuels from the GREET1 model and provide the basis for materials such as steel, copper, and stainless steel. The life cycle results for fossil fuels are also consistent with the above referenced LCA models. The remaining upstream emissions are derived from the USLCI database and the GREET1 model. The heaviest materials of construction include concrete and asphalt. These materials; however, require relatively low upstream emissions in their manufacture. GHG emissions associated with metals manufacturing includes energy for mining, smelting, and processing to materials of construction, and transport to manufacturing facilities.

Table C-13. Upstream Emissions for Construction Materials

Pollutant	Unit	CO_2	CH_4	N_2O
Upstream Diesel	(g/mmBtu), HHV[1]	20,036	20	0.1
Upstream LPG	(g/mmBtu), HHV[1]	10,425	162	0.2
Upstream Gasoline E10	(g/mmBtu), HHV[1]	21,883	20	0.2
Upstream Marine Fuel	(g/mmBtu), HHV[1]	15,984	10	0.1
Upstream Power (g/KwWh)[2]	(g/mmBtu), HHV[1]	46.2	0.1	0.004
Upstream Diesel	tonne[3]	1,317	1.3	0.01
Upstream LPG	tonne[3]	147	2.3	0.00
Upstream Gasoline E10	tonne[3]	757	0.7	0.01
Upstream Marine Fuel	tonne[3]	1,334	0.9	0.01
Upstream Electricity	tonne[3]	665	1.5	0.06
Dredging Organic C[4]	tonne[3]	1,609	0	0
Total		**5,829**	**7**	**0.1**

1. Upstream life cycle results from GREET inputs in Appendix A to the FSEIS (see Appendix B). Washington electricity and crude oil resource mix for petroleum fuels.
2. Cowlitz PUD generation mix with 14,400 MWh of power consumed during construction.
3. GHG emissions based on fuel energy in Table C-9 combined with emissions factors from this table.
4. 1.67 wt%. 50%, carbon 126,000 CY, 2 MT/m^3

Decommissioning

Emissions would result from activities associated with shutting down the facility and removing surface features. The primary source of emissions will be diesel powered construction equipment, upstream fuel and purchased power. All metals are assumed to be recycled and concrete and asphalt will remain on-site. Underground elements (such as piles and ground improvements) will also remain. Decommissioning uses the same indirect emissions rates as construction. Table C-14 lists the energy inputs for emissions associated with decommissioning the facility.

Table C-14. Energy Inputs for Direct Decommissioning Emissions

Construction Fuel	Gallons[1]	Lb	mmBtu, HHV	Source
Construction diesel	179,109	1,240,613	23,835	NWIW
LPG	65,187	276,357	5,959	NWIW
Commute gasoline	70,990	442,844	8,650	
Shuttle diesel	1,116	7,727	148	635 employees, 36 month

1. Fuel properties from GREET are in Appendix A to the FSEIS (see Appendix C to Appendix A).

Emissions

Project construction

Construction of the project will require imported materials and emissions for fuel use during construction (direct and upstream). Direct and Indirect fuel use are assumed to occur fully in Washington State. Indirect emission from materials are assumed to be outside of Washington State with the exception of aggregate, cement and asphalt which are assumed to occur in Washington State. Table C-15 indicates emission from construction.

Table C-15. Construction Emissions

Greenhouse Gas Emissions (MT)	Total CO_2	WA State CO_2	Total CH_4	WA State CH_4	Total N_2O	WA State N_2O
Direct Fuel Use	20,115	10,523	1.0	0.53	0.30	0.07
Indirect Fuel	4,153	1,502	32	8.23	0.05	0.02
Material Production	546,561	97,967	1,051	110	6.08	0.28
Purchased Power	665.1	598.6	1.5	1.4	0.06	0.05
Dredging Organic C	1,609	1,609	0	0	0	0
Total	**573,103**	**112,199**	**1,086**	**120**	**6.48**	**0.41**

Project decommissioning

Decommissioning excludes materials and requires an estimated 25% of the workforce of construction. Table C-16 reports decommissioning emissions.

Table C-16. Decommissioning Emissions

Greenhouse Gas Emissions (MT)	Total CO_2	WA State CO_2	Total CH_4	WA State CH_4	Total N_2O	WA State N_2O
Direct Fuel Use	2,793	2,793	0.15	0.2	0.017	0.017
Indirect Fuel	714	349	5.11	2.1	0.013	0.008
Purchased Power	66.5	59.9	0.15	0.14	0.006	0.005
Total	**3,574**	**3,201**	**5.41**	**2.4**	**0.036**	**0.030**

Purchased power

The proposed project will import 100 MW (864,000 MWh) of electric power from the regional power market through the Cowlitz PUD transmission system during continuous operation. Power demand is reflected in Megawatt Hours (MWh). Total power demand is shown in Table C-17 for the ULE Alternative. Power demand over the 100 MW provided by purchased power is provided for by the on-site natural gas combustion turbines (emissions from the on-site power generation are captured in the ULE Production Scenarios).

Table C-17. ULE Power Demand

Primary Source	Demand (MWh)
Air Separation Units	656,640
Make-Up Compressors	319,680
Loop Circulators	311,040
Natural Gas Compressors	95,040
Pumps, air coolers, misc.	416,100
Wastewater Treatment	21,900
Water Treatment Planta	1,180
Total	**1,821,580**

Note: This represents the power needed for the Port's collector well to deliver 4.5 million gallons per day (mgd). See FEIS Section 2.6.1.4, page 2-24. This is a Port of Kalama facility and will be connected to the PUD grid and obtain power from the PUD. It is not considered a new industrial load.

Emissions resulting from the 100 MW of purchased power to be used by the KMMEF are presented in Table C-18. Emissions are provided for three power generation scenarios: Low, where all power is provided by renewable technologies; Mid, where the type of generation changes over time based on the goals in the CETA legislation; and High, where power generation is provided by the marginal resource (combined cycle natural gas) determined in the 2015 NW Power Council study.

Table C-18. Emissions from Purchased Power

Purchased Power GHG Emissions (kg GHG/MT MeOH)	Low (100% Renewable)	Mid[1] (CETA Resource Mix)	High (Marginal Power)
CO_2	0.14	48.19	96
CH_4	3.48E-04	0.14	0.29
N_2O	2.26E-06	6.79E-04	1.35E-03
CO_2e	**0.15**	**51.98**	**103.54**

1. Emissions for Mid case are the average value between 2020 and 2060.

ULE alternative methanol production Scenario 1: continuous operations

Table C-19 represents the emission from continuous operations of the ULE alternative.

Table C-19. ULE Alternative Methanol Production Scenario 1: Continuous Operations

Greenhouse Gas Emissions (MT/yr)	CO_2	CH_4	N_2O
Boilers	347,574	5.9	0.6
Firebox Heaters	0	0	0
Cooling Tower	0	0	0
Flare Pilot	154.7	0.003	0
Flare[1]	0	0	0
Tank Vent Scrubber	5.6	0	0
Ship Vent Scrubber[2]	3.4	0	0
Tanks	0.06	0	0
Emergency Generators	271.9	0.01	0.002
Emergency Fire Pump	44.8	0.0	0.0
Component Leaks	0.1	0.4	0
Combustion Turbines	379,232	7.2	0.7
Total	**727,284**	**13.51**	**1.30**

1. Flare emission occur intermittently during upset conditions. Normal operations cease during these situations and GHG emissions during these time periods would be lower. Therefore, no emission values are provided for the flare.
2. The vent scrubber results in VOC emission that are reported as fully oxidized CO_2.

ULE alternative methanol production Scenario 2: maximum potential to emit

Table C-20 represents the emission from the ULE Alternative Scenario 2.

Table C-20. ULE Alternative Methanol Production Scenario 2: Maximum Potential to Emit

Greenhouse Gas Emissions (MT/yr)	CO_2	CH_4	N_2O
Boilers	548,103	9.25	0.93
Firebox Heaters	1,399.81	0.026	0.0026
Cooling Tower	0	0	0
Flare Pilot	46.27	0.00091	0.00009
Flare	3,171.57	0.06	0.019
Tank Vent Scrubber	2.81	0	0
Ship Vent Scrubber	3.4	0	0
Tanks	0.028	0	0
Emergency Generators	272.16	0.011	0.0022
Emergency Fire Pump	65.32	0.0026	0.00053
Component Leaks	0.11	0.42	0
Combustion Turbines	421,022	7.98	0.80
Total	**974,086**	**17.75**	**1.75**

Other operational emissions

Catalyst material manufacturing and transport

A catalyst is necessary for methanol synthesis. Catalyst lifetime is 4 years. The catalyst is a combination of materials and is manufactured in the United Kingdom. Table C-21 provides emissions from catalyst replacement on a per annum basis. Emissions are included for the production and transport. The methanol synthesis is the same for each alternative and each scenario so only one value is provided. A small segment of the marine transport emissions occurs within Washington State along with required truck transport from the destination port.

Table C-21. Emissions from Catalyst Replacements

Greenhouse Gas Emissions (MT/yr)	CO_2 Total	CO_2 WA	CH_4 Total	CH_4 WA	N_2O Total	N_2O WA
Catalyst	2,844	0	6.737	0	0.063	0
Transport	42.67	13.1	0.002	0.0008	0.001	0.00003
Total	2,886	13.1	6.740	0.0008	0.064	0.00003

Employee commuting

Approximately 192 employees will be necessary to operate the facility. Emissions are calculated for employee commuting for both direct (combustion of petroleum) and upstream (production of petroleum fuels) emissions. Table C-22 shows direct and indirect emissions from employee commuting during operations on a yearly basis. Employee counts do not change between each alternative and each scenario and only one value is provided. All emissions are assumed to occur within Washington State.

Table C-22. Employee Commuting Emissions

Greenhouse Gas Emissions (MT/yr)	CO_2	CH_4	N_2O
Direct	686.1	0.029	0.0058
Indirect (upstream)	210.0	0.192	0.0014
Total	**896.2**	**0.221**	**0.0072**

Waste disposal

Waste from the ZLD, RO-EDI and from catalyst recycling (once every 4 years) requires transport to the local landfill (for waste from the ZLD and RO-EDI) and to a recycling facility (for the catalyst). Table C-23 shows emission from waste disposal on an annual basis. Emissions are calculated for both direct (combustion of petroleum) and upstream (production of petroleum fuels) emissions. These waste products are inert and void of any significant organics and no emissions from decomposition are included. All emissions are assumed to occur within Washington State.

Table C-23. Waste Disposal Emissions

Greenhouse Gas Emissions (MT/yr)	CO_2	CH_4	N_2O
Direct	17.5	0.0011	0.00004
Indirect (upstream)	4.0	0.024	0.0000
Total	**21.5**	**0.025**	**0.00004**

Methanol transport

Two scenarios were developed for transport of methanol to the representative port in China including return trip of empty vessels. Table C-24 reflects vessels with a capacity of 100,000 MT and Table C-25 reflects vessels with a capacity of 50,000 MT. Direct emissions are those from vessel fuel use in tanker, assist tugs and pilot helicopters. Upstream emissions reflect fuel production. A portion of the tanker emissions as well as assist tug and helicopter fuel use while at the Port of Kalama and for crossing the Columbia River Bar.

Table C-24. Emissions from Transport Scenario 1: 100,000 MT Vessel

Greenhouse Gas Emissions (MT/yr)	CO_2 Total	CO_2 WA State	CH_4 Total	CH_4 WA State	N_2O Total	N_2O WA State
Direct	164,552	2,324	8.9	0.13	3.87	0.05
Upstream	23,212	3,183	324	44.5	0.34	0.05
Total	**187,764**	**5,508**	**333**	**44.6**	**4.21**	**0.10**

Table C-25. Emissions from Transport Scenario 2: 50,000 MT Vessel

Greenhouse Gas Emissions (MT/yr)	CO_2 Total	CO_2 WA State	CH_4 Total	CH_4 WA State	N_2O Total	N_2O WA State
Direct	247,166	3,491	13.3	0.19	5.81	0.08
Upstream	34,866	4,782	487	66.8	0.52	0.07
Total	**282,032**	**8,273**	**500**	**67.0**	**6.33**	**0.15**

Appendix

Input Assumptions for GHG Emissions for Petroleum Fuels Used in China and Washington.

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Appendix D:
Mitigation Framework

Northwest Innovation Works-Kalama

Voluntary Greenhouse Gas Mitigation Program Framework

August 10, 2020

Purpose and overview

Northwest Innovation Works (NWIW) is committed to producing a cleaner, less greenhouse gas ("GHG") intensive methanol to reduce the environmental impacts of producing everyday products from polar fleece to contact lenses. In furtherance of this mission, NWIW proposes to voluntarily mitigate for 100 percent of all in-state direct and indirect GHG emissions from the Kalama Manufacturing and Marine Export Facility ("Facility"). In implementing the Voluntary Mitigation Program Framework ("VMPF"), NWIW will partner with stakeholders with shared interests and expertise in GHG mitigation and climate impacts, including state, tribal and local governments, environmental and environmental health nonprofit organizations, and labor organizations.

As explained in the Facility's Draft and Final Supplemental Environmental Impact Statements (collectively the "EIS"), NWIW's VMPF is intended to encompass and exceed permit conditions that have been applied to our Project, including Condition 4 of the June 8, 2017 Shoreline Conditional Use Permit ("SCUP"). Now, NWIW has not only committed to fulfilling the mandate of the state's Clean Air Rule (notwithstanding that the law would not otherwise apply to the project), we have committed to fully offsetting in-state GHG impacts.

This VMPF is the first of its kind in Washington State to describe a process to fully mitigate the climate change impacts of a new industrial facility. This framework document is intended to set a charter for the operations of the VMP advisory board ("VMP Board"), described below. NWIW expects that detailed governing documents will be developed by the stakeholders as the Project proceeds to commence operations.

Our VMPF is also committed to looking first to opportunities for GHG mitigation and reduction in southwest Washington and Washington State, where our facility will operate, and in communities that will suffer disproportionately from a changing climate. In so doing, NWIW is doing its part to reduce environmental impacts from manufacturing and demonstrating its commitment to go beyond regulatory requirements in limiting environmental impacts in Washington.

The VMPF is structured to accommodate updates in climate science, GHG modeling and climate regulations over the operational life of the Facility. NWIW has built accountability into the VMPF through the Department of Ecology ("Ecology") and Cowlitz County's roles in assessing GHG impacts in Washington, reviewing qualified mitigation projects identified by the VMP Board and by requiring that NWIW submit GHG emission reporting and mitigation compliance to the Department of Ecology and Cowlitz County. Additionally, consistent with the approaches employed in existing internationally recognized GHG mitigation frameworks, the carbon benefit of qualifying mitigation projects must be confirmed by an independent third-party verification entity.

This VMPF provides an outline of what will ultimately be implemented as part of NWIW's Voluntary Mitigation Program ("VMP"). Additional specificity and required implementing documentation[40] will be developed, in coordination with Cowlitz County and the Department of Ecology, following the completion of the environmental review of the Facility. These documents will be subject to review and oversight by Cowlitz County and the Department of Ecology.

VMP oversight

NWIW will implement the VMPF with the approval of Cowlitz County and the Department of Ecology and in partnership with representatives from the environmental, business and community stakeholders who will serve on the independent VMP Board. NWIW will facilitate VMP costs and administration, but the VMP Board will independently review and provide recommendations on the emissions obligations and subsequent audits to the regulatory agencies, identify and nominate cost-effective GHG mitigation projects to the regulatory authorities, and award and disperse funding for voluntary mitigation projects or, where necessary, the purchase of carbon credits.

The VMP Board will provide independent, knowledgeable, objective and unbiased facilitation of the VMP. The VMP Board shall be comprised of representatives from, state, tribal and local government and the public, including, for example, representation from labor, the Department of Ecology and Cowlitz County (*ex officio*), environmentally focused nonprofit organizations and environmental justice organizations.[41] The VMP Board will also be charged with formally drafting the VMP governing documents consistent with this document and the recommendations of Cowlitz County and the Department of Ecology with the purpose of funding verified cost- effective carbon reduction or offset projects. In the event the VMP Board is unable to discharge its duties, NWIW is required to fulfill its mitigation obligations and functions in accordance with the purposes and intent of this VMP framework.

With reporting to the Department of Ecology under Ch. 173-441 WAC as described in the Greenhouse Gas Emissions Accounting section of this document, Ecology and Cowlitz County will set the total annual VMP obligation and verify that the verified cost-effective mitigation projects recommended by the VMP Board are consistent with VMP goals and parameters. The VMP Board shall provide a regular accounting of mitigation actions and outcomes to Cowlitz County and the Department of Ecology, subject to their approval and/or further direction on VMP administration of this program.

[40] Operating agreements will include processes for resolving potential conflicts between parties.
[41] NWIW is undertaking research as to how to configure and account for the VMP, including consideration of forming an independent nonprofit arm to administer the funds.

VMP GHG mitigation methods and priorities

Mitigation methods

The VMP Board will build and recommend a mitigation project portfolio that meets the 100 percent GHG mitigation commitment for direct and indirect in-state emissions. All mitigation projects will meet the following criteria[42]:

1. Real, specific, identifiable, and quantifiable
2. Permanent
3. Verifiable, and
4. Additional

The VMP Board will first solicit local proposals from third parties for GHG mitigation or reduction projects. Ultimately, NWIW seeks to have a portfolio of cost-effective, verifiable carbon sequestration and reduction projects in Washington that achieve full mitigation for VMP emissions.

The VMP Board will also solicit carbon offset projects. Qualifying offset protocols will be those that qualify for use through protocols published by a) established internationally recognized registries, including, but not limited to Verra (formerly Verified Carbon Standard), American Carbon Registry, Climate Action Reserve, or the Gold Standard or b) through regulated carbon markets[43]. The VMP Board will require project applicants to verify their GHG reduction or offset benefits. Qualified protocols are subject to review and approval by the Department of Ecology and Cowlitz County.

The VMP obligations based on Project VMP GHG emissions may be accomplished through a variety of methods, including:

1. Investments made by the VMP Board in projects and programs that cause additional and verifiable carbon emission reductions and carbon sequestration in the state of Washington;
2. Investments made by the VMP Board in projects and programs that cause additional and verifiable carbon emission reductions and carbon sequestration in the Pacific Northwest; and/or

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[42] These criteria will be consistent with specific project types through internationally recognized carbon market protocols.

[43] Note that this nonexclusive list of offset verification programs are examples of protocols used to calculate offsets before the California Air Resources Board. *See* https://ww2.arb.ca.gov/our-work/programs/cap-and-trade-program.. Over the life of the project, other protocols and regulatory resources the meet the criteria established in this VMPF are likely to become available. The VMPF is structured to accommodate those updates in science, internationally recognized registries and regulatory frameworks.

3. Investments made by the VMP Board in projects and programs that cause additional and verifiable carbon emission reductions through internationally recognized carbon market protocols.

The implementation of these methods and mitigation priorities are discussed in greater detail in the following section.

The intent of this program is to develop a cost-effective suite of mitigation projects that maximize carbon reduction and local co-benefits (in no case less than the total VMP obligation identified by the Department of Ecology and Cowlitz County), and address the local and project priority preferences described below. Where the proposed portfolio of local mitigation projects does not fully discharge the VMP obligation, the VMP Board shall purchase carbon credits from U.S. carbon credit markets[44] or voluntary U.S. carbon registries.

An annual budget for funding the mitigation portfolio will be established by multiplying the total VMP obligation in metric tons of greenhouse gases in a given year by the then-current average cost of U.S. carbon allowance markets in dollars per metric ton of greenhouse gases.

Where the total cost of the proposed local or regional projects in the portfolio exceeds the budget for a given year, the VMP Board shall then achieve the emission reduction obligation through a combination of local or regional projects combined with the purchase of carbon credits from U.S. carbon markets. In this case, carbon credits will be purchased only to the extent necessary to meet the portion of the mitigation obligation that cannot be met with local or regional projects within the budget. In this way, the annual budget will satisfy the full mitigation obligation.

Mitigation priorities

In making its recommendations and requests to the Department of Ecology and Cowlitz County, the VMP Board will prioritize projects which are located in southwest Washington and Washington State. The VMP Board will also prioritize projects that generate co-benefits, including benefits to ecological systems, endangered and threatened species, and communities that suffer economic hardships and have high environmental and health disparities that may be exacerbated by climate change.

In the selection of third-party carbon reduction projects, the VMP Board will make all reasonable and good faith efforts to invest GHG mitigation funds in local projects, giving priority to:

1. Projects within Cowlitz County
2. Projects within Southwest Washington
3. Projects within the state of Washington

[44] NWIW recognizes that purchasing allowances from the California Cap and Trade Program will require NWIW to become a Voluntarily Associated Entity (VAE) in California, including registration with CARB, and prior approval of the CARB executive officer, establishing a presence in California or designating an agent for service of process in California and acquiring and maintaining the ability to retire allowances in California's tracking system.

4. Projects within the Pacific Northwest

Recognizing that some communities have a disproportionate share of environmental burden, the VMP will give preference to:

1. Projects located within communities defined by the Washington State Department of Health as having high Environmental Health Disparities
2. Projects located in communities with high unemployment, with priority on Cowlitz County

Duration

NWIW's VMP will commence upon start of construction of the Facility and will continue for the life of its operation (currently estimated at 40 years). If, during that time, it is determined there is a comparable national, state, or local programmatic, regulatory, or statutory framework adopted for reducing and/or mitigating GHG emissions (including, for example, imposition of a carbon tax or GHG emission cap and/or reduction programs for industrial facilities) that directly applies to the proposed project and replaces some or all of the full mitigation contemplated, then that alternative GHG emission mitigation requirement shall replace whatever portion of the VMP obligation that is addressed by the replacement program.

Greenhouse gas emission accounting

NWIW is committed to accounting for its VMP obligation based on the best available scientific information, including information from international associations who publish consensus approaches to GHG accounting.[45] The VMP shall include all direct and indirect emissions from the project that occur within the State of Washington ("VMP Emissions").

NWIW will calculate and report VMP GHG Emissions by submitting an annual GHG report to the Department of Ecology that complies with Ch. 173-441 WAC. This report will include all GHG emissions subject to mitigation, including both emissions required to be reported under WAC 173-441-030(1) and all other emissions that will be voluntarily reported under WAC 173-441-030(4). All applicable GHGs in WAC 173-441-040 will be included. All reports will be submitted electronically in a format specified by Ecology. NWIW will work with Ecology to supplement their report to provide any supplemental information necessary to verify the report or estimate emissions in Washington from other sources.

Calculation methods for all emissions will be established by Ecology consistent with WAC 173-441-120(3). If the GHG emissions have calculation methods specified in Table 120-1 of WAC 173-441-120, NWIW will use the methods specified in Table 120-1. For all other GHG emissions not covered in Table 120-1, NWIW will contact Ecology for an appropriate calculation method no later than one hundred eighty days prior to the emissions report deadline established in

[45] For example, the Intergovernmental Panel on Climate Change ("IPCC") publishes assessment reports providing guidance of GHG accounting methodologies.

WAC 173-441-050(2) or submit a petition for alternative calculation methods according to the requirements of WAC 173-441-140. Such alternative calculation methods must be approved by Ecology prior to reporting and must meet the requirements of WAC 173-441-140. Ecology may update calculation methods as needed.

Construction emissions

VMP Emissions includes all project-related construction emissions. Construction emissions will be offset in the year they are emitted rather than being pro-rated over the life of the Facility as estimated in the EIS and SEIS. If the VMP Board is not yet constituted and operational prior to Project construction, VMP obligations may be banked and spent in conjunction with the first-year of VMP operational obligations. Alternatively, the County may pre-determine a GHG mitigation project that meets the GHG offset requirement for estimated construction emissions. Following the completion of construction, estimated VMP Emissions from construction will be updated to account for actual emissions (where available) and updated estimates (where actual emissions cannot accurately be obtained). Any surplus or deficiency between first year estimates and actual construction emissions shall be added or subtracted (as needed) from year two VMP obligations

Operational emissions

The year one VMP Emissions from operations will be based on the Baseline Scenario minus prorated construction emissions and incorporating any additional mitigation that NWIW commits to prior to the commencement of operations that reduce GHG emissions. At the end of the first year of Facility operation, the actual Project VMP Emissions shall be calculated using the methods provided above. Any surplus or deficiency between first year estimates and actual VMP Emissions shall be added or subtracted (as needed) from year two VMP obligations.

For each subsequent year, VMP Emissions shall be measured, calculated or estimated using the methods provided above.

Verification of emissions

Emissions will be verified by Ecology consistent with Ch. 173-441 WAC.