DISCUSSION BRIEF

Towards a climate test for industry: Assessing a gas-based methanol plant

Key messages

- Industry is a major contributor to climate change. Industrial products are also needed to build a low-carbon economy. A "climate test" for new industrial development would help policy-makers balance these tradeoffs.
- To be consistent with a deeply low-carbon economy, a new industrial facility should make its product with low GHG emissions *and* not lock in a technology or product inconsistent with a low-carbon transition.
- By these measures, the proposed methanol facility at the Port of Kalama in Washington State appears to fall short. The facility would use natural gas to make methanol as a primary product for olefins (plastics). There are several ways to produce olefins with much lower GHG emissions.
- The Kalama facility would offer a climate benefit if it were to displace higher-emitting coal-based methanol plants, but there is little evidence that this would be the outcome. Instead, it could displace more common olefin production methods, based on ethane or naphtha feedstocks, and increase global GHG emissions.

A petrochemical plant at twilight

Industry is a major contributor to climate change. About a quarter of global greenhouse gas emissions come from the making of plastics, metals, cement, glass, and other raw materials. Large quantities of coal, oil, and gas are burned to make the heat required for refining oil or gas, smelting iron or aluminum ore, converting minerals to glass and cement, and processing food.

At the same time, industrial processes are some of the most difficult to decarbonize, or make much less greenhouse gas (GHG) emissions-intensive. It is not as easy to stop making steel from coal as it is to stop making power (electricity) from coal, for example. Furthermore, steel and many other industrial commodities will be critical to the low-carbon transition itself; they are essential for making wind turbines, efficient buildings, and trains and tracks.

The fact that industry is a major contributor to climate change and difficult to decarbonize poses unique challenges for policy-makers. Chiefly: how should policy-makers who are committed to addressing climate change evaluate new emissions-intensive industrial development in their jurisdiction?

Such development will increase emissions and make local climate goals harder to achieve. But if the new facility is so efficient that it leads to reductions in global emissions – and helps bring about a transition to a low-carbon future – it might be worthwhile from a climate perspective.

This discussion brief seeks to get at the core of this dilemma, by focusing on a case study in the U.S. State of Washington. Here, a debate regarding a new chemical facility – to make methanol, a building block of plastics – has centered on its GHG emissions. Proponents have claimed the facility would yield significant climate benefits, but a government regulatory body invalidated a key permit because, in part, the local agencies that performed the environmental review had "failed to fully analyze the impacts of greenhouse gas emissions from the Project"[1].

In this brief, we use this case study to develop principles for assessing whether major industrial development is consistent with climate goals. We look at how GHG emissions effects are assessed, and show the importance of taking a more global perspective that examines the emissions effects beyond jurisdictional boundaries.

We also consider the importance of being able to determine, with confidence, that large long-lived industrial investments fit into a deeply low-carbon future. If new industrial facilities themselves are not consistent with the Paris Agreement goal to keep warming "well below" 2 degrees Celsius, then they could actually make a transition to a low-carbon future more difficult. Furthermore, workers and communities may be left stranded if new industrial development is so inconsistent with a low-carbon economy that such a transition renders them no longer financially viable.

The principles we develop – as well as the detailed information we present on the methanol facility itself – should be useful to policy-makers in Washington State and beyond who are considering the climate change implications of their industrial development strategies.

The Kalama methanol proposal

Though used in petrochemical plants, transportation fuels, and some household products, methanol (methyl alcohol) is not a product familiar to most consumers. Furthermore, no methanol is currently produced in Washington State nor is the natural gas that would be used to manufacture it. For this reason, it is worth zooming out to understand the changing market dynamics that led to this proposal.

The United States, as well as parts of western Canada, have experienced an unprecedented surge in natural gas production since the mid-2000s. Because of this boom in low-cost gas, producers have been looking to new markets, especially in Asia.

At the same time, Asia's economy has grown rapidly and countries there have been seeking to diversify and expand their sources of energy and raw materials. In recent years, they have focused on moving away from coal, both for pollution and climate reasons. These developments have led China and other major Asian economies to seek access to oil and gas resources in other regions.

The Kalama methanol facility sits at the intersection of these trends. The facility – and others like it proposed for the west coast of North America – would connect the growing supply of gas from the U.S. and Canada with the growing demand for gas and gas-derived products from east and Southeast Asia, including China.

Specifically, the company Northwest Innovation Works (NWIW) has proposed building a methanol manufacturing and marine export facility in southern Washington. The facility would sit along the Columbia River, which provides easy access to the Pacific Ocean, where the methanol would be shipped to China. NWIW and their partners, including the Port of Kalama, have stated that their counterparts in China would use the methanol in the manufacture of olefins, which are chemical building blocks also known as alkenes (e.g. ethylene and propylene). This would in turn be used to make plastics (e.g. polyethylene and polypropylene) and other consumer products.

The proposed Kalama refinery would, if built, be the world's largest natural-gas-to-methanol facility, producing up to 3.6 million tons of methanol per year. At full operation, the facility's demand would constitute about one-quarter of Washington State's natural gas consumption. Some of this gas would be combusted on-site for process heat and electricity production, while a large majority would be converted into methanol.[2]

GHG emissions in methanol production

The process of making methanol from gas leads to GHG emissions from several sources.

First, GHG emissions are released in the process of extracting, processing, and transporting natural gas to the facility. Then, GHG emissions are released in the process of converting the gas into methanol, both from burning fuels (including gas) directly, as well as burning fuels to make any electricity used by the facility. Lastly, emissions are released in transporting the methanol across the Pacific Ocean to reach its final destination at an olefin manufacturing facility in China.

Estimates for some of these emissions sources appear in the facility's Final Environmental Impact Statement (FEIS), a report required by local regulators before such facilities can receive the necessary permits. (See Box 1).

In the discussion here, we build from the FEIS – which counted only the emissions associated with converting the gas into methanol. We use a number of published sources to estimate emissions from sources that were neglected (or erroneously analyzed) in the FEIS. The most significant of these is the extraction and transportation of natural gas.[3]

The process of producing and transporting natural gas leads to both methane (CH_4) and carbon dioxide (CO_2) emissions. Carbon dioxide emissions result from the combustion of natural gas or any other fossil fuel used in the course of producing and transporting the gas, as well as when gas is flared during extraction and processing. Methane is emitted when gas is vented during extraction and processing operations, and from leaks that occur during well drilling and gas gathering, processing, transmission, and distribution.

Despite considerable research, large uncertainties remain with respect to the scale of these methane emissions.[14] The U.S. Department of Energy estimates that the average leakage rate for natural gas supply systems nationally is 1.6% for extraction, processing, and transportation, with a slightly lower rate of 1.4% when no distribution is required (as would be the case for the Kalama methanol facility).[16] U.S. EPA's annual GHG inventory also provides estimates of total U.S. methane emissions from natural gas supply systems that imply leakage rates of a similar scale.

However, research based on atmospheric measurements suggests that bottom-up estimates – such as those from the EPA and DOE, which extrapolate average leakage rates from specific device and facility measurements – consistently underestimate methane emissions. Brandt finds that leakage could be 25% to 75% higher than inventory-based estimates – which would mean leakage rates of more like 1.9% to 2.6% for the U.S. on average.[6,8]

Field measurements also suggest that emission rates for unconventional (e.g. shale) gas may be higher than for conventional gas.[10,12] The DOE study found that the average leakage rate for Rocky Mountain tight gas – the unconventional gas supply that would be a possible source of supply for the Kalama facility – is 2.8%, with considerable uncertainty. One recent global review of natural gas methane emissions arrived at average global leakage rates of 4.3% for shale gas production.[10,12]

For the 20-year lifespan of a facility such as the Kalama methanol refinery, it seems plausible that methane leakage, in a best-case scenario, could be reduced to 1% on average – if industry and policy efforts to reduce emissions are successful.[14] However, it also seems plausible that leakage rates could be as high as 3% or more, espe-

Box 1: Flaws in the Kalama facility's Final Environmental Impact Statement (FEIS)

The Washington State Environmental Policy Act (SEPA) requires an environmental review of major infrastructure projects, and specifically requires an environmental impact statement (EIS) from any project likely to have an adverse environmental impact, such as on climate change.

However, the final EIS submitted by Port of Kalama and Cowlitz County contains at least two serious flaws in its assessment of greenhouse gas emissions effects.

The first error relates to GHG emissions from off-site power generation. The facility proposed is electricity-intensive, and would draw up to 100 MW of electricity from the grid. The FEIS characterizes those emissions using the recent average (total) mix of electricity-generating resources in the Northwest. However, average rates are inappropriate metrics for estimating emissions effects of facilities that would increase electricity demand (as the Kalama facility would).[4,5] This is especially true when the mix of existing generation resources is different than those available "on the margin", as is the case in the Pacific NW.[5,7,9] The largest fraction of existing generation comes from low-GHG hydroelectricity, whereas the Northwest Power and Conservation Council estimates that a sizeable fraction of the resources on the margin are likely to use natural gas, at least for the near future.[11] For this reason, analysts should use marginal emission rates that reflect the plants that would be run and/or built in response to additional electricity demands. Doing so here would increase estimated GHG emissions from off-site power generation by 20% to 150% relative to those reported in the FEIS.[4]

Second, the FEIS uses a flawed approach for assessing the GHG emissions associated with the production and transportation of natural gas. As the FEIS notes, the process of producing and transporting natural gas leads to GHG emissions – both methane (CH_4) and carbon dioxide (CO_2) – from "fugitive losses" as well as ongoing emissions from operating the wells. However, in all cases, the FEIS claims that the GHG emissions attributed to the Project should be zero. To support this, it claims that the Project "does not include development of any natural gas wells", that increasing the rate of production from existing wells will "not necessarily" increase methane releases from those wells, and that it is "not possible" to determine whether transporting more gas through existing pipelines will result in increased methane leakage or fuel combustion (FEIS, page 4-20).

These arguments defy good practice for assessing the GHG emissions effects of new natural gas demand. Most critically, it is implausible that existing wells can supply the 270,000 dekatherms of natural gas needed daily for the Facility Project starting in 2021, given competing demands for that gas. More importantly, the FEIS offered no justification for why the Project should have preferential access to the dwindling supply of natural gas from existing wells, nor how any other displaced demands for natural gas would be otherwise met.

Numerous studies have looked at the GHG emissions associated with natural gas well completion and operation, as well as transportation and distribution of the gas to customers. In the main text, we use these studies to construct our own estimate of the emissions associated with natural gas extraction and transportation to the Kalama facility.

cially if the Kalama facility draws from shale gas resources, and regulations such as the EPA methane rule (which the Trump Administration has sought to block) are not successfully implemented.

Combining this 1% to 3% range of leakage rates with the FEIS estimates of on-site emissions[22], Figure 1 shows the total GHG emissions associated with producing methanol at the Kalama refinery. We estimate that, in total, production and delivery of methanol from the Kalama refinery to Chinese ports would lead to 2.6 million to 4 million tons CO_2e annually, assuming a 100-year Global Warming Potential (GWP). A 20-year GWP raises it to 3.7 million to 7 million tons CO_2e. These estimates are two to six times higher than the FEIS estimate of 1.3 million tons CO_2e (as shown in Figure 1). The biggest difference – by far – is the contribution of natural gas supply (both CO_2 and CH_4) to the total GHG emissions effect of the proposed facility.

Since natural gas supply emissions would occur largely out of state, only about 1.4 million tons CO_2e (from direct emissions on-site and power generation) would be counted in Washington State's annual GHG emissions inventory. Still, this amounts to an increase of 1% to 2% to the State's emissions, which were 94.4 million tons CO_2e in 2013, the most recent year assessed[17]. This would create an added challenge for state policy-makers, who have committed to reducing the State's emissions at a rate of 1.7% per year to reach the statutory target of 50% below 1990 levels by 2050. Perhaps, however, that is a challenge worth taking, if producing methanol at the Kalama facility is likely to reduce global GHG emissions by displacing higher emitting industrial processes elsewhere in the world. We turn to that question next.

Is gas-to-methanol a lower-emissions way of making plastics?

The project developer, NWIW, argues that the Kalama facility would reduce emissions "by 90% compared to coal-based methanol," because its gas-based methanol would displace the production of coal-based methanol in China. Indeed, if a new facility were to displace more emissions-intensive activity, there could be a rationale for climate-focused policy-makers to give preference to the facility on the grounds that it could help reduce global emissions. To examine whether or not this might be the case, we need to examine the markets for methanol and what it might be used for.

Several technologies produce olefins. The predominant technology globally has been steam cracking of naphtha (a product of crude oil refining) and, to a lesser extent,

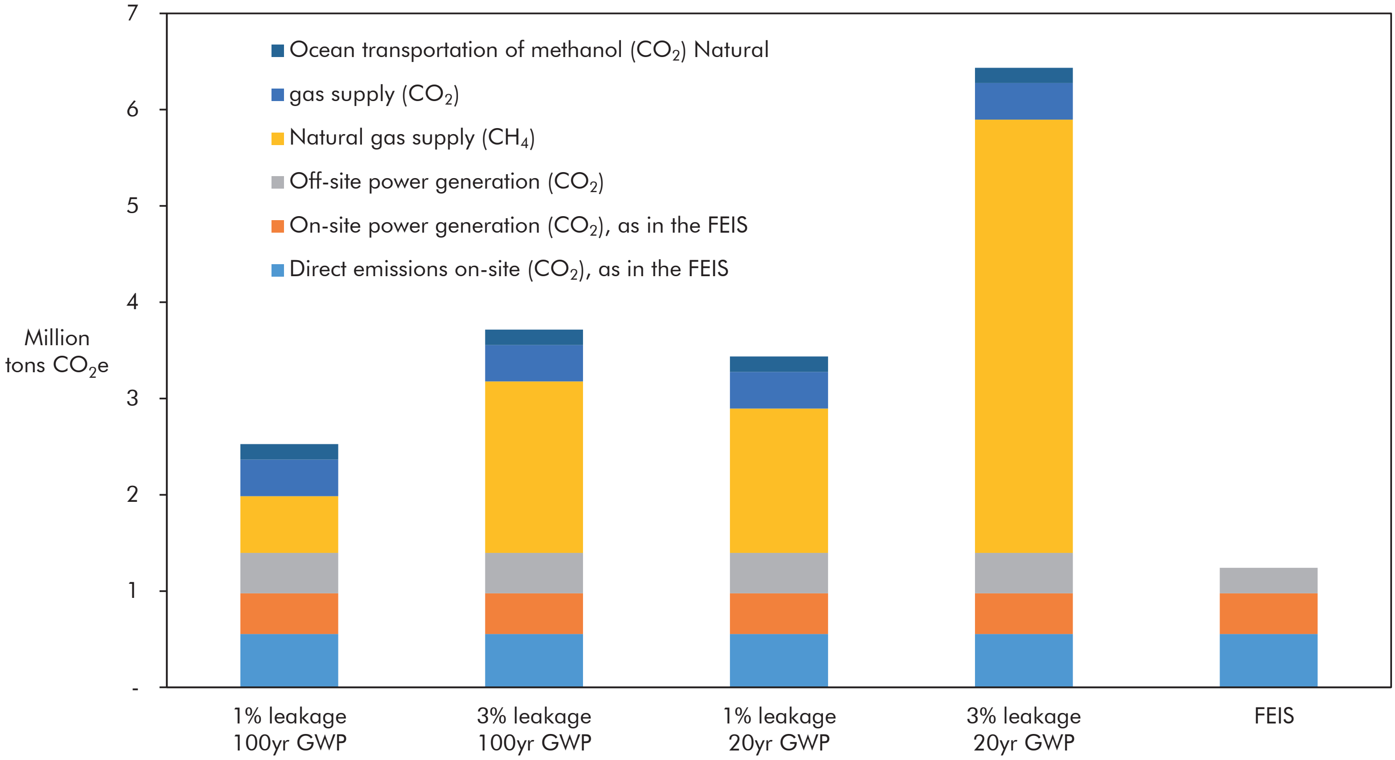

Figure 1: Greenhouse gas emissions associated with proposed Kalama facility under alternative assumptions about methane (CH_4) leakage, as compared to FEIS estimates

Source: SEI Analysis based on the Kalama EIS, as supplemented with estimates of methane leakage from of 1 to 3% and ocean transportation from Xiang et al 2015,[13] and with global warming potentials (GWP) for methane of 34 times higher than CO_2 over a 100-year timeframe and 86 times higher over a 20-year timeframe, based on IPCC.[15] No emissions are associated with natural gas supply or with ocean transportation in the Kalama FEIS and so zero are listed in this Figure. Our estimate of emissions from off-site power generation reflect a marginal rather than average approach and this differs from the FEIS as discussed below.

ethane (a co-product of natural gas production).[18] For example, in 2016, 82% of global ethylene (the dominant olefin) production capacity was naphtha and ethane-based, and only 2% was methanol-based.[19]

Figure 2 shows the GHG emissions implications of these and other alternative pathways to making olefins, in comparison with an efficient Chinese facility using methanol produced by the Kalama natural gas refinery. As shown, producing a ton of olefins from naphtha would result in 0.7 to 1.1 tons CO_2e, depending on whether best or average practice is followed. That is roughly half the GHG emissions as a facility using natural-gas-based methanol from Kalama (1.6 to 2.2 tons CO_2e, depending on methane leakage rates).

In contrast, the GHG emissions of producing a ton of olefins from coal-based methanol would be far higher than any other route – 9.7 tons CO_2e. Therefore, if indeed gas-based methanol from Kalama could directly displace the production of methanol from coal, GHG savings could be quite significant.

We find two reasons to doubt that the Kalama facility would displace coal-based methanol rather than avoid other lower-emission routes to olefin production.

The first is that the economics of new coal-based methanol facilities in China are not as favorable as they once were. The boom in construction of these facilities appears to have been short-lived, driven by a relatively short-term spike in oil prices above $100/barrel that made them more cost-competitive to naphtha-based plants.[19] These economics may not return, however, especially if electric vehicles and commitments to address climate change cut into future oil demand. For example, IEA's forecast of oil prices under a scenario that meets the Paris Agreement goals shows oil prices that briefly regain a price above $70 per barrel in 2025 only to fall consistently in subsequent decades.[14] Under such a future, the economics of building out new coal-to-methanol capacity, which is very capital intensive, seems in doubt.[23,24,19]

Second, China has taken important steps to curb coal, both in response to air pollution concerns and its own commitments to address climate change. Indeed, some analysts believe that coal consumption in China, which in recent years was increasing rapidly, has now already peaked and is beginning a long decline.[25,26]

Together, these two factors suggest that there is no guarantee that production of gas-based methanol at the Kalama facility would avoid an equivalent amount of coal-based methanol production in China. By contrast, it seems just as or more likely that it would displace the other, lower-GHG olefin routes that appear likely to dominate globally.

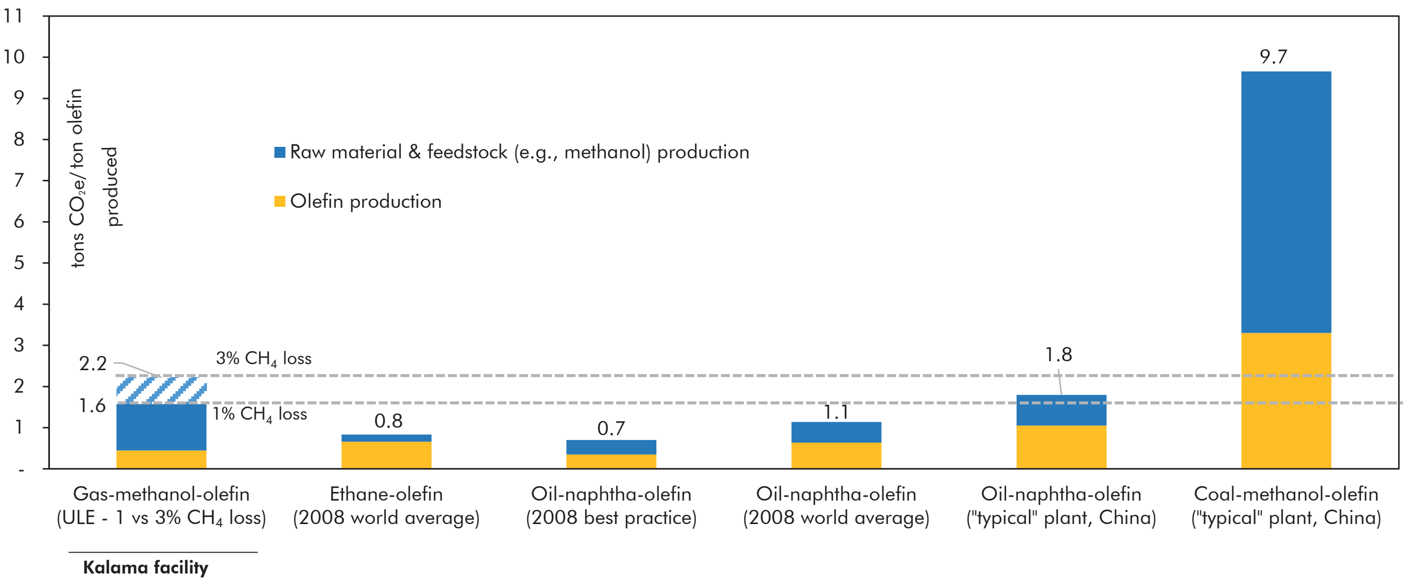

Figure 2: Greenhouse gas intensity of alternative olefin production pathways

Source: SEI Analysis based on the following sources. GHG emissions intensity of methanol production at the proposed Kalama facility is drawn from the facility FEIS, adjusted to account for a range of methane leakage rates of 1% to 3% and the use of a marginal emissions rate for grid electricity. GHG emissions intensity of olefin production from the Kalama facility's methanol is assumed to be 2008 best practice from Ren et al 2008.[20] GHG emissions intensity of the ethane-olefin and oil-naphtha-olefin routes are 2008 values drawn from Ren et al 2008.[20] GHG emissions intensity of the oil-naphtha-olefin and coal-methanol-olefin pathways in China are based on current plants of "typical" capacity as drawn from Xiang et al 2014.[20,21]

The bigger question: is gas-to-methanol part of a low-carbon economy?

The standard way to assess the climate and GHG effects of a new industrial facility is to quantify how much it would likely reduce or increase emissions relative to one or more reference (or counterfactual) technologies or practices. From this perspective, it is conceivable that the Kalama facility could reduce emissions were it to lead to a corresponding reduction in coal-based methanol production in China. We find that over the life of the facility, it would be more likely to displace other olefins routes (e.g., naphtha- or ethane-based) with significantly lower GHG emissions. We therefore conclude that the facility would be just as likely to increase global GHG emissions as to decrease them.

Box 2: Transportation and other potential methanol uses

Given the over-supply of the olefin market in Asia,[27] it is conceivable that methanol produced in North America could find its way to other markets. Globally, less than 20% of methanol is destined for the olefins market targeted by the proponents of the Kalama facility. The predominant use remains formaldehyde production (over a quarter) followed by a wide variety of other uses, including about 20% that goes to a mix of transportation applications. That includes methanol's direct use as a fuel and the manufacture of MTBE (methyl tert-butyl ether), an additive to gasoline to increase the oxygen content (for local air pollution control).

Indeed, some analysts see a growing demand for methanol to be used in vehicle fuel in China. Just as for olefin production, if gas-based methanol were to displace coal-based methanol for vehicle fuels, then there would likely be significant GHG benefits. But as with olefin manufacture, there is no clear reason to believe that bringing more gas-derived methanol to market would directly reduce an equivalent amount of coal-based methanol production in China. Instead, what appears more likely on the margin is that it would increase global liquid fuel supplies (as liquid fuel markets are indeed global) with a mix of impacts. In the short run, increased gas-based methanol would substitute gasoline and diesel, and possibly some coal-based methanol in the Chinese market. In the longer run, increased supplies would also increase total fuel use, leading to added GHG emissions and potentially slowing a transition to electric vehicles.[28]

The GHG impact of bringing gas-based methanol to fuel markets is thus difficult to discern. Again, as with olefin markets, unless increased gas-based methanol production can directly lead to substantial reductions in coal-based methanol production, the effect is likely to be an increase in GHG emissions. Research suggests that blending gasoline with gas-derived methanol would increase GHG emissions: for example, an 85% blend of gas-derived methanol would yield life-cycle GHG emissions 15% to 19% higher than conventional gasoline, and 27% to 37% higher if a 20-year GWP were used.[29] The market effects of inducing additional liquid fuel consumption could also increase emissions by up to 60% on top of that.[30] It thus appears more likely that bringing added gas-based methanol to transportation fuel markets would increase GHG emissions globally, while potentially slowing a transition to the low-carbon transportation system needed to meet state as well as global climate goals.

Still, even if the facility *were* to reduce emissions relative to a business-as-usual reference technology, its construction and operation might not be consistent with long-term climate goals. A low-carbon transition – in line with the globally-agreed goal of keeping warming "well below" 2 degrees Celsius – might call for investment in even lower-emitting production processes. In other words, comparing against a "business-as-usual" technology – regardless of whether that technology is coal-based methanol or instead a more common naphtha-based route – may simply be inadequate for assessing whether a facility "makes sense" in light of the need to steeply reduce global emissions.

A fuller climate test would also need to examine whether the proposed technology and the products it delivers would be viable – and not significantly *increase* emissions – under a scenario that has a reasonable chance of meeting a limit of well below 2 degrees warming. There are at least three ways to examine consistency with a low-emissions pathway.

First, one can examine whether there are cost-competitive alternatives that could deliver similar outcomes but with lower emissions. In the case of the Kalama facility, there are already proven and cost-competitive olefin production pathways that, as shown in Figure 2, consume half or less the GHG emissions as the gas-methanol-olefin route proposed here.

Second, one can look to available long-term, low-emissions scenarios for added insights. Do these scenarios suggest that the technology in question (or others of similar or higher emissions) would expand in market share? How might demand, supply, and prices for key feedstocks (e.g. coal, naphtha or natural gas) and products (e.g. methanol or olefins) change, and how might that affect the viability of the proposed facility? Fully addressing these questions is beyond the scope of this brief, but it is not entirely certain that fossil-fuel-based olefins (and plastics) themselves are part of a low-carbon economy, as bioplastics – still in their early stages – show promise for potentially even lower GHG pathways.[24]

Third, one can simply examine what these scenarios and other studies imply for a price on GHG emissions, given that such scenarios may lack the depth on particular industries such as olefin production. This would include examining the effect such a price would have on the relative economics of different production pathways. For example, a widespread, high price on carbon might lead to a rapid phase-out of coal-based methanol production due to its very high emissions intensity (as shown in Figure 2). Such an outcome could create new market opportunities for natural-gas-based methanol. Alternatively, markets could turn away from fossil-fuel-derived methanol altogether and towards lower emitting olefin manufacturing processes (see Figure 2) or, in the longer-term, bioplastics. Under these conditions, Kalama could become a "stranded asset" – no longer financially viable, with the potential for disruptive employment and economic impacts on the surrounding region. Indeed, financial institutions are increasingly asking investors to take these 'transition risks' into account in order to avoid such disruptions.[31]

Principles for assessing new industrial development

Proposals to build emissions-intensive manufacturing and export facilities – such as the Kalama methanol refinery and port – present formidable challenges for policy-makers who care deeply about climate change. The tools and resources typically provided to assess their GHG and climate implications have often had too narrow a focus to provide adequate guidance, as in the case of the Kalama FEIS.

In the analysis above, we have explored the possible GHG emissions effects and climate implications of the proposed gas-to-methanol facility, while evaluating many of the claims made by the proponents of the project in Kalama, Washington. Our findings indicate that gaining a more complete picture of the facility's potential impacts requires analysts to:

- Take a global perspective, as GHGs have the same impact on climate regardless of where they are emitted, and to consider the full lifecycle from raw material inputs to the ultimate product uses; by contrast, it is insufficient to look only at local emissions associated with an industrial facility.
- Take markets and market/technology developments into account when assessing what new production is likely to displaced, since these dynamics ultimately determine whether a facility will increase or decrease emissions; by contrast, it is important not to simply pick a single hypothetical alternative technology as the sole point of comparison.
- Consider scale effects when increasing supply. Unless a facility directly leads to the shutdown of another facility (with a similar lifetime), it can increase supply of a commodity and, from there, consumption too.

Based on these considerations, for a new, emissions-intensive industrial facility to pass a climate 'test', an analyst should be able to conclude, with some confidence, that the facility will:

- Have significantly lower emissions per unit of product made, compared to the likely sources or practices displaced; and
- Be consistent with a transition to a deeply low-carbon future (and with keeping warming well below 2 degrees). This means:
    - — Products of the facility will be needed, ideally in increasing amounts
    - — Facility is not locking in a technology that would slow, preclude, or lock "out" lower-emitting alternatives
    - — Risk of stranding assets, workers, and communities is limited, i.e. the facility is resilient to a low-carbon transition and therefore the 'transition risk' of the facility is low.

Alone, principles such as these can provide useful guideposts for climate-minded decision-makers. Even better, straightforward methodologies could be developed that enable analysts to apply these principles in a clear, consistent manner. We suggest that researchers and regulators make this a priority. Such methodology development can build on a rich foundation of related efforts including: industry benchmarking studies conducted for emissions trading programs;[32] baseline methodologies developed for carbon offset programs; and scenario analysis to define investment consistent with the Paris Agreement goals as called for by the Task Force on Climate-related Financial Disclosures.[31]

In the case presented here, available information suggests that the Kalama facility would likely not reduce the emissions associated with olefin manufacture. Furthermore, it also shows that the gas-to-methanol facility is far from a low-GHG means of producing plastics or, alternatively, of providing transportation fuel. Accordingly, its approval and construction would not appear to be consistent with globally agreed climate goals of keeping warming at less than 2 degrees Celsius.

Endnotes

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2. Methanol (CH_3OH) is made by adding one oxygen atom to methane (CH_4), the primary constituent of natural gas.

3. The FEIS also did not cover emissions associated with transporting methanol across the Pacific; they are relatively small – about 0.16 million tons CO_2e per year – so we include them but do not discuss them further here.

4. The average emission factor for the regional grid used in the EIS (eGrid2012 total output) was 304 tons CO_2e/GWh. Alternative sources of marginal emission rates range from the Northwest Power Planning Council's marginal rate forecast for 2020 (372 tCO_2/GWh) to the eGrid2012 non-baseload emissions rate (744 tons CO_2e/GWh).

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